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Liberty Utilities

Salem Area Study 2020

ControlPoint TECHNOLOGIES

Version History

REV	DATE	Description	Prepared	Reviewed
0	9/1/2020	Final for NHPUC Filing	ControlPoint Technologies	Liberty Utilities

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1.0 Executive Summary

ControlPoint Technologies with the assistance of Liberty Utilities completed the Salem, NH distribution planning study for 2020. The revised Liberty Utilities Distribution Planning Criteria[1] was used to determine any Electric Supply System upgrades required to meet existing and future capacity requirements. The study focused on the distribution requirements needed to supply the proposed 13.5-18.5-megawatt (MW) (See Table 5) Tuscan Village business park development located at the former Rockingham Park Track. The study also focused on addressing asset concerns at Barron Ave Substation and Salem Depot Substation. The recommended solution would address Distribution Planning Criteria violations at Golden Rock Substation and Spicket River Substation while integrating system operation and maintenance enhancements in an economically responsible manner.

This study is a revision of the 2016 Salem Area Study performed by ControlPoint. The Study's main objective is to review prudency of the 115kV Rockingham supply alternative (Plan 6) and to compare with New Hampshire Public Utilities Commission (NHPUC) Staff's recommended alternative, which further relies on the 22.8kV sub-transmission system supply and existing 13.2kV distribution substations as an overall solution to address the area's deficiencies (Plan 1). Additional 22.8 kV alternatives were also evaluated for comparison.

As described in this report, there exists multiple alternatives for addressing the problems identified in the area. These plans resolved the issues with differing effectiveness and with differing costs. The plans that involve investing and relying on the 22.8 kV system were shown to be similar or more costly than the recommended plan.

The major components of the recommended plan are focused on upgrading the source of supply to the 13.2 kV distribution system from a 22.8kV/13.2 modular substation-based system to a 115kV/13.2kV bulk substation-based system. This shift towards a 115kV based bulk system has been utilized in Liberty's rebuild of Pelham Substation, Michael Ave Substation and Mt Support Substation. See Appendix H – Comparable Past Studies to Salem for details.

Thus far, Liberty and National Grid have completed the work listed below related to the preferred 115kV alternative[2]:

- Phase 1 - Installation of a 115/13.2 kV - 33/44/55 MVA transformer, a 115kV in-line breaker and two 13.2kV feeders at the Golden Rock Substation and the offload of Barron Avenue Substation was completed in 2019[3]. Extension of Pelham 14L4 was completed in 2018 to provide temporary load relief and system capacity in the Salem Area. This temporary transfer of approximately 7 MVA enables Liberty to

[1] As approved under Order No. 26,376 in DE 19-064 Liberty Utilities (Granite State Electric) Corp. d/b/a Liberty Utilities, Petition for Permanent and Temporary Rates.
[2] For purposes of this review, the resulting loading from the completed work below will not be included in the 2019 base case load model for Alternative #4 and #5 to allow an even comparison between alternatives.
[3] The Liberty Utilities portion of the Golden Rock project has been approved by the New Hampshire Public Utilities Commission under Order No. 26,376 in DE 19-064 Liberty Utilities (Granite State Electric) Corp. d/b/a Liberty Utilities, Petition for Permanent and Temporary Rates.

provide electric service to a portion, but not all, of Tuscan Village Development anticipated load while the Rockingham Substation is constructed. Installation of a third Golden Rock feeder to reduce load at risk at Spicket River substation is expected to be completed in 2021. Installation of a second 115kV transmission line into Golden Rock Substation is expected to be completed in 2020 by National Grid.

- Phase 2 – Purchase of land within the Tuscan Village Development to construct the new Rockingham #21 Substation was completed. Liberty is in the process of finalizing engineering activities for the Transmission Line and Substation projects and ordering long lead material items. Construction of the 115kV line project will begin in the winter of 2020 and is expected to be completed in 2022. The Rockingham Substation and associated feeders are expected to be completed in 2021. The Rockingham Substation will be designed to ultimately have ten feeder positions and two capacitor bank positions. Five feeders and one capacitor bank would be supplied by each transformer. Initially, five feeders, two and three from each transformer, will be installed in 2021. These will be utilized to supply the Tuscan Village load, allow the retirement of the Salem Depot Substation and provide backup to the Spicket River Substation.

- Phase 3 – Liberty has not developed any firm plans in its capital budget for Phase 3 within the 15-year planning horizon. For future reference, Phase 3 could replace the 115/22.8 kV transformer at Golden Rock with a 115/13.2kV transformer, convert the substation to a breaker and half scheme and re-purpose the 22.8 kV lines as 13.2kV feeders.

2.0 Introduction

2.1 Purpose

The purpose of this study was to resolve all identified area concerns in the Salem Area through the 15-year 2020-2036 study horizon. An in-depth review of the area was performed that included the analysis of thermal loading, voltage, reliability, asset condition, power quality, environmental, safety and voltage performance. Alternative plans were developed, which included NHPUC Staff's proposed alternative, and a preferred plan was recommended as being most prudent after detailed plan comparisons.

2.2 Problem

A study's initial system assessment is typically based on the needs identified through the problem identification process guided by the Company's Planning Criteria. In addition to the assessment performed in the 2016 version of the Study, updated system characteristics were evaluated to use 2019 loading and existing system configuration to identify a variety of normal and contingency capacity issues in the Salem Area.

A major point of concern is several existing asset condition concerns with substation equipment and layout.

Furthermore, another concern is the proposed 13.5-18.5-megawatt (MW) business park at Tuscan Village. Available capacity to supply the proposed development is not sufficient from the existing system.

3.0 Background

3.1 Geographic Scope

This study was performed on the Liberty Utilities Distribution System supplying Salem, New Hampshire. The system is confined to the City of Salem, NH with small excursions into Windham and Derry, NH and Methuen, MA. See Figure 1 below:

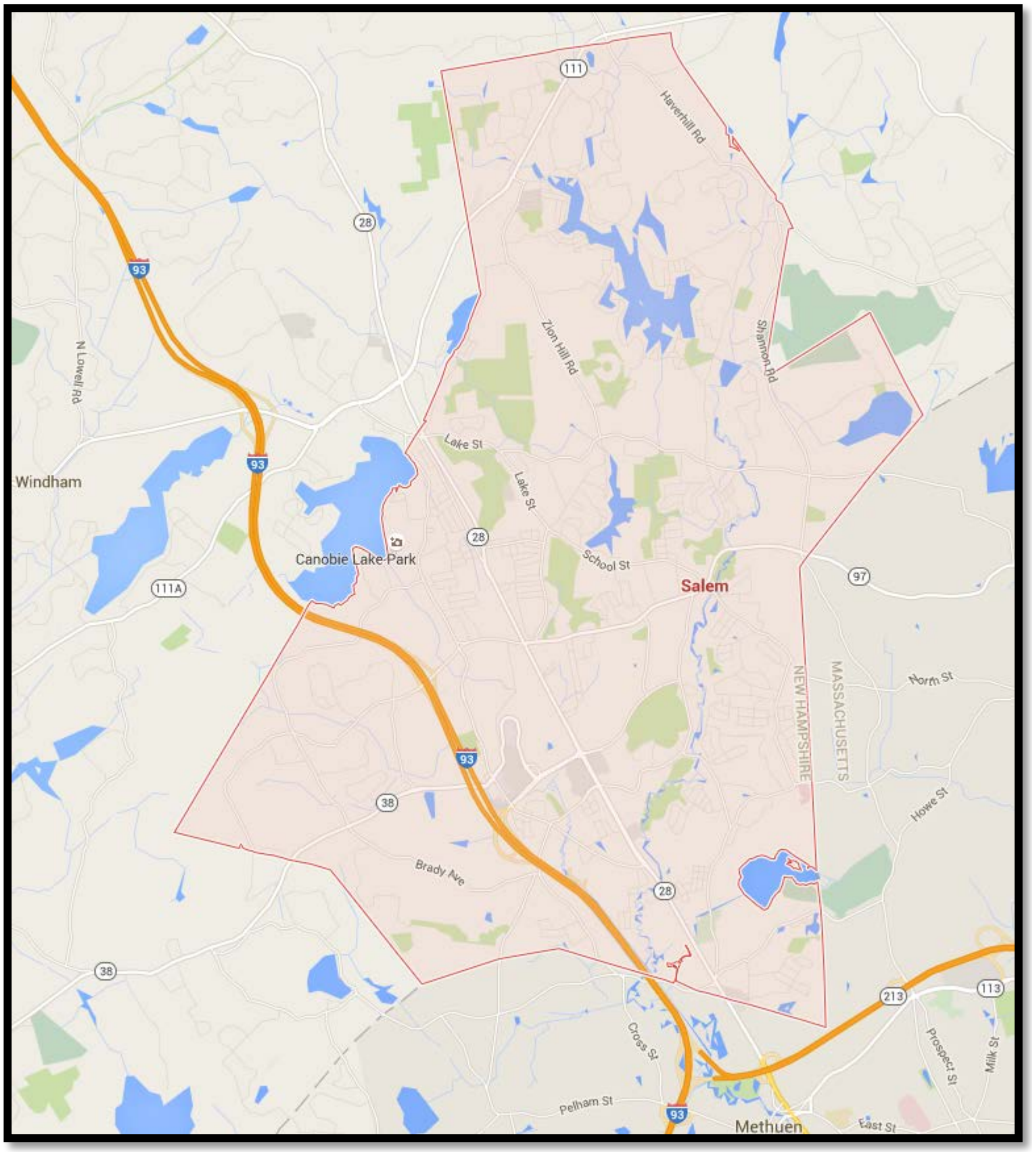

Figure 1 Salem, NH Geographical Map

3.2 Electrical Scope

The Salem Area includes 115 kV, 22.8 kV, and 13.2 kV facilities interconnected through five area substations. The Table 1 below summarizes these interconnections:

Supply	Alternate Supply	Station	Feeder	Customers
2352	2393	**Salem Depot 9**	**9L1**	967
2352	2393		**9L2**	128
2352	2393		**9L3**	1,261
2393	2353 (National Grid)	**Barron Ave 10**	**10L1**	813
2393	2353 (National Grid)		**10L2**	884
2353 (National Grid)	2393		**10L4**	775
2376 (National Grid)	2353 (National Grid)[4]	**Spicket River 13**	**13L1**	2,081
			13L2	1,899
			13L3	2,438
2352	2393	**Olde Trolley 18**	**18L1**	62
2352	2393		**18L2**	1,929
2393	2352		**18L3**	842
2393	2352		**18L4**	693
G133W (National Grid)	2353 & 2376 (National Grid)	**Golden Rock 19**[5]	**2352**	4,347
			2393	3,232

Table 1: Salem Area Electric System

One 115 kV radial transmission supply line crosses the Massachusetts/New Hampshire border from Methuen, MA to feed two transformers at the Golden Rock Substation. Figure 2 in Appendix A – System One Lines shows the 22.8 kV Supply System. Figure 4 in Appendix A – System One Lines shows the 13.2 kV Distribution System.

Liberty Utilities serves 22,351 Customers in the Salem Area. In 2019, the Salem Planning Study Area generated a peak demand of 98.72 MW. The Salem area consists of approximately 13.1 miles of 22.8 kV three-phase supply line and approximately 143 miles of 13.2 kV three-phase mainline.

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[4] Approximately 5.2 miles of the 2376 is exposed to outages without any backup, with 4.3 miles in National Grid maintenance territory and 0.9 miles in Liberty Utilities territory.

[5] Customers supplied by the 2352 and 2393 supply lines are a summation of customers supplied from the related substation transformers. These supply lines do not directly serve customers at 22.8 kV service voltage.

3.3 Load and Load Forecast

The Salem Study Area is a summer peaking area and is limited by summer equipment ratings. The study was conducted using load data beginning with the recorded 2019 peak load; refer to Table 2, below:

Station	Circuit	2019 Peak Load (Amps)	Limiting Element	SN Amps	% of SN
BARRON AVENUE 10	10L1	107	250 E Fuse	387	28%
BARRON AVENUE 10	10L2	268	4/0 CU Bus	526	51%
BARRON AVENUE 10	10L4	176	1-5/6.25 MVA Xfmr	339	52%
OLDE TROLLEY 18	18L1	133	1000 Al Cable	503	26%
OLDE TROLLEY 18	18L2	404	1000 Al Cable	503	80%
OLDE TROLLEY 18	18L3	375	336.4 Al	515	73%
OLDE TROLLEY 18	18L4	387	333 kVA Reg	516	75%
SALEM DEPOT 9	9L1	271	1-5/6.25/7 MVA Xfmr	322	84%
SALEM DEPOT 9	9L2	224	1-5/6.25/7 MVA Xfmr	322	70%
SALEM DEPOT 9	9L3	319	1-7.5/9.375 MVA Xfmr	507	63%
SPICKET RIVER 13	13L1	326	333 kVA	522	62%
SPICKET RIVER 13	13L2	290	333 kVA	522	56%
SPICKET RIVER 13	13L3	442	333 kVA	522	85%
Golden Rock	2352	776	2 X 1000 CU Cable	1376	56%
Golden Rock	2393	654	2 X 1000 CU Cable	1376	47%

Table 2 Salem Area 2019 Peak Loads

The Company developed an econometric model to forecast peak demands through 2036. The forecast model incorporates the impact of weather as well as demographic and local economic conditions on peak demands. The load was escalated through 2036 using the seasonal peak forecast under a 90/10 extreme weather scenario; refer to Table 3, below:

Year	MW	% Increase
2019	192.581	
2020	207.731	7.87%
2021	208.283	0.27%
2022	208.823	0.26%
2023	209.373	0.26%
2024	209.899	0.25%
2025	210.407	0.24%
2026	210.901	0.23%
2027	211.378	0.23%
2028	211.837	0.22%
2029	212.282	0.21%
2030	212.719	0.21%
2031	213.149	0.20%
2032	213.562	0.19%
2033	213.958	0.19%
2034	214.336	0.18%
2035	214.698	0.17%
2036	215.051	0.16%

Table 3 LUNH 2020-2036 90/10 seasonal peak forecast

The forecast model was then adjusted for spot loads to reflect new customer demands larger than 300 kilowatts ("kW"), refer to Table 4 below. The Distribution System was modeled and analyzed using the CYME application to perform the load flow analysis.

Year	Distribution Circuit	Location	Load (Amps)
2020	18L1	Rockingham Mall	65
2020	18L4	Tuscan Village Development South	274
2020	9L1	Tuscan Village Development North	174
2020	9L2	Data Center Expansion	44
2020	9L3	Commercial Development / Medical / Nursing	36
2021	18L4	Tuscan Village Development South	363

Table 4 Salem Area Spot Loads

Table 5 below tabulates detailed estimated loads for the Tuscan Village business park. This includes completed, under construction, in progress and no current tenant categories. Consistent with Company practice, anticipated kW demand represents diversified load, understanding that all loads are not active at the same time, at full power.

Tuscan Village Demand			
End Use	**Diversified kW Demand**	**Tuscan Section**	**Status**
Dolben 1	[redacted]	North	Complete
Blackbrook	[redacted]	North	Complete
Ford	[redacted]	North	Complete
Market Basket	[redacted]	North	Opened July 2019
Home Sense	[redacted]	North	Opened Sept 2019
Sierra	[redacted]	North	Awaiting opening due to covid
MB Retail 3	71	North	No tenant due to Covid
MB Retail 4	56	North	No tenant due to Covid
Starbucks & Retail	[redacted]	North	Under Construction
Retail 1 - 4	30	North	Under Construction
Restaurant 1	87	North	2021
Restaurant 2	127	North	2021
35 N BROADWAY	[redacted]	North	Sal's Redevelopment - added by JR 6/3/2020
Hanover Apts	[redacted]	South	In Progress
Klemms	[redacted]	South	Complete
St Lt 1	[redacted]	South	In Progress
St Lt2+3 and well	[redacted]	South	In Progress
OMJ Buildings	[redacted]	South	In Progress
Pressed	[redacted]	South	In Progress
Mass General (with Solar)	[redacted]	South	In Progress
Building 100 (11.7)	245	South	In Progress
Building 200 (15.2)	317	South	In Progress
Building 300 (5.2)	109	South	In Progress
Building 400 (9)	188	South	In Progress
Building 500 (6.5)	107	South	In Progress
Building 520 (2.1) EV	44	South	In Progress
Building 600 w/ev (18.4)	386	South	In Progress
Building 700 (8.1)	154	South	In Progress
Building 800 w/ev (11.2)	235	South	In Progress
Building 900 (1.3)	28	South	In Progress
Building 1100 Drive (11.3)	236	South	In Progress
Hotel/Conf/Retail	1,300	South	No tenant
Resi Village	368	South	No tenant
Offices Spaces	4,025	South	No tenant
Over 55+	166	South	No tenant
Retail	2,426	South	No tenant
Dolben 2 (255 units)	[redacted]	South	In Progress
Total North	3,961		Includes Sal's Redevelopment (378kVA)
Total South	14,494		
Total Tuscan Village	**18,433**		
Total Tuscan Village Completed/In-Progress	**10,043**		These are for secured tenants
Total Tuscan Village without signed tenant	**8,412**		This is an estimate based on targeted end use

Table 5 Tuscan Village Diversified Loads

3.4 Modeling and Criteria

CYME models were created for the Salem area 13.2 kV distribution system. PSS/e models were created for the 22.8 kV supply system. Transformers, supply lines, and distribution circuits were evaluated and modeled for each year thru 2036. The peak load and the available tie capacity for each component of the system was determined. Contingencies for the loss of a major component of the electrical system (N-1) were developed, and the system consequences reviewed.

As the Golden Rock 19L6 and 19L8 13.2 kV feeders were new additions to the area, energized in December 2019, the original 2019 base models did not include the feeders. Area load was allocated under the prior system configuration before the installation of the 19L6 and 19L8. Subsequently, the system model was reconfigured to depict 19L6 and 19L8 as planned. It should be noted that this study would have resulted in increased loading violations if these feeders were not present.

The in-progress construction of the Tuscan Village business park was modeled for all Plans as a total load of 13.5 MW, which is a minimum expected demand, and is 5 MW or 37% lower than Liberty's expected, diversified demand for the development as proposed at 18.5 MW. See Table 5. This demand assumes a conservative 1.5 MW for the northern Tuscan parcel and 12 MW for the southern parcel. If the Tuscan Village development grows to a demand closer to what is reflected in Table 5, the overloads and voltages presented in this study worsen considerably and could result in new violations not currently identified.

Each Alternative Plan was reviewed on the 13.2 kV and 22.8 kV system.

Distribution System Ratings were used to identify any station, supply line, and distribution circuit system capacity and reliability deficiencies, as applicable to Liberty Utilities Planning Criteria. The Liberty Utilities Planning Criteria has been reviewed and updated with PUC Staff input.

Condition	Sub-Transmission	Substation Transformer	Distribution Circuit
Normal	Loading to remain within 100% of normal rating. Voltage at customer meter to remain within acceptable range. Circuit phasing is to remain balanced.	Loading to remain within 100% of normal rating. Voltage at customer meter to remain within acceptable range. Circuit phasing is to remain balanced.	Loading to remain within 100% of normal rating. Voltage at customer meter to remain within acceptable range. Circuit phasing is to remain balanced.
N-1 Contingency, which results in facilities operating above their Long-Term Emergency (LTE) rating but below their Short-Term Emergency (STE) rating.	Load must be transferred to other supply lines in the area to within their LTE rating. Repairs are expected to be made within 24 hours. Evaluate alternatives if more than **120 MWhr** of load at risk results following post-contingency switching.	Load must be transferred to nearby transformer to within their LTE rating. Repairs or installation of Mobile Transformer expected to take place within 24 hours. For transformers larger than 10 MVA nameplate, evaluate alternatives if more than **180 MWhr** of load at risk results following post-contingency switching.	Load must be transferred to nearby feeder to within their LTE rating. Repairs expected to be made within 24 hours. Evaluate alternatives if more than **16 MWhr** of load at risk results following post. (Guideline)
N-1 Contingency, which results in facilities operating above their Short-Term Emergency (STE) rating.	As Needed - Typically 15 min for OH conductors and 24 hours for UG cables.	Loads must be reduced within 15 minutes to operate within their LTE rating.	As Needed - Typically 15 min for OH conductors and 1-24 hours for UG cables.

Table 6 Liberty Utilities Planning Criteria

3.5 Active & Completed Projects

Installation of a 115 kV/13.2 kV - 33/44/55 MVA transformer, a 115kV in-line breaker and two 13.2kV feeders at the Golden Rock Substation and the offload of Barron Avenue Substation was completed in December 2019 (Barron Ave Substation modular feeders will remain available for emergency use throughout construction of the recommended plan).

- An extension of Pelham 14L4 was completed in 2018 to provide temporary load relief and system capacity in the Salem Area. This temporary solution enables Liberty to provide electric service to a portion, but not all, of Tuscan Village Development anticipated load while the Rockingham Substation is constructed.

- Installation of the third Golden Rock feeder to reduce load at risk at Spicket River substation is expected to be completed in 2020. Installation of a second 115kV at Golden Rock is expected to be completed in 2020.

4.0 Problem Identification

4.1 Thermal Loading – Existing Violations

Existing system analysis reviewed two base cases, one being the 2019 peak case, without a new 115 kV / 22.8 kV supply transformer at Golden Rock. A second base case was also reviewed, as the recent addition of a 115 kV / 22.8 kV supply transformer at Golden Rock with three distribution feeders is needed to adequately reflect the Salem Area system modifications that have been approved by the NHPUC. Analysis results in this section represent the 2019 peak base case.

4.1.1 Normal Configuration – based on 2019 peak loads

4.1.1.1 Sub-Transmission System

Analysis resulted in no violations.

4.1.1.2 Transformers

Analysis resulted in no violations.

4.1.1.3 Feeders

The 13.2 kV distribution system supplies the peak load demand with no violations. However, to accommodate this loading the feeder 14L4 supplied from the Pelham Substation has been temporarily placed in an abnormal configuration. It is supplying load transferred from Salem to allow for the Tuscan Village increasing load.

4.1.2 N-1 Contingency & Load-At-Risk

4.1.2.1 Sub-Transmission System

Base Case 22.8 kV Analysis determined that the 22.8 kV supply system is nearing Summer Emergency limits in certain first contingency scenarios, refer to Appendix C – Area Loading Analysis, Table 13. As a result, no additional load should be added to the Salem 22.8 kV system, and no future load growth can occur without future overloads.

The Spicket River No.13 Station is currently supplied at 22.8 kV by the 2376 circuit from the National Grid Ward Hill Substation in Methuen, MA.

The 2376 circuit ties with the 2353 circuit, which also originates from Ward Hill, via a pole mounted recloser loop scheme. The tie is located in the Spicket River Massachusetts Right of Way. Downstream of the 2376/2353 tie, the 2376 continues for 4.3 miles in National Grid territory crossing into New Hampshire and continuing 0.9 miles to the Spicket River No. 13 Substation. Approximately 5.2 miles of the 2376 is exposed to outages without any backup, with 4.3 miles in National Grid maintenance territory and 0.9 miles in Liberty Utilities territory.

The loss of the 22.8 kV source for an outage on the 5.2-mile section would require the Spicket River circuits to be backed up by existing distribution circuit ties, however area feeders are not positioned geographically to re-supply the Spicket River distribution feeders. To resolve low voltage issues during contingency, even cascading load does not re-supply Spicket River in all scenarios. While analysis shows that Spicket River distribution feeders can be partially re-supplied via distribution ties to avoid exceeding MWHr criteria, a minimum of fifteen switching steps would be required for partial re-supply; presenting operability challenges. Appendix E – Spicket River Backup Analysis for details.

Liberty Utilities relies on the Transmission provider to expedite repairs should an outage related problem occur anywhere along the 4.2 miles of transmission owned 2376 sub-transmission line downstream of the 2376/2353 tie. Loss of the 23 kV sub-transmission supply circuit to the Spicket River No.13 Station could cause Liberty Utilities to have up to 226 MWHrs of load at risk, after restorative switching occurs and for an assumed repair time of 12 hours. This violates Liberty's planning criteria of 120 MWhrs. In 2021 an express feeder 19L4 will be installed from the Golden Rock Substation to Spicket River to reduce the load at risk to below 120 MWhrs.

4.1.2.2 Transformers

The Golden Rock Station is currently supplied radially from National Grid's G133 115 kV line which originates in West Methuen Station in MA. The station is backed up by National Grid's 22.8 kV lines 2376 and 2353 which originate in Methuen and West Methuen Stations in MA. Liberty Utilities relies on the Transmission provider to expedite repairs should an outage related problem occur on the 115 kV line or on the substation transformer. Loss of either could cause Liberty Utilities to have up to 300 MWHrs of load at risk, after restorative switching occurs and for an assumed repair time of 24 hours. This violates Liberty's planning criteria of 180 MWhrs. In 2021, a new 115kV transmission line will be installed from Methuen to Salem NH to resolve the load at risk related to the loss of the 115 kV transmission line. This however does not address the load at risk issue with the loss of the 115-22.8 kV transformer at Golden Rock. See Appendix D – MWHr Summary for details.

4.1.2.3 Feeders

Analysis resulted in no violations.

4.2 Thermal Loading – Predicted Violations

System analysis for this section reviewed two base cases, one being the 2019 peak case, without a new 115 kV / 22.8 kV supply transformer at Golden Rock. A second base case was also reviewed, as the recent addition of a 115 kV / 22.8 kV supply transformer at Golden Rock with three distribution feeders is needed to adequately reflect the Salem Area system modifications that have been approved by the NHPUC. Analysis results in this section represent the 2022 Base Case with Tuscan Village development, and the recent addition of a 115 kV / 22.8 kV supply transformer at Golden Rock in-service.

4.2.1 Normal Configuration

4.2.1.1 Sub-Transmission System

Analysis resulted in no violations.

4.2.1.2 Transformers

Analysis resulted in the following violations:

- Salem Depot 9L1 Feeder at 99% in 2022, up to 102% in 2036

Loading percentages are versus Summer Normal Ratings. See Appendix C – Area Loading Analysis, Table 15. It is assumed that the predicted demand for the Tuscan Village Development would normally be supplied by the 9L1 and 18L4 feeders. The 14L4 feeder has been extended from Pelham NH to Salem NH to provide temporary load relief on the 18L4 feeder to allow Tuscan Village to grow as the recommended solution is implemented. Until the recommended solution is implemented, the development will not be able to fully expand to its final configuration due to the lack of capacity of the distribution system.

4.2.1.3 Feeders

Analysis resulted in the following violations:

- Salem Depot 9L1 Feeder at 99% in 2022, up to 102% in 2036

Loading percentages are versus Summer Normal Ratings. See Appendix C – Area Loading Analysis, Table 14.

4.2.2 N-1 Contingency & Load at Risk

4.2.2.1 Sub-Transmission System

The Salem 22.8 kV distribution system was originally designed as a dual fed and redundant system with automatic transfer schemes at the substations. If loading exceeds the emergency rating on the adjacent line, steps need to be taken to block transfer at substation which could potentially result in prolonged outages to avoid overload and damage to equipment. While some overloads may not result in excess of 120 MWHr criteria, all supply line overloads are prevented, as they could constitute a conductor sag hazard or could cause permanent damage to equipment. Once an interruption occurs, there are several steps that are taken to ensure that the load can be strategically and safely be placed back in service to within ratings of the equipment. This could result in many customer outages of long duration.

Analysis resulted in the following predicted violations:

- 2352 overloads:
    - Golden Rock to Barron Ave Tap at 99% in 2022, up to 102% in 2036
    - Olde Trolley Tap to Olde Trolley at 104% in 2022, up to 107% in 2036
- 2393 overloads:
    - Golden Rock to Barron Ave Tap at 99% in 2022, up to 102% in 2036
    - Barron Ave Tap to Olde Trolley Tap at 115% in 2022, up to 118% in 2036
    - Olde Trolley Tap to Olde Trolley at 104% in 2022, up to 107% in 2036
- 2353 MECo to Golden Rock at 142% in 2022, up to 149% in 2036.

Loading percentages are versus Summer Emergency Ratings. See Appendix C – Area Loading Analysis, Table 18.

4.2.2.2 Transformers

Analysis resulted in the following violations:

- Salem Depot 9L1 Transformer at 119% in 2022, up to 123% in 2036
- Salem Depot 9L2 Transformer at 131% in 2022, up to 135% in 2036
- Salem Depot 9L3 Transformer at 104% in 2022, up to 107% in 2036
- Olde Trolley 18L1 Transformer at 98% in 2022, up to 101% in 2036
- Olde Trolley 18L2 Transformer at 98% in 2022, up to 101% in 2036
- Olde Trolley 18L3 Transformer at 97% in 2022, up to 100% in 2036
- Olde Trolley 18L4 Transformer at 97% in 2022, up to 100% in 2036

Loading percentages are versus Summer Emergency Ratings. See Appendix C – Area Loading Analysis, Table 17).

4.2.2.3 Feeders

Analysis resulted in the following Year 2022 violations:

- Spicket River 13L2 Feeder has a MWHr violation at 17.5 MWHrs
- Olde Trolley 18L3 Feeder has a MWHr violation at 23.5 MWHrs
- Olde Trolley 18L4 Feeder has a MWHr violation at 23.4 MWHrs

4.3 Asset Condition

ControlPoint and Liberty Utilities' Engineering and Substation teams reviewed asset conditions within the Study Area. The evaluation included the following:

1. Site visits to all Salem area Stations.

2. Review of past condition assessment reports provided to Liberty Utilities by National Grid and by United Power Group, Inc in 2014.

3. Review - National Grid Internal Strategy Document Distribution Substation Transformers Revised Strategy – October 2009.

4. Recent DGA Tests for available transformers at Barron Ave and Salem Depot.

5. Consultation with Liberty Utilities' Operations and Control Center personnel

6. Walkthrough of the area substations with PUC Staff. This walkthrough was performed in June 2020 with PUC Staff to visit all of the Salem Area substations to discuss benefits of the 115kV sourced substations and drawbacks and limitations of the existing 23kV sourced substations. Preliminary findings of the Salem Area Study was provided for discussion.

Field reviews assessed the feasibility of adding additional modular feeder positions at each substation and upgrading existing equipment. Asset condition concerns were found at Barron Ave and Salem Depot Substations and are documented below.

4.3.1 Barron Ave Substation

The following is a list of asset condition concerns at Barron Ave Substation:

- The substation was originally constructed in early 1960s
- In 2009, the 10L1 supply transformer was deemed in "need of replacement" by 2014 due to "combustible gasses present"[6]
- The 10L1 Transformer bushings are showing signs of deterioration.[7]
- In 2009, the 10L4 supply transformer was deemed in "need of replacement" by 2025 due to "combustible gasses present" [8]

[6] Annex A - National Grid Internal Strategy Document Distribution Substation Transformers Revised Strategy – October 2009

[7] Annex B – 10L1 Testing & Maintenance Report: United Power Group - August 2014

[8] Annex A - National Grid Internal Strategy Document Distribution Substation Transformers Revised

- The 10L4 Transformer bushings are showing signs of deterioration and are leaking oil around the bottom valve.[9]
- The 10L1 recloser has a McGraw-Edison Form 3 Control, which uses cartridges to select a limited number of protection curves. The device is obsolete, so finding a reliable source for new cartridges or parts is difficult. Other area utilities are actively retiring Form 3s because of its shortcomings with protection coordination and parts availability.
- Circuit Regulator Contacts are nearing end of useful life. The internal contacts are not a regular maintenance items, typical practice would be to replace the units entirely.
- Height to live parts inside the substation is below minimum height clearance requirements for a modern substation (See Appendix B – Asset Condition Documents, Figure 49, Figure 50, and Figure 51). Space is limited for new equipment access for installation & maintenance. Maintenance work near live parts requires extra time and/or outages to be able to maintain worker safety. The load growth in the area will further strain the equipment and will limit the ability of the Company to re-supply the load from alternate supplies to perform maintenance and/or emergency restorations.
- Recent Dissolved Gas Analysis (DGA) tests from April 2020 concluded that 10L1 and 10L2 transformers are both showing elevated levels of carbon monoxide and/or carbon dioxide, indicating signs of overheated cellulose insulation.[10]
- System Control has multiple concerns with operating the facilities at Barron Ave Station. Lack of monitoring and remote control of the equipment is a major concern. It is difficult to react efficiently while being forced to rely on customer calls for outages. Additional safety concerns exist given the lack of ability to remotely de-energize facilities quickly in emergency situations.

4.3.2 Salem Depot Substation

The following is a list of asset condition concerns at Salem Depot Substation:

- The substation was originally constructed in 1950s
- The existing 9L1 and 9L2 Breaker Positions and bus are constructed on Wood Pole Structures with limited clearance. The concern with wood pole structures is they lose their structural integrity over time. This deterioration causes equipment and brackets containing equipment to not function as designed and could lead to catastrophic equipment failure and faults during operation. In addition, maintenance work near live parts requires extra time and/or outages to be able to maintain worker safety. The added load growth will limit the ability of the Company to re-supply load from alternate supplies to perform maintenance and/or emergency restorations.
- Both the 9L1 and 9L2 transformers contain Polychlorinated Biphenyl (PCB) oil. The 9L1 contains 690 gallons of PCB oil. The 9L2 transformer contains 1,010 gallons of PCB oil. PCB oil is a widely recognized environmental risk.

Strategy – October 2009

[9] Annex C – 10L4 Testing & Maintenance Report: United Power Group - September 2014

[10] Annex E – 2020 Dissolved Gas Analysis: Weidmann

- Height to live parts inside the substation is below minimum height clearance requirements for a modern substation (See Appendix B – Asset Condition Documents, Figure 52, Figure 53, and Figure 54).
- 9L1 has shown previous history of combustible gas over 1,000 (µL/L). In 2009 it was recommended to be replaced by 2014.[11]
- 9L2 has shown previous history of combustible gas over 1,000 (µL/L). In 2009 it was recommended to be replaced by 2014. Recent tests indicate an immediate risk of failure.[12]
- 9L3 has shown previous history of elevated combustible gas. In 2009 it was recommended to be replaced by 2025. [13]
- 9L1 and 9L2 Circuit Regulator Contacts are nearing end of useful life. Typical practice would be to replace the units entirely.
- The existing bus structure configuration for two of the existing feeders greatly restricts the ability to upgrade/replace the existing transformers and require a complete rebuild.
- The 9L3 Transformer 9T3's H3 bushing is showing signs of deterioration.[14]
- System Control has multiple concerns with operating the facilities at Salem Depot Station. Lack of monitoring and remote control of the equipment is a major concern. It is difficult to react efficiently while being forced to rely on customer calls for outages. Additional safety concerns exist given the lack of ability to remotely de-energize facilities quickly in emergency situations.

4.3.3 New 22.8 / 13.2 kV Substation Construction Feasibility

It is expected per the Asset Condition Review performed by ControlPoint that any new feeder additions or equipment replacements at either Barron Ave or Salem Depot Substations will trigger significant modifications and the need for complete rebuild of the substations to ensure proper OSHA/NESC clearances for worker safety, and conformance with Company requirements for SCADA, GridMod, communications, and other monitoring and control protocols.

Safety concerns with improper clearances would require large portions of the substation to be de-energized and re-supplied from alternate feeds while the modifications are made. The load growth in the area will prevent these planned outages from taking place and could impact the Company’s ability to modify these substations and meet customer expectations of electric service in a timely manner.

Conceptual designs were developed as a part of the review to approximate the required footprint needed to rebuild Barron Ave and Salem Depot Substations. The conceptual designs account for the space needed for incoming 22.8 kV supply lines, 22.8 kV protective devices, supply transformers, 13.2 kV breakers, circuit regulators

[11] Annex A - National Grid Internal Strategy Document Distribution Substation Transformers Revised Strategy – October 2009

[12] **Annex E – 2020 Dissolved Gas Analysis: Weidmann**
Barron Ave 10L2 - Test Report #

[13] Annex A - National Grid Internal Strategy Document Distribution Substation Transformers Revised Strategy – October 2009

[14] Annex D – 9L3 Testing & Maintenance Report: United Power Group - August 2014

and space to accommodate maintenance for each modular feeder position. See Appendix B – Asset Condition Documents, Figure 45 and Figure 46 for conceptual equipment layouts, and Figure 47 and Figure 48 for site layout sketches. Please note that the substation designs are conceptual, meant only to approximate required space for new facilities.

At Barron Ave Substation, the space for a substation rebuild to accommodate an anticipated (4) four 13.2 kV feeders is limited by the existing parcel. The Spicket River travels along the southern border of the parcel, Public Way limits the northern border, and the Salem Rail Trail limits the eastern border.

A rebuild of the substation would require much of the existing infrastructure to be temporarily moved or taken out of service to make room for new construction. Operating the system with these facilities unavailable presents many challenges. With the existing off-schedule equipment, construction would be limited to light loading periods, and additional outages could prove difficult to restore. Care would need to be taken to avoid environmental concerns associated with temporary or permanent construction in the vicinity of Spicket River. Integrating adequate access to the equipment for operation and maintenance, expanding the station footprint, adding a control house, developing feeder getaway routes, all present challenges.

Salem Depot Substation also has space constraints for additions or rebuild of the substation. To get an anticipated five (5) 13.2 kV feeders served from Salem Depot, the required substation footprint challenges the limits of the parcel. A rebuild of the substation would require much of the existing infrastructure to be temporarily moved or taken out of service to make room for new construction. Operating the system with these facilities unavailable presents many challenges. With the existing off-schedule equipment, additional outages could prove difficult to restore. Integrating adequate access to the equipment for operation and maintenance, expanding the station footprint, adding a control house, developing feeder getaway routes, all present challenges.

At Salem Depot Substation, purchase of the parcels adjacent to the existing substation parcel was investigated. The property owner of the nearby residential property was not interested in selling. When contacted, the now vacant lot which previously held a restaurant was not interested in selling. Since then, the restaurant is no longer operating due to fire damage.

4.4 Power Quality & Voltage Performance

4.4.1 Supply System Loss Comparison

Each of the studied supply system configurations was evaluated for performance from a system losses perspective. These values represent losses on the supply system, including supply transformers, with proposed Tuscan Village load. See Section 3.4 for configuration descriptions.

- Supply Configuration #1 (@ 22.8 kV): Area losses: 2.1 + j26.9 MVA = 26.98 MVA
- Supply Configuration #2 (@ 115 kV): Area losses: 1.0 + j15.4 MVA = 15.43 MVA

Results show that the options utilizing a 115 kV supply system would have approximately half the kW supply losses when compared to a 22.8 kV supply system. Under a 115kV supply configuration, Liberty's distribution customers could save up to $761,813 annually. With regards to energy service, customers could save up to $623,633 annually. This reflects transmission savings.

4.4.2 13.2 kV Distribution System Loss Comparison

Each of the studied distribution system configurations was evaluated for performance from a system losses perspective. These values represent losses on the primary (13.2 kV) lines only, with proposed Tuscan Village load.

Alt # 1 Feeder	Alt # 1 Feeder kW Losses	Alt # 2 Feeder	Alt # 2 Feeder kW Losses	Alt # 3 Feeder	Alt # 3 Feeder kW Losses	Alt # 4 Feeder	Alt # 4 Feeder kW Losses	Alt # 5 Feeder	Alt # 5 Feeder kW Losses	Alt # 6 Feeder	Alt # 6 Feeder kW Losses	Alt # 7 Feeder	Alt # 7 Feeder kW Losses
10L1	110.55	10L1	132.17	10L1	157.74	10L1	8.17	10L1	8.24	21L1	46.23	10L1	51.58
10L2	31.55	10L2	156.07	10L2	57.75	10L2	150.35	10L2	149.90	21L5	127.82	10L2	19.50
10L4	40.01	10L4	33.86	10L4	33.86	10L4	40.01	10L4	40.03	13L1	196.33	10L4	33.84
13L1	206.79	13L1	194.34	13L1	41.11	10L5	40.88	21L11	23.18	13L2	95.54	13L1	195.38
13L2	114.89	13L2	95.55	13L2	20.11	13L1	22.26	13L1	41.11	13L3	93.59	13L2	94.44
13L3	79.22	13L3	96.92	13L3	9.94	13L2	23.59	13L2	23.31	18L1	7.06	13L3	91.90
18L1	5.79	18L1	7.01	18L1	192.02	13L3	5.79	13L3	25.18	18L2	35.43	18L1	7.01
18L2	0.02	18L2	2.82	18L2	7.06	14L4	123.17	14L4	262.18	18L3	109.96	18L2	78.56
18L3	118.16	18L3	110.14	18L3	2.82	18L1	108.8	18L1	7.06	18L4	123.94	18L3	108.79
18L4	3.26	18L4	10.55	18L4	108.79	18L2	3.31	18L2	124.55	21L6	45.27	18L4	48.07
9L1	29.06	9L1	29.06	9L1	10.55	18L3	294.01	18L3	108.79	21L7	7.95	9L1	27.28
9L2	26.53	9L2	35.84	9L2	10.14	18L4	6.09	18L4	3.31	21L8	31.22	9L2	35.84
9L3	76.50	9L3	106.51	9L3	35.84	9L1	9.68	9L1	9.69	19L4	13.14	9L3	104.70
19L4	8.34	19L4	13.14	19L4	106.51	9L2	35.83	9L2	35.84	19L6	48.27	19L4	98.87
19L6	3.23	19L6	60.11	19L6	13.14	9L3	106.51	9L3	106.51	19L8	50.78	19L6	1.64
19L8	388.96	19L8	205.17	19L8	310.16	9L4	49.47	21L9	317.47	14L4	3.71	14L6	112.50
14L4	486.26	14L4	192.02	14L4	205.17	9L5	334.24	21L10	43.63			14L4	401.91
				10L5	33.06								
				9L4	0.08								
				9L5	334.24								
Alt # 1 Total Losses	1,729.12	Alt # 2 Total Losses	1,481.28	Alt # 3 Total Losses	1,690.09	Alt # 4 Total Losses	1,362.16	Alt # 5 Total Losses	1,329.98	Alt # 6 Total Losses	1,036.24	Alt # 7 Total Losses	1,511.81

Table 7 13.2 kV Feeder Losses by Alternative

4.4.3 Power Quality – Existing Violations

4.4.3.1 Normal Configuration

22.8 kV Sub Transmission System

Olde Trolley 23 kV bus at .9411 per-unit and Salem Depot 23 kV bus at .9328 per-unit.

Feeders

Analysis resulted in no violations.

4.4.3.2 N-1 Contingency

Sub Transmission System

Olde Trolley 23 kV bus at .87171 per-unit for either 2352 or Golden Rock 115/23 kV transformer out-of-service.

Salem Depot 23 kV bus at .86229 per-unit for either 2352 or Golden Rock 115/23 kV transformer out-of-service.

Feeders

Voltage violations exist during 13L1 contingency. Refer to Appendix C – Area Loading Analysis, Figure 55.

4.4.4 Power Quality – Proposed Plans

Analysis of multiple Alternative Plans resulted in the following remaining voltage violations. See Appendix F – 22.8 kV Voltage Analysis for details.

Alternative Plan 3 analysis resulted in the following voltage violations during contingency:

- Salem Depot 23 kV bus at .9375 per-unit. Olde Trolley 23 kV bus at .9471 per-unit during normal operating conditions.
- Olde Trolley 23 kV bus at .87857 per-unit for 2352 and Golden Rock 115/23 kV transformer out-of-service.
- Salem Depot 23 kV bus at .8676 per-unit for 2352 and Golden Rock 115/23 kV transformer out-of-service.

Alternative Plan 5 analysis resulted in the following voltage violations during contingency:

- Salem Depot 23 kV bus at .87524 per-unit for 2352 out-of-service. Rockingham 23 kV bus at .88188 per-unit for 2352 or second new line out-of-service.

Alternative Plan 7 analysis resulted in the following voltage violations during contingency:

- Olde Trolley 23 kV bus at .89932 per-unit for Golden Rock 115/23 kV transformer out-of-service.
- Salem Depot 23 kV bus at .89206 per-unit for Golden Rock 115/23 kV transformer out-of-service.

5.0 Plan Development

After identifying all existing and anticipated problems with the Salem Area, plans were developed to address system deficiencies.

Plan One through Plan Five focused on alternatives that made attempts to utilize and invest in the 22.8 kV system to address area issues. Plan Six was very similar to the 2016 Study recommended plan, utilizing the new Golden Rock Substation's 115kV/13.2kV transformer and proposed Rockingham Station's two 115 kV / 13.2 kV transformers to provide area load relief and support retirement of deteriorating 22.8 kV assets. Plan Seven utilizes the new Golden Rock Station 115kV/13.2kV transformer along with the existing 22.8kV/13.2kV modular feeders and installs an additional new 13.2 kV feeder circuit from Pelham Station #14 to offload Olde Trolley Station load.

It should be noted that Plans Four and Five are no longer feasible given the recent installation of a 115kV / 13.2kV transformer at Golden Rock Substation, which has been approved by NHPUC Staff. The installation of a 115kV / 13.2kV transformer at Golden Rock, common in Plans One, Two, Three, Six, and Seven of this study, provides much needed load relief to the 13.2 kV system in the area, and allows load to be transferred from the 22.8 kV supply system that without it, has existing first contingency MWHr violations. Plans Four and Five were developed for this study as a hindsight review to compare Plan 6 to Plans Four and Five, which are focused on expanding the 22.8 kV Sub-transmission system in the area.

Plans One through Three, and Plan Seven rely on an adequate supply from the *existing* 22.8 kV supply system to satisfy the area needs. The 22.8 kV supply system capabilities were analyzed in parallel with the distribution study. See Section 6.0 and Appendix C – Area Loading Analysis for details.

5.1 Plan Summary

- Plan One – NH PUC Staff Recommended Plan - Install a second 115 kV transmission line into Golden Rock Station supplying a new 115 kV/13.2 kV, 33/44/55 MVA, substation transformer with up to four (4) new circuit positions. Install three 13.2 kV feeders at Golden Rock Substation to reduce Spicket River Station load at risk, supply Tuscan Village and support system contingencies. Add four 2,500 kVA generators to provide additional non-wires contingency support. <u>This plan is estimated at $11,410,000.</u> (See Figure 5,Figure 6,Figure 7,Figure 8,Figure 9).

- Plan Two – Install a second 115 kV transmission line into Golden Rock Station supplying a new 115 kV/13.2 kV, 33/44/55 MVA, substation transformer with up to four (4) new circuit positions. Install three 13.2 kV feeders at Golden Rock Substation to reduce Spicket River Station load at risk supply Tuscan Village and support system contingencies. Rebuild Barron Ave and Salem Depot Substations to resolve issues with equipment condition. This plan is estimated at $24,000,000. (See Figure 10,Figure 11,Figure 12,Figure 13).

- Plan Three - Install a second 115 kV transmission line into Golden Rock Station supplying a new 115 kV/13.2 kV, 33/44/55 MVA, substation transformer with up to four (4) new circuit positions. Install three 13.2 kV feeders at Golden Rock Substation to reduce Spicket River Station load at risk, supply Tuscan Village and support system contingencies. Install one new feeder at Barron Ave and two new feeders at Salem Depot substations to supply Tuscan Village and support system contingencies. Rebuild remaining modular feeder at Barron Ave and Salem Depot Stations to resolve issues with equipment condition. This plan is estimated at $35,310,000. (See Figure 14, Figure 15, Figure 16, Figure 17)

- Plan Four - Install a second 115 kV transmission line into Golden Rock Station supplying a new 115 kV/22.8 kV, 33/44/55 MVA, substation transformer with four (4) new circuit positions. From the Golden Rock Substation, install one new double circuit 22.8 kV pole line along the 22.8 kV Right of Way. Install one new 13.2kV modular feeder at Barron Ave and two new 13.2kV modular feeders at Salem Depot substations to supply Tuscan Village and support system contingencies. Rebuild remaining modular feeder at Depot Ave and Salem Depot Stations to resolve issues with equipment condition. This plan is estimated at $33,940,000. (See Figure 18, Figure 19, Figure 20, Figure 21)

- Plan Five - Install a second 115 kV transmission line into Golden Rock Station supplying a new 115 kV/22.8 kV, 33/44/55 MVA, substation transformer with up to four (4) new circuit positions. From the Golden Rock Substation, install two new double circuits 22.8 kV pole line along the 22.8 kV Right of Way. Rebuild Barron Ave and Salem Depot Stations to resolve issues with equipment condition. Install a 22.8/13.2 kV Substation with three modular feeders at Tuscan Village. This plan is estimated at $33,150,000. (See Figure 22,Figure 23,Figure 24,Figure 25,Figure 26)

- Plan Six - Install a second 115 kV transmission line into Golden Rock Station supplying a new 115 kV/13.2 kV, 33/44/55 MVA, substation transformer with up to four (4) new circuit positions. Install three 13.2 kV feeders at Golden Rock Substation to reduce Spicket River Station load at risk and retire the Barron Ave Substation. Install two 115 kV transmission lines into Rockingham Station supplying two new 115 kV/13.2 kV, 33/44/55 MVA, substation transformers with up to five (5) new circuit positions each. Install five 13.2 kV feeders at Rockingham Substation to supply Tuscan Village, support system contingencies and retire Salem Depot Substation. This plan is estimated at $35,490,000. (See Figure 27, Figure 28,Figure 29,Figure 30,Figure 31,Figure 32,Figure 33, Figure 34, Figure 35,Figure 36,Figure 37, and Figure 37)

- Plan Seven – Installs a 115 kV transmission line into Golden Rock Station supplying a new 115 kV/13.2 kV, 33/44/55 MVA, substation transformer with up to four (4) new circuit positions. Install two 13.2 kV feeders at Golden Rock Substation to reduce

Spicket River Station load at risk and support system contingencies. Add a second 13.2 kV feeder 14L5 from the Pelham 115kV/13.2kV Station to off load the Olde Trolley 22.8kV/13.2kV Station to supply Tuscan Village and support system contingencies. Rebuild Barron Ave and Salem Depot Substations to resolve issues with equipment condition. This plan is estimated at $25,100,000. (See Figure 38,Figure 39,Figure 40,Figure 41,Figure 42,Figure 43,Figure 44)

6.0 Plan Considerations and Comparisons

The effectiveness of each plan to address the identified system deficiencies, including asset conditions, and meet company strategies are evaluated based on System Performance, Operability, Future Growth/Expansion Opportunities, Cost and Reserve Capacity Provided.

System Performance is evaluated based on the plan's potential to deliver reliable power to customers. In general, new supply sources should be located as close as possible to the load centers to minimize line losses, maintain voltages within limits and to minimize exposure of circuits to outages. Densely populated feeders and longer feeders experience more losses, have a higher rate of interruption and impact to system reliability. In addition, long feeders pose a challenge in maintaining nominal voltages within acceptable range. Each plan is evaluated on its ability to maintain nominal voltage within +/- 5% of nominal voltage during peak loading conditions and customer exposure to interruptions.

Operability is evaluated based on how the plan impacts the safe and efficient operation of the electric system. It evaluates how the plan's proposed additions affects the safety of field personnel and utility workers operating the electric distribution system and how it improves the ease of operation. Operability is also evaluated on how the plan aligns with the Company's strategy to be local and responsive to the needs of our customers and to reduce the reliance on the transmission provider. It is based on the plan's ability to meet the company's distribution planning criteria which represents the capability of the distribution system to provide reliable power during system intact conditions and first contingency conditions. It also represents the ability for the company to appropriately manage day-to-day contingency and storm operating risks given the company's resource base.

Future Growth is evaluated based on the plan's potential to enable future infrastructure additions and provide for expansion opportunities. For example, a plan that installs a substation nearest the load centers and has room for expansion, has better growth opportunities than a plan that installs a substation with a smaller footprint, away from the load centers.

Capacity provided is evaluated based on the plan's amount of reserve capacity gained for distribution feeders, substation transformers and supply lines beyond the present distribution system capabilities. Capacity provided is analyzed by determining the ratio of reserve capacity gained per dollar invested.

Each plan specifies capacity in two classes; Total MVA capacity and Firm MVA capacity. Total MVA capacity can be defined in this study as overall capacity made available. Firm MVA capacity gives a measure of the ability of the Plan to continue to provide capacity in absence of one major component. Total MVA capacity is often never fully available or utilized, as excess capacity always needs to be available for contingency scenarios. For example, a double-ended substation containing two supply transformers, each rated at 50 MVA thermal, would provide

100 MVA of Total MVA capacity, and 50 MVA of Firm MVA capacity. To responsibly plan for first contingency (i.e. bus, transformer, or supply failure), the loading on the substation should not be designed to serve much more than the Firm capacity, 50 MVA in this example, during normal peak conditions, so that capacity can be available in a first contingency scenario. The geographical location and ratings of feeders can also limit the available or utilized capacity of a transformer.

The effectiveness of each plan in addressing each of these areas in a cost-effective manner was evaluated.

6.1 Plan One

6.1.1 System Performance

Plan One installs a new 115 kV supply to a new 115/13.2kV transformer and three distribution feeders at the Golden Rock Substation. It adds four 2.5 MVA generators for backup power, one at Barron Ave, one at Salem Depot and two at Spicket River. This plan extends the Golden Rock 19L8 feeder and the Barron Ave 10L2 feeder approximately 2.5 miles and 1.6 miles respectively to supply the Tuscan Village Development. This results in long feeders to reach the load centers, resulting in increased kW losses. Please note that the 14L4 circuit was used during analysis to serve load planned for the 10L2 under this Plan. It is expected that kW losses shown on the 14L4 would be transferred to the extension of the 10L2.

6.1.2 Operability

Plan One does not resolve existing concerns with substation equipment at Salem Depot and Barron Ave and will further increase safety hazard risk, maintenance activities, risk of equipment failure and other concerns described in Section 4.3. Generator refueling and maintenance located at a substation that already has existing maintenance concerns also presents an operability challenge. Locating diesel fuel storage in close proximity to aging substation equipment could also prove hazardous in the event of a fire.

Strategically placed voltage support equipment such as line capacitors and regulators are required to resolve low voltage issues during a Spicket River supply contingency. Cascading load and adding voltage support results in operability challenges with partial re-supply, occupying valued resources during major outage events. Refer to Appendix E – Spicket River Backup Analysis for backup overview.

This plan is not consistent with the company's initiatives in resiliency and grid modernization and could negatively impact the Company's response to storms and emergencies. The lack of SCADA at Salem Depot and Barron Ave Substations limits visibility for emergency response. The Plan does not address any of the asset needs at those substations and limits the ability to implement any automated restoration schemes, or protection schemes related to future DER or smart grid integration.

This plan does the bare minimum to serve Tuscan Village, leaving 22.8 kV circuits mostly unavailable to re-supply Golden Rock during a contingency event. See

Appendix C – Area Loading Analysis, Table 23. This plan results in a load at risk at Golden Rock that is above the allowable per the Distribution Planning Criteria. See Appendix D – MWHr Summary. This makes outage planning longer and more difficult. It also does not reduce the reliance on the transmission provider.

6.1.3 Future Growth / Expansion Opportunities

Plan One provides limited opportunities for future expansion of the distribution system. It provides capacity to supply predicted growth in the Tuscan Village during system intact conditions but fails to adequately support the area's predicted demand during first contingency condition. This plan only provides four feeders to be used for future load growth at the Golden Rock Substation, three of which would be utilized under this plan. With no additional capacity available on the 22.8 kV sub-transmission system, future growth will require a large investment to provide additional capacity similar to what is being proposed with Plan Six.

6.1.4 Capacity Provided

Plan One provides the least capacity from all plans considered. Appendix G – Comparison of Plans – Cost vs Added Capacity shows predicted feeder capacity resulting from Plan One and how it compares with other Alternative Plans considered. It is estimated that this plan will provide a total MVA increase of 88.7 MVA and available Firm increase of 10.0 MVA.

6.1.5 Economic Comparison

Plan One is estimated at $11,410,000[15], of which $3,500,000 has been spent to date.

When reviewing cost per MVA capacity provided, Plan One has a cost of approximately $129,000 per MVA of total capacity provided, and
It also has a cost of approximately $1,410,000 per MVA of firm capacity provided.

Here is where this Plan compares with the other proposed Plans:

- Overall Cost: Lowest
- Cost per Total MVA Capacity: Lowest
- Cost per Firm MVA Capacity: Highest

6.1.6 Other Considerations

Alternative Plan #1 incorporates the use of "non-wires", using local diesel generation to help support contingency issues.

Alternative Plan #1 comes with unique siting challenges for diesel generation, fuel

[15] It should be noted that Plan One also carries with it an estimated annual operating expense of $200,000 per year for the proposed diesel generation.

storage, and electrical facilities to accommodate connection to the 13.2 kV distribution at each substation. While there exists adequate real estate to add diesel generators, installations at Barron Ave and Salem Depot will require modification of the substation fence to fit the new facilities. Diesel generator installation at the substations will be challenging due to its proximity to residential customers, where noise pollution will be a concern. Storage of diesel fuel and the refueling of the generator would present an environmental hazard and permitting challenge. Furthermore, wetlands just to the south (Spicket River) pose environmental concerns for any new construction at Barron Ave.

Alternative Plan #1 presents concerns with noise pollution and air pollution from burning diesel fuel. The installation includes two large tractor trailers containing the generator, fuel tank transformer and protective equipment. Barron Ave Substation will require electrical facilities to be expanded closer to the residential customer on the western parcel boundary. A Residential customer adjacent to the substation has been vocal with complaints with the Substation aesthetics, noise, and work being performed at Barron Ave.

6.2 Plan Two

6.2.1 System Performance

Plan Two installs a new 115 kV supply to a new 115/13.2kV transformer and three distribution feeders at the Golden Rock Substation. It builds on Plan One by rebuilding the existing modular feeders at Barron Ave Station and at Salem Depot Station. This plan extends the Golden Rock 19L8 feeder and the Barron Ave 10L2 feeder approximately 2.5 miles and 1.6 miles respectively to supply the Tuscan Village Development. This results in long feeders and the same system performance issues as discussed in Plan One.

6.2.2 Operability

Plan Two, with the rebuilding of the substation equipment at Salem Depot and Barron Ave, resolves the asset condition concerns. The rebuilding of these substations also improves resiliency, providing SCADA for system operators and adequate work clearances for line workers.

However, this plan lacks the necessary capacity to re-supply the Golden Rock substation during first contingency, resulting in MWHr violations that are above the allowable limit per the Planning Criteria. Refer to Appendix D – MWHr Summary. Refer to Appendix E – Spicket River Backup Analysis for backup overview. It also does not reduce the reliance on the transmission provider. Increasing modular transformer capacity while not addressing loaded supply lines will not add useable capacity to address area issues. The limitation of the 22.8 kV system to supply the increased load during contingency conditions make system restoration difficult or impossible, making this Plan impractical.

6.2.3 Future Growth / Expansion Opportunities

Similar to Plan One, Plan Two provides limited opportunities for future expansion of the distribution system. It provides capacity to supply predicted growth in the Tuscan Village during system intact conditions but fails to adequately support the area's predicted demand during first contingency condition.

This plan only provides four feeders to be used for future load growth at the Golden Rock substation, three of which would be utilized under this plan. Although Salem Depot Substation and Barron Ave Substations are rebuilt under this plan with additional feeder availability, lacking capacity available on the 22.8 kV sub-transmission system limits the overall load-carrying capability of the two substations. See Appendix C – Area Loading Analysis, Table 27 and Table 28. As a result, future growth will also require a large investment to provide additional capacity, similar to what is being proposed with Plan Six.

6.2.4 Capacity Provided

Plan Two provides the third least capacity from all plans considered. Appendix G – Comparison of Plans – Cost vs Added Capacity shows predicted feeder capacity resulting from Plan Two and how it compares with other Alternative Plans considered. It is estimated that this plan will provide a total MVA increase of 104.7 MVA and available Firm increase of 17.1 MVA.

6.2.5 Economic Comparison

Plan Two is estimated at $24,000,000, of which $3,500,000 has been spent to date.

When reviewing cost per MVA capacity provided, Plan One has a cost of approximately $229,000 per MVA of total capacity provided, and
It also has a cost of approximately $1,403,000 per MVA of firm capacity provided.

Here is where this Plan compares with the other proposed Plans:

- Overall Cost: 2nd Lowest
- Cost per Total MVA Capacity: 2nd Highest
- Cost per Firm MVA Capacity: 2nd Highest

6.2.6 Other Considerations

Alternative Plans #2 and #3 (described below) each require complete rebuilds of Barron Ave and Salem Depot Substations, where Salem Depot would likely require additional real estate acquisition. Refer to Section 4.3.3 for further discussion. The land required for a Substation rebuild at Barron Ave may be available, but is limited, due to Spicket River along the southern border of the parcel, Barron Ave to the north, residential property to the west, and Salem Rail Trail to the east. To utilize the existing parcel, the existing Barron Ave facilities would require removal. This puts added stress on the other modular substation transformers and further limits the system during contingency. Wetlands concern also limits the space available at Barron Ave for a complete rebuild. To rebuild Salem Depot, additional real estate acquisition would be required on parcels just north of the Substation, where the Customer was approached by Liberty and was not interested in selling. Liberty Utilities owns a 6,100' square foot strip of land adjacent to Salem Depot on Middle Street, where could be made available for an additional feeder position, however two underground feeder getaways (9L2 and 9L3) are currently routed through the parcel, along with one overhead line (9L1) and pole mounted recloser, that would require relocation. It should be noted that these feeder relocations were not considered in the Plan (applicable to Plans 2,3,4,5,7) estimates.

6.3 Plan Three

6.3.1 System Performance

Similar to Plan Two, Plan Three installs a new 115 kV supply to a new 115/13.2 kV transformer and three distribution feeders at Golden Rock Substation. Like Plan Two, It rebuilds the existing modular feeders at Barron Ave Station and at Salem Depot Station. It builds on Plan Two by installing one new modular feeder at Barron Ave Station and two new modular feeders at Salem Depot Station.

Modeling of the 23kV system identified the following violations of the Distribution Planning Criteria related to voltage performance. Refer to Appendix F – 22.8 kV Voltage Analysis.

During normal operation, Plan 3 results in voltages as low as 0.9375 per-unit at the Salem Depot 23kV bus and 0.9471 per-unit at the Olde Trolley 23kV bus.

During contingency operation, Plan 3 results in voltages as low as 0.879 per-unit at the Olde Trolley 23kV bus for either a 2352 outage or a Golden Rock T1 transformer outage. It also results in voltages as low as 0.877 per-unit for either a 2352 outage or a Golden Rock T1 transformer outage.

6.3.2 Operability

Plan Three proposes to rebuild the substation equipment at Salem Depot and Barron Ave, resolving the asset condition concerns. Refer to Section 4.3.3 for further discussion. This plan is consistent with the company's initiatives in resiliency and available capacity but still has shortcomings due to lack of supply capacity during contingencies. This plan lacks the necessary capacity to re-supply the Golden Rock substation during first contingency, resulting in MWHr violations that are above the allowable limit per the Planning Criteria. Refer to Appendix D – MWHr Summary. It also does not reduce the reliance on the transmission provider. This plan is not sustainable due to the existing 22.8 kV sub-transmission system's lack of capacity with no available source to supply it. See Appendix C – Area Loading Analysis, Table 33. The limitation of the 22.8 kV system to supply the increased load make this Plan impractical.

6.3.3 Future Growth / Expansion Opportunities

Plan Three does not provide for future capacity additions, as substations are expanded to their maximum footprint. The ultimate design of five feeders from the Salem Depot Substation, four feeders from Barron Ave coupled with the opportunity to install an additional four feeders from the Golden Rock substation adds adequate capacity on the 13.2 kV system. However, as stated for Plan Two, increasing modular transformer capacity while not addressing loaded supply lines will not add useable capacity to address area issues. There is no capacity available to support the installed capacity from the 22.8 kV sub-transmission system and as such this Plan is not viable. See Appendix C – Area Loading Analysis, Table 33.

To accommodate any future expansion or growth, a plan such as Plan Six will be required.

6.3.4 Capacity Provided

Plan Three provides the fourth least capacity from all plans considered. Appendix G – Comparison of Plans – Cost vs Added Capacity shows predicted feeder capacity resulting from Plan Three and how it compares with other Alternative Plans considered. It is estimated that this plan will provide a total MVA increase of 146.9 MVA and available Firm increase of 60.3 MVA. Lack of capacity provided by this plan on the 22.8 kV system makes this Plan not viable.

6.3.5 Economic Comparison

Plan Three is estimated at $35,310,000, of which $3,500,000 has been spent to date.

When reviewing cost per MVA capacity provided, Plan Three has a cost of approximately $240,000 per MVA of total capacity provided, and
It also has a cost of approximately $586,000 per MVA of firm capacity provided.

Here is where this Plan compares with the other proposed Plans:
- Overall Cost: 2nd Highest
- Cost per Total MVA Capacity: Highest
- Cost per Firm MVA Capacity: 4th Highest

6.3.6 Other Considerations

Plan Three has the same siting concerns as discussed in Plan Two.

6.4 Plan Four

This plan review was for comparison only and is not feasible. See Section 5.0.

6.4.1 System Performance

Plan Four installs a new 115 kV supply to a new 115/22.8 kV transformer and one 22.8 kV feeder at Golden Rock Substation. It rebuilds the existing modular feeders at Barron Ave Station and at Salem Depot Station. It also installs one new modular feeder at Barron Ave Station and two new modular feeders at Salem Depot Station. This plan extends the Barron Ave 10L2 feeder approximately 1.6 miles to supply the Tuscan Village Development. Reliability concerns posed by aging and obsolete equipment is mitigated by the replacement of the aging equipment at Salem Depot and Barron Ave Substations.

6.4.2 Operability

Plan Four has operability required to operate the system. It rebuilds two substations with six 23/13.2kV transformers, eliminating aging equipment, maintenance and operating concerns. Adds three additional modular feeders one at Barron Ave and two at Salem Depot. Refer to Section 4.3.3 for further discussion. This plan provides capacity to allow future distribution automation further improving operability of the system and storm response. The added capacity allows Liberty to re-supply the Spicket River and Golden Rock substations during first contingency condition.

6.4.3 Future Growth / Expansion Opportunities

Plan Four provides for future capacity additions in an area expected to experience significant growth. The ultimate design of five feeders from the Salem Depot Substation, four feeders from Barron Ave coupled with the additional four feeders at the Golden Rock substation adds adequate capacity on the 22.8 kV system to support the additional modular feeders. It should be noted that Barron Ave and Salem Depot Substations would be expanded to their maximum footprint after addition of the new modular feeder positions.

6.4.4 Capacity Provided

Plan Four provides the second most capacity from all plans considered.
Appendix G – Comparison of Plans – Cost vs Added Capacity shows predicted feeder capacity resulting from Plan Four and how it compares with other Alternative Plans considered. It is estimated that this plan will provide a total MVA increase of 152.1 MVA and available Firm increase of 108.1 MVA.

6.4.5 Economic Comparison

Plan Four is estimated at $33,940,000, of which $0 has been spent to date.

When reviewing cost per MVA capacity provided, Plan Three has a cost of

approximately $223,000 per MVA of total capacity provided, and
It also has a cost of approximately $314,000 per MVA of firm capacity provided.

Here is where this Plan compares with the other proposed Plans:
- Overall Cost: 3rd Highest
- Cost per Total MVA Capacity: 3rd Highest
- Cost per Firm MVA Capacity: 6th Highest

6.4.6 Other Considerations

Due to asset concerns and the need for complete substation rebuilds at Barron Ave and Salem Depot to implement a 22.8 kV-based solution, the considerations described for Plan Two are also associated with Alternatives #4 and #5. Alternative #4 also requires new 22.8 kV supply lines, however existing right-of-way corridors are expected to be adequate for the new lines. Permits for new pole locations and vegetation management would be necessary to implement Alternative #4.

Plan Four shifts the demand further out towards the end of the 23kV system which could require additional infrastructure improvements not identified in this study. At a minimum it would require replacement of two 22.8 kV line reclosers rated at 1,000 Amps continuous operating current to handle contingency power flows. A detailed protection study would be required to determine if overcurrent pickups could be increased and still achieve proper coordination among devices at Golden Rock Substation, 22.8 kV line reclosers, and Salem Depot Substation, which, based on past review may not be achievable.

6.5 Plan Five

This plan review was for comparison only and is not feasible. See Section 5.0.

6.5.1 System Performance

Plan Five installs a new 115 kV supply to a new 115/22.8 kV transformer and one 22.8 kV feeder at Golden Rock Substation. It rebuilds the existing modular feeders at Barron Ave Station and at Salem Depot Station. It installs a new 22.8/13.2 kV Tuscan Village Substation with three 13.2kV modular feeders with space for a fourth feeder. Being located centrally in the town of Salem, results in shorter feeders to supply load from Rockingham Substation and flexibility to support other parts of the study area during first contingency conditions. Shorter feeders consist of fewer elements that can fail and typically have fewer outages and less losses. Reliability concerns posed by aging and obsolete equipment is mitigated by the replacement of the aging Salem Depot and Barron Ave.

This plan results in facilities that can maintain adequate voltage on all distribution feeders during system intact and first contingency conditions but cannot maintain adequate voltages on the 23kV system during contingency conditions.

During contingency operation, Plan 5 results in voltages as low as 0.875 per-unit at the Salem Depot 23kV bus for a 2352 outage. It also results in voltages as low as 0.88 per-unit at the Rockingham 23kV bus for a Line #2 outage. Refer to Appendix F – 22.8 kV Voltage Analysis.

6.5.2 Operability

Plan Five has operability required to operate the system. It rebuilds two substations with six 23/13.2kV transformers, eliminating aging equipment, maintenance and operating concerns. Refer to Section 4.3.3 for further discussion. Adds a new substation with three additional modular feeders close to the load center. This plan provides capacity to allow future distribution automation further improving operability of the system and storm response. The added capacity allows Liberty to re-supply the Spicket River and Golden Rock substations during first contingency condition.

6.5.3 Future Growth / Expansion Opportunities

Plan Five provides for future capacity additions in an area expected to experience significant growth. The ultimate design of three updated feeders at the Salem Depot Substation, three updated feeders from Barron Ave coupled three new 22.8/13.2 kV modular feeder at the new Tuscan Village Station with the additional four feeders at the Golden Rock substation adds adequate capacity on the 22.8 kV system to support the additional modular feeders, although somewhat limited by the 23kV voltage performance.

6.5.4 Capacity Provided

Similar to Plan Four, Plan Five provides the second most capacity from all plans considered. However, it has 14.4 MVA less Firm capacity added. Appendix G – Comparison of Plans – Cost vs Added Capacity shows predicted feeder capacity resulting from Plan Five and how it compares with other Alternative Plans considered. It is estimated that this plan will provide a total MVA increase of 152.1 MVA and available Firm increase of 93.7 MVA.

6.5.5 Economic Comparison

Plan Four is estimated at $33,150,000, of which $1,500,000 has been spent to date.

When reviewing cost per MVA capacity provided, Plan Three has a cost of approximately $218,000 per MVA of total capacity provided, and
It also has a cost of approximately $354,000 per MVA of firm capacity provided.

Here is where this Plan compares with the other proposed Plans:

- Overall Cost: 4th Highest
- Cost per Total MVA Capacity: 4th Highest
- Cost per Firm MVA Capacity: 5th Highest

6.5.6 Other Considerations

Alternative #5 requires the same considerations as Alternatives #2 through #4, with the addition of a new substation at Tuscan Village, which will require real estate acquisition and environmental permitting. Liberty has purchased the land required for a proposed Rockingham Substation.

Plan Five also has the same concerns as Plan Four regarding system demand being shifted further out the 22.8 kV system and even more so with Plan 5. Like Plan Four this would require an additional protection study to determine required infrastructure improvements and if adequate coordination can be achieved.

6.6 Plan Six

6.6.1 System Performance

Plan Six installs a new 115/13.2kV Rockingham substation at the load center in the Tuscan Village Development. Being located centrally in the town of Salem, results in shorter feeders to supply load from Rockingham Substation and flexibility to support other parts of the study area during first contingency conditions. Shorter feeders consist of fewer elements that can fail and typically have fewer outages and less losses. Refer to Section 4.4 for loss comparison. This plan results in facilities that can maintain adequate voltage on all distribution feeders during system intact and first contingency conditions. Reliability concerns posed by aging and obsolete equipment is mitigated by the retirement of the aging Salem Depot and Barron Ave Substations, and the installation a more modern and robust Rockingham substation.

6.6.2 Operability

Plan Six has the best operability over the other plans. It retires two substations including six 23/13.2kV transformers, with aging, maintenance and operating concerns. This plan provides capacity to allow future distribution automation further improving operability of the system and storm response. The added capacity allows Liberty to re-supply the Spicket River and Golden Rock substations during first contingency condition resulting in the plan that most reduces the reliance in the transmission provider.

The breaker-and-a-half substation design proposed for Rockingham Substation is commonly used by utilities for new substations because it is easy to expand, provides high reliability, and allows flexibility in operation, allowing for breaker, bus, or transformer maintenance without taking an outage. This new substation would also meet Liberty Standards for SCADA, which provides valuable data for system operators and engineering.

Alternative Plan Six, compared to other Plans, installs three new supply transformers. Plans Two through Five, and Seven, invest in the limited 22.8 kV system that utilize up to nine supply transformers that require regular maintenance.

6.6.3 Future Growth / Expansion Opportunities

Plan Six provides for future capacity additions in an area expected to experience significant growth. The ultimate design of ten feeders from the Rockingham Substation coupled with the opportunity to install an additional four feeders from the Golden Rock substation makes this plan the most attractive from a future growth standpoint. At Tuscan Village, there still exist empty lots with unsecured tenants, which present the potential for future high energy applications. Possible development on these lots presents future load growth that needs to be planned for. Tuscan Village will also attract "spill-over" growth from neighboring businesses given its economic effect and strategic location in the study area.

In addition to the available capacity for additional feeders to be installed at the Rockingham station, this plan provides a path for re-purposing the 22.8 kV distribution system from Golden Rock as 13.2kV to allow for an additional four distribution feeders beyond the planning horizon.

6.6.4 Capacity Provided

Plan Six provides the most capacity from all plans considered.
Appendix G – Comparison of Plans – Cost vs Added Capacity shows predicted feeder capacity resulting from the Alternative Plans. It is estimated that this Plan will provide a total MVA increase of 177.7 MVA and available Firm increase of 142.3 MVA, even with the retirement of Barron Ave and Salem Depot Substations. After installing the six 13.2kV feeders at Rockingham Substation to resolve predicted deficiencies, Liberty will have the ability to install as required, the remaining four 13.2kV distribution feeders to address future capacity, reliability and asset condition deficiencies for many years to come.

6.6.5 Economic Comparison

Plan Four is estimated at $34,900,000, of which $5,000,000 has been spent to date.

When reviewing cost per MVA capacity provided, Plan Three has a cost of approximately $196,000 per MVA of total capacity provided, and
It also has a cost of approximately $245,000 per MVA of firm capacity provided.

Here is where this Plan compares with the other proposed Plans:

- Overall Cost: Highest
- Cost per Total MVA Capacity: 6th Highest
- Cost per Firm MVA Capacity: Lowest

6.6.6 Other Considerations

Alternative #6 utilizes the existing 22.8 kV right-of-way that parallels Route 28 to extend 115kV lines approximately 2.25 miles up to a proposed substation near Rockingham Park Boulevard. This 115kV line extension has already undergone several key approvals, including a NPCC-approved E1 exclusion afforded by the approved BES Definition. Also, ISO-New England determined no significant adverse effect identified with regard to the PPA - Rockingham project. This complex construction will also require DOT Permitting and traffic management, environmental review, town permits, and aerial easements.

Liberty has purchased the land required for the proposed Rockingham Substation.

Alternative #6 proposes new 115 kV infrastructure, which will require significantly taller structures, however with routing through a primarily commercial area, community impact is expected to be the least of all alternatives. Largest impacts may be aerial easements, construction of footings for structures, and construction at roadway crossings that could disrupt traffic. Additional lines across the street from residences on Duffy Ave may cause complaints. Some construction may temporarily disrupt use of a portion of the Salem Rail Trail.

6.7 Plan Seven

6.7.1 System Performance

Plan Seven installs a new 115 kV supply to a new 115/13.2 kV transformer and two distribution feeders at Golden Rock Substation and installs a new 13.2 kV feeder (14L5) from the rebuilt Pelham Substation. The new 13.2 kV feeder 14L5 along with the 14L4 from Pelham Station will be used to unload the Olde Trolley feeders 18L2 and 18L4. These two feeders (14L4 and 14L5) are approximately 3.4 miles long and will be on the same structures increasing the vulnerability to a hit by auto event to a significant portion of the system. In some areas three feeders (14L3, 14L4 and 14L5) will be on the same structures further increasing the vulnerability to a hit by auto event. Appendix D – MWHr Summary contains MWHr totals for losses of multiple circuits in such a scenario.

Similar to Plans One and Two, this plan lacks the necessary capacity and voltage support to re-supply the Spicket River substation during the loss of supply contingency. This plan resolves the existing concerns with substation equipment at Salem Depot and Barron Ave.

This plan results in facilities that can't maintain adequate voltages on the 23kV system during contingency conditions.

During contingency operation, Plan 7 results in voltages as low as 0.899 per-unit at the Olde Trolley 23kV bus and as low as .892 per-unit at the Salem Depot 23 kV bus for a Golden Rock T1 outage. Refer to Appendix F – 22.8 kV Voltage Analysis for details.

6.7.2 Operability

Plan Seven proposes to rebuild the substation equipment at Salem Depot and Barron Ave, resolving the asset condition concerns and providing for opportunities in Grid Modernization. Refer to Section 4.3.3 for further discussion. This plan has shortcomings due to lack of supply capacity during contingencies. This plan lacks the necessary capacity to re-supply the Golden Rock substation during first contingency, resulting in MWHr violations that are above the allowable limit per the Planning Criteria. Refer to Appendix D – MWHr Summary. It does not reduce the reliance on the transmission provider. This plan is not sustainable due to the existing 22.8 kV sub-transmission system's lack of capacity with no available source to supply it. See Appendix C – Area Loading Analysis, Table 53. The limitation of the 22.8 kV system to supply the increased load make this Plan impractical.

6.7.3 Future Growth / Expansion Opportunities

Similar to Plan One and Plan Two, Plan Seven provides limited opportunities for future expansion of the distribution system. It provides capacity to supply predicted growth in the Tuscan Village during system intact conditions but fails to adequately support the area's predicted demand during first contingency condition.

This plan only provides four feeders to be used for future load growth at the Golden Rock substation, three of which would be utilized under this plan. Although Salem Depot Substation and Barron Ave Substations are rebuilt under this plan with additional feeder availability, lacking capacity available on the 22.8 kV sub-transmission system limits the overall load-carrying capability of the two substations. See Section 4.1.2.1 for violations, which are unchanged with this Plan. As a result, future growth will also require a large investment to provide additional capacity, similar to what is being proposed with Plan Six.

6.7.4 Capacity Provided

Plan Seven provides the 5th most capacity from all plans considered. Appendix G – Comparison of Plans – Cost vs Added Capacity shows predicted feeder capacity resulting from Plan Seven and how it compares with other Alternative Plans considered. It is estimated that this plan will provide a total MVA increase of 116.7 MVA and available Firm increase of 29.1 MVA.

Plan Seven leaves considerable capacity for Golden Rock 13.2 kV feeders to offload the 22.8 kV supply system, however in contingency scenarios such as loss of the Golden Rock 115 kV / 13.2 kV supply transformer, capacity limits are exceeded on the 22.8 kV supply system.

6.7.5 Economic Comparison

Plan Four is estimated at $25,010,000, of which $3,500,000 has been spent to date.

When reviewing cost per MVA capacity provided, Plan Three has a cost of approximately $214,000 per MVA of total capacity provided, and

It also has a cost of approximately $859,000 per MVA of firm capacity provided.

Here is where this Plan compares with the other proposed Plans:

- Overall Cost: 5th Highest
- Cost per Total MVA Capacity: 5th Highest
- Cost per Firm MVA Capacity: 3rd Highest

6.7.6 Other Considerations

Due to asset concerns and the need for complete substation rebuilds at Barron Ave and Salem Depot to implement a 22.8 kV-based solution, the considerations described for Plan Two are also associated with Alternatives #7.

Plan Seven extends a new feeder for approximately 3.4 miles from Pelham to Salem and will result in multiple feeders on the same structures, increasing the vulnerability to a hit by vehicle event to a significant portion of the system. Liberty Utilities is strongly against unnecessary double and triple-circuiting for this reason. An alternative would be underground construction, which is not cost effective, as the additional feeder would only be providing a limited 12 MVA of capacity into Salem for an estimated cost of $6,800,000

See Appendix G – Comparison of Plans – Cost vs Added Capacity for a side-by-side comparison of plans that reviews cost versus added capacity. For a further comparison of the Alternative Plans, a matrix was assembled to compare each Plan's ranking in each of the criteria used to evaluate the plans. This methodology is similar to what is being used at another New Hampshire Utility. See Table 8 below:

Plan Comparison Matrix								
Evaluation Criteria	**Weight Factor**	**Plan 1**	**Plan 2**	**Plan 3**	**Plan 4**	**Plan 5**	**Plan 6**	**Plan 7**
1- SYSTEM PERFORMANCE	20%	1	3	4	5.5	5.5	7	2
2- OPERABILITY	25%	1	3	4	5.5	5.5	7	2
3- FUTURE EXPANSION	10%	1	3	4	5	6	7	2
5- CAPACITY PROVIDED	15%	1	2	4	5.5	5.5	7	3
4- COST	30%	7	6	2	3	4	1	5
Total		**2.8**	**3.75**	**3.4**	**4.7**	**5.1**	**5.2**	**3.05**
RANK		**7**	**4**	**5**	**3**	**2**	**1**	**6**

Table 8: Plan Comparison Matrix

The matrix considers the importance of each criteria, calculating a higher weight to Plans that rank higher in the most important areas.

Given this evaluation, Plans Five and Six are the highest-scoring plans. It should be noted that cost comparison may be unevenly factored in this evaluation, as several plans are relatively close in estimated cost. For example, while Plan Five is only 6% less than Plan Six, it's rank (4^{th}) boosts it score considerably, even though the cost difference is relatively minor between the four most expensive plans.

7.0 Other Plan Considerations and Comparisons

7.1 Non-Wires Alternatives Considerations

Given the widespread loading concerns and MWHr totals, Battery Energy Storage was not found to be a cost-effective method for addressing capacity and reliability concerns in the area. Preliminary estimates at $1.876M per MW[16] (assuming 4-hour Energy/Power ratio) far exceed Cost/MVA when compared to other alternatives. Non-Wires Alternatives were only considered for Plan 1.

[16] U.S. Department of Energy Hydrowires, July 2019. Energy Storage Technology and Cost Characterization Report, Table ES.1. https://www.energy.gov/sites/prod/files/2019/07/f65/Storage%20Cost%20and%20Performance%20Characterization%20Report_Final.pdf

8.0 Conclusions and Recommendations

The goal of system planning is to provide adequate capacity for safe, reliable, and economic service to customers with minimal impact on the environment. To achieve that goal, the distribution system is planned, measured, and operated with the objective of providing electric service to customers under system intact conditions (i.e., “normal”) and first contingency conditions (“N-1”). System Planning also includes careful management of system assets; addressing asset conditions where present to avoid failures and provide a safe working environment for workers.

The seven Alternative Plans were evaluated on how they address the needs of Salem area electric supply system. Alternatives were reviewed and compared for cost-effectiveness and their ability to address system performance, operability, reliability, and future growth.

Plan One does the bare minimum to serve Tuscan Village, leaving 13.2 kV and 22.8 kV circuits mostly unavailable to re-supply during contingencies. It also has several siting and environmental concerns for diesel generation. Plan One also still leaves existing Planning Criteria violations and substation condition unresolved. For these reasons, Plan One is not recommended.

The inability to add capacity to the 22.8 kV sub transmission system effectively precludes the ability to utilize any alternatives based on any expansion or upgrade of 22.8kV/13.2kV modular feeders substations. Also refer to Section 4.3.3 for constructability challenges. For these reasons, Plans Two, Three, and Plan Seven are not recommended.

As stated in Section 5.0, Plans Four and Five were developed for this study as a hindsight review, and are not feasible or buildable. The study concludes that while these options would have been feasible if pursued, they are similar in cost to Plan Six, but do not provide the MVA capacity and ability for future growth that Plan Six provides. Plan Six also retires facilities from areas facing neighborly opposition, while Plans Four and Five expand or maintain electrical equipment closer to neighboring parcels. Plan Six installs three supply transformers to serve the area, while Plans Four and Five each install nine supply transformers. Plan Six simplifies the power delivery system in the Salem Area. Plans Four and Five conflict with Liberty’s general initiative to transition towards a 115 / 13.2kV system. For these reasons, Plans Four and Five are not recommended.

Based on the comparisons of the Alternative Plans, Plan #6 is the recommended Plan. This is recommended because this provides the best solution to the identified system issues in the Salem area which include concerns with equipment condition at the Baron Ave and Salem Depot Substations and predicted overloads in the area. It is the best plan to enable Liberty to be a locally managed Company and responsive to the needs of its customers while reducing its dependence on the transmission provider. This plan best meets the Company Distribution Planning Criteria and will allow the Company to best manage its day to day, contingency, and storm operating risks given its resource base. Unlike Plans One, Two, Three and Seven, Plan Six solves all Planning Criteria violations.

The three proposed 115 kV/13.2 kV transformers (one of which has already been installed at Golden Rock) would satisfy the capacity requirements now and into the future.

It addresses the asset condition issues and safety risks by retiring end of life facilities. This eliminates the maintenance, environmental and community issues associated with the three modular feeders at Barron Ave Station and the three modular feeders at Salem Depot Station.

The installation of the new 115 kV/13.2 kV supply transformer design substations supports the integration of distribution automation and grid-modernization systems. These systems are designed to improve the operation of the distribution system. System reliability benefits from the automatic identification, isolation and minimizing of system outages along with speedy restoration to non-damaged sections. The robust nature of the updated system improves the ability to operate the system. Scheduled and emergency maintenance requirements can be addressed efficiently.

The cost per total MVA added for Plan Six is the second lowest and the cost per firm MVA added is the lowest. This means that this solution is cost-effective in providing reliable capacity today and for the future, for normal conditions and contingency scenarios.

9.0 Appendices

9.1 Appendix A – System One Lines

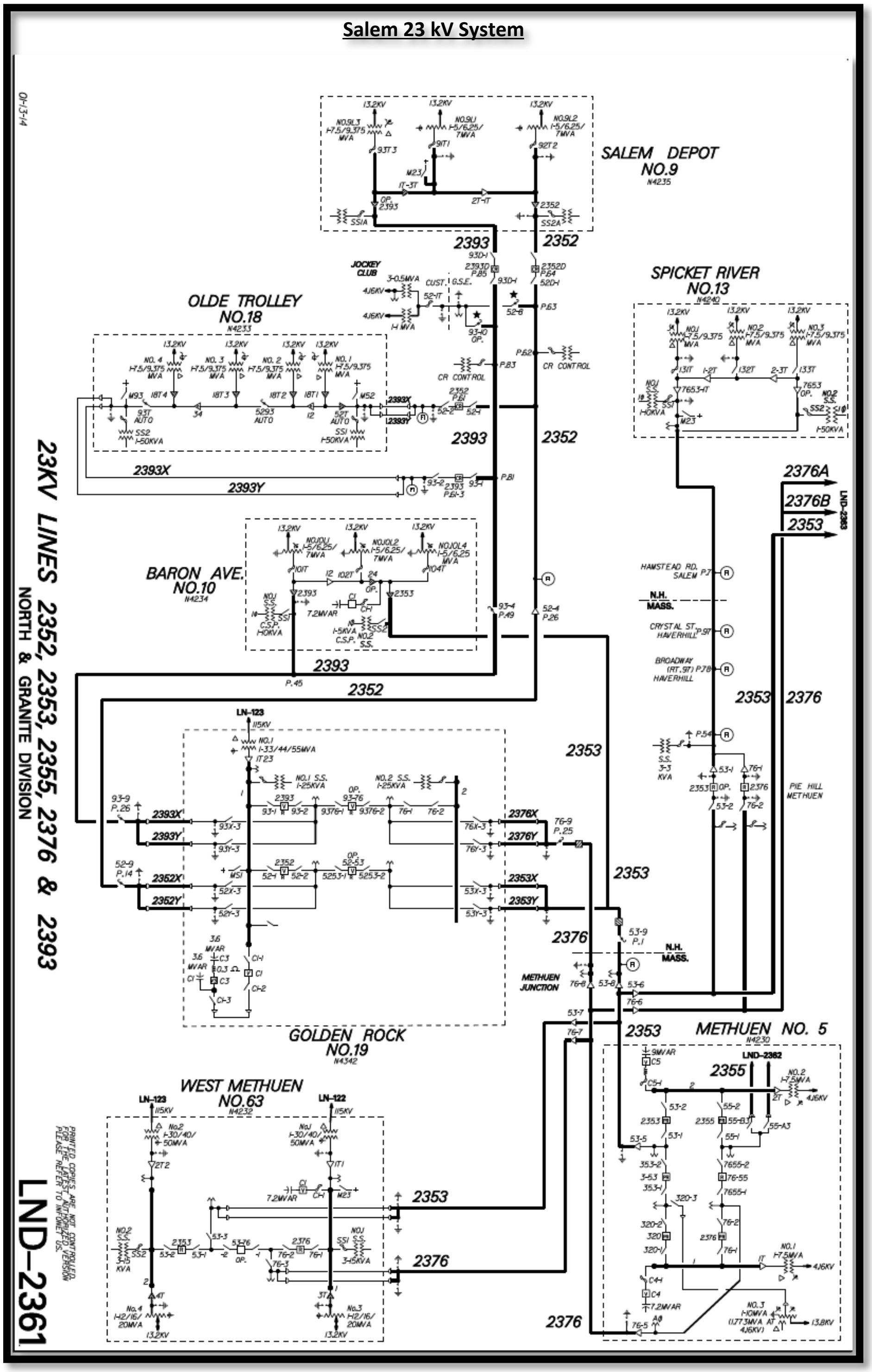


Figure 2 Salem 22.8 kV Supply System

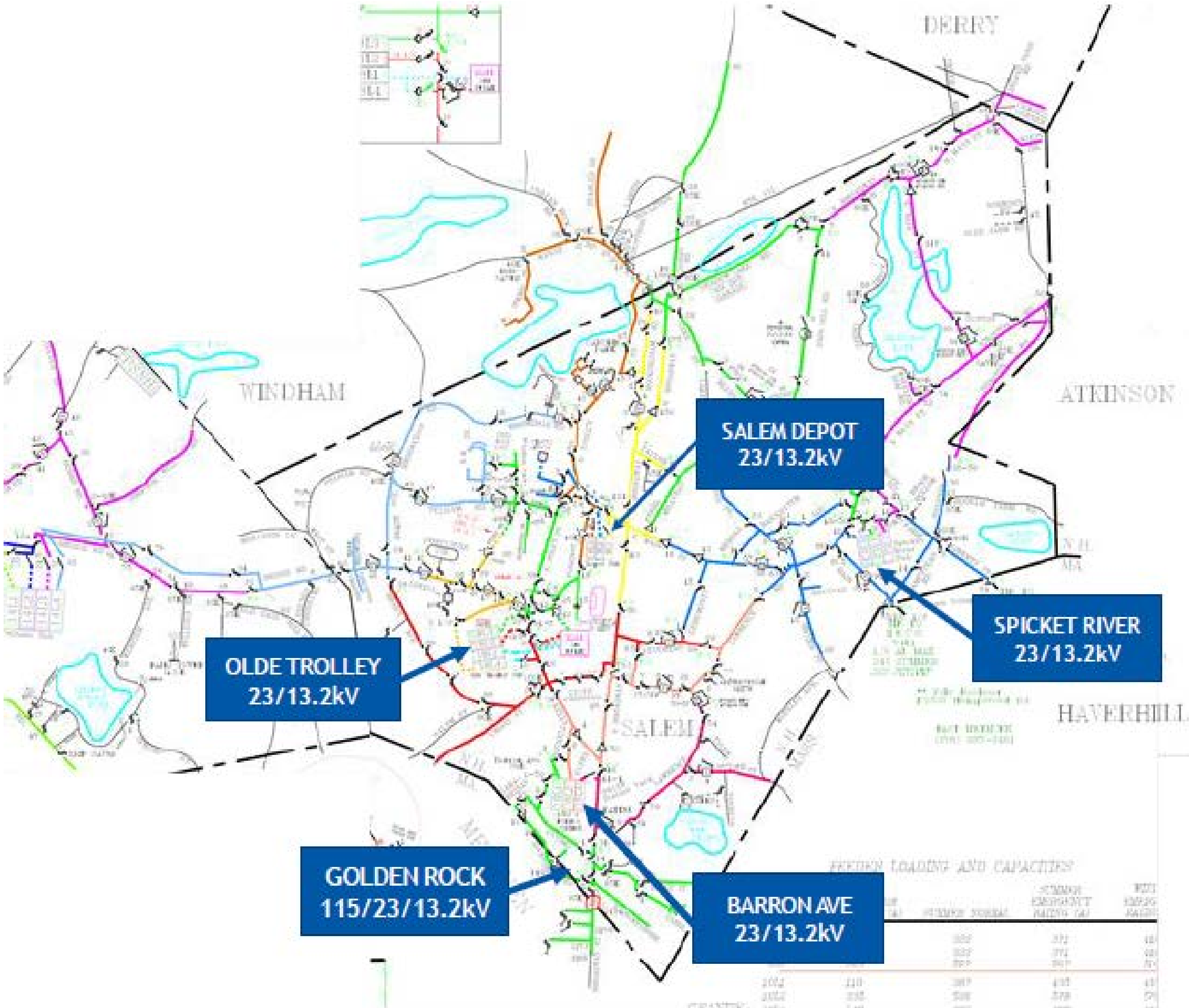


Figure 3 Salem 13.2 kV Tie Map (Alternate)

048

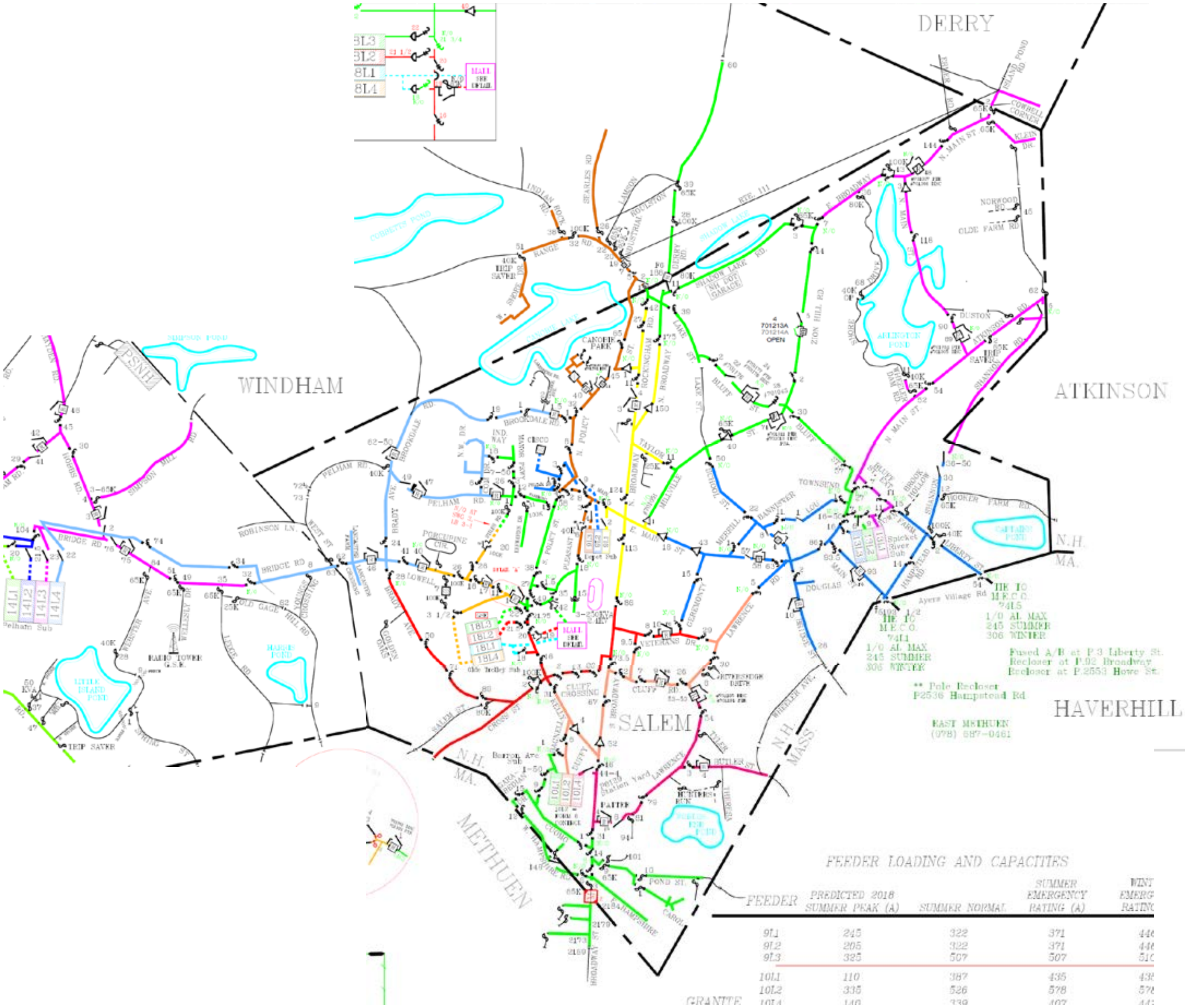


Figure 4 Salem 13.2kV Distribution System

049

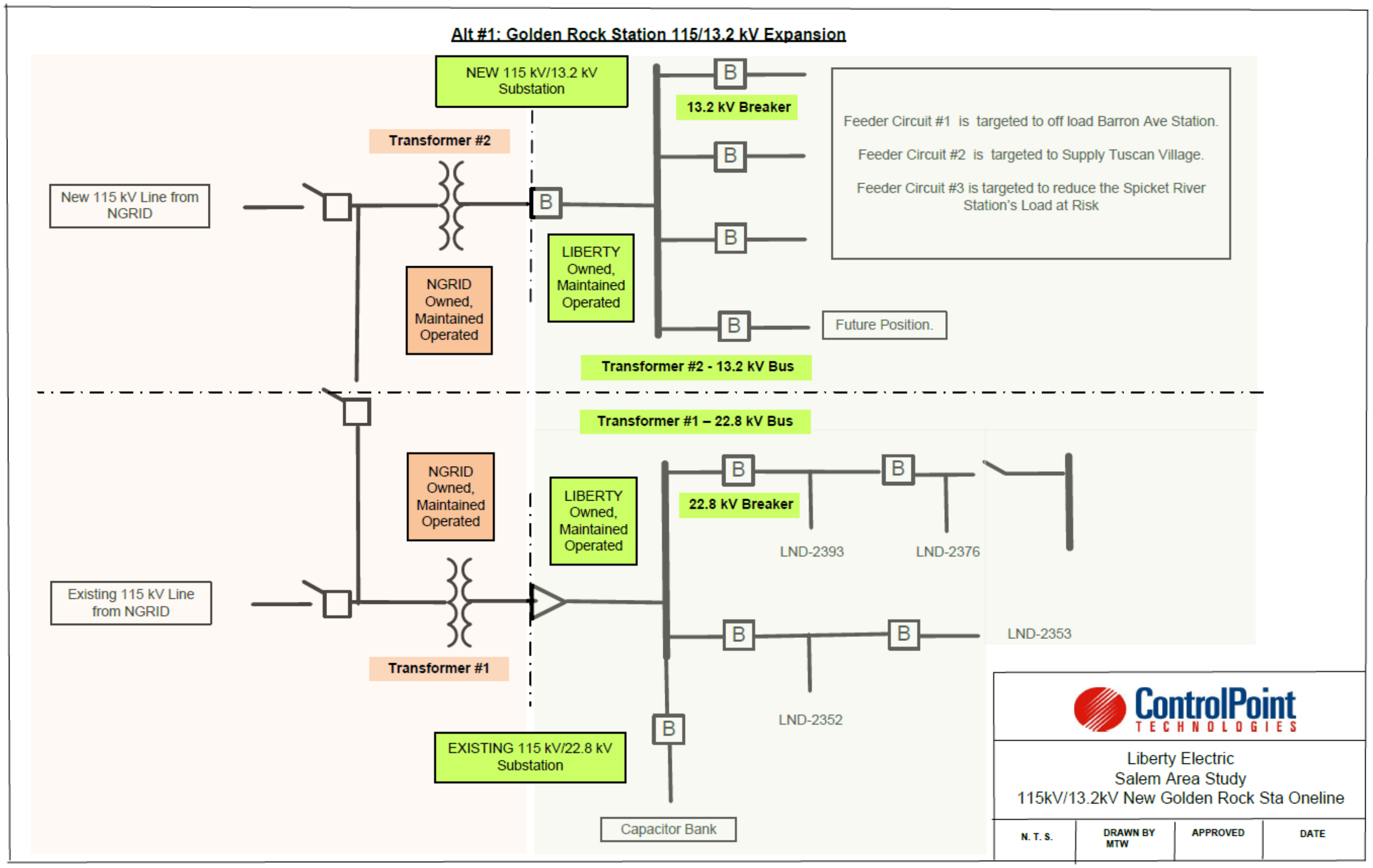
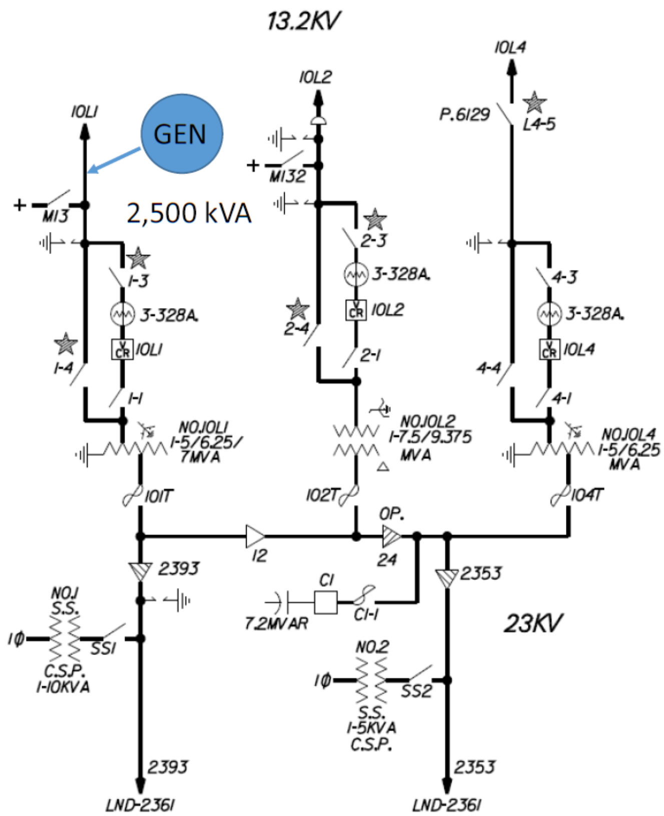


Figure 5 Alternative #1 Golden Rock Substation 115kV/13.2kV Expansion - One Line

050

Alternative #1
Existing Baron Ave



DEMARCATION LINE OF AUTHORITY
+ MOBILE SUB TAP

BARRON AVE. NO. 10
NORTH & GRANITE DIVISION

N4234

Figure 6 Alternate #1 - Barron Ave Station - One Line

ControlPoint TECHNOLOGIES

Alternative #1
Existing Salem Depot

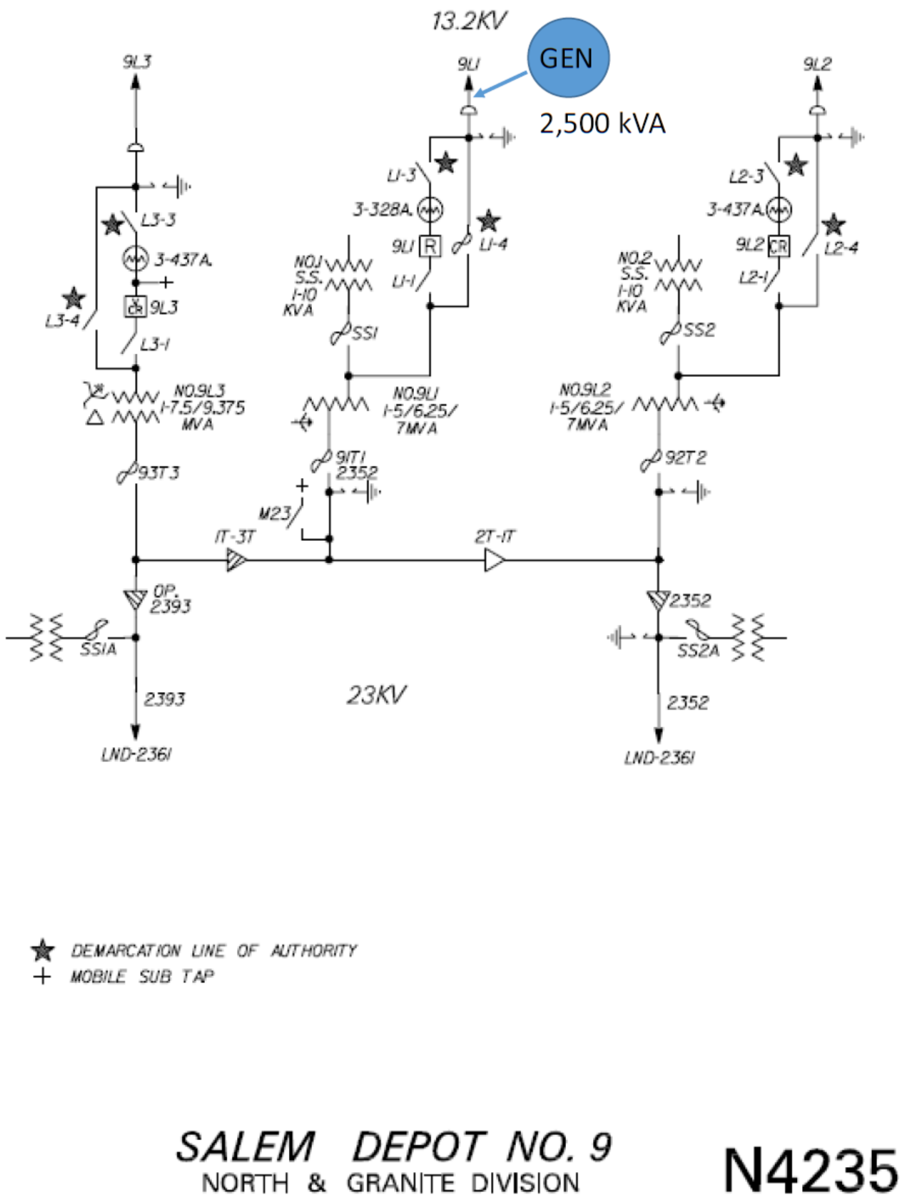


Figure 7 Alternate #1 Salem Depot Station - One Line

Alternative #1
Existing Spicket River

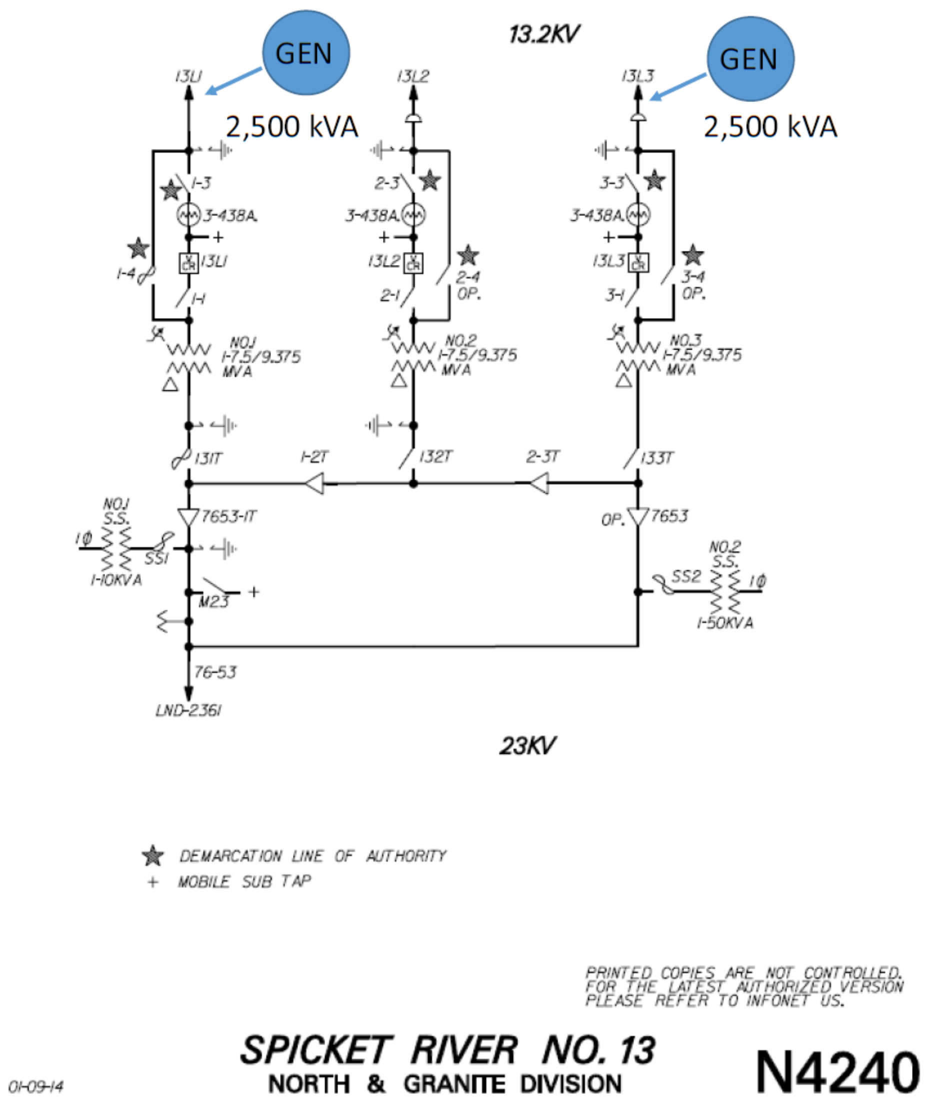


Figure 8 Alternate #1 Spicket River Station - One Line

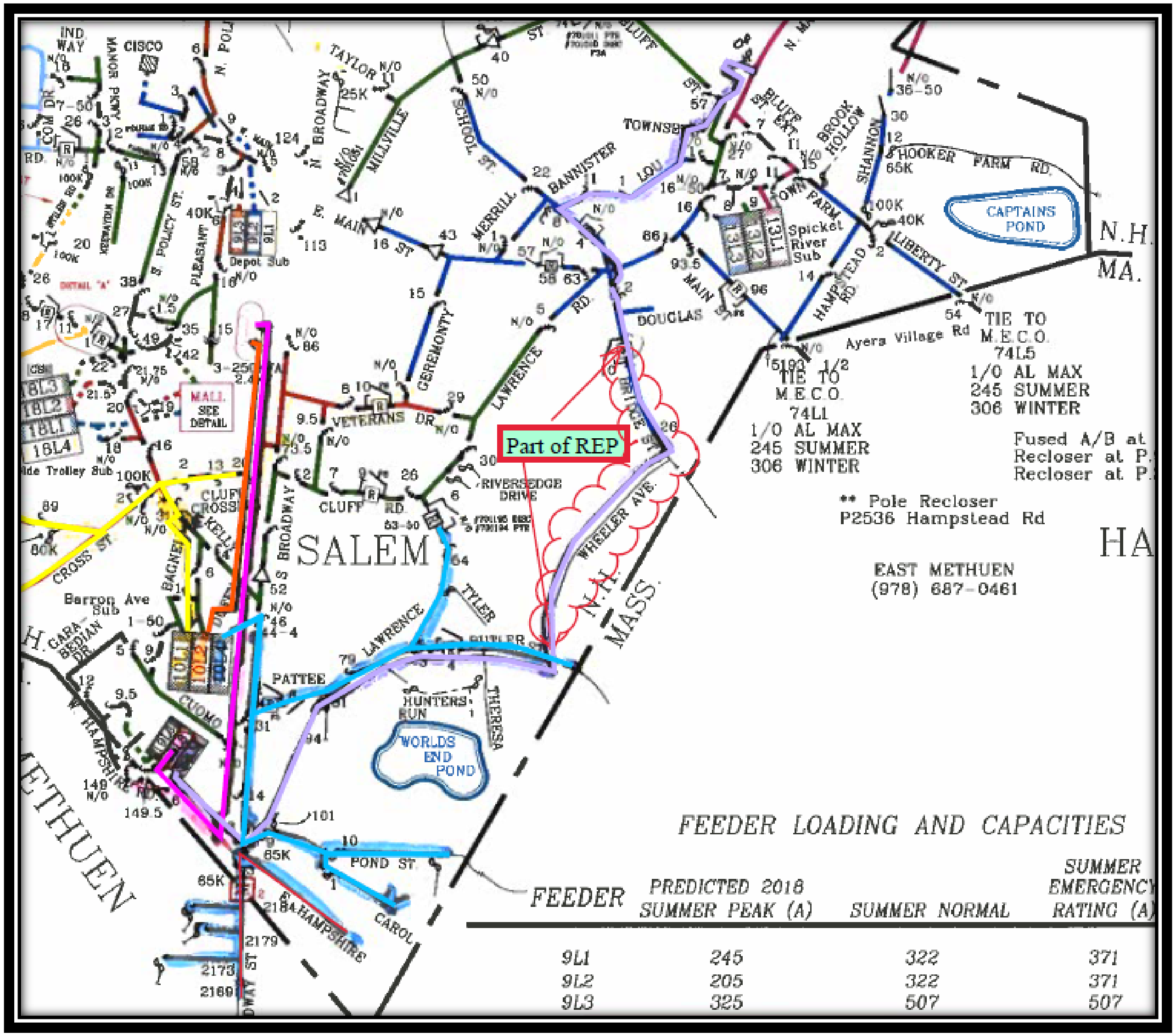


Figure 9 Alternate #1 13.2kV Overview One Line

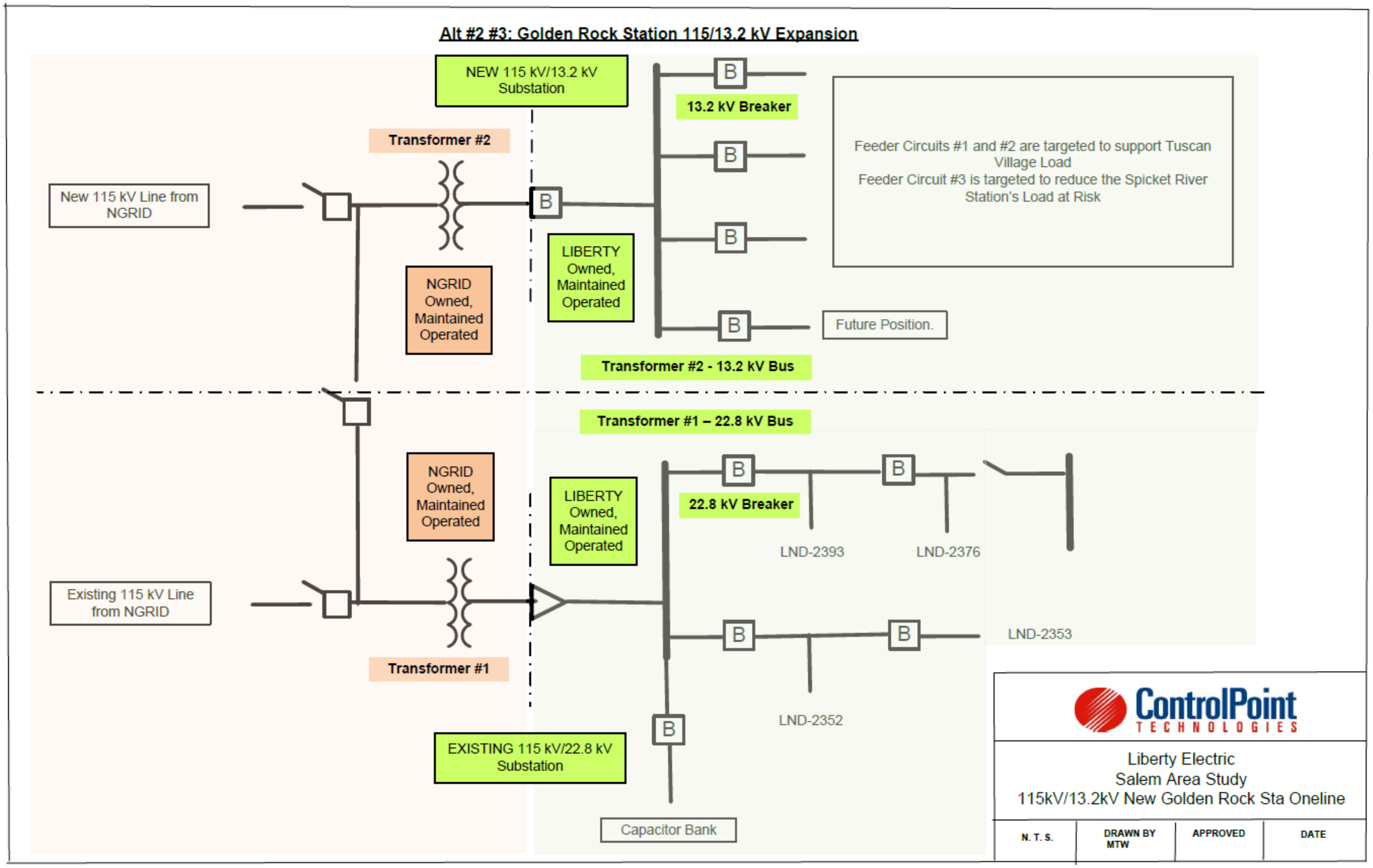


Figure 10 Alternative #2 Golden Rock Substation 115kV/13.2kV Expansion - One Line

055

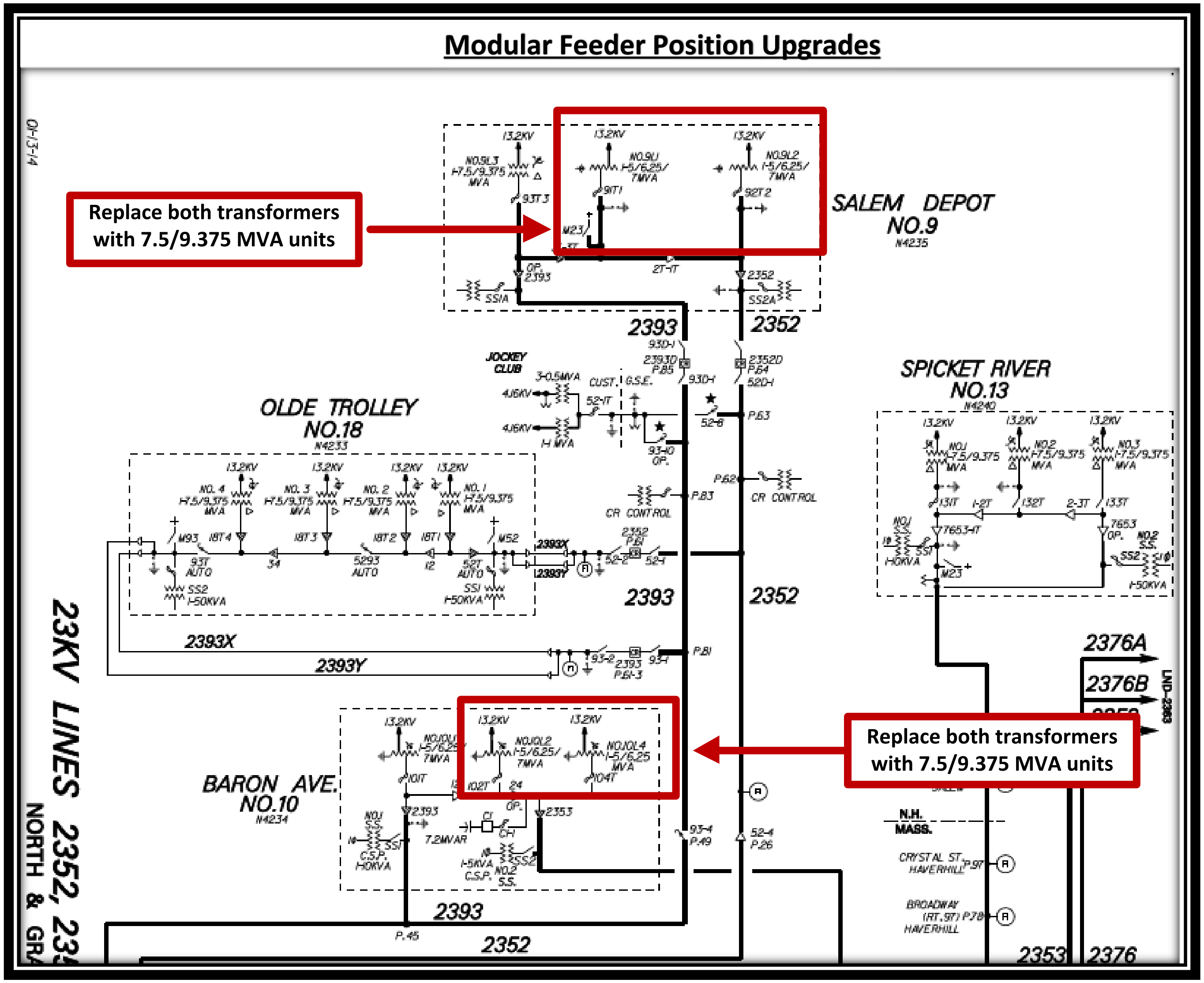


Figure 11 Alternate #2 22.8 kV Overview One Line

056

Alternative #2
Baron Ave Upgrade

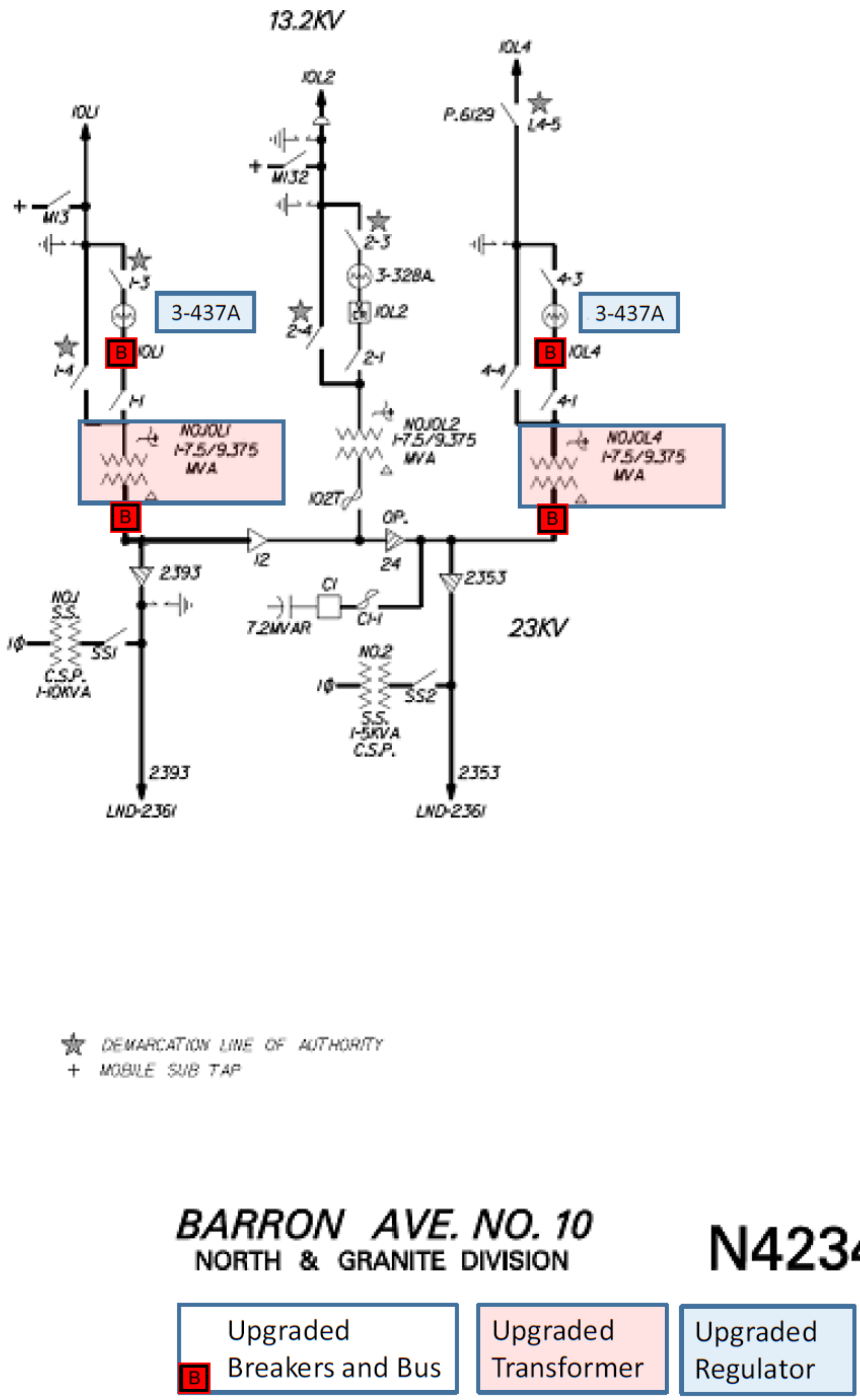


Figure 12 Alternate #2 Barron Ave Station Rebuild - One Line

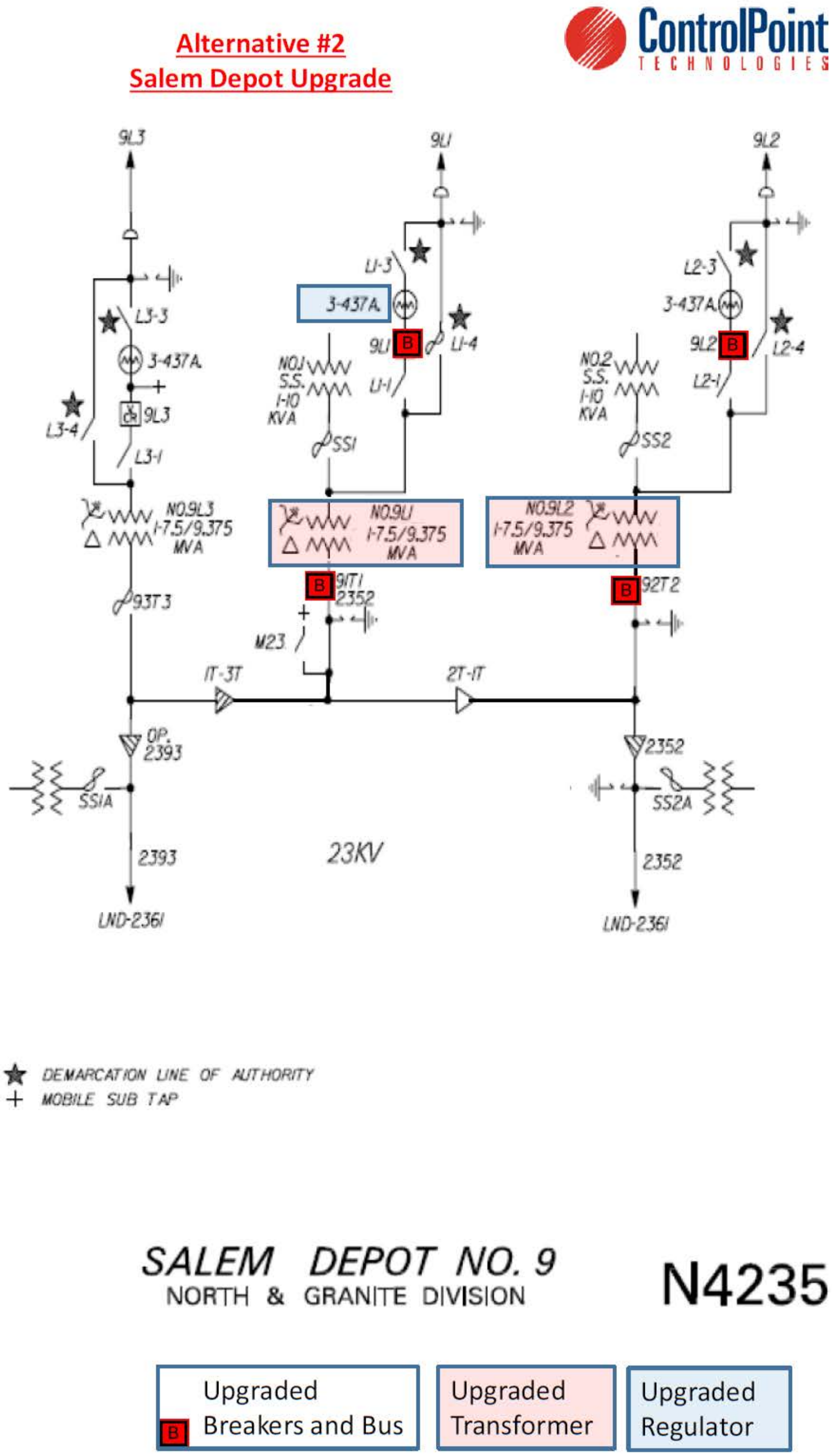


Figure 13 Alternate #2 Salem Depot Station Rebuild - One Line

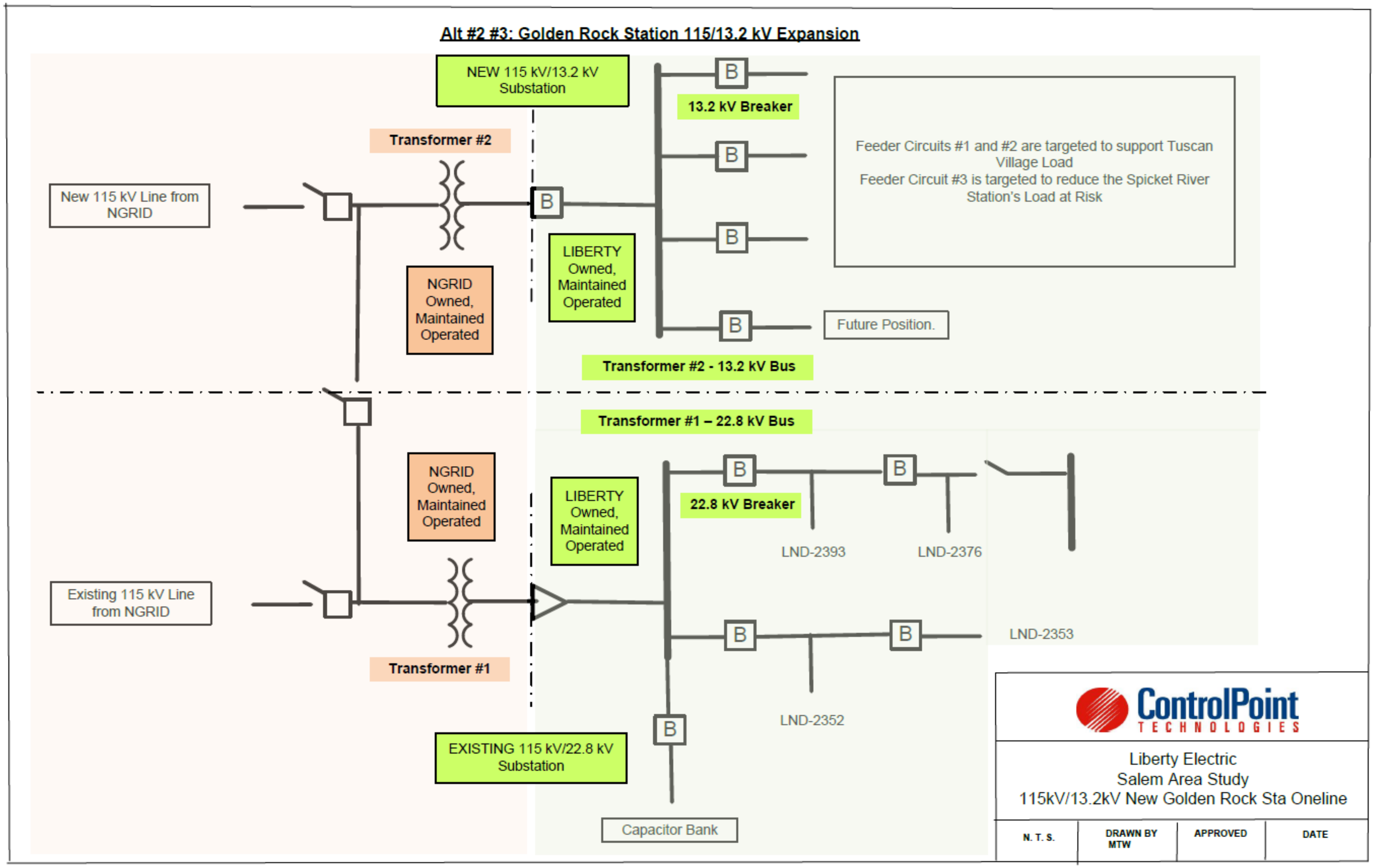


Figure 14 Alternative #3 Golden Rock Substation 115kV/13.2kV Expansion - One Line

059

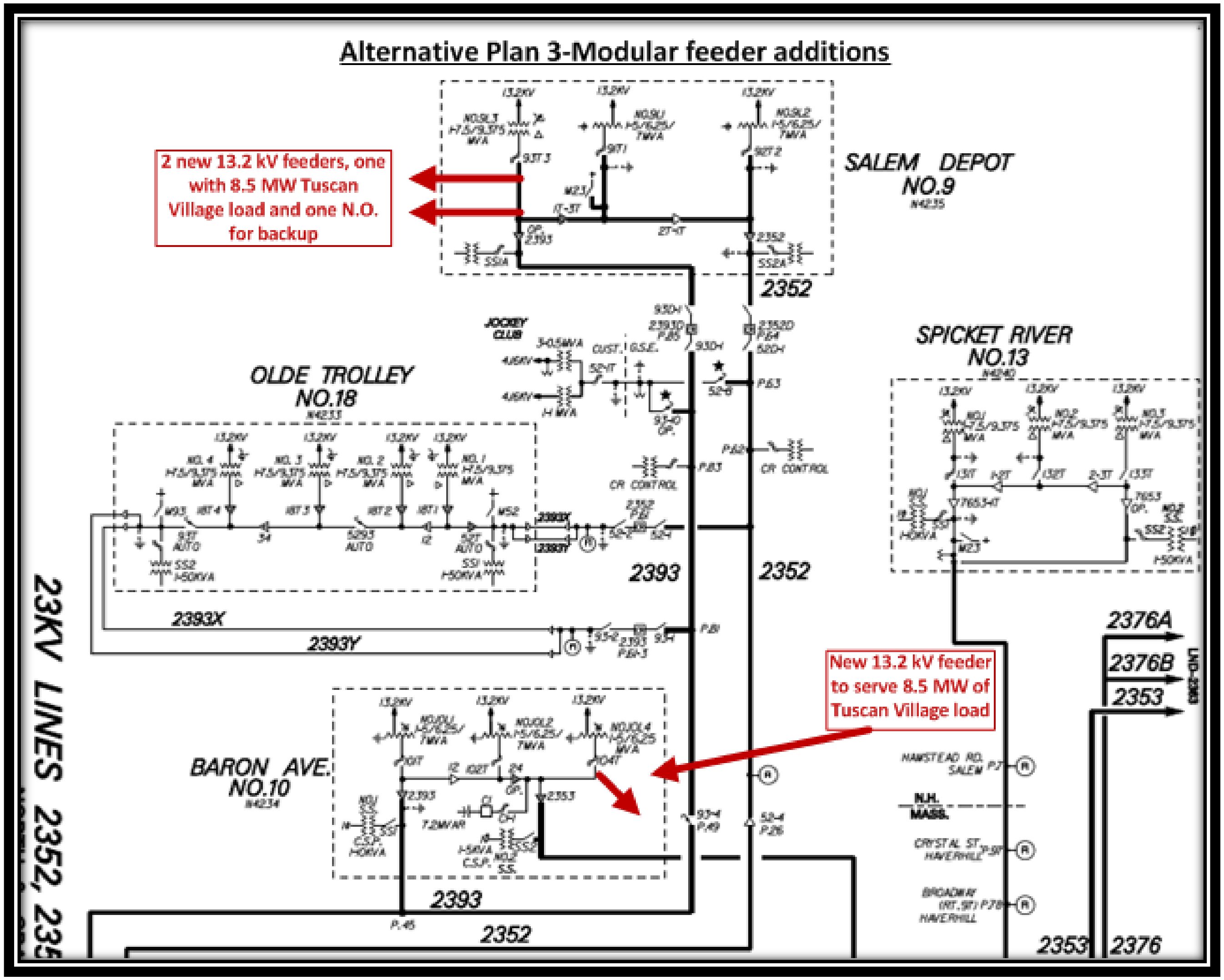


Figure 15 Alternative #3 22.8 kV Overview One Line

090

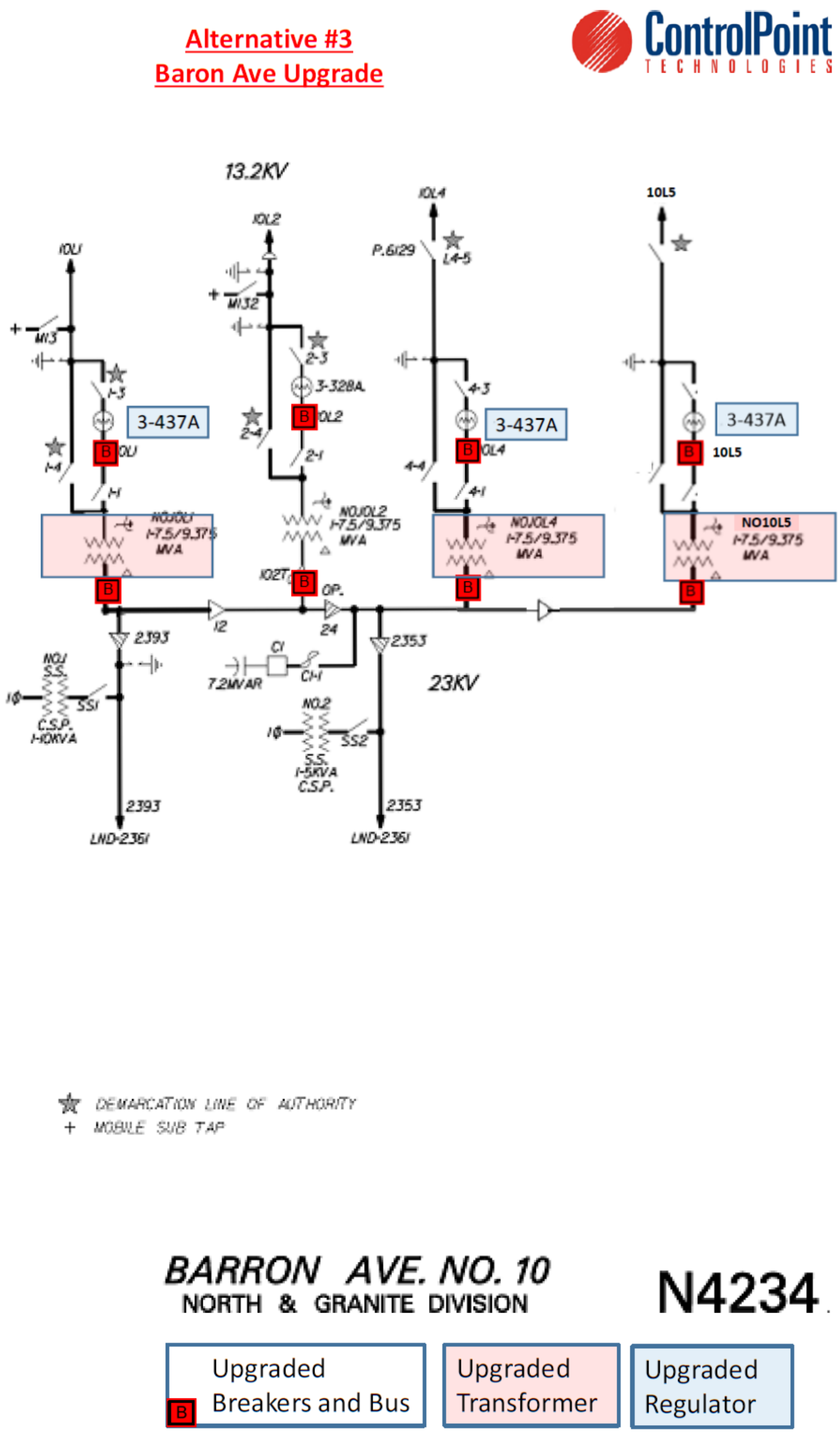


Figure 16 Alternate #3 Barron Ave Station Rebuild – One Line

Alternative #3
Salem Depot Upgrade

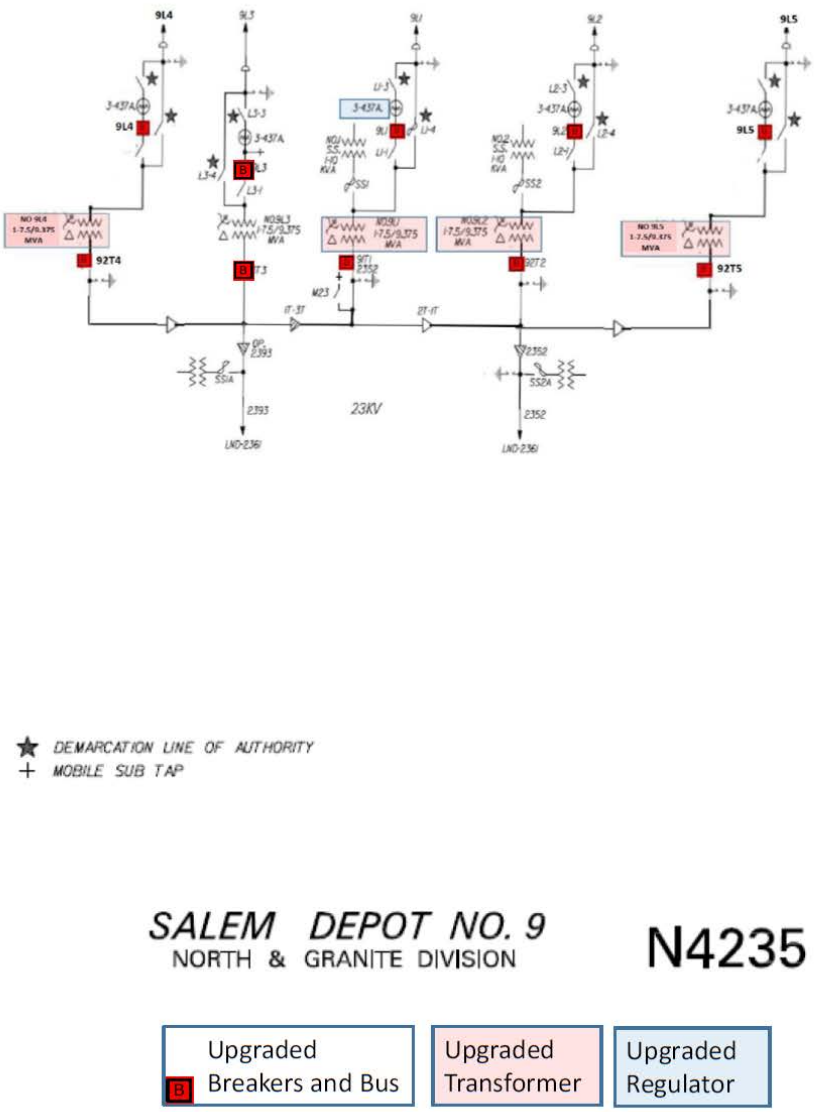


Figure 17 Alternative #3 Salem Depot Rebuild - One Line

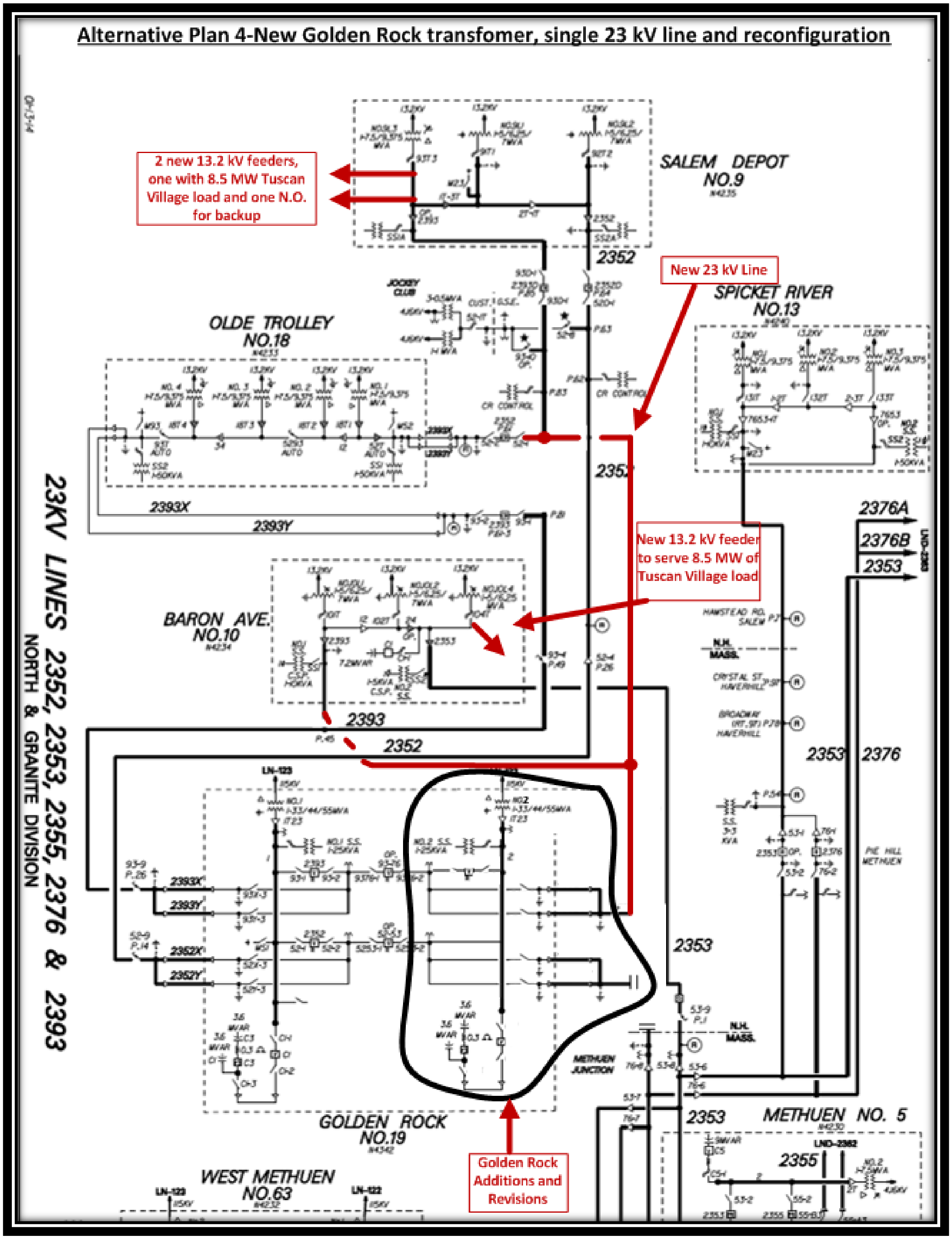


Figure 18 Alternative #4 22.8 kV Overview One Line

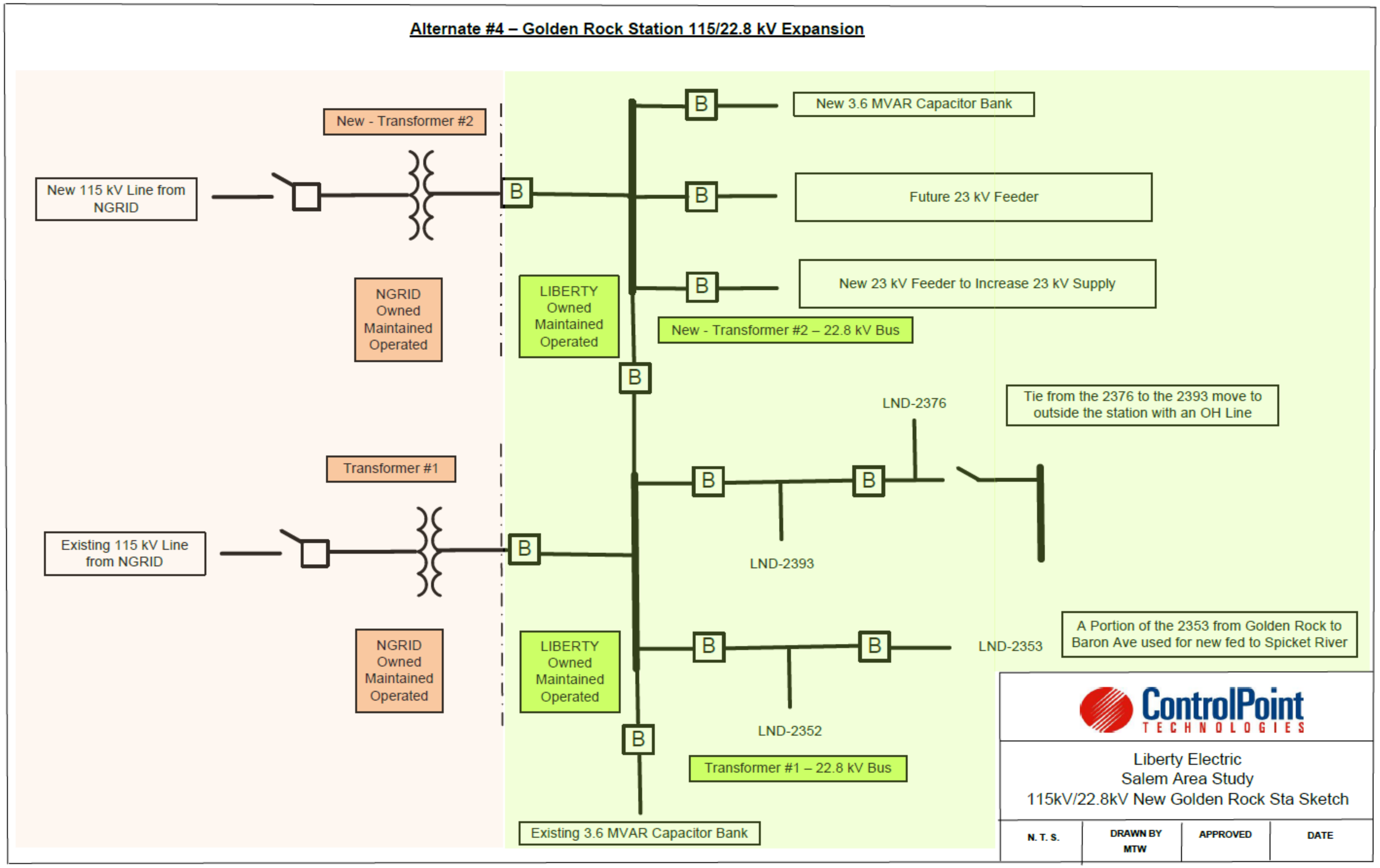


Figure 19 Alternate #4 Golden Rock Substation 115kV/22.8kV Expansion – One Line

064

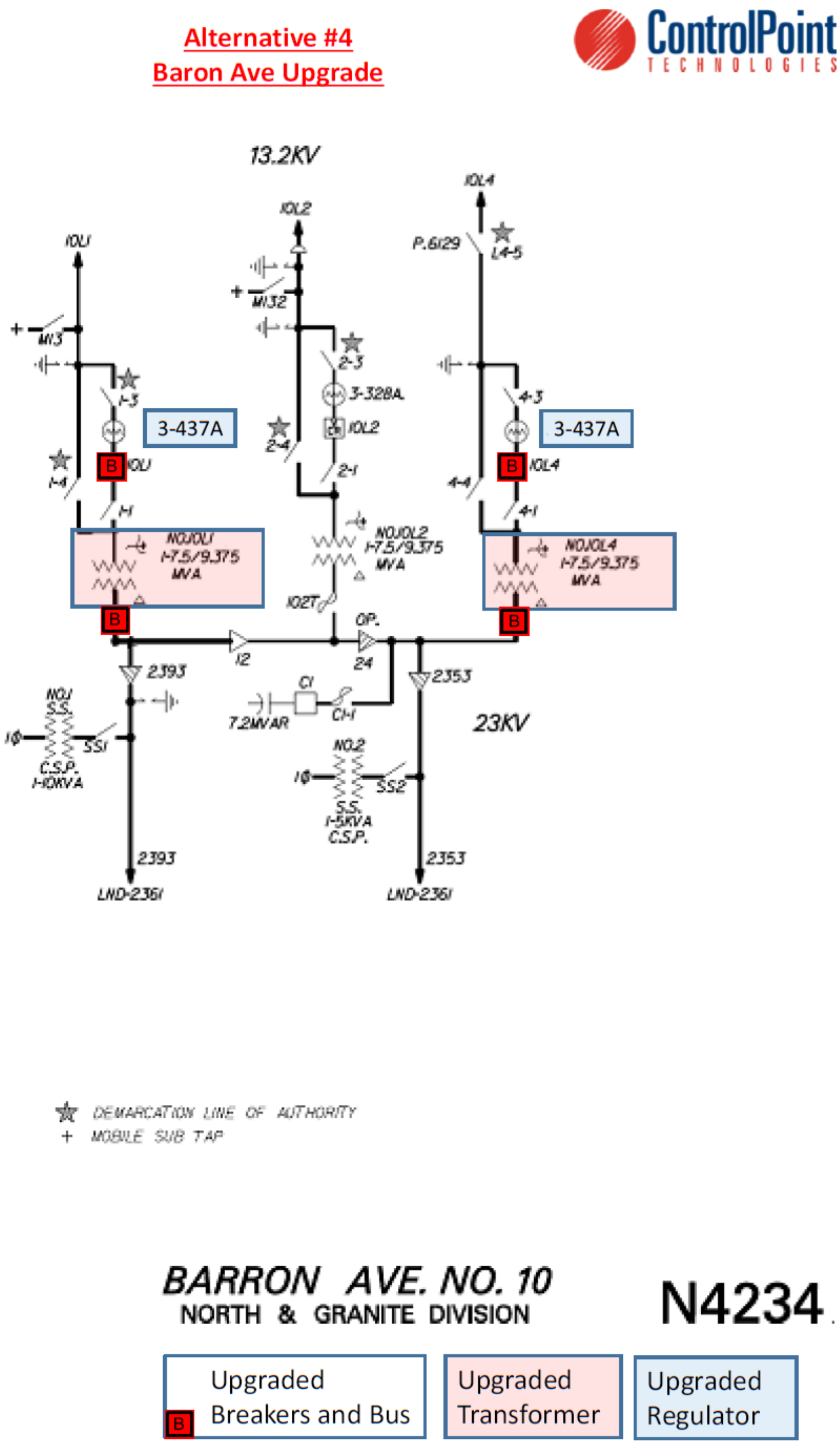


Figure 20 Alternate #4 Barron Ave Station Rebuild – One Line

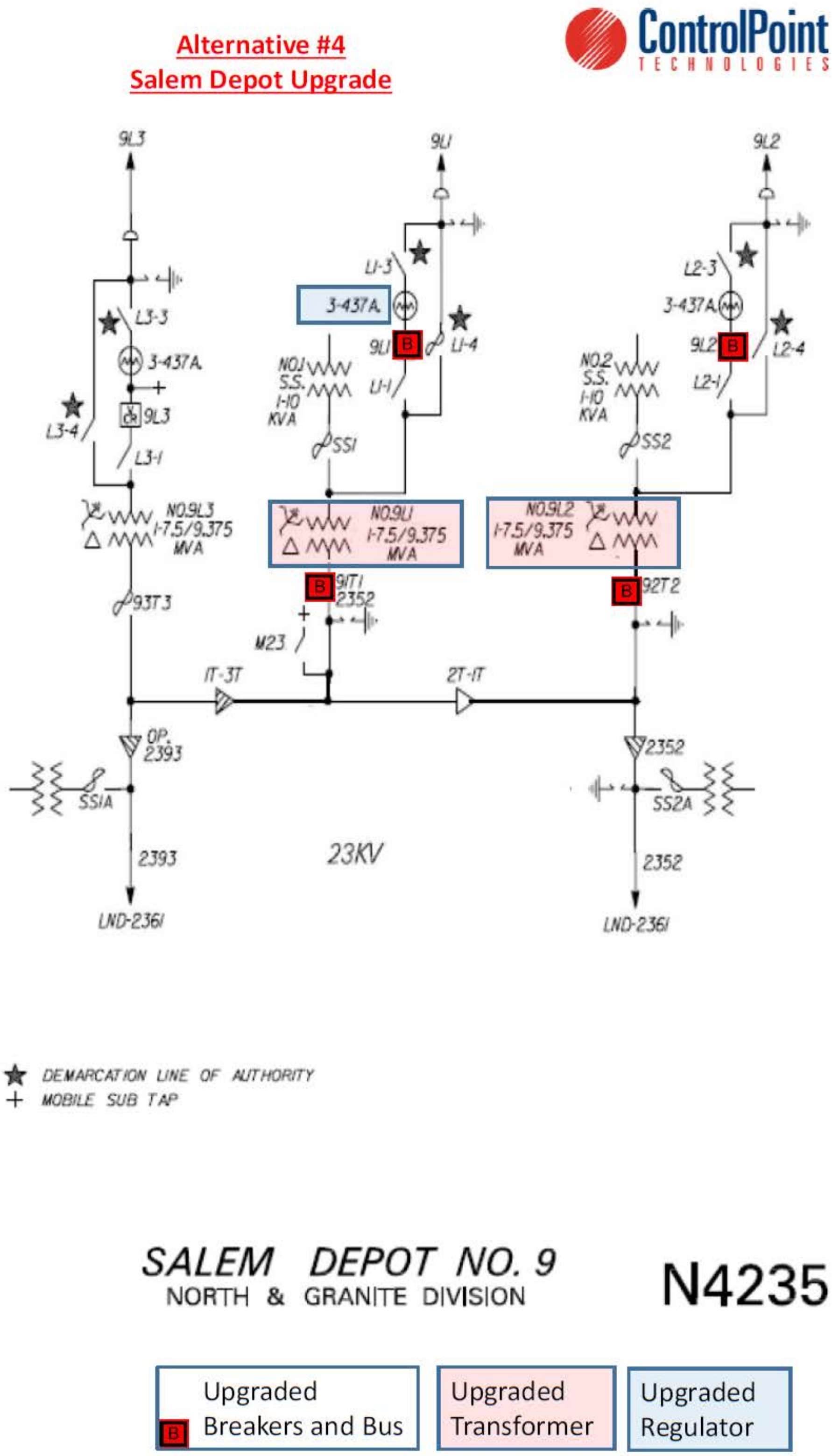


Figure 21 Alternate #4 Salem Depot Station Rebuild – One Line

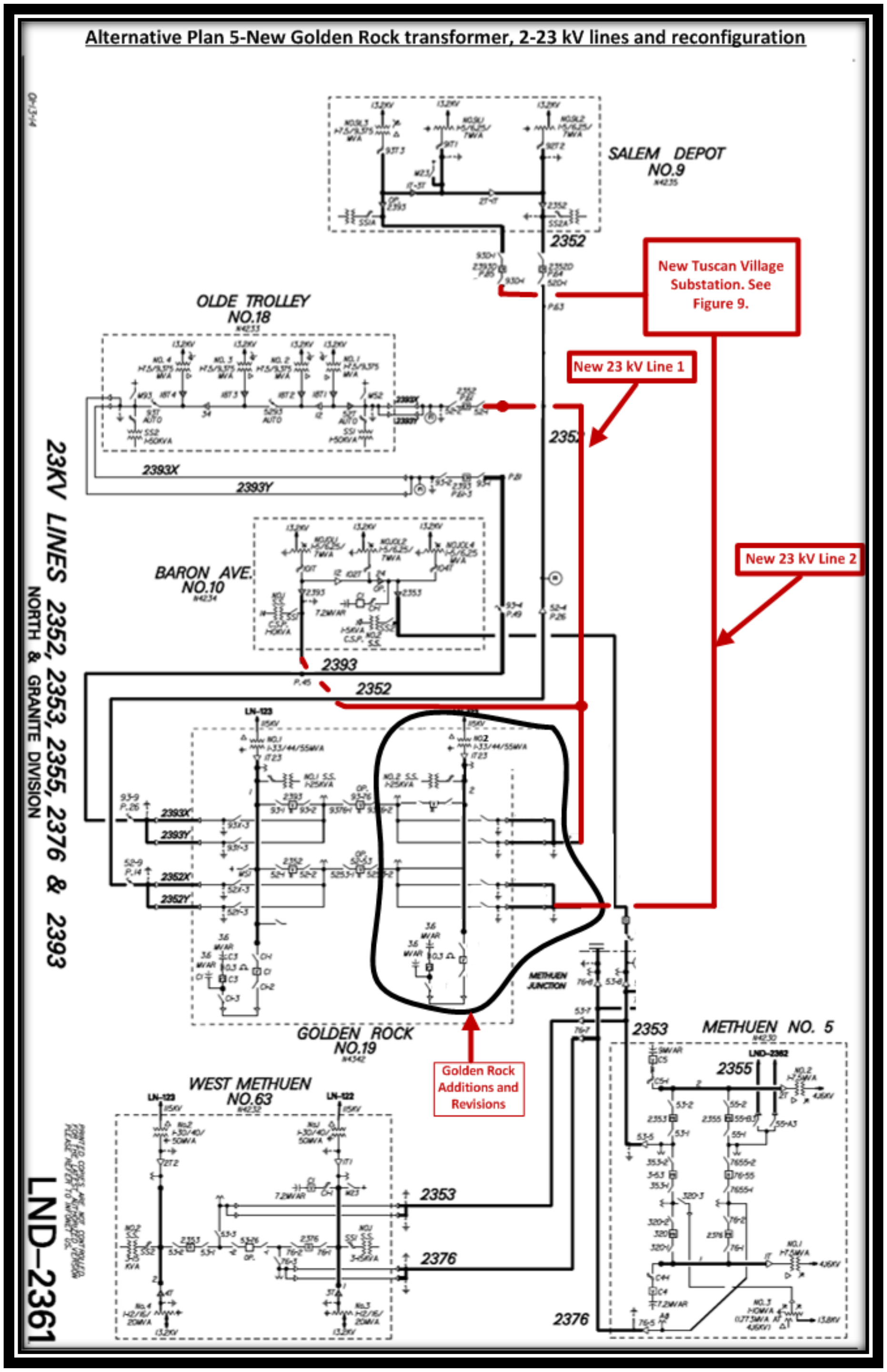


Figure 22 Alternative #5 - 22.8 kV Overview One Line

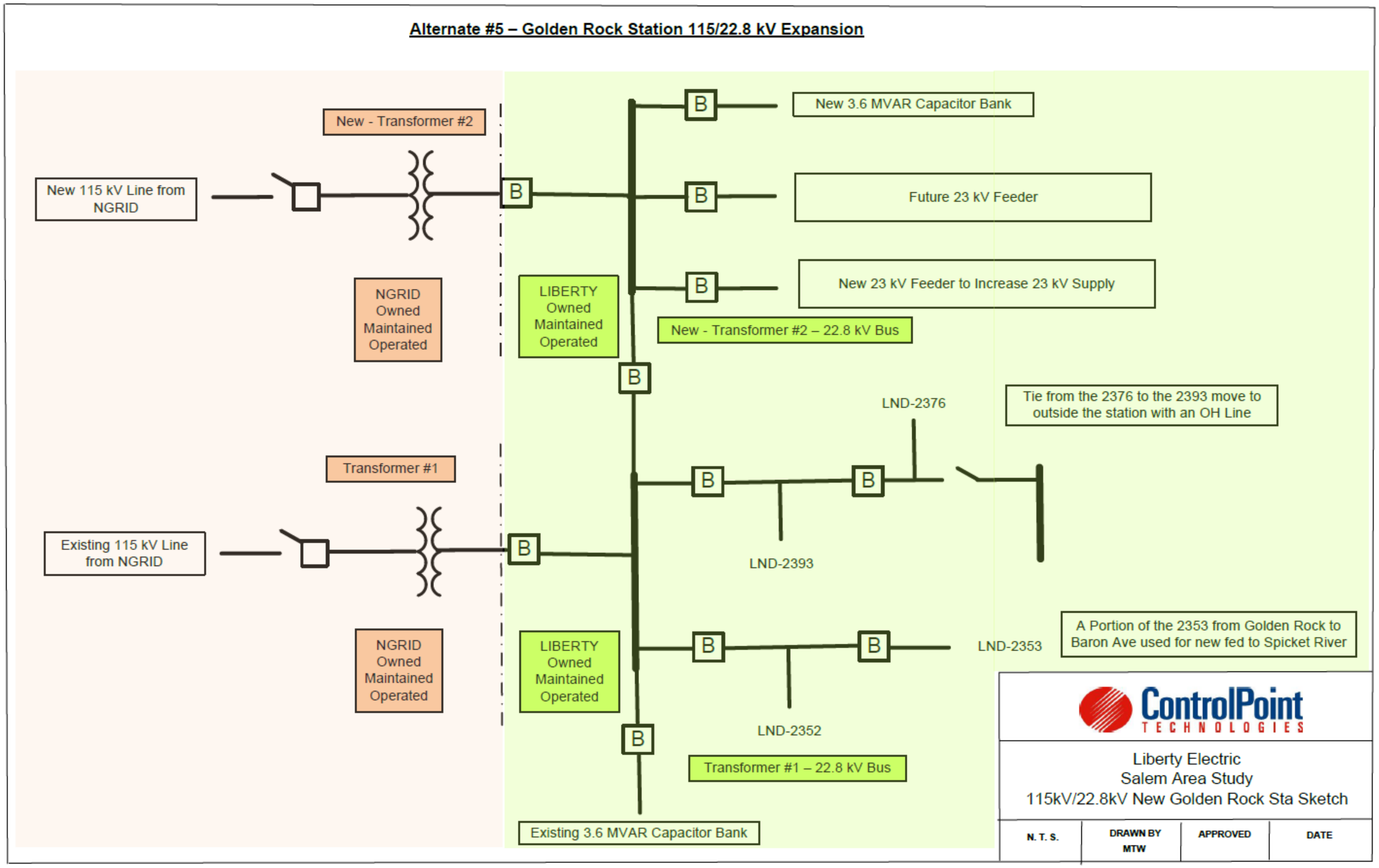


Figure 23 Alternate #5 Golden Rock Substation 115kV/22.8kV Expansion – One Line

890

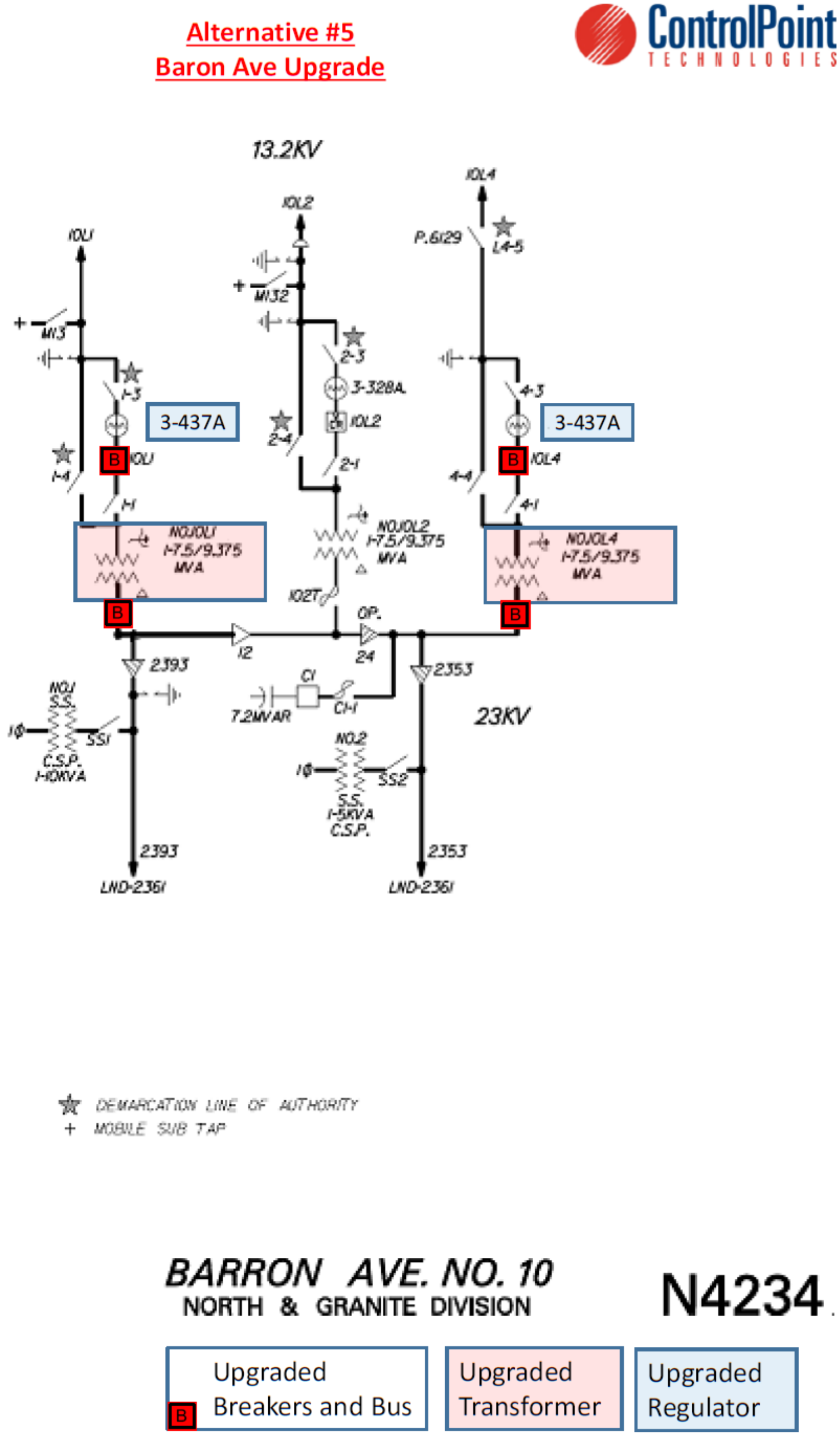


Figure 24 Alternate #5 Barron Ave Station Rebuild – One Line

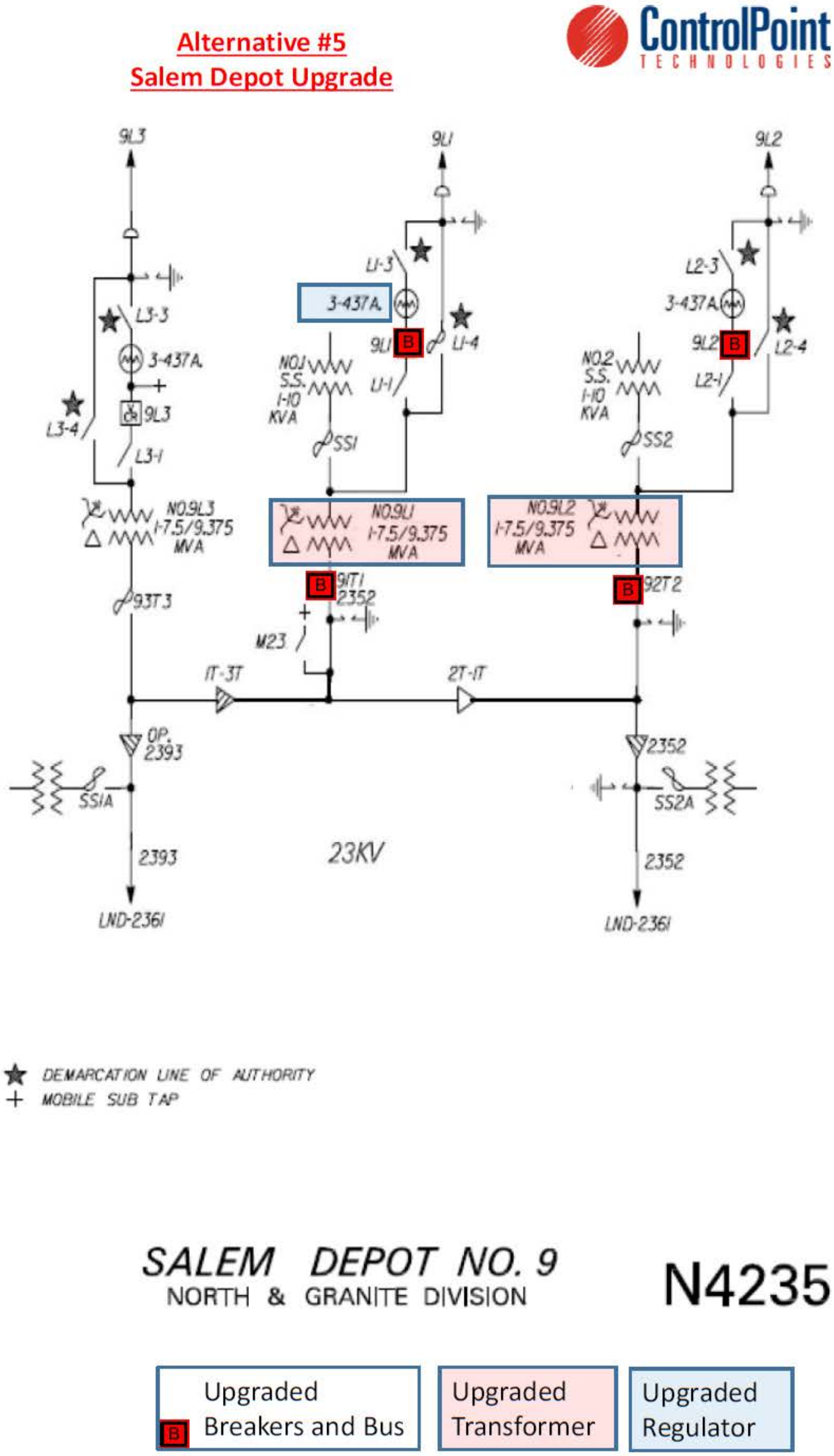


Figure 25 Alternate #5 Salem Depot Station Rebuild – One Line

Alternative Plan 5-New Tuscan Village Substation

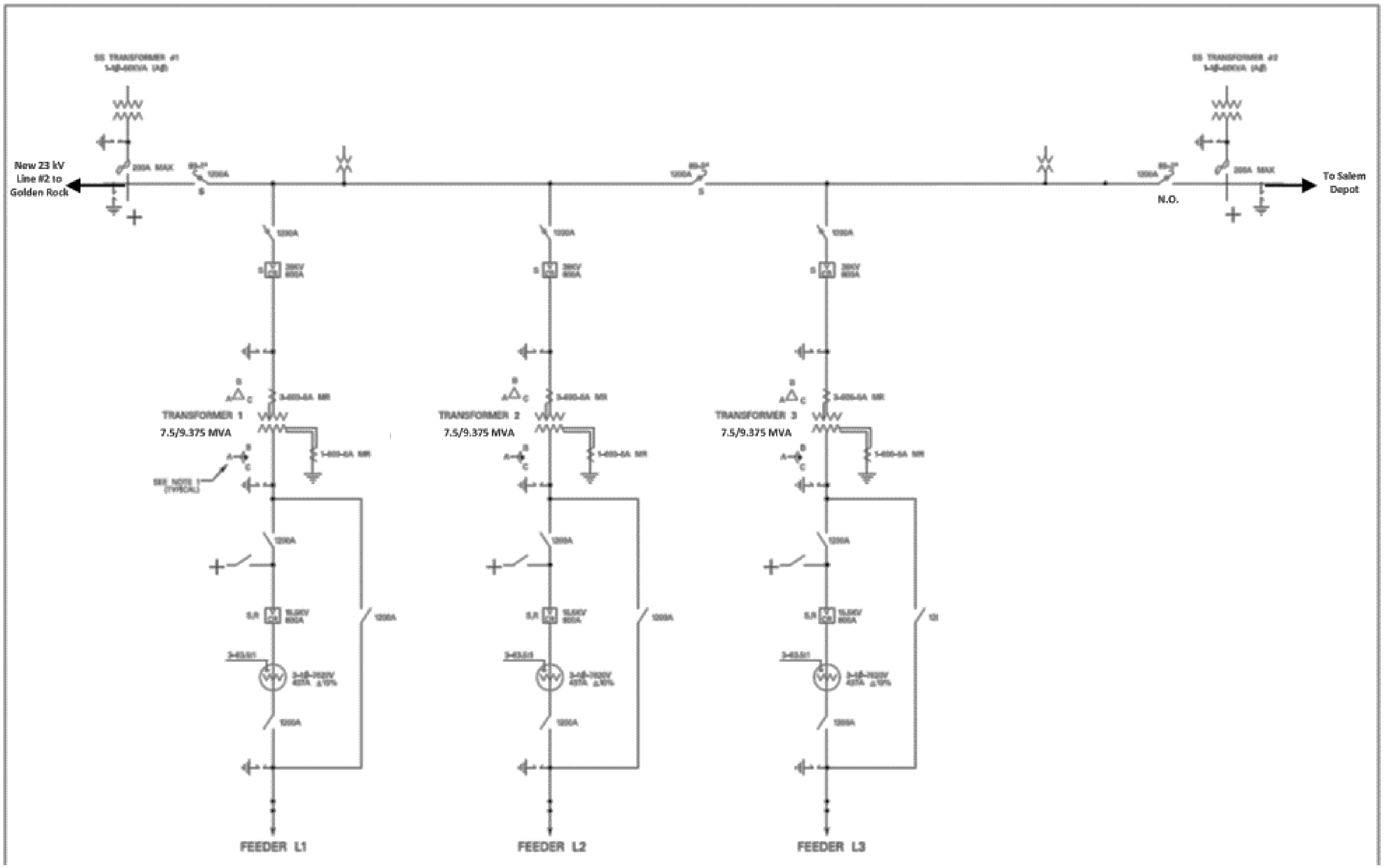


Figure 26 Alternative #5 New 22.8 kV/13.2kV Tuscan Village Substation One Line

071

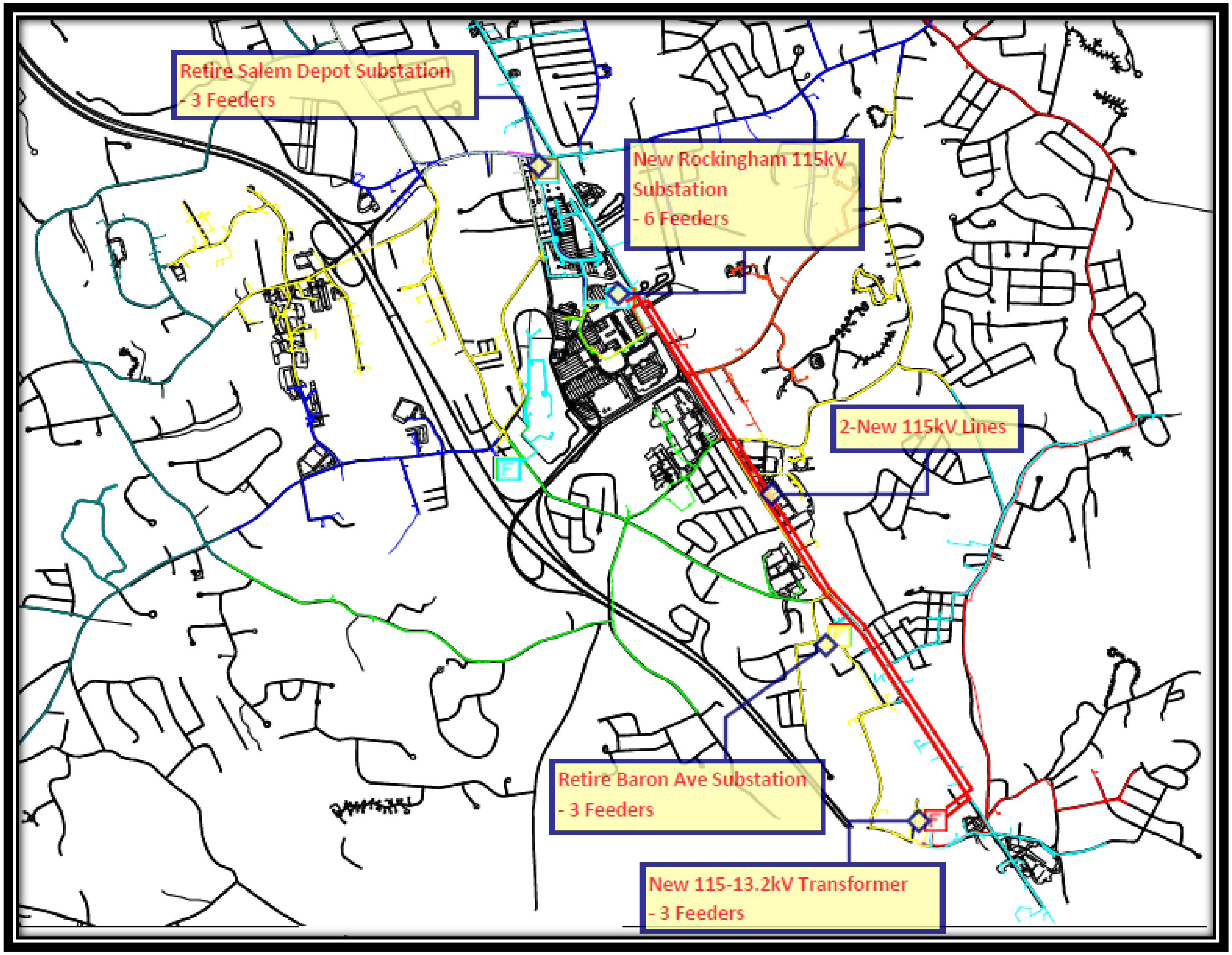


Figure 27 Alternative #6 13.2kV Overview One Line

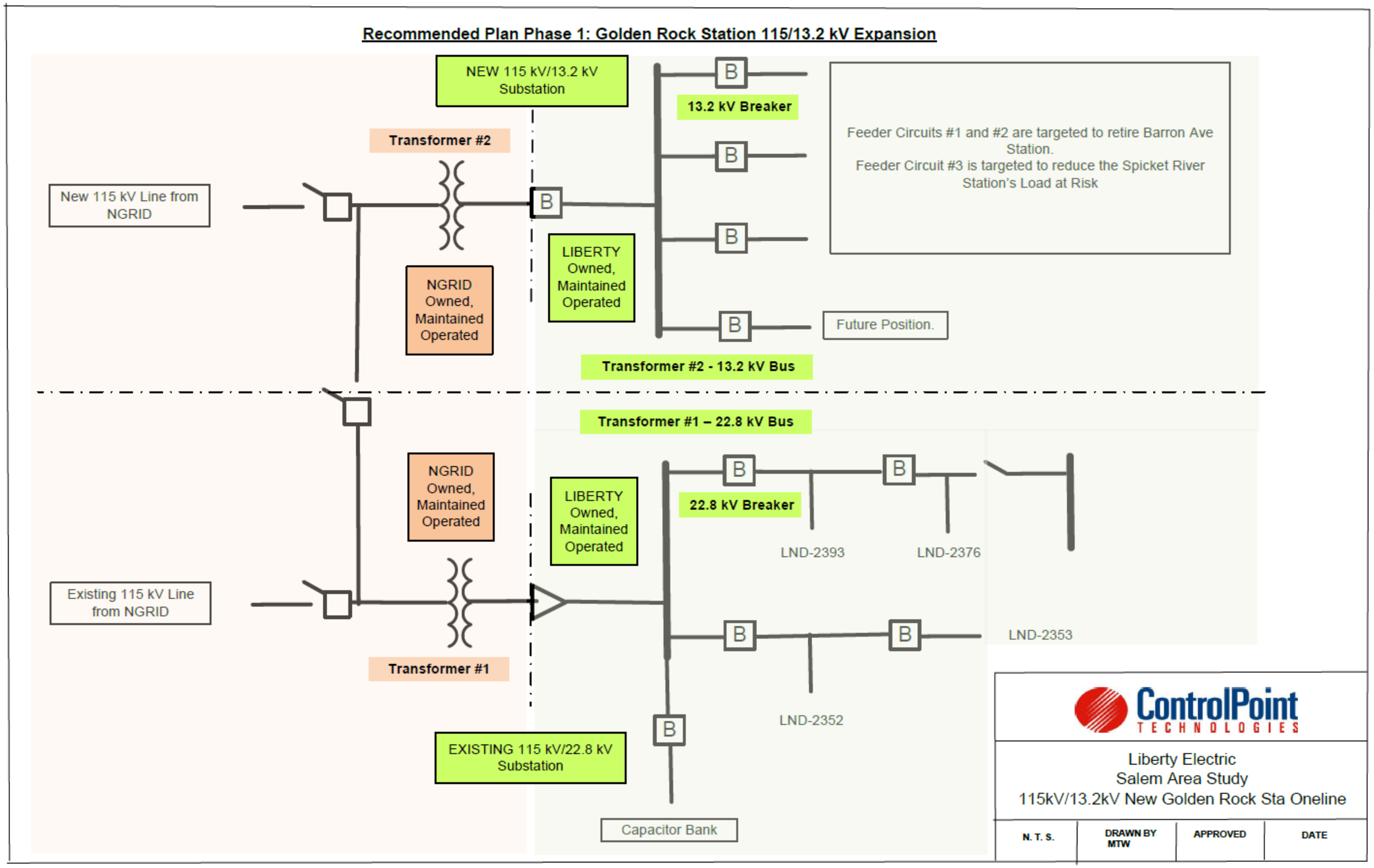


Figure 28 Alternate #6 Golden Rock Substation 115kV/13,2kV Expansion Phase One - One Line

073

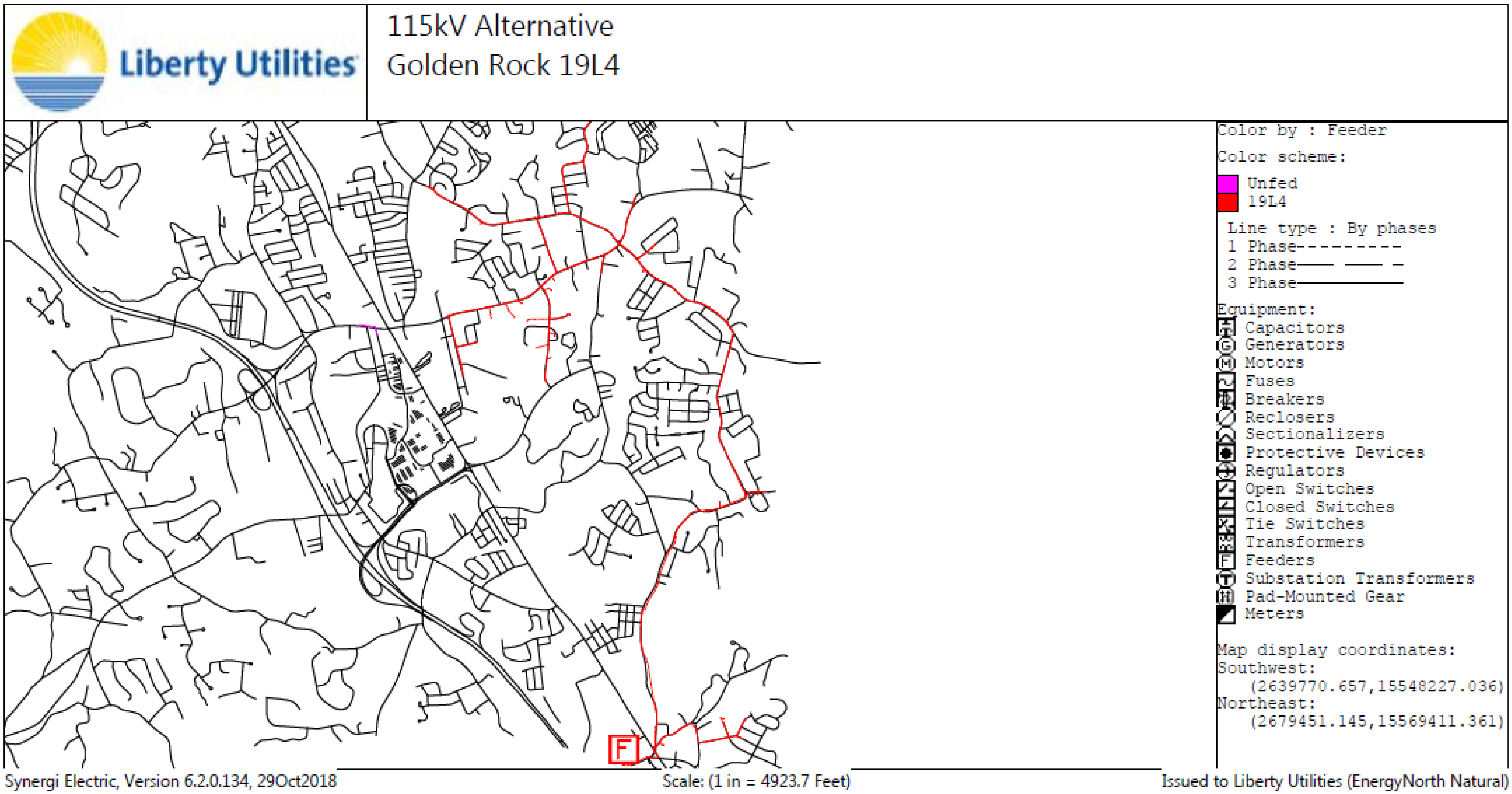


Figure 29 Alternate #6 Feeder 19L4 – One Line

074

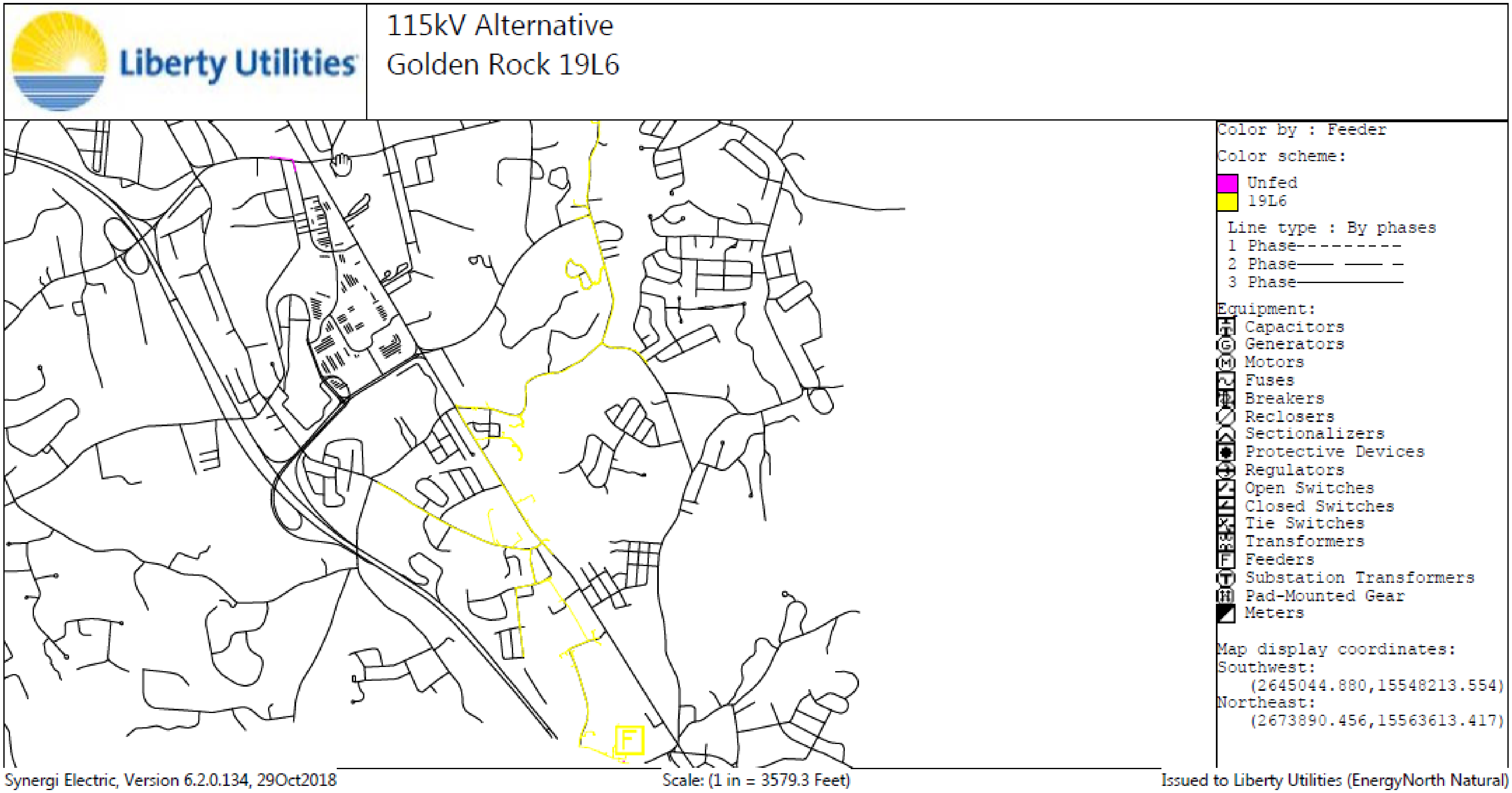


Figure 30 Alternate #6 Feeder 19L6 - One Line

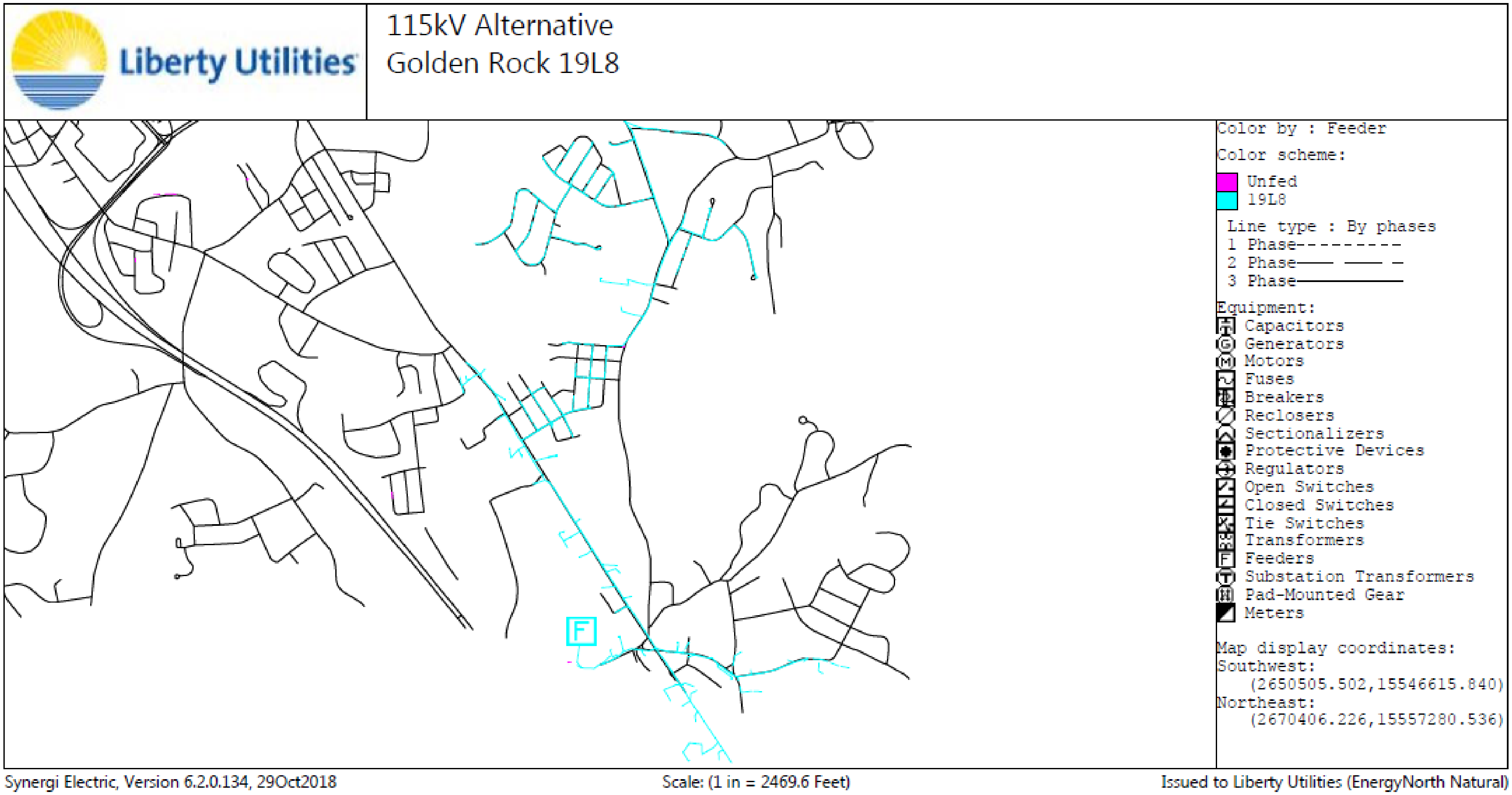


Figure 31 Alternate #6 Feeder 19L8 - One Line

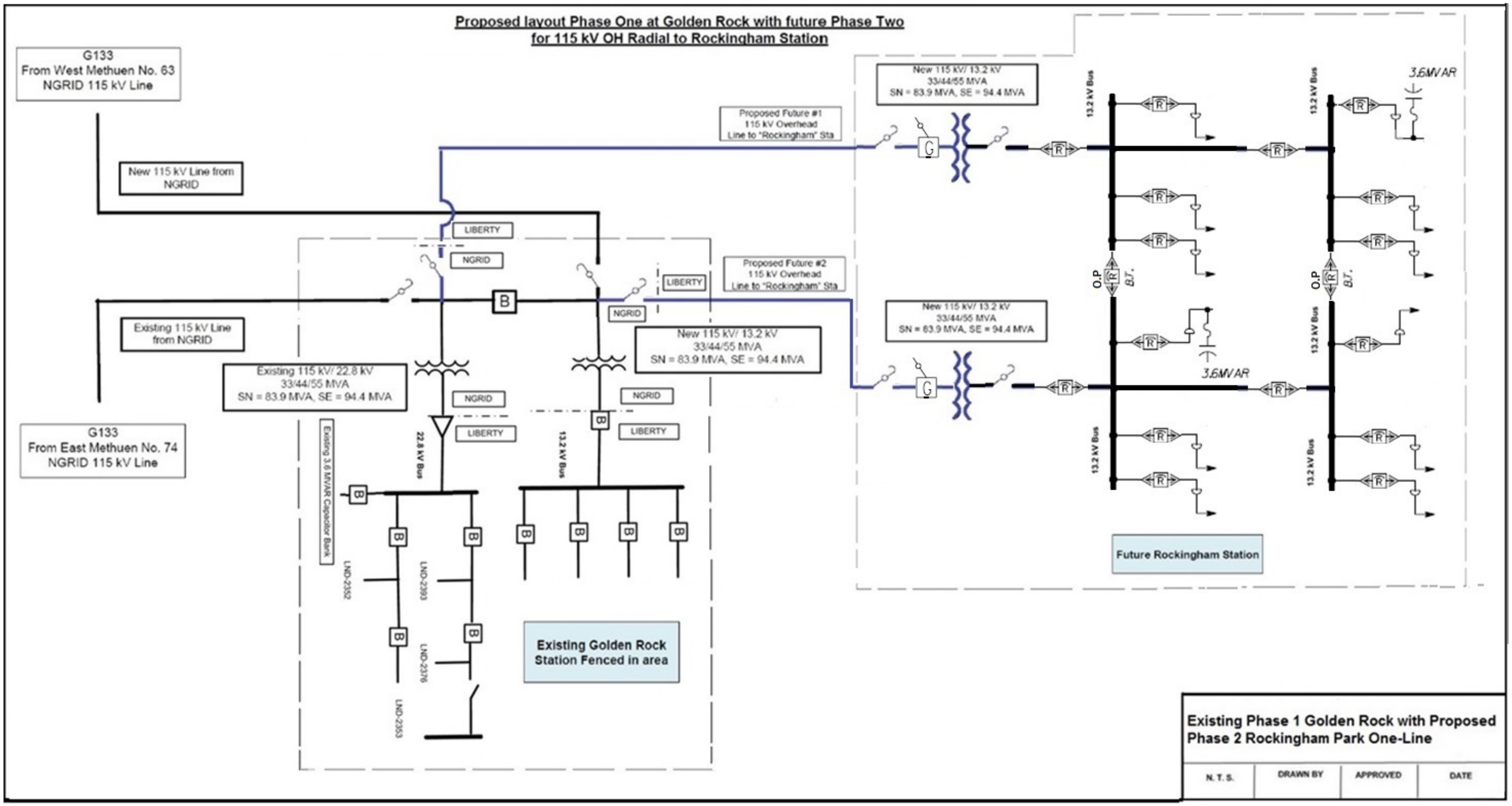


Figure 32 Alternative #6 Rockingham Substation 115kV/13.2kV Phase Two - One Line

077

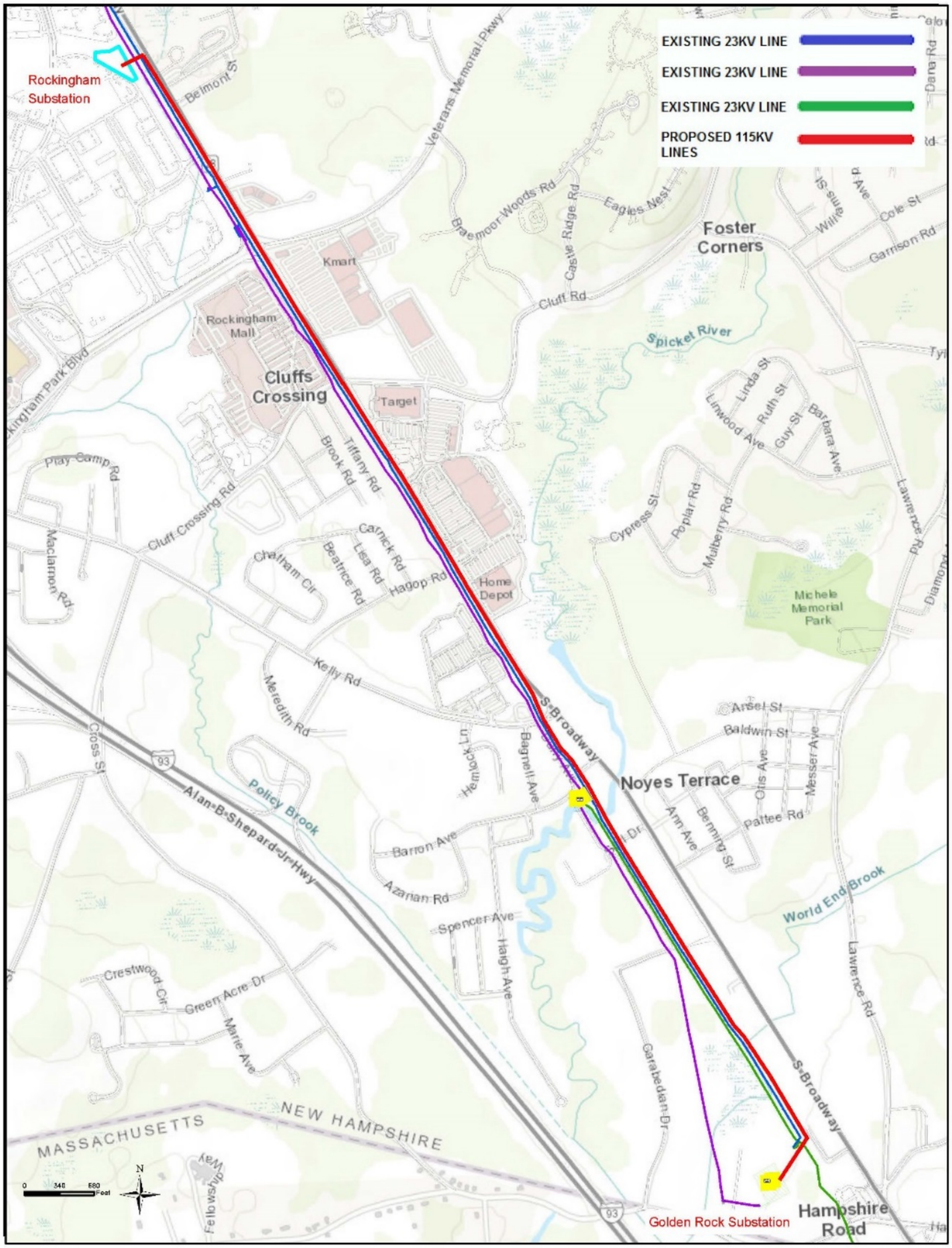
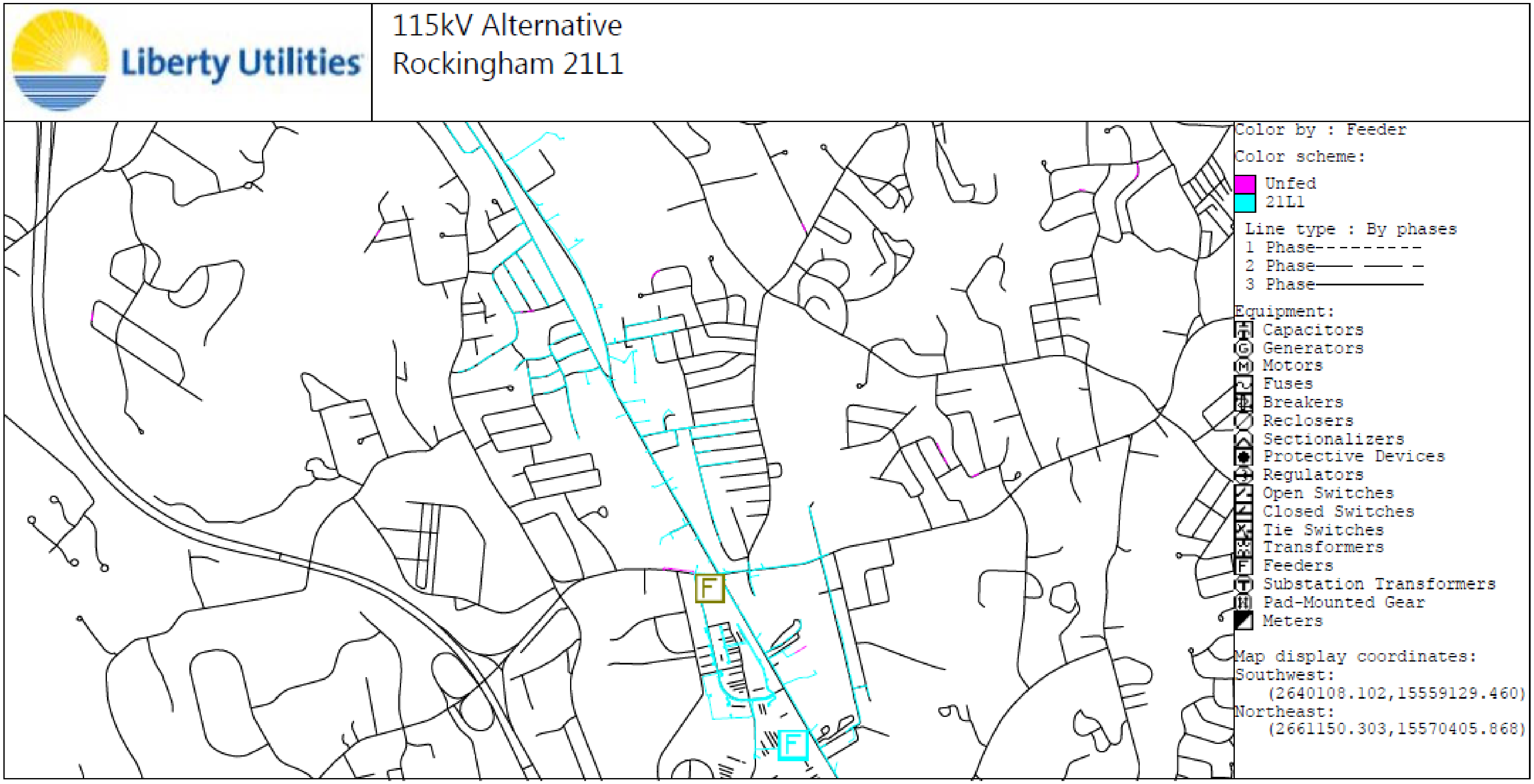


Figure 33 Proposed Plan #6 115kV Route



Synergi Electric, Version 6.2.0.134, 29Oct2018 Scale: (1 in = 2611.3 Feet) Issued to Liberty Utilities (EnergyNorth Natural)

Figure 34 Alternate #6 New Rockingham Station - Feeder 21L1 - One Line

079

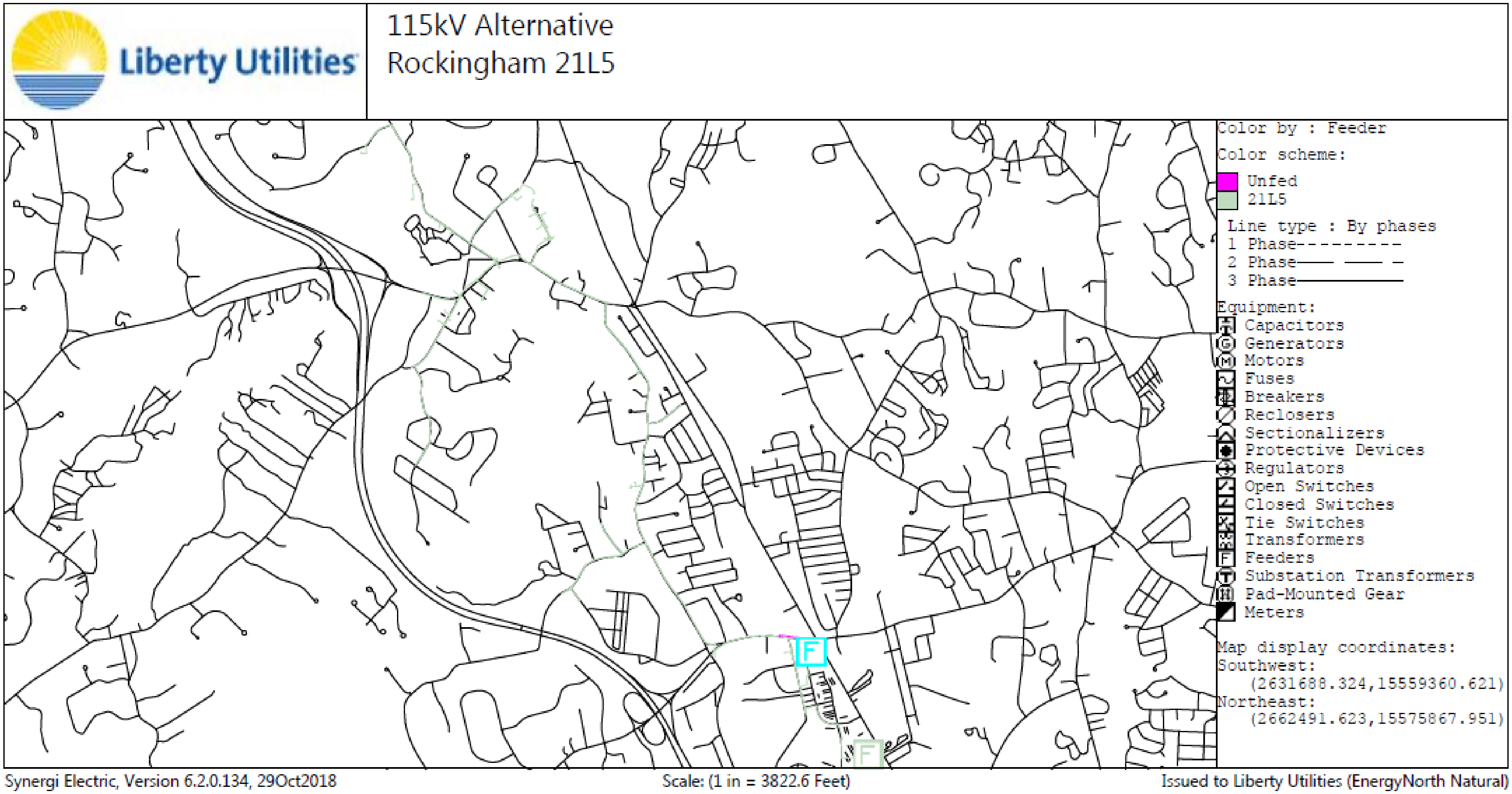


Figure 35 Alternate #6 New Rockingham Station – Feeder 21L5 - One Line

080

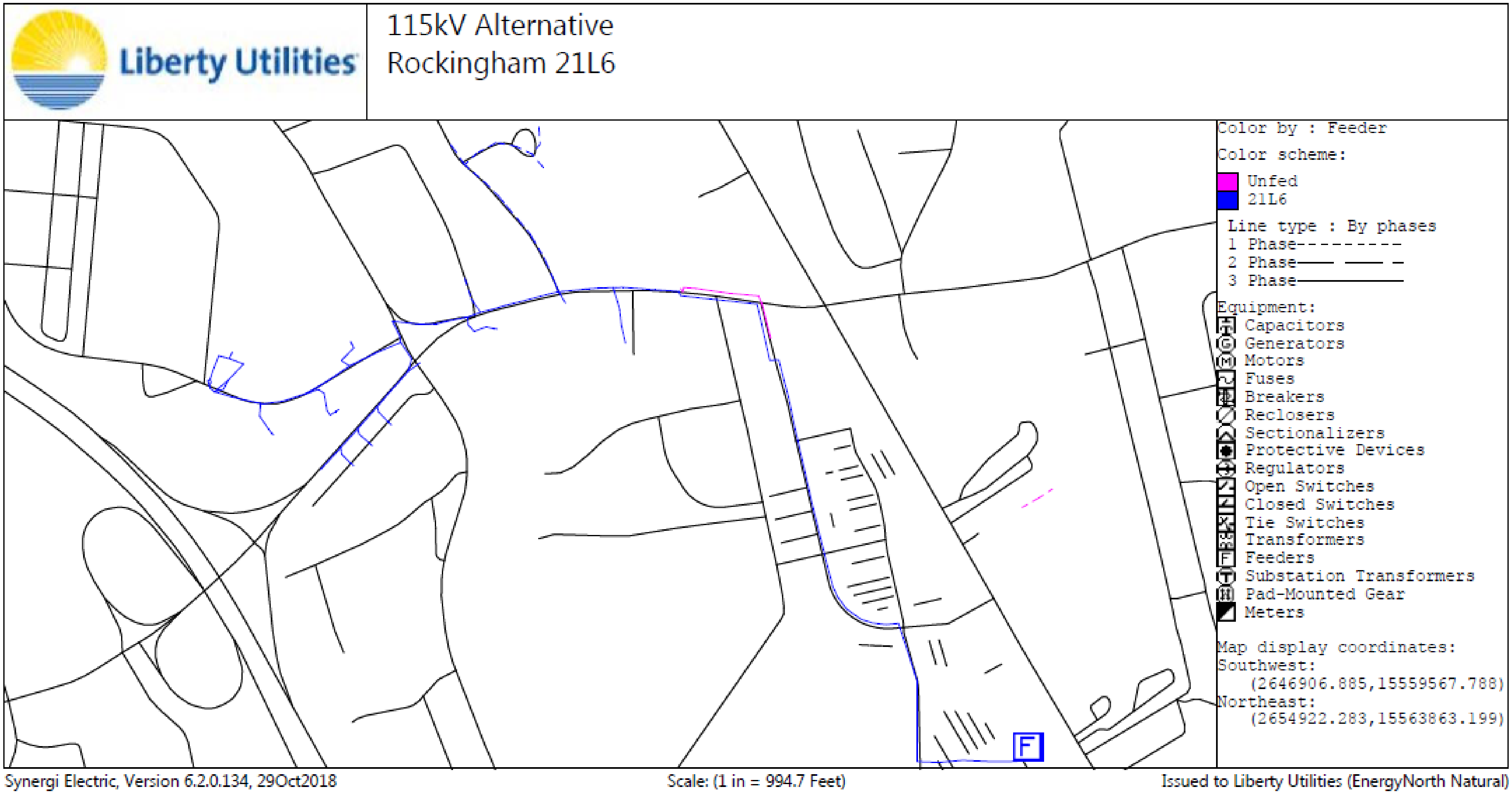


Figure 36 Alternate #6 New Rockingham Station – Feeder 21L6 - One Line

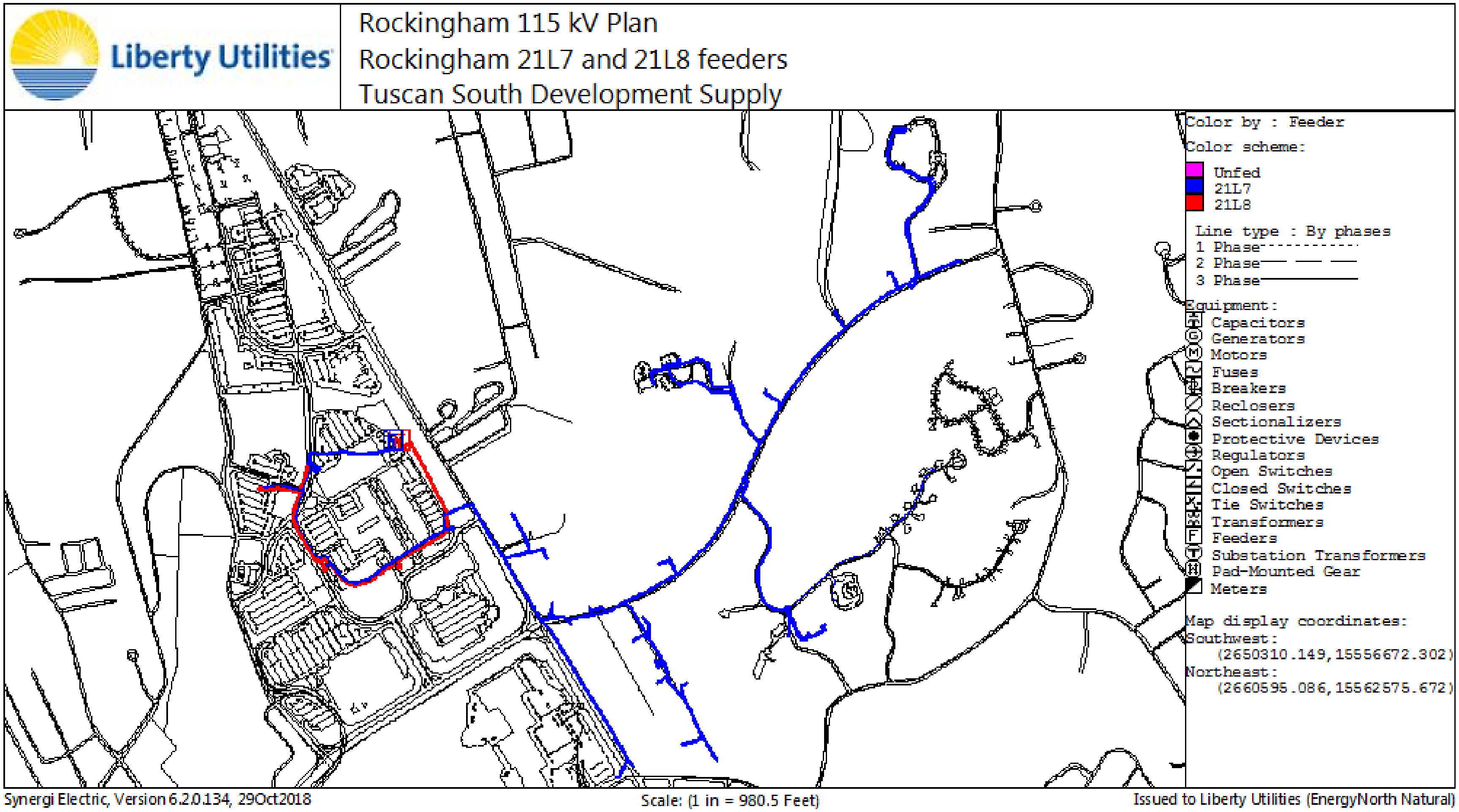


Figure 37 Alternate #6 New Rockingham Station – Feeder 21L7 & 21L8 - One Line

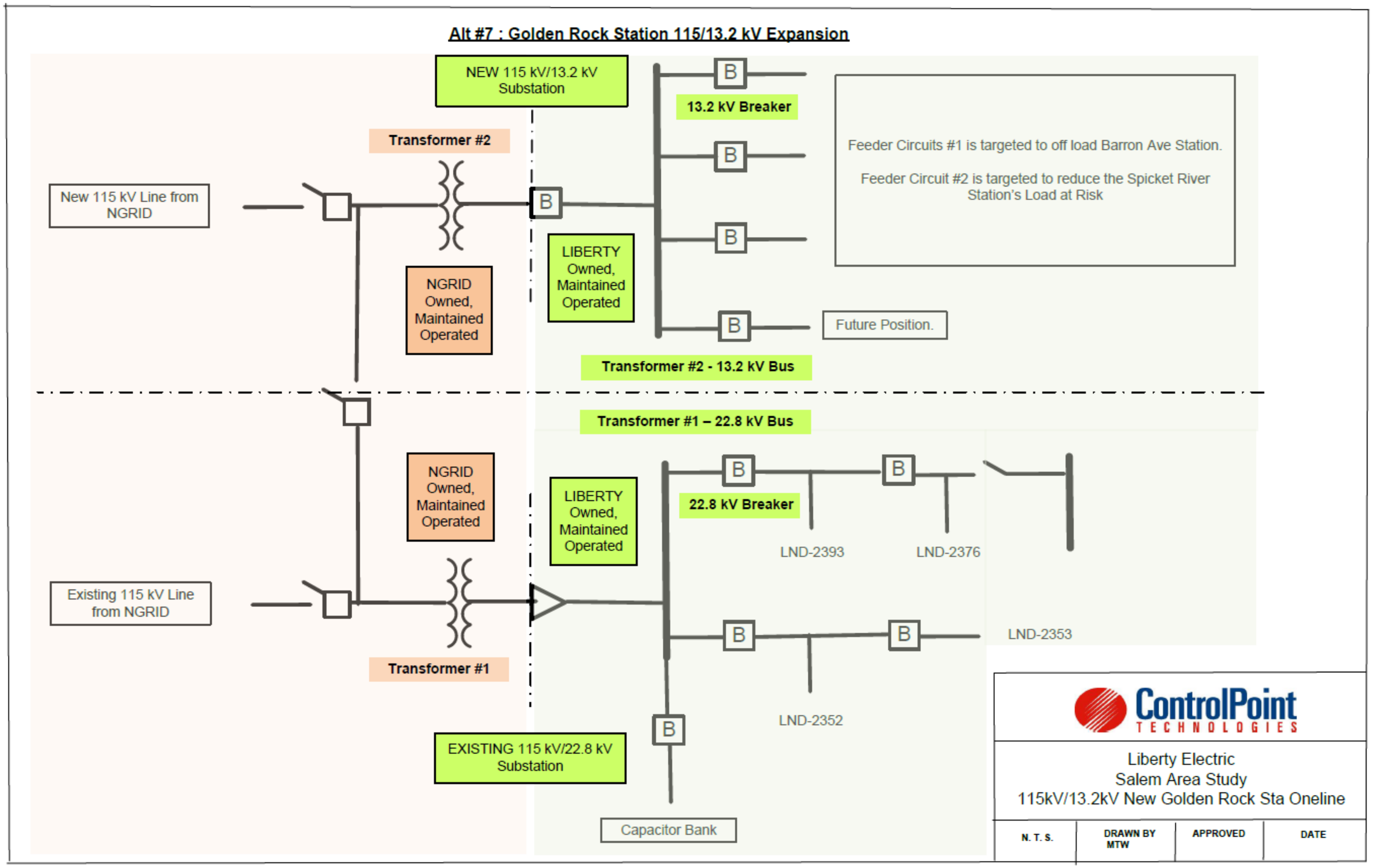


Figure 38 Alternative #7 Golden Rock Substation 115kV/13.2kV Expansion – One Line

083

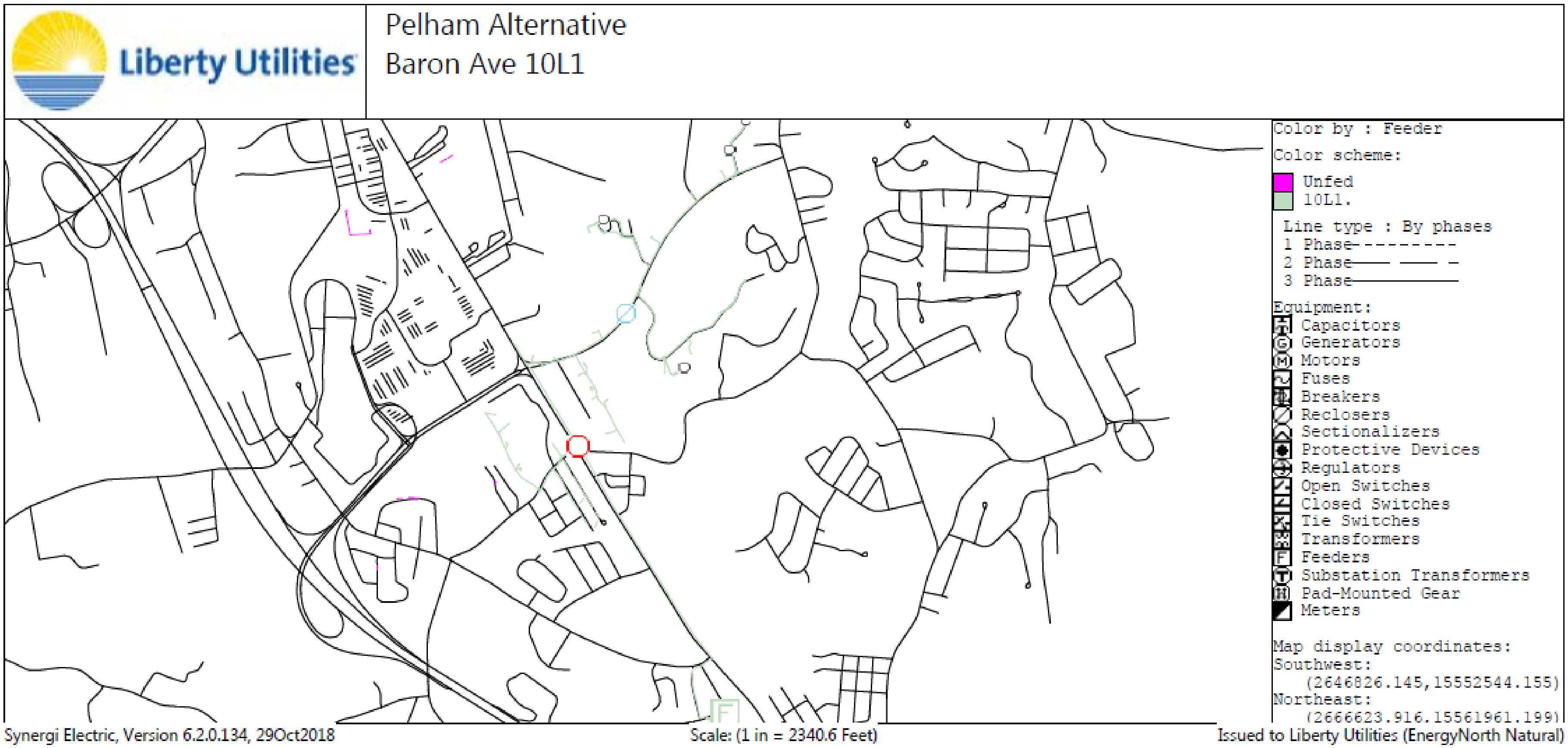


Figure 39 Alternate #7 Barron Ave 10L1 – One Line

084

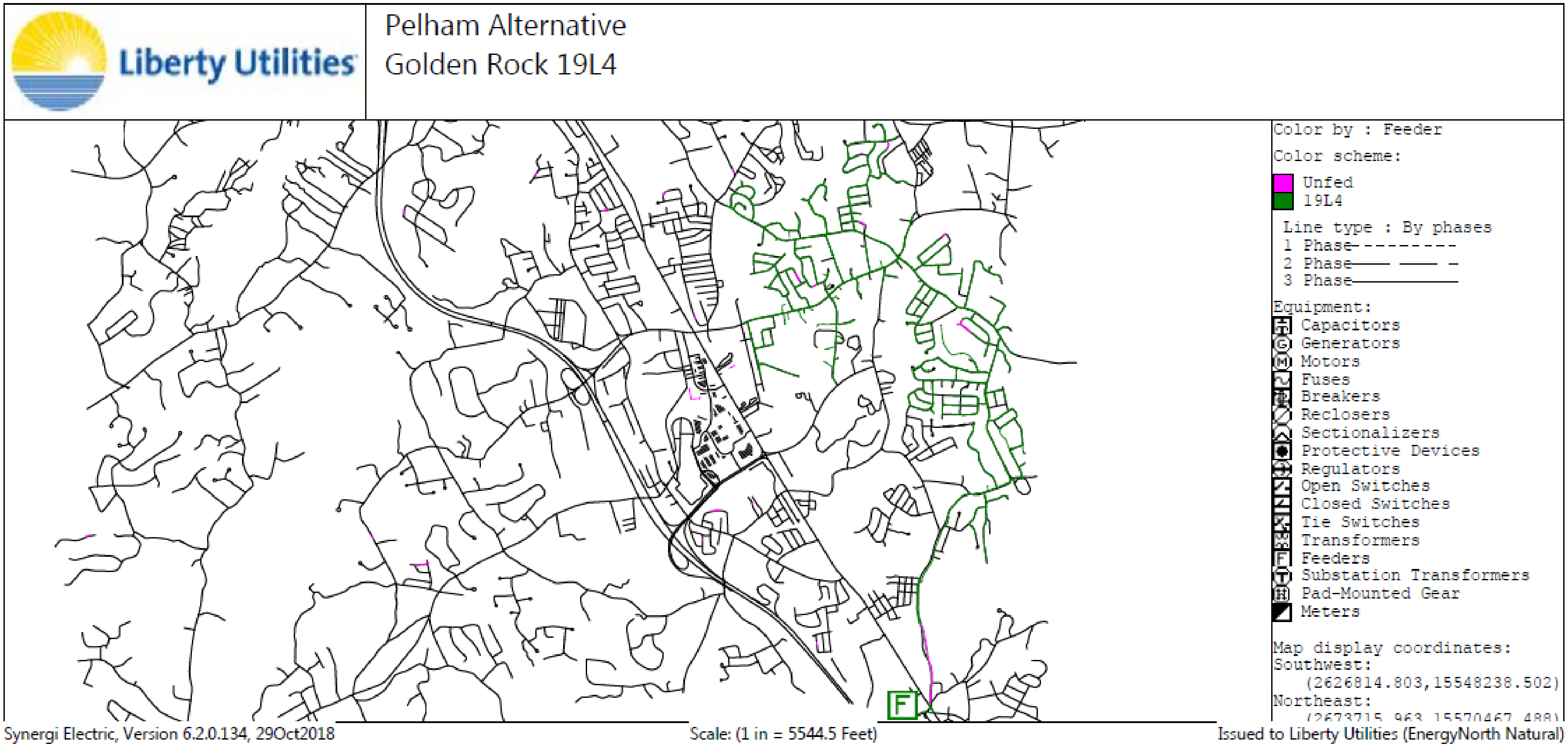


Figure 40 Alternate #7 Golden Rock 19L4 – One Line

085

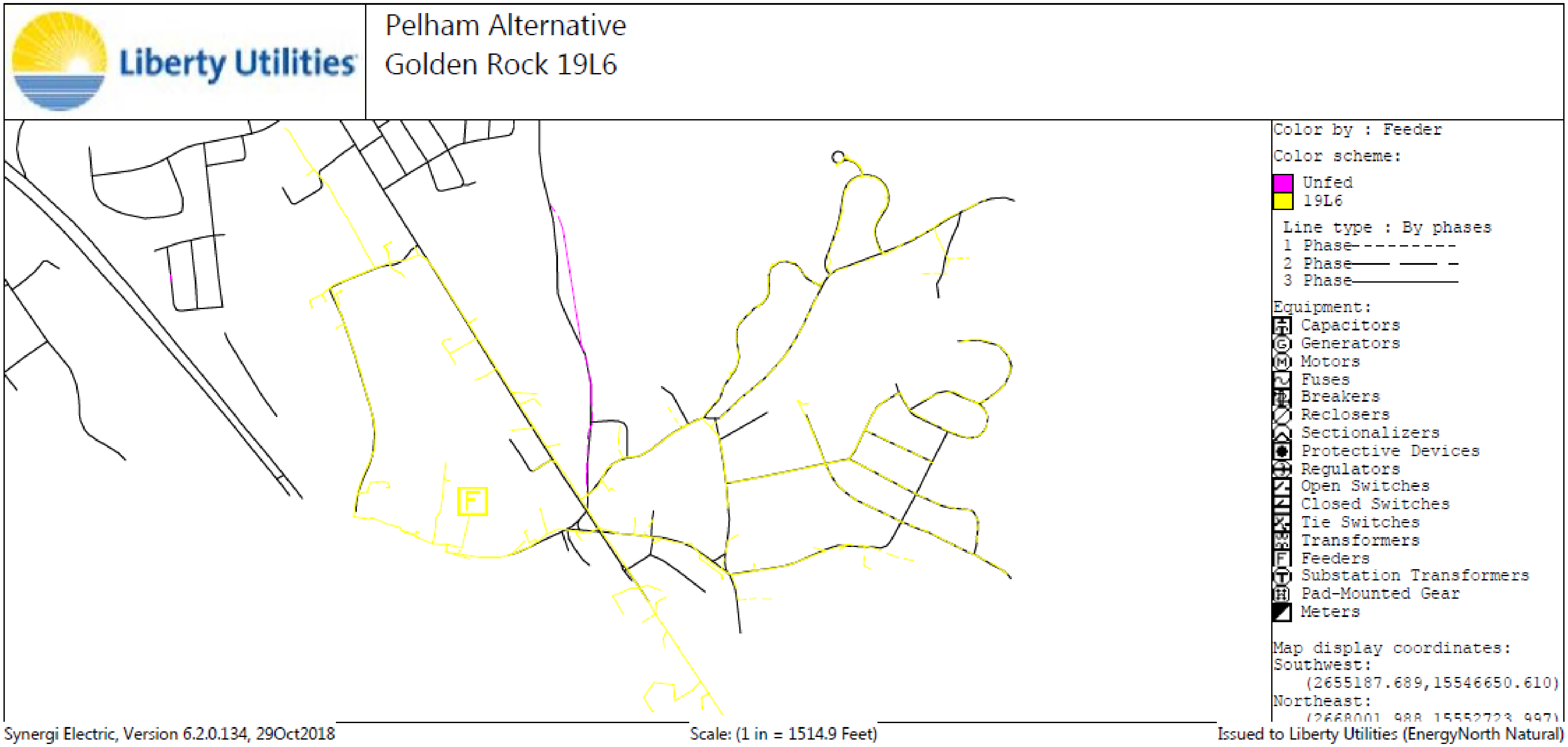


Figure 41 Alternate #7 Golden Rock 19L6 - One Line

086

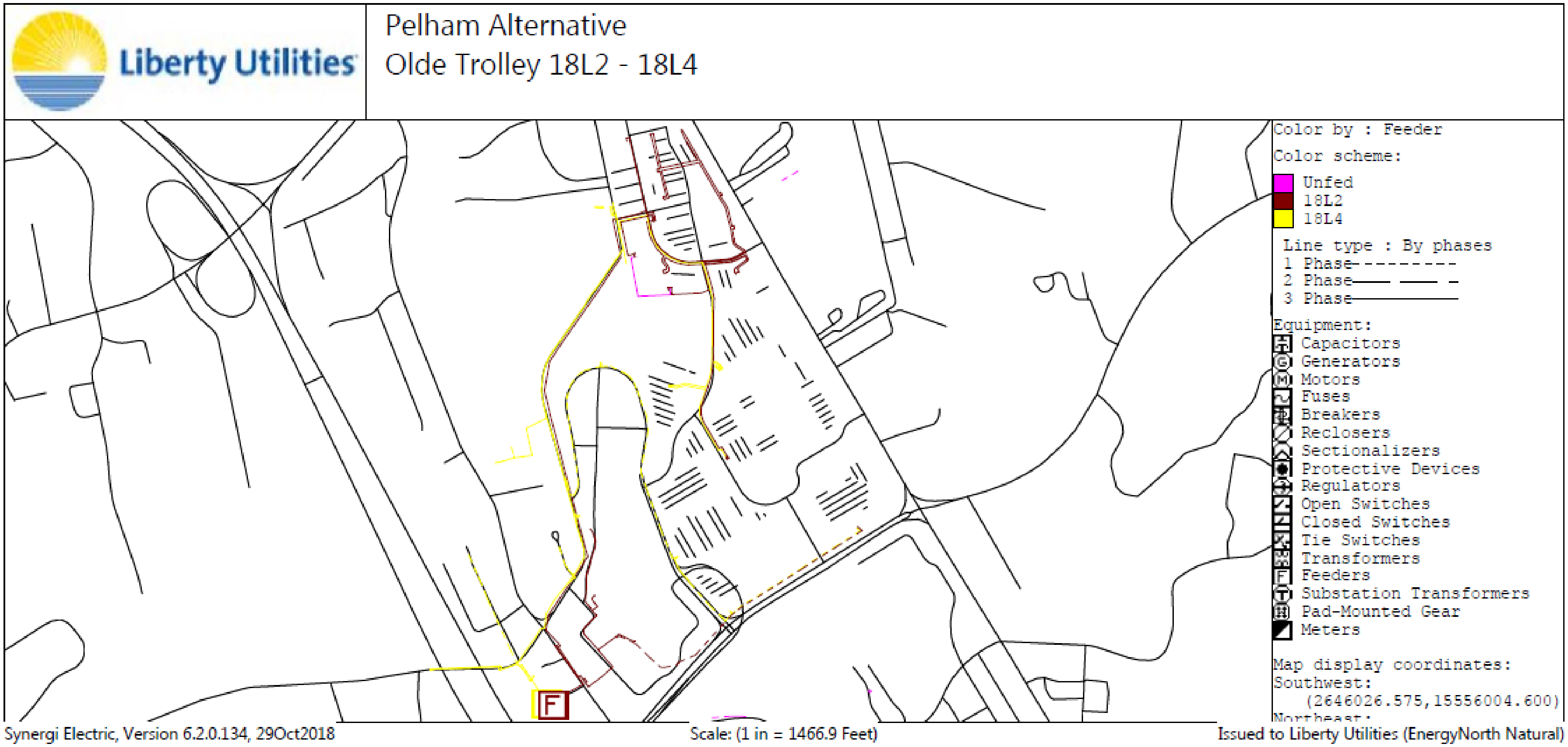


Figure 42 Alternate #7 Olde Trolley 18L2 and 18L4 – One Line

087

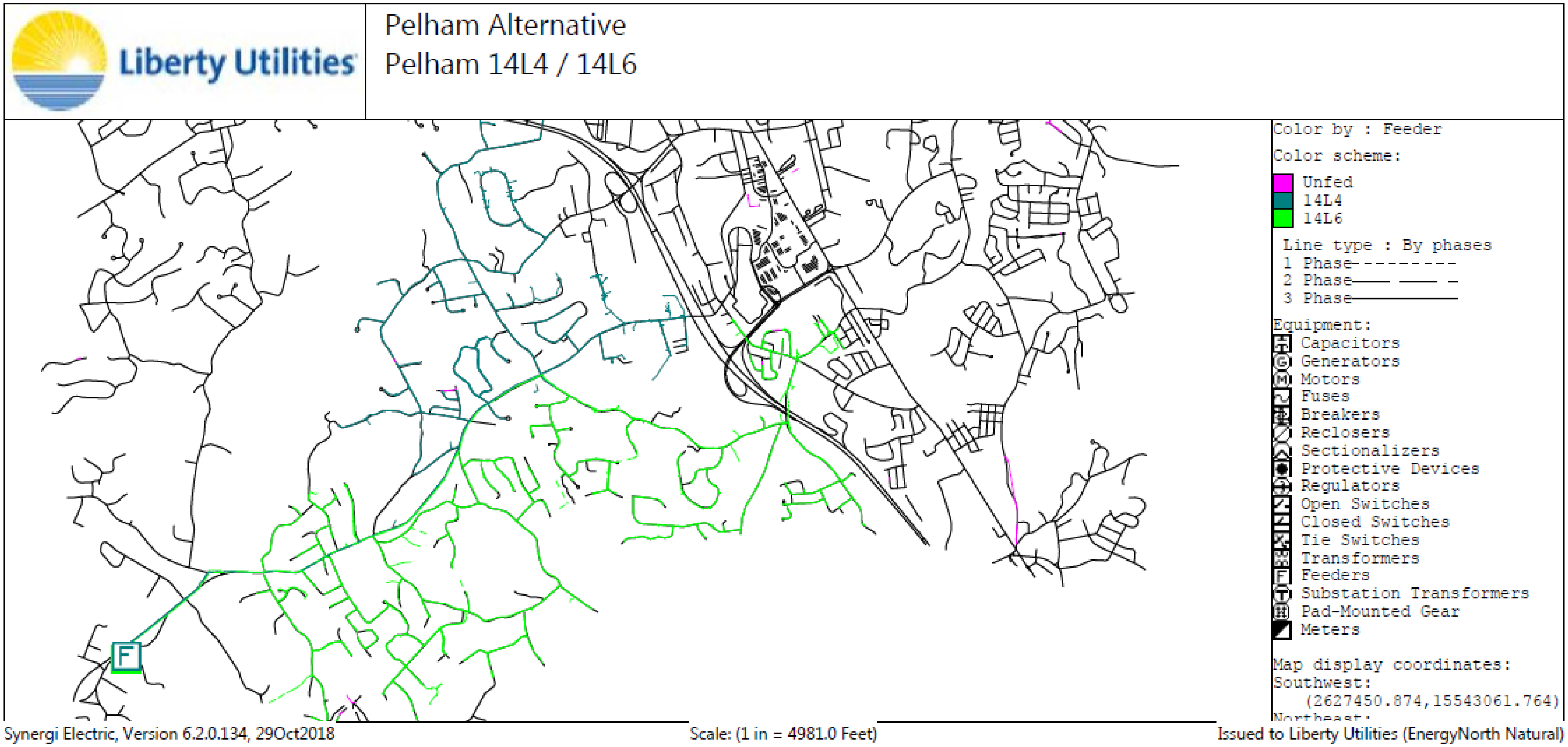


Figure 43 Alternate #7 Pelham 14L4 and 14L6 – One Line

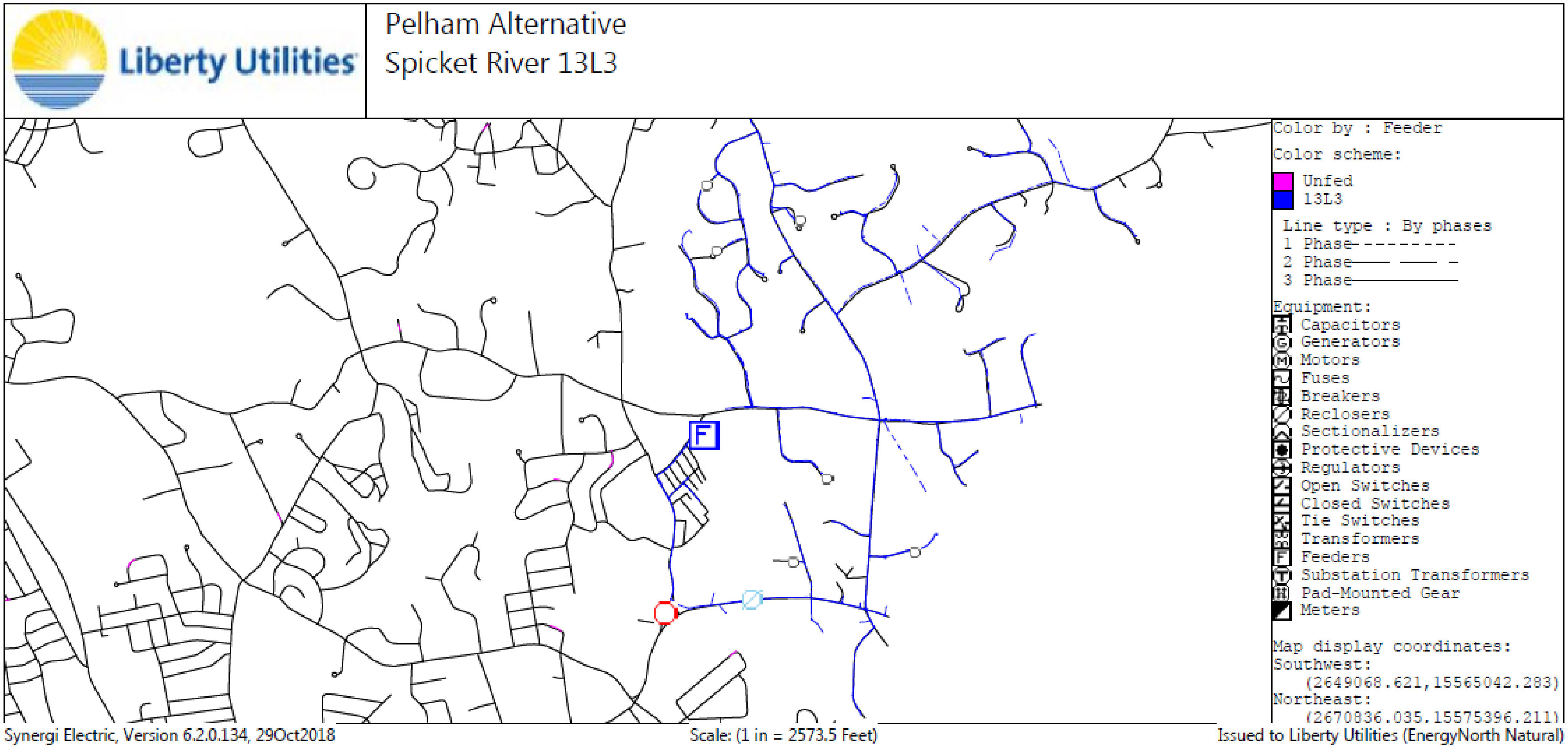


Figure 44 Alternative #7 Spicket River 13L3 - One Line

680

9.2 Appendix B – Asset Condition Documents

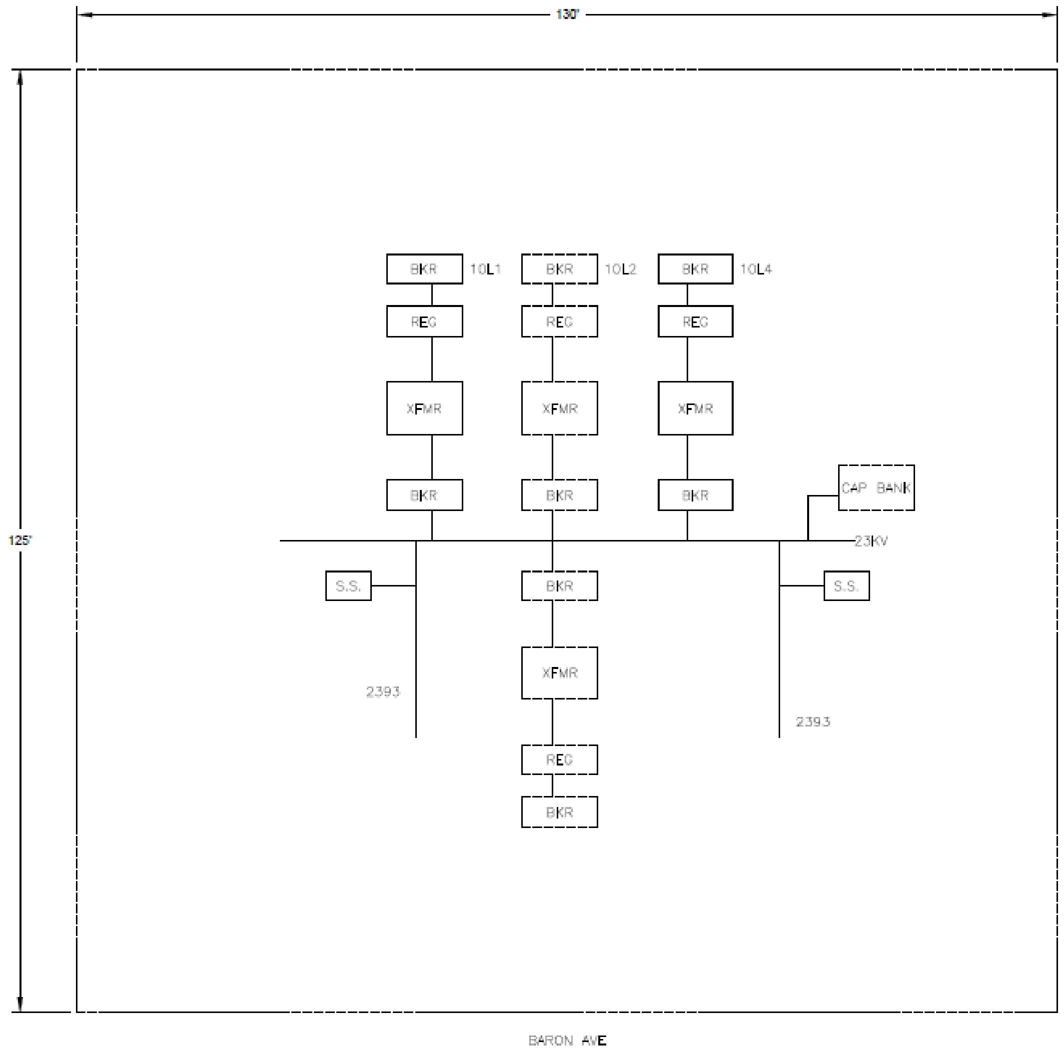


Figure 45 Barron Ave Conceptual Station Equipment Layout

060

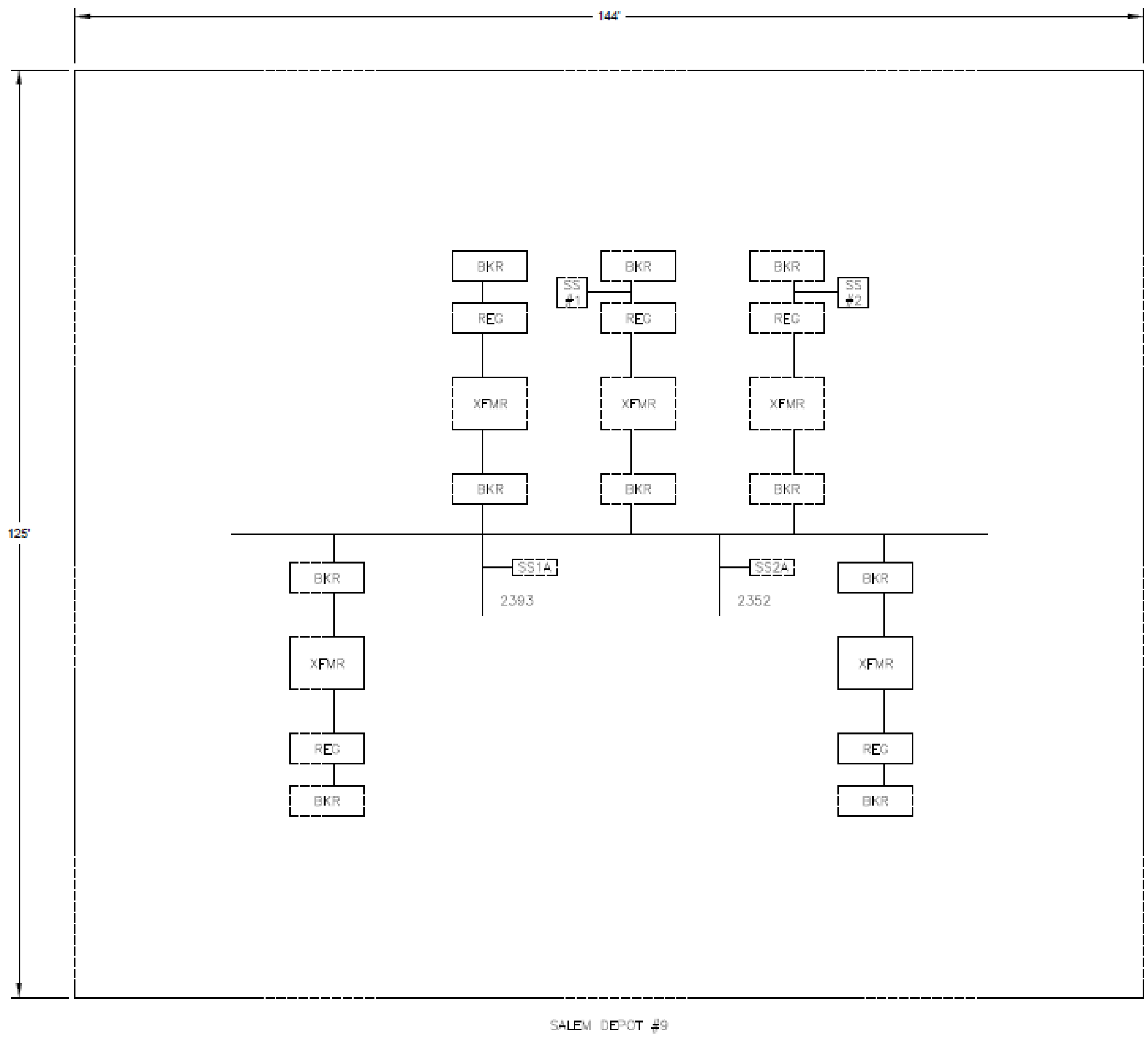


Figure 46 Salem Depot Conceptual Station Equipment Layout

Figure 47 Barron Ave Site Layout

092

Figure 48 Salem Depot Site Layout

093

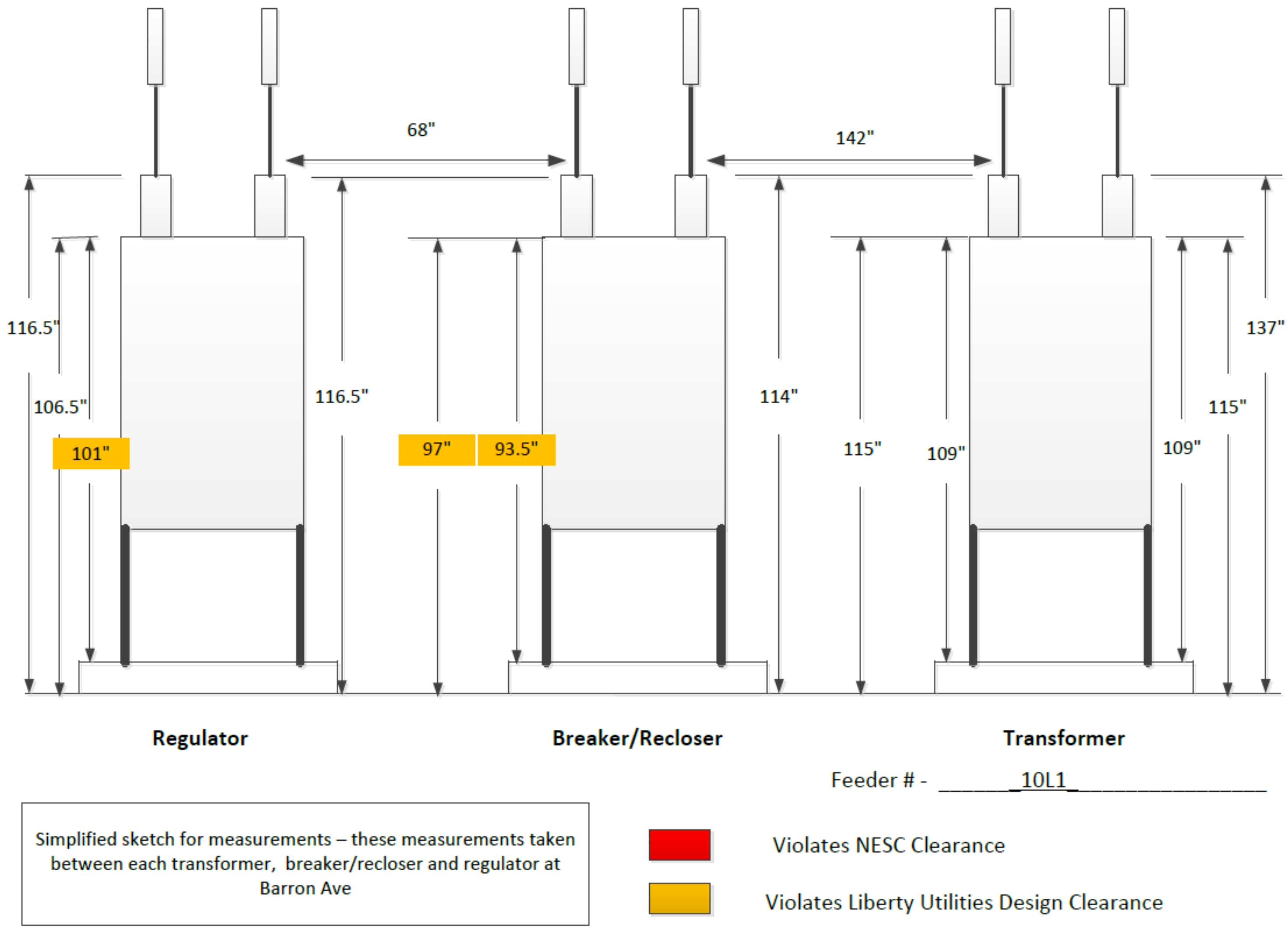


Figure 49 Barron Ave 10L1 Clearance Sketch

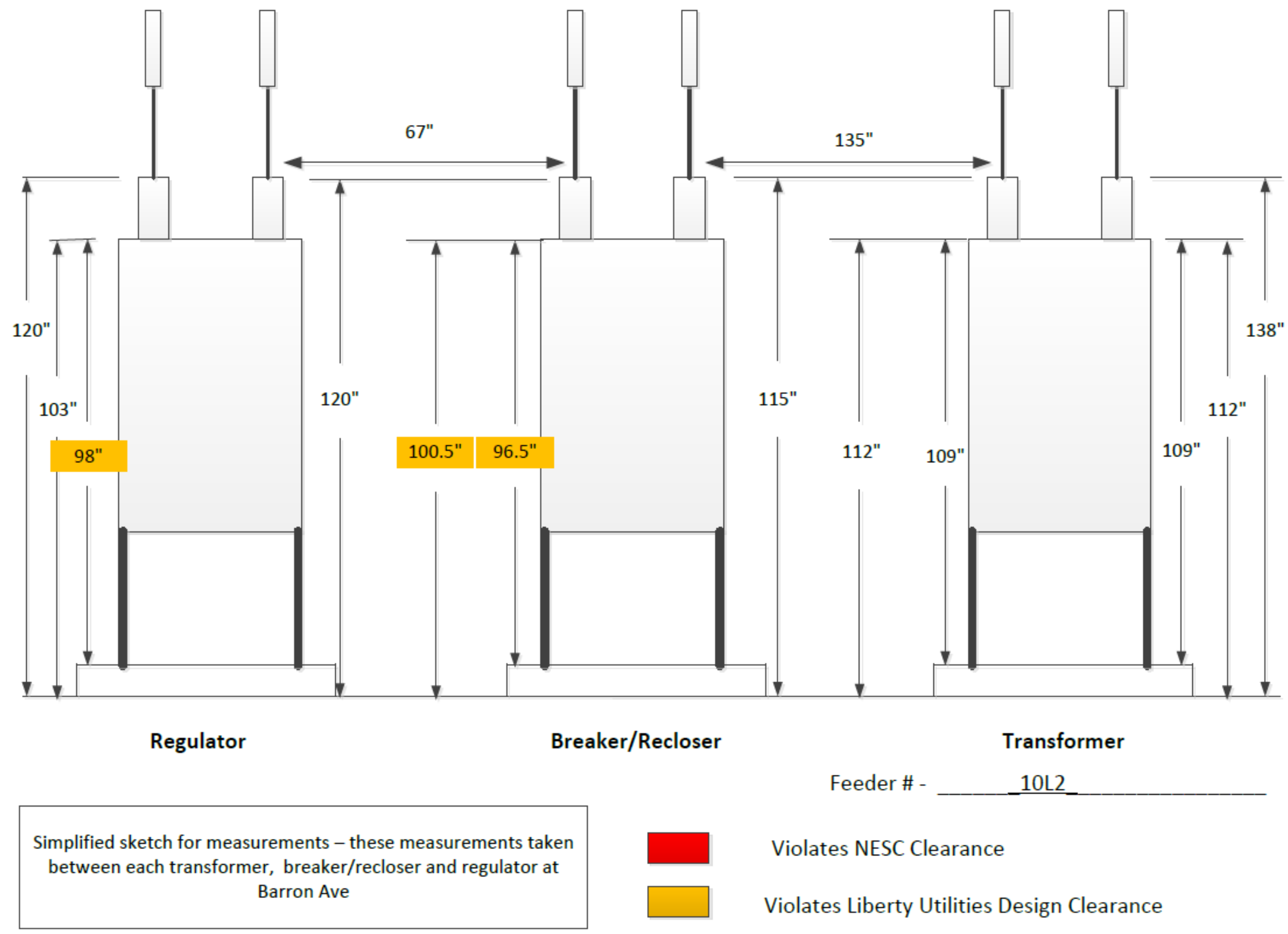


Figure 50 Barron Ave 10L2 Clearance Sketch

095

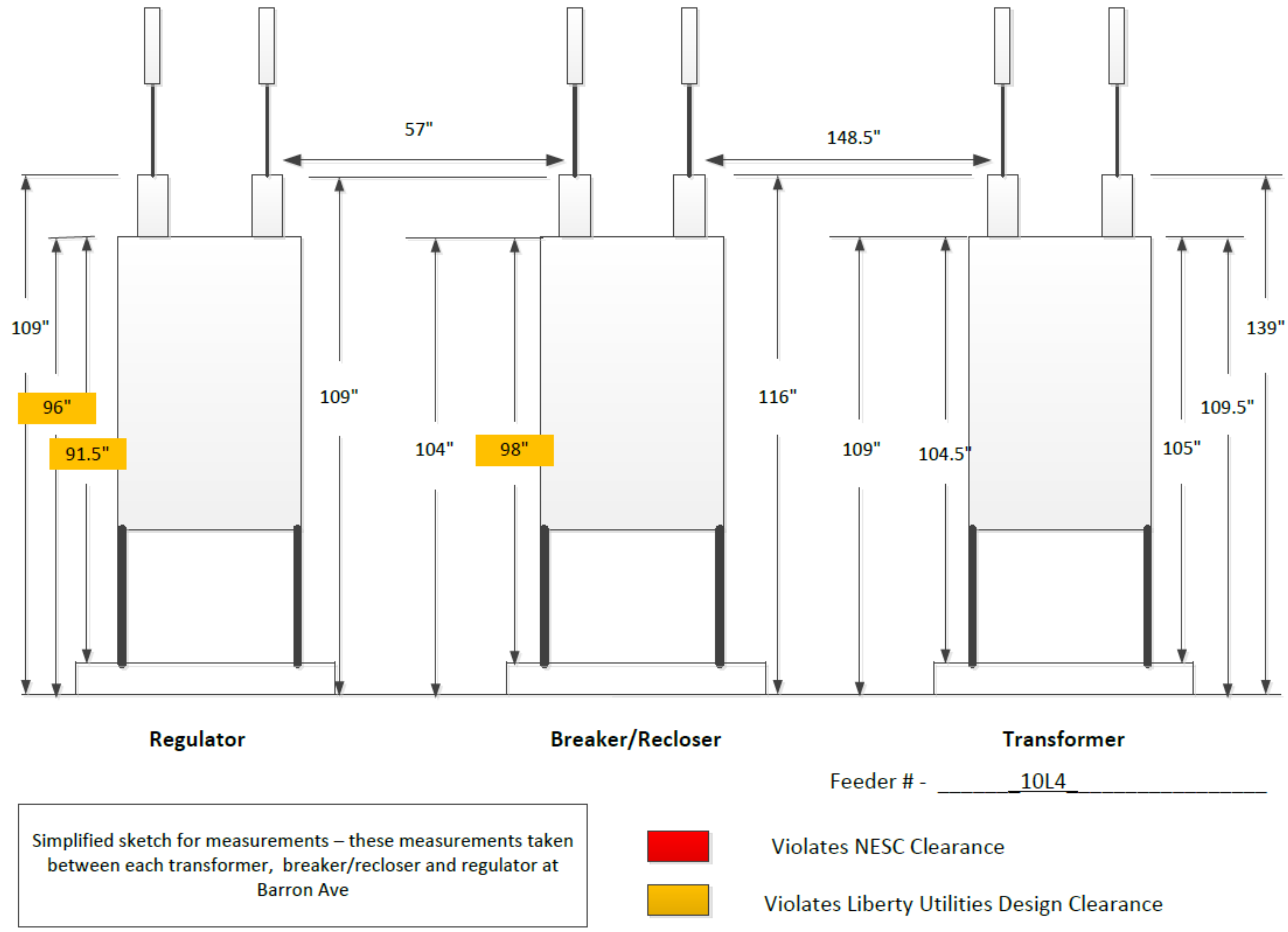


Figure 51 Barron Ave 10L4 Clearance Sketch

960

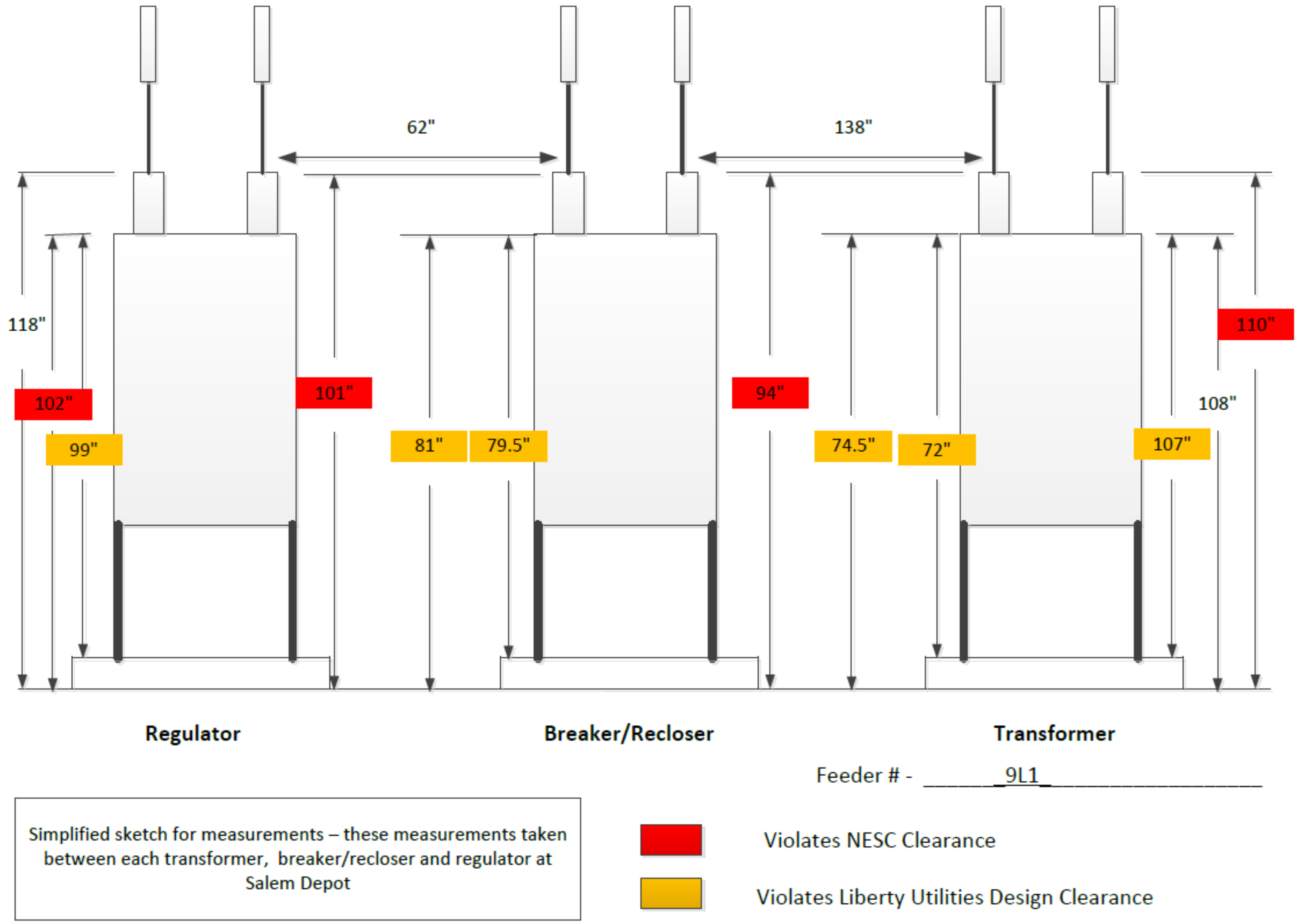


Figure 52 Salem Depot 9L1 Clearance Sketch

097

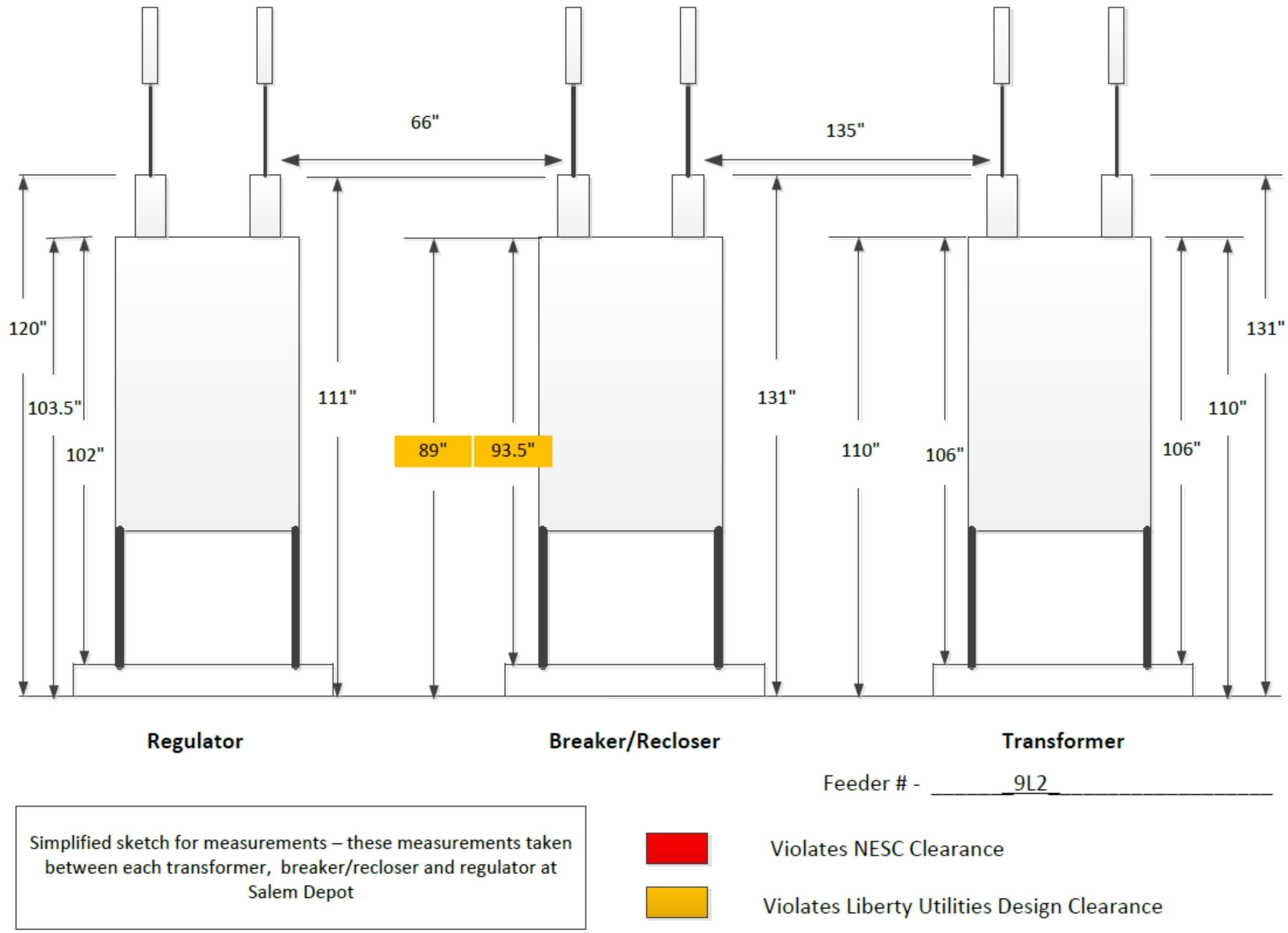


Figure 53 Salem Depot 9L2 Clearance Sketch

098

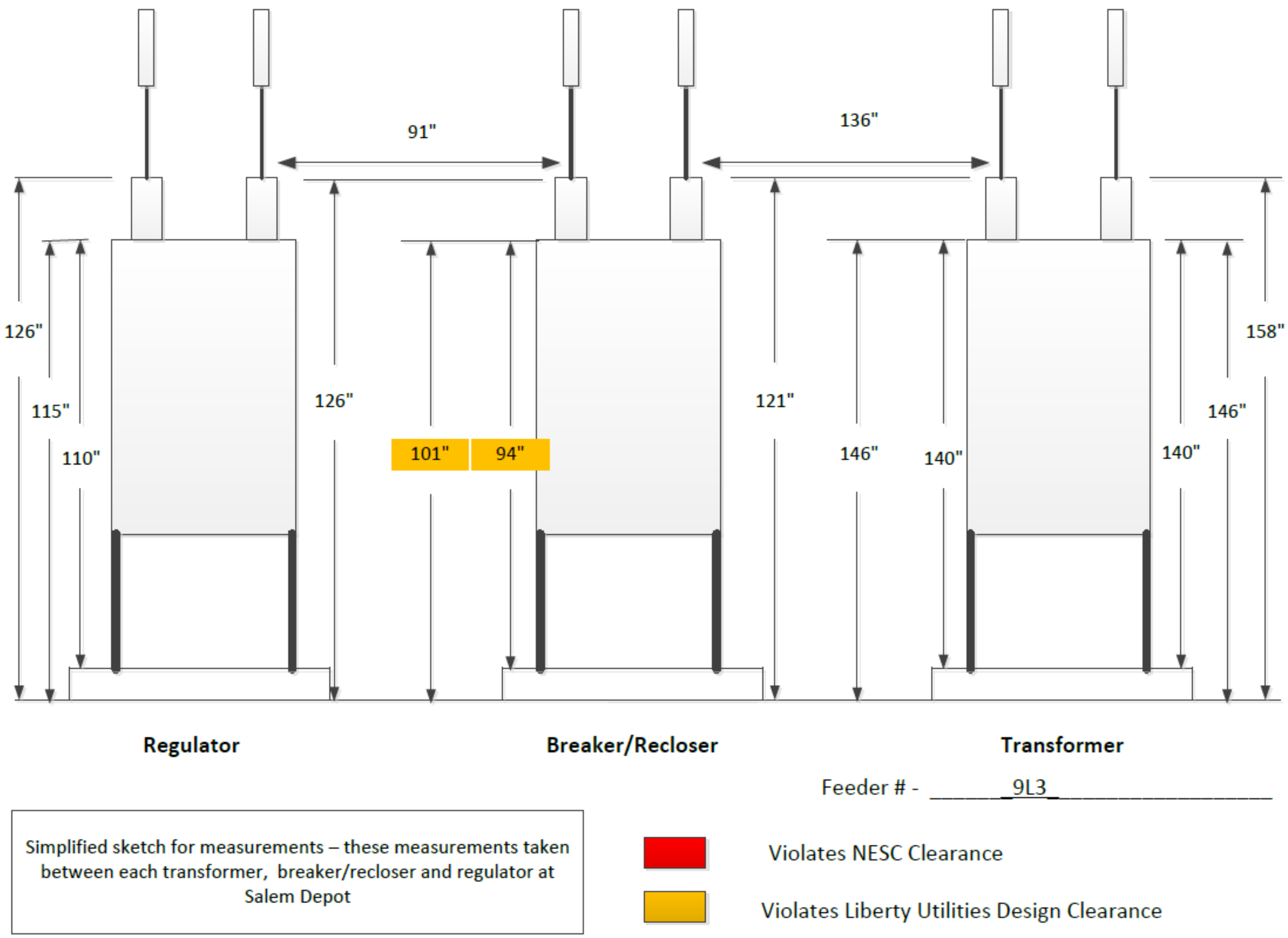


Figure 54 Salem Depot 9L3 Clearance Sketch

660

9.3 Appendix C – Area Loading Analysis

Base Case - 2019

Salem NH Feeder Analysis

Study Area	Substation	Voltage (kV)	Feeder	SN Rating (Amps)	SE Rating (Amps)	2019			2022			2036		
						Amps	N-1	%SN	Amps	N-1	%SN	Amps	N-1	%SN
Salem NH	BARRON AVENUE 10	13.2	10L1	387	462	107	355	28%	118	344	30%	121	341	31%
Salem NH	BARRON AVENUE 10	13.2	10L2	526	578	268	310	51%	290	288	55%	299	279	57%
Salem NH	BARRON AVENUE 10	13.2	10L4	339	339	176	163	52%	193	146	57%	198	141	59%
Salem NH	OLDE TROLLEY 18	13.2	18L1	503	565	133	432	27%	221	344	44%	227	338	45%
Salem NH	OLDE TROLLEY 18	13.2	18L2	503	515	404	111	80%	384	131	76%	396	119	79%
Salem NH	OLDE TROLLEY 18	13.2	18L3	515	515	375	140	73%	346	169	67%	356	159	69%
Salem NH	OLDE TROLLEY 18	13.2	18L4	516	612	387	225	75%	488	124	95%	502	110	97%
Salem NH	PELHAM 14	13.2	14L4	530	589	44	545	8%	392	197	74%	404	185	76%
Salem NH	SALEM DEPOT 9	13.2	9L1	322	371	271	100	84%	470	-99	146%	484	-113	150%
Salem NH	SALEM DEPOT 9	13.2	9L2	322	371	224	147	70%	292	79	91%	301	70	93%
Salem NH	SALEM DEPOT 9	13.2	9L3	507	507	319	188	63%	391	116	77%	402	105	79%
Salem NH	SPICKET RIVER 13	13.2	13L1	515	515	326	189	63%	352	163	68%	363	152	70%
Salem NH	SPICKET RIVER 13	13.2	13L2	515	515	290	225	56%	316	199	61%	325	190	63%
Salem NH	SPICKET RIVER 13	13.2	13L3	522	522	442	80	85%	463	59	89%	477	45	91%

Table 9 Base Case - Normal Configuration – 13.2 kV Feeder Loading

Salem NH Transformer Analysis

Study Area	Substation	Tranf. ID.	System Voltage (kV) From	System Voltage (kV) To	Maximum Nameplate Rating	Rating (MVA) SN	Rating (MVA) SE	Projected Load 2019 MVA	2019 N-1	2019 % SN	2022 MVA	2022 N-1	2022 % SN	2036 MVA	2036 N-1	2036 % SN
Salem NH	GOLDEN ROCK 19	T1	115	23	50	78.7	91.6	56.9	34.7	72%	68.6	23.0	87%	70.6	21.0	90%
Salem NH	BARRON AVENUE 10	L1	23	13.2	7	9.4	10.9	2.4	8.5	26%	2.7	8.2	29%	2.8	8.1	29%
Salem NH	BARRON AVENUE 10	L2	23	13.2	7	13.6	14.2	6.1	8.1	45%	6.6	7.6	49%	6.8	7.4	50%
Salem NH	BARRON AVENUE 10	L4	23	13.2	7	9.1	10.3	4.0	6.3	44%	4.4	5.9	48%	4.5	5.8	50%
Salem NH	OLDE TROLLEY 18	L1	23	13.2	9.375	12.4	12.9	3.0	9.9	25%	5.0	7.9	41%	5.2	7.7	42%
Salem NH	OLDE TROLLEY 18	L2	23	13.2	9.375	12.4	12.9	9.2	3.7	75%	8.8	4.1	71%	9.0	3.9	73%
Salem NH	OLDE TROLLEY 18	L3	23	13.2	9.375	12.5	13	8.6	4.4	69%	7.9	5.1	63%	8.1	4.9	65%
Salem NH	OLDE TROLLEY 18	L4	23	13.2	9.375	12.5	13	8.8	4.2	71%	11.2	1.8	89%	11.5	1.5	92%
Salem NH	SALEM DEPOT 9	L1	23	13.2	7	7.36	10.1	6.2	3.9	84%	10.7	-0.6	146%	11.1	-1.0	150%
Salem NH	SALEM DEPOT 9	L2	23	13.2	7	7.36	9.2	5.1	4.1	70%	6.7	2.5	91%	6.9	2.3	93%
Salem NH	SALEM DEPOT 9	L3	23	13.2	9.375	11.6	11.6	7.3	4.3	63%	8.9	2.7	77%	9.2	2.4	79%
Salem NH	SPICKET RIVER 13	L1	23	13.2	9.375	14.4	14.4	7.5	6.9	52%	8.1	6.3	56%	8.3	6.1	58%
Salem NH	SPICKET RIVER 13	L2	23	13.2	9.375	13.9	14.4	6.6	7.8	48%	7.2	7.2	52%	7.4	7.0	53%
Salem NH	SPICKET RIVER 13	L3	23	13.2	9.375	13.9	14.4	10.1	4.3	73%	10.6	3.8	76%	10.9	3.5	78%

Table 10 Base Case - Normal Configuration - Transformer Loading

Salem NH Supply Line Analysis

Study Area	Circuit	Voltage	Line Section From	Line Section To	Limiting	Element	Rating (MVA) SN	Rating (MVA) SE	Projected Load 2019 MVA	2019 %SN	2022 MVA	2022 %SN	2036 MVA	2036 %SN
Salem NH	2352	23	Golden Rock	Barron Ave. Tap	UG Cable	2-1000 Cu	54.8	65.4	30.9	56%	40.2	73%	41.4	75%
Salem NH	2352	23	Barron Ave. Tap	Olde Trolley Tap	OH Line	1113 ACSR	56.4	72.5	30.9	55%	40.2	71%	41.4	73%
Salem NH	2352	23	Olde Trolley Tap	Olde Trolley	Recloser	800 A.	31.9	31.9	12.3	39%	13.8	43%	14.2	45%
Salem NH	2352	23	Olde Trolley Tap	Salem Depot #9	Relay	Relay	27.1	27.1	18.6	69%	26.4	97%	27.1	100%
Salem NH	2393	23	Golden Rock	Barron Ave. Tap	UG Cable	2-1000 Cu	54.8	65.4	26.0	47%	28.4	52%	29.2	53%
Salem NH	2393	23	Barron Ave. Tap	Olde Trolley Tap	OH Line	795 ACSR	45.2	58.2	17.4	38%	19.1	42%	19.6	43%
Salem NH	2393	23	Olde Trolley Tap	Olde Trolley	UG Cable	2-500 Cu	31.9	31.9	17.4	55%	19.1	60%	19.6	62%
Salem NH	2393	23	Olde Trolley Tap	Salem Depot #9	Recloser	800 A.	27.1	27.1	0.0	0%	0.0	0%	0.0	0%
Methuen	2353	23	Meth Jnctn	Golden Rock	Relay	600 A.	23.9	23.9	4.0	17%	0.0	0%	0.0	0%
Methuen	2376	23	Meth Jnctn	Golden Rock	Relay	600 A.	23.9	23.9		0%		0%	0.0	0%
Methuen	2376	23	SPICKET RIVER TAP	SPICKET RIVER	OH Line	795 AAC	35.9	40.7	24.2	67%	25.9	72%	27.3	76%

Table 11 Base Case 2019 Supply Line Normal Loading

Salem NH Transformer Contingency Analysis

Study Area	Substation	Tranf. ID.	System Voltage (kV)		Maximum Nameplate Rating	Rating (MVA)		Projected Contingency					
								2019		2022		2036	
			From	To		SN	SE	MVA	% SE	MVA	% SE	MVA	% SE
Salem NH	GOLDEN ROCK 19	T1	115	23	50	78.70	91.60	0.0	0%	0.0	0%	0.0	0%
Salem NH	BARRON AVENUE 10	L1	23	13.2	7	9.40	10.90	4.2	39%	7.0	64%	7.2	66%
Salem NH	BARRON AVENUE 10	L2	23	13.2	7	13.60	14.20	4.2	30%	7.0	49%	7.2	51%
Salem NH	BARRON AVENUE 10	L4	23	13.2	7	9.10	10.30	4.2	41%	7.0	68%	7.2	70%
Salem NH	OLDE TROLLEY 18	L1	23	13.2	9.375	12.40	12.90	9.9	77%	11.3	88%	11.6	90%
Salem NH	OLDE TROLLEY 18	L2	23	13.2	9.375	12.40	12.90	9.9	77%	11.3	88%	11.6	90%
Salem NH	OLDE TROLLEY 18	L3	23	13.2	9.375	12.50	13.00	9.9	76%	11.3	87%	11.6	90%
Salem NH	OLDE TROLLEY 18	L4	23	13.2	9.375	12.50	13.00	9.9	76%	11.3	87%	11.6	90%
Salem NH	SALEM DEPOT 9	L1	23	13.2	7	7.36	10.10	4.7	46%	12.0	119%	12.4	123%
Salem NH	SALEM DEPOT 9	L2	23	13.2	7	7.36	9.20	4.7	51%	12.0	131%	12.4	135%
Salem NH	SALEM DEPOT 9	L3	23	13.2	9.375	11.60	11.60	4.7	40%	12.0	104%	12.4	107%
Salem NH	SPICKET RIVER 13	L1	23	13.2	9.375	14.40	14.40	12.1	84%	13.4	93%	13.8	96%
Salem NH	SPICKET RIVER 13	L2	23	13.2	9.375	13.90	14.40	12.1	84%	13.4	93%	13.8	96%
Salem NH	SPICKET RIVER 13	L3	23	13.2	9.375	13.90	14.40	12.1	84%	13.4	93%	13.8	96%

Table 12 Base Case 2019 Transformer Contingency Loading

Salem NH Supply Line Contingency Analysis

Study Area	Circuit	Voltage (kV)	Line Section		Rating (MVA)		Projected Contingency								
							2019			2022			2036		
			From	To	SN	SE	MVA	Load > SE	% SE	MVA	Load > SE	% SE	MVA	Load > SE	% SE
Salem NH	2352	23	Golden Rock	Barron Ave. Tap	54.8	65.4	**48.3**	0.0	74%	**59.3**	0.0	91%	**61.0**	0.0	93%
Salem NH	2352	23	Barron Ave. Tap	Olde Trolley Tap	56.4	72.5	**48.3**	0.0	67%	**59.3**	0.0	82%	**61.0**	0.0	84%
Salem NH	2352	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	**29.7**	0.0	93%	**32.9**	1.0	103%	**33.9**	2.0	106%
Salem NH	2352	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	**18.6**	0.0	69%	**26.4**	0.0	97%	**27.1**	0.0	100%
Salem NH	2393	23	Golden Rock	Barron Ave. Tap	54.8	65.4	**56.9**	0.0	87%	**68.6**	3.2	105%	**70.6**	5.2	108%
Salem NH	2393	23	Barron Ave. Tap	Olde Trolley Tap	45.2	58.2	**56.9**	0.0	98%	**68.6**	10.4	118%	**70.6**	12.4	121%
Salem NH	2393	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	**29.7**	0.0	93%	**32.9**	1.0	103%	**33.9**	2.0	106%
Salem NH	2393	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	**18.6**	0.0	69%	**26.4**	0.0	97%	**27.1**	0.0	100%
Methuen MA	2353	23	Meth Jnctn	Golden Rock	23.9	23.9	**34.9**	11.0	146%	**44.6**	20.7	187%	**47.1**	23.2	197%
Methuen MA	2376	23	Meth Jnctn	Golden Rock	23.9	23.9	**26.0**	2.1	109%	**28.4**	4.5	119%	**30.0**	6.1	125%
Methuen MA	2376	23	SPICKET RIVER TAP	SPICKET RIVER	35.9	40.7	**24.2**	0.0	59%	**25.9**	0.0	64%	**27.3**	0.0	67%

Table 13 Base Case 2019 Supply Line Contingency Loads

Base Case - Golden Rock 115 /13.2 kV in Service

Salem NH Feeder Analysis

Study Area	Substation	Voltage (kV)	Feeder	SN Rating (Amps)	SE Rating (Amps)	2022			2036		
						Amps	N-1	%SN	Amps	N-1	%SN
Salem NH	BARRON AVENUE 10	13.2	10L1	387	462	0	462	0%	0	462	0%
Salem NH	BARRON AVENUE 10	13.2	10L2	526	578	0	578	0%	0	578	0%
Salem NH	BARRON AVENUE 10	13.2	10L4	339	339	0	339	0%	0	339	0%
Salem NH	OLDE TROLLEY 18	13.2	18L1	503	565	196	369	39%	202	363	40%
Salem NH	OLDE TROLLEY 18	13.2	18L2	503	515	336	179	67%	346	169	69%
Salem NH	OLDE TROLLEY 18	13.2	18L3	515	515	433	82	84%	446	69	87%
Salem NH	OLDE TROLLEY 18	13.2	18L4	516	612	480	132	93%	494	118	96%
Salem NH	PELHAM 14	13.2	14L4	530	589	292	297	55%	301	288	57%
Salem NH	SALEM DEPOT 9	13.2	9L1	322	371	320	51	99%	329	42	102%
Salem NH	SALEM DEPOT 9	13.2	9L2	322	371	242	129	75%	249	122	77%
Salem NH	SALEM DEPOT 9	13.2	9L3	507	507	386	121	76%	397	110	78%
Salem NH	SPICKET RIVER 13	13.2	13L1	515	515	470	45	91%	484	31	94%
Salem NH	SPICKET RIVER 13	13.2	13L2	515	515	352	163	68%	362	153	70%
Salem NH	SPICKET RIVER 13	13.2	13L3	522	522	344	178	66%	354	168	68%
Salem NH	GOLDEN ROCK 19	13.2	19L4	530	589	76	513	14%	78	511	15%
Salem NH	GOLDEN ROCK 19	13.2	19L6	530	589	233	356	44%	240	349	45%
Salem NH	GOLDEN ROCK 19	13.2	19L8	530	589	212	377	40%	218	371	41%

Table 14 Base Case (w/ Golden Rock 13.2 kV) Feeder Normal Loading

Salem NH Transformer Analysis

Study Area	Substation	Tranf. ID.	System Voltage (kV)		Maximum Nameplate Rating	Rating (MVA)		Projected Load 2022			Projected Load 2036		
			From	To		SN	SE	MVA	N-1	% SN	MVA	N-1	% SN
Salem NH	BARRON AVENUE 10	L1	23	13.2	7	9.4	10.9	0.0	10.9	0%	0.0	10.9	0%
Salem NH	BARRON AVENUE 10	L2	23	13.2	7	13.6	14.2	0.0	14.2	0%	0.0	14.2	0%
Salem NH	BARRON AVENUE 10	L4	23	13.2	7	9.1	10.3	0.0	10.3	0%	0.0	10.3	0%
Salem NH	OLDE TROLLEY 18	L1	23	13.2	9.375	12.4	12.9	4.5	8.4	36%	4.6	8.3	37%
Salem NH	OLDE TROLLEY 18	L2	23	13.2	9.375	12.4	12.9	7.7	5.2	62%	7.9	5.0	64%
Salem NH	OLDE TROLLEY 18	L3	23	13.2	9.375	12.5	13	9.9	3.1	79%	10.2	2.8	82%
Salem NH	OLDE TROLLEY 18	L4	23	13.2	9.375	12.5	13	11.0	2.0	88%	11.3	1.7	90%
Salem NH	SALEM DEPOT 9	L1	23	13.2	7	7.36	10.1	7.3	2.8	99%	7.5	2.6	102%
Salem NH	SALEM DEPOT 9	L2	23	13.2	7	7.36	9.2	5.5	3.7	75%	5.7	3.5	77%
Salem NH	SALEM DEPOT 9	L3	23	13.2	9.375	11.6	11.6	8.8	2.8	76%	9.1	2.5	78%
Salem NH	SPICKET RIVER 13	L1	23	13.2	9.375	14.4	14.4	10.7	3.7	75%	11.1	3.3	77%
Salem NH	SPICKET RIVER 13	L2	23	13.2	9.375	13.9	14.4	8.0	6.4	58%	8.3	6.1	60%
Salem NH	SPICKET RIVER 13	L3	23	13.2	9.375	13.9	14.4	7.9	6.5	57%	8.1	6.3	58%
Salem NH	GOLDEN ROCK 19	T2	115	13.2	50	83.9	94.4	11.9	82.5	14%	12.3	82.1	15%

Table 15 Base Case (w/ Golden Rock 13.2 kV) Transformer Normal Loads

Salem NH Supply Line Analysis

Study Area	Circuit	Voltage	Line Section		Rating (MVA)		Projected Load			
							2022		2036	
			From	To	SN	SE	MVA	%SN	MVA	%SN
Salem NH	2352	23	Golden Rock	Barron Ave. Tap	54.7	67.4	33.8	62%	34.8	64%
Salem NH	2352	23	Barron Ave. Tap	Olde Trolley Tap	72.5	72.5	33.8	47%	34.8	48%
Salem NH	2352	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	12.2	38%	12.5	39%
Salem NH	2352	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	21.7	80%	22.3	82%
Salem NH	2393	23	Golden Rock	Barron Ave. Tap	54.7	67.4	20.9	38%	21.5	39%
Salem NH	2393	23	Barron Ave. Tap	Olde Trolley Tap	45.2	58.2	20.9	46%	21.5	48%
Salem NH	2393	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	20.9	65%	21.5	67%
Salem NH	2393	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	0.0	0%	0.0	0%
Methuen	2353	23	Meth Jnctn	Golden Rock	23.9	23.9	0.0	0%	0.0	0%
Methuen	2376	23	Meth Jnctn	Golden Rock	23.9	23.9		0%	0.0	0%
Methuen	2376	23	SPICKET RIVER TAP	SPICKET RIVER	35.9	40.7	26.7	74%	28.1	78%

Table 16 Base Case (w/ Golden Rock 13.2 kV) Supply Line Normal Loading

Salem NH Transformer Contingency Analysis

Study Area	Substation	Tranf. ID.	System Voltage (kV)		Maximum	Rating (MVA)		Projected Contingency			
								2022		2036	
			From	To	Nameplate Rating	SN	SE	MVA	% SE	MVA	% SE
Salem NH	BARRON AVENUE 10	L1	23	13.2	7	9.40	10.90	0.0	0%	0.0	0%
Salem NH	BARRON AVENUE 10	L2	23	13.2	7	13.60	14.20	0.0	0%	0.0	0%
Salem NH	BARRON AVENUE 10	L4	23	13.2	7	9.10	10.30	0.0	0%	0.0	0%
Salem NH	OLDE TROLLEY 18	L1	23	13.2	9.375	12.40	12.90	12.6	98%	13.0	101%
Salem NH	OLDE TROLLEY 18	L2	23	13.2	9.375	12.40	12.90	12.6	98%	13.0	101%
Salem NH	OLDE TROLLEY 18	L3	23	13.2	9.375	12.50	13.00	12.6	97%	13.0	100%
Salem NH	OLDE TROLLEY 18	L4	23	13.2	9.375	12.50	13.00	12.6	97%	13.0	100%
Salem NH	SALEM DEPOT 9	L1	23	13.2	7	7.36	10.10	12.0	119%	12.4	123%
Salem NH	SALEM DEPOT 9	L2	23	13.2	7	7.36	9.20	12.0	131%	12.4	135%
Salem NH	SALEM DEPOT 9	L3	23	13.2	9.375	11.60	11.60	12.0	104%	12.4	107%
Salem NH	SPICKET RIVER 13	L1	23	13.2	9.375	14.40	14.40	10.7	75%	11.1	77%
Salem NH	SPICKET RIVER 13	L2	23	13.2	9.375	13.90	14.40	10.7	75%	11.1	77%
Salem NH	SPICKET RIVER 13	L3	23	13.2	9.375	13.90	14.40	10.7	75%	11.1	77%
Salem NH	GOLDEN ROCK 19	T2	115	13.2	50	83.90	94.40	35.2	37%	36.2	38%

Table 17 Base Case (w/ Golden Rock 13.2 kV) Transformer Contingency Loading

Salem NH Supply Line Contingency Analysis													
Study Area	Circuit	Voltage (kV)	Line Section		Rating (MVA)		Projected Contingency						
							2022			2036			
			From	To	SN	SE	MVA	Load > SE	% SE	MVA	Load > SE	% SE	
Salem NH	2352	23	Golden Rock	Barron Ave. Tap	54.7	67.4	**66.6**	0.0	99%	**68.6**	1.2	102%	
Salem NH	2352	23	Barron Ave. Tap	Olde Trolley Tap	72.5	72.5	**66.6**	0.0	92%	**68.6**	0.0	95%	
Salem NH	2352	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	**33.0**	1.1	104%	**34.0**	2.1	107%	
Salem NH	2352	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	**21.7**	0.0	80%	**22.3**	0.0	82%	
Salem NH	2393	23	Golden Rock	Barron Ave. Tap	54.7	67.4	**66.6**	0.0	99%	**68.6**	1.2	102%	
Salem NH	2393	23	Barron Ave. Tap	Olde Trolley Tap	45.2	58.2	**66.6**	8.5	115%	**68.6**	10.4	118%	
Salem NH	2393	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	**33.0**	1.1	104%	**34.0**	2.1	107%	
Salem NH	2393	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	**21.7**	0.0	80%	**22.3**	0.0	82%	
Methuen MA	2353	23	Meth Jnctn	Golden Rock	23.9	23.9	**33.8**	9.9	142%	**35.7**	11.8	149%	
Methuen MA	2376	23	Meth Jnctn	Golden Rock	23.9	23.9	**20.9**	0.0	87%	**22.0**	0.0	92%	
Methuen MA	2376	23	SPICKET RIVER TAP	SPICKET RIVER	35.9	40.7	**26.7**	0.0	65%	**28.1**	0.0	69%	

Table 18 Base Case (w/ Golden Rock 13.2 kV) Supply Line Contingency Loading

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Alternative Plan #1 Loading

Salem NH Feeder Analysis														
						2019			2022			2036		
Study Area	Substation	Voltage (kV)	Feeder	SN Rating (Amps)	SE Rating (Amps)	Amps	N-1	%SN	Amps	N-1	%SN	Amps	N-1	%SN
Salem NH	BARRON AVENUE 10	13.2	10L1	387	462	107	355	28%	463	-1	120%	477	-15	123%
Salem NH	BARRON AVENUE 10	13.2	10L2	526	578	268	310	51%	320	258	61%	330	248	63%
Salem NH	BARRON AVENUE 10	13.2	10L4	339	339	176	163	52%	260	79	77%	268	71	79%
Salem NH	OLDE TROLLEY 18	13.2	18L1	503	565	133	432	27%	196	369	39%	201	364	40%
Salem NH	OLDE TROLLEY 18	13.2	18L2	503	515	404	111	80%	6	509	1%	6	509	1%
Salem NH	OLDE TROLLEY 18	13.2	18L3	515	515	375	140	73%	349	166	68%	359	156	70%
Salem NH	OLDE TROLLEY 18	13.2	18L4	516	612	387	225	75%	204	408	40%	210	402	41%
Salem NH	PELHAM 14	13.2	14L4	530	589	44	545	8%	317	272	60%	326	263	62%
Salem NH	SALEM DEPOT 9	13.2	9L1	322	371	271	100	84%	302	69	94%	311	60	97%
Salem NH	SALEM DEPOT 9	13.2	9L2	322	371	224	147	70%	240	131	75%	247	124	77%
Salem NH	SALEM DEPOT 9	13.2	9L3	507	507	319	188	63%	391	116	77%	402	105	79%
Salem NH	SPICKET RIVER 13	13.2	13L1	515	515	326	189	63%	358	157	70%	369	146	72%
Salem NH	SPICKET RIVER 13	13.2	13L2	515	515	290	225	56%	225	290	44%	232	283	45%
Salem NH	SPICKET RIVER 13	13.2	13L3	522	522	442	80	85%	483	39	93%	497	25	95%
Salem NH	GOLDEN ROCK 19	13.2	19L4	530	589		589	0%	77	512	14%	79	510	15%
Salem NH	GOLDEN ROCK 19	13.2	19L6	530	589		589	0%	246	343	46%	252	337	48%
Salem NH	GOLDEN ROCK 19	13.2	19L8	530	589		589	0%	359	230	68%	369	220	70%

Table 19 Alt #1 Feeder Normal Loading

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Salem NH Transformer Analysis

			System Voltage (kV)		Maximum	Rating (MVA)		Projected Load								
								2019			2022			2036		
Study Area	Substation	Tranf. ID.	From	To	Nameplate Rating	SN	SE	MVA	N-1	% SN	MVA	N-1	% SN	MVA	N-1	% SN
Salem NH	BARRON AVENUE 10	L1	23	13.2	7	9.4	10.9	2.4	8.5	26%	10.6	0.3	113%	10.9	0.0	116%
Salem NH	BARRON AVENUE 10	L2	23	13.2	7	13.6	14.2	6.1	8.1	45%	7.3	6.9	54%	7.5	6.7	55%
Salem NH	BARRON AVENUE 10	L4	23	13.2	7	9.1	10.3	4.0	6.3	44%	5.9	4.4	65%	6.1	4.2	67%
Salem NH	OLDE TROLLEY 18	L1	23	13.2	9.375	12.4	12.9	3.0	9.9	25%	4.5	8.4	36%	4.6	8.3	37%
Salem NH	OLDE TROLLEY 18	L2	23	13.2	9.375	12.4	12.9	9.2	3.7	75%	0.1	12.8	1%	0.1	12.8	1%
Salem NH	OLDE TROLLEY 18	L3	23	13.2	9.375	12.5	13	8.6	4.4	69%	8.0	5.0	64%	8.2	4.8	66%
Salem NH	OLDE TROLLEY 18	L4	23	13.2	9.375	12.5	13	8.8	4.2	71%	4.7	8.3	37%	4.8	8.2	38%
Salem NH	SALEM DEPOT 9	L1	23	13.2	7	7.36	10.1	6.2	3.9	84%	6.9	3.2	94%	7.1	3.0	97%
Salem NH	SALEM DEPOT 9	L2	23	13.2	7	7.36	9.2	5.1	4.1	70%	5.5	3.7	75%	5.6	3.6	77%
Salem NH	SALEM DEPOT 9	L3	23	13.2	9.375	11.6	11.6	7.3	4.3	63%	8.9	2.7	77%	9.2	2.4	79%
Salem NH	SPICKET RIVER 13	L1	23	13.2	9.375	14.4	14.4	7.5	6.9	52%	8.2	6.2	57%	8.4	6.0	59%
Salem NH	SPICKET RIVER 13	L2	23	13.2	9.375	13.9	14.4	6.6	7.8	48%	5.1	9.3	37%	5.3	9.1	38%
Salem NH	SPICKET RIVER 13	L3	23	13.2	9.375	13.9	14.4	10.1	4.3	73%	11.0	3.4	79%	11.4	3.0	82%
Salem NH	GOLDEN ROCK 19	T2	115	13.2	50	78.7	91.6	0.0	91.6	0%	15.6	76.0	20%	16.0	75.6	20%

Table 20 Alt #1 Transformer Normal Loading

Salem NH Supply Line Analysis

			Line Section		Rating (MVA)		Projected Load					
							2019		2022		2036	
Study Area	Circuit	Voltage	From	To	SN	SE	MVA	%SN	MVA	%SN	MVA	%SN
Salem NH	2352	23	Golden Rock	Barron Ave. Tap	54.8	65.4	30.9	56%	25.9	47%	26.7	49%
Salem NH	2352	23	Barron Ave. Tap	Olde Trolley Tap	56.4	72.5	30.9	55%	25.9	46%	26.7	47%
Salem NH	2352	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	12.3	39%	4.6	14%	4.7	15%
Salem NH	2352	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	18.6	69%	21.3	79%	22.0	81%
Salem NH	2393	23	Golden Rock	Barron Ave. Tap	54.8	65.4	26.0	47%	30.6	56%	31.5	57%
Salem NH	2393	23	Barron Ave. Tap	Olde Trolley Tap	45.2	58.2	17.4	38%	12.6	28%	13.0	29%
Salem NH	2393	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	17.4	55%	12.6	40%	13.0	41%
Salem NH	2393	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	0.0	0%	0.0	0%	0.0	0%
Methuen	2353	23	Meth Jnctn	Golden Rock	23.9	23.9	4.0	17%	0.0	0%	0.0	0%
Methuen	2376	23	Meth Jnctn	Golden Rock	23.9	23.9		0%		0%	0.0	0%
Methuen	2376	23	SPICKET RIVER TAP	SPICKET RIVER	35.9	40.7	24.2	67%	24.4	68%	25.7	72%

Table 21 Alt #1 Supply Line Normal Loading

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Salem NH Transformer Contingency Analysis

Study Area	Substation	Tranf. ID.	System Voltage (kV)		Maximum Nameplate Rating	Rating (MVA)		Projected Contingency					
								2019		2022		2036	
			From	To		SN	SE	MVA	% SE	MVA	% SE	MVA	% SE
Salem NH	BARRON AVENUE 10	L1	23	13.2	7	9.40	10.90	6.3	58%	8.8	80%	9.0	83%
Salem NH	BARRON AVENUE 10	L2	23	13.2	7	13.60	14.20	6.3	44%	8.8	62%	9.0	63%
Salem NH	BARRON AVENUE 10	L4	23	13.2	7	9.10	10.30	6.3	61%	8.8	85%	9.0	87%
Salem NH	OLDE TROLLEY 18	L1	23	13.2	9.375	12.40	12.90	9.9	77%	11.5	89%	11.8	92%
Salem NH	OLDE TROLLEY 18	L2	23	13.2	9.375	12.40	12.90	9.9	77%	11.5	89%	11.8	92%
Salem NH	OLDE TROLLEY 18	L3	23	13.2	9.375	12.50	13.00	9.9	76%	11.5	88%	11.8	91%
Salem NH	OLDE TROLLEY 18	L4	23	13.2	9.375	12.50	13.00	9.9	76%	11.5	88%	11.8	91%
Salem NH	SALEM DEPOT 9	L1	23	13.2	7	7.36	10.10	9.3	92%	9.3	92%	9.6	95%
Salem NH	SALEM DEPOT 9	L2	23	13.2	7	7.36	9.20	9.3	101%	9.3	101%	9.6	104%
Salem NH	SALEM DEPOT 9	L3	23	13.2	9.375	11.60	11.60	9.3	80%	9.3	80%	9.6	82%
Salem NH	SPICKET RIVER 13	L1	23	13.2	9.375	14.40	14.40	12.1	84%	8.4	58%	8.7	60%
Salem NH	SPICKET RIVER 13	L2	23	13.2	9.375	13.90	14.40	12.1	84%	8.4	58%	8.7	60%
Salem NH	SPICKET RIVER 13	L3	23	13.2	9.375	13.90	14.40	12.1	84%	8.4	58%	8.7	60%
Salem NH	GOLDEN ROCK 19	T2	115	13.2	50	78.70	91.60	8.4	9%	17.0	19%	17.5	19%

Table 22 Alt #1 Transformer Contingency Loading

Salem NH Supply Line Contingency Analysis

Study Area	Circuit	Voltage (kV)	Line Section		Rating (MVA)		Projected Contingency								
							2019			2022			2036		
			From	To	SN	SE	MVA	Load > SE	% SE	MVA	Load > SE	% SE	MVA	Load > SE	% SE
Salem NH	2352	23	Golden Rock	Barron Ave. Tap	54.8	65.4	**48.3**	0.0	74%	**38.6**	0.0	59%	**39.7**	0.0	61%
Salem NH	2352	23	Barron Ave. Tap	Olde Trolley Tap	56.4	72.5	**48.3**	0.0	67%	**38.6**	0.0	53%	**39.7**	0.0	55%
Salem NH	2352	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	**29.7**	0.0	93%	**17.2**	0.0	54%	**17.8**	0.0	56%
Salem NH	2352	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	**18.6**	0.0	69%	**21.3**	0.0	79%	**22.0**	0.0	81%
Salem NH	2393	23	Golden Rock	Barron Ave. Tap	54.8	65.4	**56.9**	0.0	87%	**56.5**	0.0	86%	**58.2**	0.0	89%
Salem NH	2393	23	Barron Ave. Tap	Olde Trolley Tap	45.2	58.2	**56.9**	0.0	98%	**56.5**	0.0	97%	**58.2**	0.0	100%
Salem NH	2393	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	**29.7**	0.0	93%	**17.2**	0.0	54%	**17.8**	0.0	56%
Salem NH	2393	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	**18.6**	0.0	69%	**21.3**	0.0	79%	**22.0**	0.0	81%
Methuen MA	2353	23	Meth Jnctn	Golden Rock	23.9	23.9	**34.9**	11.0	146%	**31.9**	8.0	133%	**33.7**	9.7	141%
Methuen MA	2376	23	Meth Jnctn	Golden Rock	23.9	23.9	**26.0**	2.1	109%	**30.6**	6.7	128%	**32.2**	8.3	135%
Methuen MA	2376	23	SPICKET RIVER TAP	SPICKET RIVER	35.9	40.7	**24.2**	0.0	59%	**24.4**	0.0	60%	**25.7**	0.0	63%

Table 23 Alt #1 Supply Line Contingency Loading

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Alternative #2 Loading

Salem NH Feeder Analysis														
						2019			2022			2036		
Study Area	**Substation**	**Voltage (kV)**	**Feeder**	**SN Rating (Amps)**	**SE Rating (Amps)**	**Amps**	**N-1**	**%SN**	**Amps**	**N-1**	**%SN**	**Amps**	**N-1**	**%SN**
Salem NH	BARRON AVENUE 10	13.2	10L1	387	462	107	355	28%	427	151	81%	440	138	84%
Salem NH	BARRON AVENUE 10	13.2	10L2	526	578	268	310	51%	259	319	49%	266	312	51%
Salem NH	BARRON AVENUE 10	13.2	10L4	339	339	176	163	52%	181	397	34%	186	392	35%
Salem NH	OLDE TROLLEY 18	13.2	18L1	503	565	133	432	27%	217	348	43%	223	342	44%
Salem NH	OLDE TROLLEY 18	13.2	18L2	503	515	404	111	80%	44	471	9%	45	470	9%
Salem NH	OLDE TROLLEY 18	13.2	18L3	515	515	375	140	73%	349	166	68%	359	156	70%
Salem NH	OLDE TROLLEY 18	13.2	18L4	516	612	387	225	75%	205	407	40%	211	401	41%
Salem NH	PELHAM 14	13.2	14L4	530	589	44	545	8%	317	272	60%	326	263	62%
Salem NH	SALEM DEPOT 9	13.2	9L1	322	371	271	100	84%	303	275	58%	312	266	59%
Salem NH	SALEM DEPOT 9	13.2	9L2	322	371	224	147	70%	288	290	55%	297	281	57%
Salem NH	SALEM DEPOT 9	13.2	9L3	507	507	319	188	63%	391	187	74%	402	176	77%
Salem NH	SPICKET RIVER 13	13.2	13L1	515	515	326	189	63%	347	168	67%	357	158	69%
Salem NH	SPICKET RIVER 13	13.2	13L2	515	515	290	225	56%	312	203	61%	321	194	62%
Salem NH	SPICKET RIVER 13	13.2	13L3	522	522	442	80	85%	386	136	74%	397	125	76%
Salem NH	GOLDEN ROCK 19	13.2	19L4	530	589		589	0%	84	528	16%	87	525	17%
Salem NH	GOLDEN ROCK 19	13.2	19L6	530	589		589	0%	313	299	60%	322	290	61%
Salem NH	GOLDEN ROCK 19	13.2	19L8	530	589		589	0%	413	199	79%	425	187	81%

Table 24 Alt #2 Feeder Normal Loading

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Salem NH Transformer Analysis

			System Voltage (kV)		Maximum	Rating (MVA)		Projected Load								
								2019			2022			2036		
Study Area	Substation	Tranf. ID.	From	To	Nameplate Rating	SN	SE	MVA	N-1	% SN	MVA	N-1	% SN	MVA	N-1	% SN
Salem NH	GOLDEN ROCK 19	T1	115	23	50	78.7	91.6	56.9	34.7	72%	56.7	34.9	72%	58.4	33.2	74%
Salem NH	BARRON AVENUE 10	L1	23	13.2	7	9.4	10.9	2.4	8.5	26%	9.8	1.1	78%	10.0	3.0	80%
Salem NH	BARRON AVENUE 10	L2	23	13.2	7	13.6	14.2	6.1	8.1	45%	5.9	8.3	43%	6.1	8.1	45%
Salem NH	BARRON AVENUE 10	L4	23	13.2	7	9.1	10.3	4.0	6.3	44%	4.1	6.2	33%	4.3	8.7	34%
Salem NH	OLDE TROLLEY 18	L1	23	13.2	9.375	12.4	12.9	3.0	9.9	25%	5.0	7.9	40%	5.1	7.8	41%
Salem NH	OLDE TROLLEY 18	L2	23	13.2	9.375	12.4	12.9	9.2	3.7	75%	1.0	11.9	8%	1.0	11.9	8%
Salem NH	OLDE TROLLEY 18	L3	23	13.2	9.375	12.5	13	8.6	4.4	69%	8.0	5.0	64%	8.2	4.8	66%
Salem NH	OLDE TROLLEY 18	L4	23	13.2	9.375	12.5	13	8.8	4.2	71%	4.7	8.3	37%	4.8	8.2	39%
Salem NH	SALEM DEPOT 9	L1	23	13.2	7	7.36	10.1	6.2	3.9	84%	6.9	3.2	55%	7.1	5.9	57%
Salem NH	SALEM DEPOT 9	L2	23	13.2	7	7.36	9.2	5.1	4.1	70%	6.6	2.6	53%	6.8	6.2	54%
Salem NH	SALEM DEPOT 9	L3	23	13.2	9.375	11.6	11.6	7.3	4.3	63%	8.9	2.7	77%	9.2	2.4	79%
Salem NH	SPICKET RIVER 13	L1	23	13.2	9.375	14.4	14.4	7.5	6.9	52%	7.9	6.5	55%	8.2	6.2	57%
Salem NH	SPICKET RIVER 13	L2	23	13.2	9.375	13.9	14.4	6.6	7.8	48%	7.1	7.3	51%	7.3	7.1	53%
Salem NH	SPICKET RIVER 13	L3	23	13.2	9.375	13.9	14.4	10.1	4.3	73%	8.8	5.6	63%	9.1	5.3	65%
Salem NH	GOLDEN ROCK 19	T2	115	13.2	50	78.7	91.6	0.0	91.6	0%	18.5	73.1	24%	19.1	72.5	24%

Table 25 Alt #2 Transformer Normal Loading

Salem NH Supply Line Analysis

			Line Section		Rating (MVA)		Projected Load					
							2019		2022		2036	
Study Area	Circuit	Voltage	From	To	SN	SE	MVA	%SN	MVA	%SN	MVA	%SN
Salem NH	2352	23	Golden Rock	Barron Ave. Tap	54.8	65.4	30.9	56%	28.4	52%	29.2	53%
Salem NH	2352	23	Barron Ave. Tap	Olde Trolley Tap	56.4	72.5	30.9	55%	28.4	50%	29.2	52%
Salem NH	2352	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	12.3	39%	6.0	19%	6.1	19%
Salem NH	2352	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	18.6	69%	22.4	83%	23.1	85%
Salem NH	2393	23	Golden Rock	Barron Ave. Tap	54.8	65.4	26.0	47%	28.3	52%	29.2	53%
Salem NH	2393	23	Barron Ave. Tap	Olde Trolley Tap	45.2	58.2	17.4	38%	12.7	28%	13.0	29%
Salem NH	2393	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	17.4	55%	12.7	40%	13.0	41%
Salem NH	2393	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	0.0	0%	0.0	0%	0.0	0%
Methuen	2353	23	Meth Jnctn	Golden Rock	23.9	23.9	4.0	17%	0.0	0%	0.0	0%
Methuen	2376	23	Meth Jnctn	Golden Rock	23.9	23.9		0%		0%	0.0	0%
Methuen	2376	23	SPICKET RIVER TAP	SPICKET RIVER	35.9	40.7	24.2	67%	23.9	67%	25.2	70%

Table 26 Alt #2 Supply Line Normal Loading

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Salem NH Transformer Contingency Analysis													
Study Area	Substation	Tranf. ID.	System Voltage (kV)		Maximum Nameplate Rating	Rating (MVA)		Projected Contingency					
								2019		2022		2036	
			From	To		SN	SE	MVA	% SE	MVA	% SE	MVA	% SE
Salem NH	BARRON AVENUE 10	L1	23	13.2	7	9.40	10.90	6.3	58%	11.3	87%	11.6	89%
Salem NH	BARRON AVENUE 10	L2	23	13.2	7	13.60	14.20	6.3	44%	11.3	79%	11.6	82%
Salem NH	BARRON AVENUE 10	L4	23	13.2	7	9.10	10.30	6.3	61%	11.3	87%	11.6	89%
Salem NH	OLDE TROLLEY 18	L1	23	13.2	9.375	12.40	12.90	9.9	77%	11.5	89%	11.8	92%
Salem NH	OLDE TROLLEY 18	L2	23	13.2	9.375	12.40	12.90	9.9	77%	11.5	89%	11.8	92%
Salem NH	OLDE TROLLEY 18	L3	23	13.2	9.375	12.50	13.00	9.9	76%	11.5	88%	11.8	91%
Salem NH	OLDE TROLLEY 18	L4	23	13.2	9.375	12.50	13.00	9.9	76%	11.5	88%	11.8	91%
Salem NH	SALEM DEPOT 9	L1	23	13.2	7	7.36	10.10	9.3	92%	11.8	91%	12.1	93%
Salem NH	SALEM DEPOT 9	L2	23	13.2	7	7.36	9.20	9.3	101%	11.8	91%	12.1	93%
Salem NH	SALEM DEPOT 9	L3	23	13.2	9.375	11.60	11.60	9.3	80%	11.8	102%	12.1	105%
Salem NH	SPICKET RIVER 13	L1	23	13.2	9.375	14.40	14.40	12.1	84%	13.4	93%	13.8	96%
Salem NH	SPICKET RIVER 13	L2	23	13.2	9.375	13.90	14.40	12.1	84%	13.4	93%	13.8	96%
Salem NH	SPICKET RIVER 13	L3	23	13.2	9.375	13.90	14.40	12.1	84%	13.4	93%	13.8	96%
Salem NH	PELHAM 14	T1	115	13.2	40	50.30	56.00	8.4	15%	17.0	30%	17.5	31%
Salem NH	PELHAM 14	T2	115	13.2	40	50.30	56.00	8.4	15%	17.0	30%	17.5	31%
Salem NH	GOLDEN ROCK 19	T2	115	13.2	50	78.70	91.60		0%		0%		0%

Table 27 Alt #2 Transformer Contingency Loading

Salem NH Supply Line Contingency Analysis															
Study Area	Circuit	Voltage (kV)	Line Section		Rating (MVA)		Projected Contingency								
							2019			2022			2036		
			From	To	SN	SE	MVA	Load > SE	% SE	MVA	Load > SE	% SE	MVA	Load > SE	% SE
Salem NH	2352	23	Golden Rock	Barron Ave. Tap	54.8	65.4	**48.3**	0.0	74%	**41.1**	0.0	63%	**42.3**	0.0	65%
Salem NH	2352	23	Barron Ave. Tap	Olde Trolley Tap	56.4	72.5	**48.3**	0.0	67%	**41.1**	0.0	57%	**42.3**	0.0	58%
Salem NH	2352	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	**29.7**	0.0	93%	**18.6**	0.0	58%	**19.2**	0.0	60%
Salem NH	2352	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	**18.6**	0.0	69%	**22.4**	0.0	83%	**23.1**	0.0	85%
Salem NH	2393	23	Golden Rock	Barron Ave. Tap	54.8	65.4	**56.9**	0.0	87%	**56.7**	0.0	87%	**58.4**	0.0	89%
Salem NH	2393	23	Barron Ave. Tap	Olde Trolley Tap	45.2	58.2	**56.9**	0.0	98%	**56.7**	0.0	98%	**58.4**	0.2	100%
Salem NH	2393	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	**29.7**	0.0	93%	**18.6**	0.0	58%	**19.2**	0.0	60%
Salem NH	2393	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	**18.6**	0.0	69%	**22.4**	0.0	83%	**23.1**	0.0	85%
Methuen MA	2353	23	Meth Jnctn	Golden Rock	23.9	23.9	**34.9**	11.0	146%	**32.5**	8.6	136%	**34.3**	10.4	144%
Methuen MA	2376	23	Meth Jnctn	Golden Rock	23.9	23.9	**26.0**	2.1	109%	**28.3**	4.4	119%	**29.9**	6.0	125%
Methuen MA	2376	23	SPICKET RIVER TAP	SPICKET RIVER	35.9	40.7	**24.2**	0.0	59%	**23.9**	0.0	59%	**25.2**	0.0	62%

Table 28 Alt #2 Supply Line Contingency Loading

Alternative #3 Loading

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Salem NH Feeder Analysis

Study Area	Substation	Voltage (kV)	Feeder	SN Rating (Amps)	SE Rating (Amps)	2019			2022			2036		
						Amps	N-1	%SN	Amps	N-1	%SN	Amps	N-1	%SN
Salem NH	BARRON AVENUE 10	13.2	10L1	387	462	107	355	28%	460	118	88%	473	105	90%
Salem NH	BARRON AVENUE 10	13.2	10L2	526	578	268	310	51%	276	302	52%	284	294	54%
Salem NH	BARRON AVENUE 10	13.2	10L4	339	339	176	163	52%	181	397	34%	186	392	35%
Salem NH	OLDE TROLLEY 18	13.2	18L1	503	565	133	432	27%	217	348	43%	224	341	44%
Salem NH	OLDE TROLLEY 18	13.2	18L2	503	515	404	111	80%	44	471	9%	45	470	9%
Salem NH	OLDE TROLLEY 18	13.2	18L3	515	515	375	140	73%	341	174	66%	351	164	68%
Salem NH	OLDE TROLLEY 18	13.2	18L4	516	612	387	225	75%	204	408	40%	210	402	41%
Salem NH	PELHAM 14	13.2	14L4	530	589	44	545	8%	317	272	60%	326	263	62%
Salem NH	SALEM DEPOT 9	13.2	9L1	322	371	271	100	84%	219	359	42%	226	352	43%
Salem NH	SALEM DEPOT 9	13.2	9L2	322	371	224	147	70%	288	290	55%	297	281	56%
Salem NH	SALEM DEPOT 9	13.2	9L3	507	507	319	188	63%	391	187	74%	402	176	77%
Salem NH	SPICKET RIVER 13	13.2	13L1	515	515	326	189	63%	168	347	33%	173	342	34%
Salem NH	SPICKET RIVER 13	13.2	13L2	515	515	290	225	56%	146	369	28%	150	365	29%
Salem NH	SPICKET RIVER 13	13.2	13L3	522	522	442	80	85%	102	420	19%	105	417	20%
Salem NH	GOLDEN ROCK 19	13.2	19L4	530	589		589	0%	84	528	16%	86	526	16%
Salem NH	GOLDEN ROCK 19	13.2	19L6	530	589		589	0%	542	70	103%	558	54	106%
Salem NH	GOLDEN ROCK 19	13.2	19L8	530	589		589	0%	275	337	52%	283	329	54%
Salem NH	BARRON AVENUE 10	13.2	10L5	516	589		589	0%	121	468	23%	125	464	24%
Salem NH	SALEM DEPOT 9	13.2	9L4	516	589		589	0%	8	581	2%	8	581	2%
Salem NH	SALEM DEPOT 9	13.2	9L5	516	589		589	0%	466	123	90%	480	109	93%

Table 29 Alt #3 Feeder Normal Loading

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Salem NH Transformer Analysis

Study Area	Substation	Tranf. ID.	System Voltage (kV)		Maximum Nameplate Rating	Rating (MVA)		Projected Load 2019			2022			2036		
			From	To		SN	SE	MVA	N-1	% SN	MVA	N-1	% SN	MVA	N-1	% SN
Salem NH	BARRON AVENUE 10	L1	23	13.2	7	9.4	10.9	2.4	8.5	26%	10.5	0.4	84%	10.8	2.2	87%
Salem NH	BARRON AVENUE 10	L2	23	13.2	7	13.6	14.2	6.1	8.1	45%	6.3	7.9	46%	6.5	7.7	48%
Salem NH	BARRON AVENUE 10	L4	23	13.2	7	9.1	10.3	4.0	6.3	44%	4.1	6.2	33%	4.3	8.7	34%
Salem NH	OLDE TROLLEY 18	L1	23	13.2	9.375	12.4	12.9	3.0	9.9	25%	5.0	7.9	40%	5.1	7.8	41%
Salem NH	OLDE TROLLEY 18	L2	23	13.2	9.375	12.4	12.9	9.2	3.7	75%	1.0	11.9	8%	1.0	11.9	8%
Salem NH	OLDE TROLLEY 18	L3	23	13.2	9.375	12.5	13	8.6	4.4	69%	7.8	5.2	62%	8.0	5.0	64%
Salem NH	OLDE TROLLEY 18	L4	23	13.2	9.375	12.5	13	8.8	4.2	71%	4.7	8.3	37%	4.8	8.2	38%
Salem NH	SALEM DEPOT 9	L1	23	13.2	7	7.36	10.1	6.2	3.9	84%	5.0	5.1	40%	5.2	7.8	41%
Salem NH	SALEM DEPOT 9	L2	23	13.2	7	7.36	9.2	5.1	4.1	70%	6.6	2.6	53%	6.8	6.2	54%
Salem NH	SALEM DEPOT 9	L3	23	13.2	9.375	11.6	11.6	7.3	4.3	63%	8.9	2.7	77%	9.2	2.4	79%
Salem NH	SPICKET RIVER 13	L1	23	13.2	9.375	14.4	14.4	7.5	6.9	52%	3.9	10.5	27%	4.0	10.4	28%
Salem NH	SPICKET RIVER 13	L2	23	13.2	9.375	13.9	14.4	6.6	7.8	48%	3.3	11.1	24%	3.4	11.0	25%
Salem NH	SPICKET RIVER 13	L3	23	13.2	9.375	13.9	14.4	10.1	4.3	73%	2.3	12.1	17%	2.4	12.0	17%
Salem NH	GOLDEN ROCK 19	T2	115	13.2	50	78.7	91.6	0.0	91.6	0%	20.6	71.0	26%	21.2	70.4	27%
Salem NH	BARRON AVENUE 10	L5	23	13.2	9.375	14.4	14.4	0.0	14.4	0%	2.8	11.6	19%	2.8	11.4	21%
Salem NH	SALEM DEPOT 9	L4	23	13.2	9.375	14.4	14.4	0.0	14.4	0%	0.2	14.2	1%	0.2	14.0	1%
Salem NH	SALEM DEPOT 9	L5	23	13.2	9.375	14.4	14.4	0.0	14.4	0%	10.7	3.7	74%	11.0	3.2	81%

Table 30 Alt #3 Transformer Normal Loading

Salem NH Supply Line Analysis

Study Area	Circuit	Voltage	Line Section		Rating (MVA)		Projected Load 2019		2022		2036	
			From	To	SN	SE	MVA	%SN	MVA	%SN	MVA	%SN
Salem NH	2352	23	Golden Rock	Barron Ave. Tap	54.8	65.4	30.9	56%	37.3	68%	38.4	70%
Salem NH	2352	23	Barron Ave. Tap	Olde Trolley Tap	56.4	72.5	30.9	55%	37.3	66%	38.4	68%
Salem NH	2352	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	12.3	39%	6.0	19%	6.1	19%
Salem NH	2352	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	18.6	69%	31.4	116%	32.3	119%
Salem NH	2393	23	Golden Rock	Barron Ave. Tap	54.8	65.4	26.0	47%	29.3	53%	30.1	55%
Salem NH	2393	23	Barron Ave. Tap	Olde Trolley Tap	45.2	58.2	17.4	38%	12.5	28%	12.8	28%
Salem NH	2393	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	17.4	55%	12.5	39%	12.8	40%
Salem NH	2393	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	0.0	0%	0.0	0%	0.0	0%
Methuen	2353	23	Meth Jnctn	Golden Rock	23.9	23.9	4.0	17%	6.9	29%	7.3	30%
Methuen	2376	23	Meth Jnctn	Golden Rock	23.9	23.9		0%		0%	0.0	0%
Methuen	2376	23	SPICKET RIVER TAP	SPICKET RIVER	35.9	40.7	24.2	67%	9.5	26%	10.0	28%

Table 31 Alt #3 Supply Line Normal Loading

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Salem NH Transformer Contingency Analysis

Study Area	Substation	Tranf. ID.	System Voltage (kV)		Maximum Nameplate Rating	Rating (MVA)		Projected Contingency					
								2019		2022		2036	
			From	To		SN	SE	MVA	% SE	MVA	% SE	MVA	% SE
Salem NH	BARRON AVENUE 10	L1	23	13.2	7	9.40	10.90	4.2	39%	7.9	61%	8.1	63%
Salem NH	BARRON AVENUE 10	L2	23	13.2	7	13.60	14.20	4.2	30%	7.9	56%	8.1	57%
Salem NH	BARRON AVENUE 10	L4	23	13.2	7	9.10	10.30	4.2	41%	7.9	61%	8.1	63%
Salem NH	OLDE TROLLEY 18	L1	23	13.2	9.375	12.40	12.90	9.9	77%	6.1	48%	6.3	49%
Salem NH	OLDE TROLLEY 18	L2	23	13.2	9.375	12.40	12.90	9.9	77%	6.1	48%	6.3	49%
Salem NH	OLDE TROLLEY 18	L3	23	13.2	9.375	12.50	13.00	9.9	76%	6.1	47%	6.3	49%
Salem NH	OLDE TROLLEY 18	L4	23	13.2	9.375	12.50	13.00	9.9	76%	6.1	47%	6.3	49%
Salem NH	SALEM DEPOT 9	L1	23	13.2	7	7.36	10.10	4.7	46%	7.8	60%	8.1	62%
Salem NH	SALEM DEPOT 9	L2	23	13.2	7	7.36	9.20	4.7	51%	7.8	60%	8.1	62%
Salem NH	SALEM DEPOT 9	L3	23	13.2	9.375	11.60	11.60	4.7	40%	7.8	68%	8.1	70%
Salem NH	SPICKET RIVER 13	L1	23	13.2	9.375	14.40	14.40	12.1	84%	4.8	33%	4.9	34%
Salem NH	SPICKET RIVER 13	L2	23	13.2	9.375	13.90	14.40	12.1	84%	4.8	33%	4.9	34%
Salem NH	SPICKET RIVER 13	L3	23	13.2	9.375	13.90	14.40	12.1	84%	4.8	33%	4.9	34%
Salem NH	GOLDEN ROCK 19	T2	115	13.2	50	78.70	91.60	0.0	0%		0%		0%
Salem NH	BARRON AVENUE 10	L5	23	13.2	9.375	14.40	14.40		0%	7.9	56%	8.1	57%
Salem NH	SALEM DEPOT 9	L4	23	13.2	9.375	14.40	14.40		0%	7.8	55%	8.1	57%
Salem NH	SALEM DEPOT 9	L5	23	13.2	9.375	14.40	14.40		0%	7.8	55%	8.1	57%

Table 32 Alt #3 Transformer Contingency Loading

Salem NH Supply Line Contingency Analysis

Study Area	Circuit	Voltage (kV)	Line Section		Rating (MVA)		Projected Contingency								
							2019			2022			2036		
			From	To	SN	SE	MVA	Load > SE	% SE	MVA	Load > SE	% SE	MVA	Load > SE	% SE
Salem NH	2352	23	Golden Rock	Barron Ave. Tap	54.8	65.4	**48.3**	0.0	74%	**50.0**	0.0	76%	**51.5**	0.0	79%
Salem NH	2352	23	Barron Ave. Tap	Olde Trolley Tap	56.4	72.5	**48.3**	0.0	67%	**50.0**	0.0	69%	**51.5**	0.0	71%
Salem NH	2352	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	**29.7**	0.0	93%	**18.4**	0.0	58%	**19.0**	0.0	60%
Salem NH	2352	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	**18.6**	0.0	69%	**31.4**	4.3	116%	**32.3**	5.2	119%
Salem NH	2393	23	Golden Rock	Barron Ave. Tap	54.8	65.4	**56.9**	0.0	87%	**66.4**	1.0	102%	**68.4**	3.0	105%
Salem NH	2393	23	Barron Ave. Tap	Olde Trolley Tap	45.2	58.2	**56.9**	0.0	98%	**66.4**	8.3	114%	**68.4**	10.2	118%
Salem NH	2393	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	**29.7**	0.0	93%	**18.4**	0.0	58%	**19.0**	0.0	60%
Salem NH	2393	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	**18.6**	0.0	69%	**31.4**	4.3	116%	**32.3**	5.2	119%
Methuen MA	2353	23	Meth Jnctn	Golden Rock	23.9	23.9	**34.9**	11.0	146%	**41.5**	17.6	174%	**43.8**	19.9	183%
Methuen MA	2376	23	Meth Jnctn	Golden Rock	23.9	23.9	**26.0**	2.1	109%	**29.3**	5.4	123%	**30.9**	7.0	129%
Methuen MA	2376	23	SPICKET RIVER TAP	SPICKET RIVER	35.9	40.7	**24.2**	0.0	59%	**9.5**	0.0	23%	**10.0**	0.0	25%

Table 33 Alt #3 Supply Line Contingency Loading

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Alternative #4 Loading

Salem NH Feeder Analysis														
Study Area	Substation	Voltage (kV)	Feeder	SN Rating (Amps)	SE Rating (Amps)	2019			2022			2036		
						Amps	N-1	%SN	Amps	N-1	%SN	Amps	N-1	%SN
Salem NH	BARRON AVENUE 10	13.2	10L1	387	462	107	355	28%	117	461	22%	121	457	23%
Salem NH	BARRON AVENUE 10	13.2	10L2	526	578	268	310	51%	479	99	91%	493	85	94%
Salem NH	BARRON AVENUE 10	13.2	10L4	339	339	176	163	52%	192	386	36%	197	381	38%
Salem NH	OLDE TROLLEY 18	13.2	18L1	503	565	133	432	27%	217	348	43%	224	341	44%
Salem NH	OLDE TROLLEY 18	13.2	18L2	503	515	404	111	80%	411	104	82%	423	92	84%
Salem NH	OLDE TROLLEY 18	13.2	18L3	515	515	375	140	73%	341	174	66%	351	164	68%
Salem NH	OLDE TROLLEY 18	13.2	18L4	516	612	387	225	75%	133	479	26%	137	475	26%
Salem NH	PELHAM 14	13.2	14L4	530	589	44	545	8%	382	207	72%	393	196	74%
Salem NH	SALEM DEPOT 9	13.2	9L1	322	371	271	100	84%	201	377	38%	207	371	39%
Salem NH	SALEM DEPOT 9	13.2	9L2	322	371	224	147	70%	288	290	55%	297	281	57%
Salem NH	SALEM DEPOT 9	13.2	9L3	507	507	319	188	63%	391	187	74%	402	176	77%
Salem NH	SPICKET RIVER 13	13.2	13L1	515	515	326	189	63%	168	347	33%	173	342	34%
Salem NH	SPICKET RIVER 13	13.2	13L2	515	515	290	225	56%	146	369	28%	150	365	29%
Salem NH	SPICKET RIVER 13	13.2	13L3	522	522	442	80	85%	204	318	39%	210	312	40%
Salem NH	BARRON AVENUE 10	13.2	10L5	516	589		589	0%	169	420	33%	174	415	34%
Salem NH	SALEM DEPOT 9	13.2	9L4	516	589		589	0%	500	89	97%	515	74	100%
Salem NH	SALEM DEPOT 9	13.2	9L5	516	589		589	0%	466	123	90%	480	109	93%

Table 34 Alt #4 Feeder Normal Loading

Salem NH Transformer Analysis

Study Area	Substation	Tranf. ID.	System Voltage (kV) From	System Voltage (kV) To	Maximum Nameplate Rating	Rating (MVA) SN	Rating (MVA) SE	Projected Load 2019 MVA	2019 N-1	2019 % SN	2022 MVA	2022 N-1	2022 % SN	2036 MVA	2036 N-3	2036 % SN
Salem NH	GOLDEN ROCK 19	T1	115	23	50	78.7	91.6	56.9	34.7	72%	53.0	38.6	67%	60.7	30.9	77%
Salem NH	GOLDEN ROCK 19	T2	115	23	50	78.7	91.6		91.6	0%	28.0	63.6	36%	61.3	30.3	78%
Salem NH	BARRON AVENUE 10	L1	23	13.2	7	9.4	10.9	2.4	8.5	26%	2.7	8.2	29%	2.8	10.2	22%
Salem NH	BARRON AVENUE 10	L2	23	13.2	7	13.6	14.2	6.1	8.1	45%	11.0	3.2	81%	11.3	2.9	83%
Salem NH	BARRON AVENUE 10	L4	23	13.2	7	9.1	10.3	4.0	6.3	44%	4.4	5.9	48%	4.5	8.5	36%
Salem NH	OLDE TROLLEY 18	L1	23	13.2	9.375	12.4	12.9	3.0	9.9	25%	5.0	7.9	40%	5.1	7.8	41%
Salem NH	OLDE TROLLEY 18	L2	23	13.2	9.375	12.4	12.9	9.2	3.7	75%	9.4	3.5	76%	9.7	3.2	78%
Salem NH	OLDE TROLLEY 18	L3	23	13.2	9.375	12.5	13	8.6	4.4	69%	7.8	5.2	62%	8.0	5.0	64%
Salem NH	OLDE TROLLEY 18	L4	23	13.2	9.375	12.5	13	8.8	4.2	71%	3.0	10.0	24%	3.1	9.9	25%
Salem NH	SALEM DEPOT 9	L1	23	13.2	7	7.36	10.1	6.2	3.9	84%	4.6	5.5	62%	4.7	8.3	38%
Salem NH	SALEM DEPOT 9	L2	23	13.2	7	7.36	9.2	5.1	4.1	70%	6.6	2.6	90%	6.8	6.2	54%
Salem NH	SALEM DEPOT 9	L3	23	13.2	9.375	11.6	11.6	7.3	4.3	63%	8.9	2.7	77%	9.2	2.4	79%
Salem NH	SPICKET RIVER 13	L1	23	13.2	9.375	14.4	14.4	7.5	6.9	52%	3.9	10.5	27%	4.0	10.4	28%
Salem NH	SPICKET RIVER 13	L2	23	13.2	9.375	13.9	14.4	6.6	7.8	48%	3.3	11.1	24%	3.4	11.0	25%
Salem NH	SPICKET RIVER 13	L3	23	13.2	9.375	13.9	14.4	10.1	4.3	73%	4.7	9.7	34%	4.8	9.6	35%
Salem NH	BARRON AVENUE 10	L5	23	13.2	9.375	14.4	14.4	0.0	14.4	0%	3.9	10.5	27%	4.0	10.2	29%
Salem NH	SALEM DEPOT 9	L4	23	13.2	9.375	14.4	14.4	0.0	14.4	0%	11.4	3.0	79%	11.8	2.4	87%
Salem NH	SALEM DEPOT 9	L5	23	13.2	9.375	14.4	14.4	0.0	14.4	0%	10.7	3.7	74%	11.0	3.2	81%

Table 35 Alt #4 Transformer Normal Loading

Salem NH Supply Line Analysis

Study Area	Circuit	Voltage	Line Section From	Line Section To	Rating (MVA) SN	Rating (MVA) SE	Projected Load 2019 MVA	2019 %SN	2022 MVA	2022 %SN	2036 MVA	2036 %SN
Salem NH	2352	23	Golden Rock	Barron Ave. Tap	54.8	65.4	18.6	34%	42.2	77%	43.4	79%
Salem NH	2352	23	Barron Ave. Tap	Olde Trolley Tap	56.4	72.5	18.6	33%	42.2	75%	43.4	77%
Salem NH	2352	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	0.0	0%	0.0	0%	0.0	0%
Salem NH	2352	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	18.6	69%	42.2	156%	43.4	160%
Salem NH	2393	23	Golden Rock	Barron Ave. Tap	54.8	65.4	17.4	32%	10.8	20%	11.2	20%
Salem NH	2393	23	Barron Ave. Tap	Olde Trolley Tap	45.2	58.2	17.4	38%	10.8	24%	11.2	25%
Salem NH	2393	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	0.0	0%	10.8	34%	11.2	35%
Salem NH	2393	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	0.0	0%	0.0	0%	0.0	0%
Methuen	2353	23	Meth Jnctn	Golden Rock	23.9	23.9	4.0	17%	3.9	16%	4.0	17%
Methuen	2376	23	Meth Jnctn	Golden Rock	23.9	23.9		0%		0%	0.0	0%
Methuen	2376	23	SPICKET RIVER TAP	SPICKET RIVER	35.9	40.7	24.2	67%	11.8	33%	12.2	34%
Salem NH	Line #3	23	Golden Rock	Barron Ave. Tap	54.8	65.4	20.9		28.0	51%	28.8	53%
Salem NH	Line #3	23	Barron Ave. Tap	Rockingham Tap	56.4	72.5	0.0		14.4	25%	14.8	26%

Table 36 Alt #4 Supply Lines Normal Loading

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Salem NH Transformer Contingency Analysis

Study Area	Substation	Tranf. ID.	System Voltage (kV)		Maximum	Rating (MVA)		Projected Contingency					
								2019		2022		2036	
			From	To	Nameplate Rating	SN	SE	MVA	% SE	MVA	% SE	MVA	% SE
Salem NH	GOLDEN ROCK 19	T1	115	23	50	78.70	91.60		0%	81.0	88%	83.4	91%
Salem NH	GOLDEN ROCK 19	T2	115	23	50	78.70	91.60		0%	81.0	88%	83.4	91%
Salem NH	BARRON AVENUE 10	L1	23	13.2	7	9.40	10.90	4.2	39%	7.3	56%	7.5	58%
Salem NH	BARRON AVENUE 10	L2	23	13.2	7	13.60	14.20	4.2	30%	7.3	51%	7.5	53%
Salem NH	BARRON AVENUE 10	L4	23	13.2	7	9.10	10.30	4.2	41%	7.3	56%	7.5	58%
Salem NH	OLDE TROLLEY 18	L1	23	13.2	9.375	12.40	12.90	9.9	77%	8.4	65%	8.6	67%
Salem NH	OLDE TROLLEY 18	L2	23	13.2	9.375	12.40	12.90	9.9	77%	8.4	65%	8.6	67%
Salem NH	OLDE TROLLEY 18	L3	23	13.2	9.375	12.50	13.00	9.9	76%	8.4	65%	8.6	67%
Salem NH	OLDE TROLLEY 18	L4	23	13.2	9.375	12.50	13.00	9.9	76%	8.4	65%	8.6	67%
Salem NH	SALEM DEPOT 9	L1	23	13.2	7	7.36	10.10	4.7	46%	10.6	81%	10.9	84%
Salem NH	SALEM DEPOT 9	L2	23	13.2	7	7.36	9.20	4.7	51%	10.6	81%	10.9	84%
Salem NH	SALEM DEPOT 9	L3	23	13.2	9.375	11.60	11.60	4.7	40%	10.6	91%	10.9	94%
Salem NH	SPICKET RIVER 13	L1	23	13.2	9.375	14.40	14.40	12.1	84%	5.9	41%	6.1	42%
Salem NH	SPICKET RIVER 13	L2	23	13.2	9.375	13.90	14.40	12.1	84%	5.9	41%	6.1	42%
Salem NH	SPICKET RIVER 13	L3	23	13.2	9.375	13.90	14.40	12.1	84%	5.9	41%	6.1	42%
Salem NH	BARRON AVENUE 10	L5	23	13.2	9.375	14.40	14.40	4.2	29%	7.3	51%	7.5	53%
Salem NH	SALEM DEPOT 9	L4	23	13.2	9.375	14.40	14.40	4.7	32%	10.6	74%	10.9	76%
Salem NH	SALEM DEPOT 9	L5	23	13.2	9.375	14.40	14.40	4.7	32%	10.6	74%	10.9	76%

Table 37 Alt #4 Transformer Contingency Loading

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Salem NH Supply Line Contingency Analysis

Study Area	Circuit	Voltage (kV)	Line Section		Rating (MVA)		Projected Contingency								
							2019			2022			2036		
			From	To	SN	SE	MVA	Load > SE	% SE	MVA	Load > SE	% SE	MVA	Load > SE	% SE
Salem NH	2352	23	Golden Rock	Barron Ave. Tap	54.8	65.4	**36.0**	0.0	55%	**42.2**	0.0	65%	**43.4**	0.0	66%
Salem NH	2352	23	Barron Ave. Tap	Olde Trolley Tap	56.4	72.5	**36.0**	0.0	50%	**42.2**	0.0	58%	**43.4**	0.0	60%
Salem NH	2352	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	**29.7**	0.0	93%	**0.0**	0.0	0%	**0.0**	0.0	0%
Salem NH	2352	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	**18.6**	0.0	69%	**42.2**	15.1	156%	**43.4**	16.4	160%
Salem NH	2393	23	Golden Rock	Barron Ave. Tap	54.8	65.4	**48.3**	0.0	74%	**30.0**	0.0	46%	**30.8**	0.0	47%
Salem NH	2393	23	Barron Ave. Tap	Olde Trolley Tap	45.2	58.2	**48.3**	0.0	83%	**30.0**	0.0	52%	**30.8**	0.0	53%
Salem NH	2393	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	**29.7**	0.0	93%	**30.0**	0.0	94%	**30.8**	0.0	97%
Salem NH	2393	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	**18.6**	0.0	69%	**0.0**	0.0	0%	**0.0**	0.0	0%
Methuen MA	2353	23	Meth Jnctn	Golden Rock	23.9	23.9	**18.6**	0.0	78%	**18.0**	0.0	75%	**19.0**	0.0	80%
Methuen MA	2376	23	Meth Jnctn	Golden Rock	23.9	23.9	**17.4**	0.0	73%	**0.0**	0.0	0%	**0.0**	0.0	0%
Methuen MA	2376	23	SPICKET RIVER TAP	SPICKET RIVER	35.9	40.7	**24.2**	0.0	59%	**11.8**	0.0	29%	**12.5**	0.0	31%
Salem NH	Line #3	23	Golden Rock	Barron Ave. Tap	54.8	65.4	**20.9**	0.0	32%	**55.8**	0.0	85%	**58.9**	0.0	90%
Salem NH	Line #3	23	Barron Ave. Tap	Rockingham Tap	56.4	72.5	**0.0**	0.0	0%	**42.2**	0.0	58%	**44.5**	0.0	61%
Salem NH	Line #3	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	**0.0**	0.0	0%	**42.2**	15.1	156%	**44.5**	17.4	164%

Table 38 Alt #4 Supply Line Contingency Loading

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Alternative #5 Loading

Salem NH Feeder Analysis														
						2019			2022			2036		
Study Area	**Substation**	**Voltage (kV)**	**Feeder**	**SN Rating (Amps)**	**SE Rating (Amps)**	**Amps**	**N-1**	**%SN**	**Amps**	**N-1**	**%SN**	**Amps**	**N-1**	**%SN**
Salem NH	BARRON AVENUE 10	13.2	10L1	387	462	107	355	28%	117	461	22%	121	457	23%
Salem NH	BARRON AVENUE 10	13.2	10L2	526	578	268	310	51%	475	103	90%	489	89	93%
Salem NH	BARRON AVENUE 10	13.2	10L4	339	339	176	163	52%	191	387	36%	197	381	38%
Salem NH	OLDE TROLLEY 18	13.2	18L1	503	565	133	432	27%	217	348	43%	224	341	44%
Salem NH	OLDE TROLLEY 18	13.2	18L2	503	515	404	111	80%	409	106	81%	421	94	84%
Salem NH	OLDE TROLLEY 18	13.2	18L3	515	515	375	140	73%	341	174	66%	351	164	68%
Salem NH	OLDE TROLLEY 18	13.2	18L4	516	612	387	225	75%	133	479	26%	137	475	26%
Salem NH	PELHAM 14	13.2	14L4	530	589	44	545	8%	382	207	72%	393	196	74%
Salem NH	SALEM DEPOT 9	13.2	9L1	322	371	271	100	84%	201	377	38%	207	371	39%
Salem NH	SALEM DEPOT 9	13.2	9L2	322	371	224	147	70%	288	290	55%	297	281	57%
Salem NH	SALEM DEPOT 9	13.2	9L3	507	507	319	188	63%	391	187	74%	402	176	77%
Salem NH	SPICKET RIVER 13	13.2	13L1	515	515	326	189	63%	168	347	33%	173	342	34%
Salem NH	SPICKET RIVER 13	13.2	13L2	515	515	290	225	56%	164	351	32%	169	346	33%
Salem NH	SPICKET RIVER 13	13.2	13L3	522	522	442	80	85%	206	316	40%	212	310	41%
Salem NH	ROCKINGHAM 21 -23kV	13.2	21L9	516	589		589	0%	460	129	89%	474	115	92%
Salem NH	ROCKINGHAM 21 -23kV	13.2	21L10	516	589		589	0%	500	89	97%	515	74	100%
Salem NH	ROCKINGHAM 21 -23kV	13.2	21L11	516	589		589	0%	170	419	33%	175	414	34%

Table 39 Alt #5 Feeder Normal Loading

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Salem NH Transformer Analysis

Study Area	Substation	Tranf. ID.	System Voltage (kV) From	System Voltage (kV) To	Maximum Nameplate Rating	Rating (MVA) SN	Rating (MVA) SE	Projected Load 2019 MVA	2019 N-1	2019 % SN	2022 MVA	2022 N-1	2022 % SN	2036 MVA	2036 N-1	2036 % SN
Salem NH	GOLDEN ROCK 19	T1	115	23	50	78.7	91.6	56.9	34.7	72%	31.0	60.6	39%	31.9	59.7	40%
Salem NH	GOLDEN ROCK 19	T2	115	23	50	78.7	91.6	0.0	91.6	0%	53.7	37.9	68%	55.3	36.3	70%
Salem NH	BARRON AVENUE 10	L1	23	13.2	7	9.4	10.9	2.4	8.5	26%	2.7	8.2	29%	2.8	10.2	22%
Salem NH	BARRON AVENUE 10	L2	23	13.2	7	13.6	14.2	6.1	8.1	45%	10.9	3.3	80%	11.2	3.0	82%
Salem NH	BARRON AVENUE 10	L4	23	13.2	7	9.1	10.3	4.0	6.3	44%	4.4	5.9	48%	4.5	8.5	36%
Salem NH	OLDE TROLLEY 18	L1	23	13.2	9.375	12.4	12.9	3.0	9.9	25%	5.0	7.9	40%	5.1	7.8	41%
Salem NH	OLDE TROLLEY 18	L2	23	13.2	9.375	12.4	12.9	9.2	3.7	75%	9.4	3.5	75%	9.6	3.3	78%
Salem NH	OLDE TROLLEY 18	L3	23	13.2	9.375	12.5	13	8.6	4.4	69%	7.8	5.2	62%	8.0	5.0	64%
Salem NH	OLDE TROLLEY 18	L4	23	13.2	9.375	12.5	13	8.8	4.2	71%	3.0	10.0	24%	3.1	9.9	25%
Salem NH	SALEM DEPOT 9	L1	23	13.2	7	7.36	10.1	6.2	3.9	84%	4.6	5.5	62%	4.7	8.3	38%
Salem NH	SALEM DEPOT 9	L2	23	13.2	7	7.36	9.2	5.1	4.1	70%	6.6	2.6	90%	6.8	6.2	54%
Salem NH	SALEM DEPOT 9	L3	23	13.2	9.375	11.6	11.6	7.3	4.3	63%	8.9	2.7	77%	9.2	2.4	79%
Salem NH	SPICKET RIVER 13	L1	23	13.2	9.375	14.4	14.4	7.5	6.9	52%	3.9	10.5	27%	4.0	10.4	28%
Salem NH	SPICKET RIVER 13	L2	23	13.2	9.375	13.9	14.4	6.6	7.8	48%	3.8	10.6	27%	3.9	10.5	28%
Salem NH	SPICKET RIVER 13	L3	23	13.2	9.375	13.9	14.4	10.1	4.3	73%	4.7	9.7	34%	4.9	9.5	35%
Salem NH	ROCKINGHAM 21 -23kV	L9	23	13.2	9.375	12.5	13	0.0	13.0	0%	10.5	2.5	84%	10.8	2.2	87%
Salem NH	ROCKINGHAM 21 -23kV	L10	23	13.2	9.375	12.5	13	0.0	13.0	0%	11.4	1.6	91%	11.8	1.2	94%
Salem NH	ROCKINGHAM 21 -23kV	L11	23	13.2	9.375	12.5	13	0.0	13.0	0%	3.9	9.1	31%	4.0	9.0	32%

Table 40 Alt #5 Transformer Normal Loading

Salem NH Supply Line Analysis

Study Area	Circuit	Voltage	Line Section From	Line Section To	Rating (MVA) SN	Rating (MVA) SE	Projected Load 2019 MVA	2019 %SN	2022 MVA	2022 %SN	2036 MVA	2036 %SN
Salem NH	2352	23	Golden Rock	Barron Ave. Tap	54.8	65.4	30.9	56%	20.1	37%	20.7	38%
Salem NH	2352	23	Barron Ave. Tap	Olde Trolley Tap	56.4	72.5	30.9	55%	20.1	36%	20.7	37%
Salem NH	2352	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	12.3	39%		0%	0.0	0%
Salem NH	2352	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	18.6	69%	20.1	74%	20.7	76%
Salem NH	2393	23	Golden Rock	Barron Ave. Tap	54.8	65.4	26.0	47%	10.8	20%	11.2	20%
Salem NH	2393	23	Barron Ave. Tap	Olde Trolley Tap	45.2	58.2	17.4	38%	10.8	24%	11.2	25%
Salem NH	2393	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	17.4	55%	10.8	34%	11.2	35%
Salem NH	2393	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	0.0	0%	0.0	0%	0.0	0%
Methuen	2353	23	Meth Jnctn	Golden Rock	23.9	23.9	4.0	17%		0%	0.0	0%
Methuen	2376	23	Meth Jnctn	Golden Rock	23.9	23.9		0%		0%	0.0	0%
Methuen	2376	23	SPICKET RIVER TAP	SPICKET RIVER	35.9	40.7	24.2	67%	12.3	34%	12.7	35%
Salem NH	Line #3	23	Golden Rock	Barron Ave. Tap	54.8	65.4			27.9	51%	28.7	52%
Salem NH	Line #3	23	Barron Ave. Tap	Rockingham Tap	56.4	72.5			14.3	25%	14.7	26%
Salem NH	Line #3	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1			0.0	0%	0.0	0%
Salem NH	Line #4	23	Golden Rock	Barron Ave. Tap	54.8	65.4			25.8	47%	26.6	49%
Salem NH	Line #4	23	Barron Ave. Tap	Rockingham Tap	56.4	72.5			25.8	46%	26.6	47%
Salem NH	Line #4	23	Olde Trolley Tap	Salem Depot #9	56.4	72.5			0.0	0%	0.0	0%

Table 41 Alt #5 Supply Line Normal Loading

Salem NH Transformer Contingency Analysis													
Study Area	Substation	Tranf. ID.	System Voltage (kV)		Maximum	Rating (MVA)		Projected Contingency					
								2019		2022		2036	
			From	To	Nameplate Rating	SN	SE	MVA	% SE	MVA	% SE	MVA	% SE
Salem NH	GOLDEN ROCK 19	T1	115	23	50	78.70	91.60		0%	84.7	92%	87.2	95%
Salem NH	GOLDEN ROCK 19	T2	115	23	50	78.70	91.60		0%	84.7	92%	87.2	95%
Salem NH	BARRON AVENUE 10	L1	23	13.2	7	9.40	10.90	6.3	58%	9.0	69%	9.2	71%
Salem NH	BARRON AVENUE 10	L2	23	13.2	7	13.60	14.20	6.3	44%	9.0	63%	9.2	65%
Salem NH	BARRON AVENUE 10	L4	23	13.2	7	9.10	10.30	6.3	61%	9.0	69%	9.2	71%
Salem NH	OLDE TROLLEY 18	L1	23	13.2	9.375	12.40	12.90	9.9	77%	8.4	65%	8.6	67%
Salem NH	OLDE TROLLEY 18	L2	23	13.2	9.375	12.40	12.90	9.9	77%	8.4	65%	8.6	67%
Salem NH	OLDE TROLLEY 18	L3	23	13.2	9.375	12.50	13.00	9.9	76%	8.4	65%	8.6	66%
Salem NH	OLDE TROLLEY 18	L4	23	13.2	9.375	12.50	13.00	9.9	76%	8.4	65%	8.6	66%
Salem NH	SALEM DEPOT 9	L1	23	13.2	7	7.36	10.10	9.3	92%	10.1	77%	10.4	80%
Salem NH	SALEM DEPOT 9	L2	23	13.2	7	7.36	9.20	9.3	101%	10.1	77%	10.4	80%
Salem NH	SALEM DEPOT 9	L3	23	13.2	9.375	11.60	11.60	9.3	80%	10.1	87%	10.4	89%
Salem NH	SPICKET RIVER 13	L1	23	13.2	9.375	14.40	14.40	12.1	84%	6.2	43%	6.3	44%
Salem NH	SPICKET RIVER 13	L2	23	13.2	9.375	13.90	14.40	12.1	84%	6.2	43%	6.3	44%
Salem NH	SPICKET RIVER 13	L3	23	13.2	9.375	13.90	14.40	12.1	84%	6.2	43%	6.3	44%
Salem NH	ROCKINGHAM 21 -23kV	L9	23	13.2	9.375	12.50	13.00	0.0	0%	12.9	99%	13.3	102%
Salem NH	ROCKINGHAM 21 -23kV	L10	23	13.2	9.375	12.50	13.00	0.0	0%	12.9	99%	13.3	102%
Salem NH	ROCKINGHAM 21 -23kV	L11	23	13.2	9.375	12.50	13.00	0.0	0%	12.9	99%	13.3	102%

Table 42 Alt #5 Transformer Contingency Loading

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Salem NH Supply Line Contingency Analysis

Study Area	Circuit	Voltage (kV)	Line Section		Rating (MVA)		Projected Contingency								
							2019			2022			2036		
			From	To	SN	SE	MVA	Load > SE	% SE	MVA	Load > SE	% SE	MVA	Load > SE	% SE
Salem NH	2352	23	Golden Rock	Barron Ave. Tap	54.8	65.4	**48.3**	0.0	74%	**46.0**	0.0	70%	**47.3**	0.0	72%
Salem NH	2352	23	Barron Ave. Tap	Olde Trolley Tap	56.4	72.5	**48.3**	0.0	67%	**46.0**	0.0	63%	**47.3**	0.0	65%
Salem NH	2352	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	**29.7**	0.0	93%		0.0	0%	**0.0**	0.0	0%
Salem NH	2352	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	**18.6**	0.0	69%	**46.0**	18.9	170%	**47.3**	20.2	175%
Salem NH	2393	23	Golden Rock	Barron Ave. Tap	54.8	65.4	**56.9**	0.0	87%	**25.2**	0.0	38%	**25.9**	0.0	40%
Salem NH	2393	23	Barron Ave. Tap	Olde Trolley Tap	45.2	58.2	**56.9**	0.0	98%	**25.2**	0.0	43%	**25.9**	0.0	45%
Salem NH	2393	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	**29.7**	0.0	93%	**25.2**	0.0	79%	**25.9**	0.0	81%
Salem NH	2393	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	**18.6**	0.0	69%	**0.0**	0.0	0%	**0.0**	0.0	0%
Methuen MA	2353	23	Meth Jnctn	Golden Rock	23.9	23.9	**30.9**	7.0	129%	**20.1**	0.0	84%	**21.2**	0.0	89%
Methuen MA	2376	23	Meth Jnctn	Golden Rock	23.9	23.9	**26.0**	2.1	109%	**10.8**	0.0	45%	**11.4**	0.0	48%
Methuen MA	2376	23	SPICKET RIVER TAP	SPICKET RIVER	35.9	40.7	**24.2**	0.0	59%	**12.3**	0.0	30%	**13.0**	0.0	32%
Salem NH	Line #3	23	Golden Rock	Barron Ave. Tap	54.8	65.4	**0.0**	0.0	0%	**38.7**	0.0	59%	**40.8**	0.0	62%
Salem NH	Line #3	23	Barron Ave. Tap	Rockingham Tap	56.4	72.5	**0.0**	0.0	0%	**25.2**	0.0	35%	**26.6**	0.0	37%
Salem NH	Line #3	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	**0.0**	0.0	0%		0.0	0%	**0.0**	0.0	0%
Salem NH	Line #4	23	Golden Rock	Barron Ave. Tap	54.8	65.4	**0.0**	0.0	0%	**46.0**	0.0	70%	**48.5**	0.0	74%
Salem NH	Line #4	23	Barron Ave. Tap	Rockingham Tap	56.4	72.5	**0.0**	0.0	0%	**46.0**	0.0	63%	**48.5**	0.0	67%
Salem NH	Line #4	23	Olde Trolley Tap	Salem Depot #9	56.4	72.5	**0.0**	0.0	0%	**46.0**	0.0	63%	**48.5**	0.0	67%

Table 43 Alt #5 Supply Line Contingency Loading

Alternative #6 Loading

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Salem NH Feeder Analysis

Study Area	Substation	Voltage (kV)	Feeder	SN Rating (Amps)	SE Rating (Amps)	2019			2022			2036		
						Amps	N-1	%SN	Amps	N-1	%SN	Amps	N-1	%SN
Salem NH	OLDE TROLLEY 18	13.2	18L1	503	565	107	458	21%	217	348	43%	224	341	44%
Salem NH	OLDE TROLLEY 18	13.2	18L2	503	515	268	247	53%	252	263	50%	260	255	52%
Salem NH	OLDE TROLLEY 18	13.2	18L3	515	515	176	339	34%	348	167	68%	358	157	70%
Salem NH	OLDE TROLLEY 18	13.2	18L4	516	612	133	479	26%	461	151	89%	474	138	92%
Salem NH	PELHAM 14	13.2	14L4	530	589	323	266	61%	46	543	9%	48	541	9%
Salem NH	SPICKET RIVER 13	13.2	13L1	515	515	271	244	53%	347	168	67%	357	158	69%
Salem NH	SPICKET RIVER 13	13.2	13L2	515	515	224	291	43%	312	203	61%	321	194	62%
Salem NH	SPICKET RIVER 13	13.2	13L3	522	522	319	203	61%	390	132	75%	402	120	77%
Salem NH	GOLDEN ROCK 19	13.2	19L4	530	589		589	0%	84	528	16%	86	526	16%
Salem NH	GOLDEN ROCK 19	13.2	19L6	530	589		589	0%	259	353	49%	267	345	51%
Salem NH	GOLDEN ROCK 19	13.2	19L8	530	589		589	0%	235	377	45%	242	370	46%
Salem NH	ROCKINGHAM 21	13.2	21L1	530	589		589	0%	455	134	86%	468	121	88%
Salem NH	ROCKINGHAM 21	13.2	21L2	515	589		589	0%	0	589	0%	0	589	0%
Salem NH	ROCKINGHAM 21	13.2	21L3	515	515		515	0%	0	515	0%	0	515	0%
Salem NH	ROCKINGHAM 21	13.2	21L4	515	515		515	0%	0	515	0%	0	515	0%
Salem NH	ROCKINGHAM 21	13.2	21L5	530	589		589	0%	281	308	53%	289	300	55%
Salem NH	ROCKINGHAM 21	13.2	21L6	530	589		589	0%	288	301	54%	296	293	56%
Salem NH	ROCKINGHAM 21	13.2	21L7	530	589		589	0%	372	217	70%	383	206	72%
Salem NH	ROCKINGHAM 21	13.2	21L8	530	589		589	0%	441	148	83%	454	135	86%

Table 44 Alt #6 Feeder Normal Loading

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Salem NH Transformer Analysis

Study Area	Substation	Tranf. ID.	System Voltage (kV)		Maximum	Rating (MVA)		Projected Load								
								2019			2022			2036		
			From	To	Nameplate Rating	SN	SE	MVA	N-1	% SN	MVA	N-1	% SN	MVA	N-1	% SN
Salem NH	GOLDEN ROCK 19	T1	115	23	50	78.7	91.6		91.6	0%	29.2	62.4	37%	30.1	61.5	38%
Salem NH	OLDE TROLLEY 18	L1	23	13.2	9.375	12.4	12.9	2.4	10.5	20%	5.0	7.9	40%	5.1	7.8	41%
Salem NH	OLDE TROLLEY 18	L2	23	13.2	9.375	12.4	12.9	6.1	6.8	49%	5.8	7.1	47%	5.9	7.0	48%
Salem NH	OLDE TROLLEY 18	L3	23	13.2	9.375	12.5	13	4.0	9.0	32%	8.0	5.0	64%	8.2	4.8	65%
Salem NH	OLDE TROLLEY 18	L4	23	13.2	9.375	12.5	13	3.0	10.0	24%	10.5	2.5	84%	10.8	2.2	87%
Salem NH	SPICKET RIVER 13	L1	23	13.2	9.375	14.4	14.4	6.2	8.2	43%	7.9	6.5	55%	8.2	6.2	57%
Salem NH	SPICKET RIVER 13	L2	23	13.2	9.375	13.9	14.4	5.1	9.3	37%	7.1	7.3	51%	7.3	7.1	53%
Salem NH	SPICKET RIVER 13	L3	23	13.2	9.375	13.9	14.4	7.3	7.1	52%	8.9	5.5	64%	9.2	5.2	66%
Salem NH	GOLDEN ROCK 19	T2	115	13.2	50	78.7	91.6	0.0	91.6	0%	13.2	78.4	17%	13.6	78.0	17%
Salem NH	ROCKINGHAM 21	T1	115	13.2	50	78.7	91.6	0.0	91.6	0%	25.3	66.3	32%	26.1	65.5	33%
Salem NH	ROCKINGHAM 21	T2	115	13.2	50	78.7	91.6	0.0	91.6	0%	16.7	74.9	21%	17.2	74.4	22%

Table 45 Alt #6 Transformer Normal Loading

Salem NH Supply Line Analysis

Study Area	Circuit	Voltage	Line Section		Rating (MVA)		Projected Load					
							2019		2022		2036	
			From	To	SN	SE	MVA	%SN	MVA	%SN	MVA	%SN
Salem NH	2352	23	Golden Rock	Barron Ave. Tap	54.8	65.4	9.6	17%	10.7	20%	11.0	20%
Salem NH	2352	23	Barron Ave. Tap	Olde Trolley Tap	56.4	72.5	9.6	17%	10.7	19%	11.0	20%
Salem NH	2352	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	8.6	27%	10.7	34%	11.0	35%
Salem NH	2352	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	1.0	4%	18.5	68%	19.0	70%
Salem NH	2393	23	Golden Rock	Barron Ave. Tap	54.8	65.4	7.1	13%	18.5	34%	19.0	35%
Salem NH	2393	23	Barron Ave. Tap	Olde Trolley Tap	45.2	58.2	7.1	16%	18.5	41%	19.0	42%
Salem NH	2393	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	7.1	22%	18.5	58%	19.0	60%
Salem NH	2393	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	0.0	0%	0.0	0%	0.0	0%
Methuen	2353	23	Meth Jnctn	Golden Rock	23.9	23.9	0.0	0%	0.0	0%	0.0	0%
Methuen	2376	23	Meth Jnctn	Golden Rock	23.9	23.9		0%		0%	0.0	0%
Methuen	2376	23	SPICKET RIVER TAP	SPICKET RIVER	35.9	40.7	18.6	52%	24.0	67%	25.3	71%

Table 46 Alt #6 Supply Line Normal Loading

Salem NH Transformer Contingency Analysis													
Study Area	Substation	Tranf. ID.	System Voltage (kV)		Maximum	Rating (MVA)		Projected Contingency					
								2019		2022		2036	
			From	To	Nameplate Rating	SN	SE	MVA	% SE	MVA	% SE	MVA	% SE
Salem NH	GOLDEN ROCK 19	T1	115	23	50	78.70	91.60	0.0	0%	0.0	0%	0.0	0%
Salem NH	OLDE TROLLEY 18	L1	23	13.2	9.375	12.40	12.90	5.2	40%	9.7	75%	10.0	78%
Salem NH	OLDE TROLLEY 18	L2	23	13.2	9.375	12.40	12.90	5.2	40%	9.7	75%	10.0	78%
Salem NH	OLDE TROLLEY 18	L3	23	13.2	9.375	12.50	13.00	5.2	40%	9.7	75%	10.0	77%
Salem NH	OLDE TROLLEY 18	L4	23	13.2	9.375	12.50	13.00	5.2	40%	9.7	75%	10.0	77%
Salem NH	SPICKET RIVER 13	L1	23	13.2	9.375	14.40	14.40	9.3	65%	12.0	83%	12.3	86%
Salem NH	SPICKET RIVER 13	L2	23	13.2	9.375	13.90	14.40	9.3	65%	12.0	83%	12.3	86%
Salem NH	SPICKET RIVER 13	L3	23	13.2	9.375	13.90	14.40	9.3	65%	12.0	83%	12.3	86%
Salem NH	GOLDEN ROCK 19	T2	115	13.2	50	78.70	91.60	0.0	0%		0%	0.0	0%
Salem NH	ROCKINGHAM 21	T1	115	13.2	50	78.70	91.60	0.0	0%	44.8	49%	46.1	50%
Salem NH	ROCKINGHAM 21	T2	115	13.2	50	78.70	91.60	0.0	0%	44.8	49%	46.1	50%

Table 47 Alt #6 Transformer Contingency Loading

Salem NH Supply Line Contingency Analysis															
Study Area	Circuit	Voltage (kV)	Line Section		Rating (MVA)		Projected Contingency								
							2019			2022			2036		
			From	To	SN	SE	MVA	Load > SE	% SE	MVA	Load > SE	% SE	MVA	Load > SE	% SE
Salem NH	2352	23	Golden Rock	Barron Ave. Tap	54.8	65.4	**16.7**	0.0	25%	**29.2**	0.0	45%	**30.1**	0.0	46%
Salem NH	2352	23	Barron Ave. Tap	Olde Trolley Tap	56.4	72.5	**16.7**	0.0	23%	**29.2**	0.0	78%	**30.1**	0.0	80%
Salem NH	2352	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	**15.6**	0.0	49%	**29.2**	0.0	92%	**30.1**	0.0	94%
Salem NH	2352	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	**1.0**	0.0	4%	**0.0**	0.0	0%	**0.0**	0.0	0%
Salem NH	2393	23	Golden Rock	Barron Ave. Tap	54.8	65.4	**16.7**	0.0	25%	**29.2**	0.0	45%	**30.1**	0.0	46%
Salem NH	2393	23	Barron Ave. Tap	Olde Trolley Tap	45.2	58.2	**16.7**	0.0	29%	**29.2**	0.0	78%	**30.1**	0.0	80%
Salem NH	2393	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	**15.6**	0.0	49%	**29.2**	0.0	92%	**30.1**	0.0	94%
Salem NH	2393	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	**1.0**	0.0	4%	**0.0**	0.0	0%	**0.0**	0.0	0%
Methuen MA	2353	23	Meth Jnctn	Golden Rock	23.9	23.9	**9.6**	0.0	40%	**10.7**	0.0	45%	**11.3**	0.0	47%
Methuen MA	2376	23	Meth Jnctn	Golden Rock	23.9	23.9	**7.1**	0.0	30%	**18.5**	0.0	77%	**19.5**	0.0	82%
Methuen MA	2376	23	SPICKET RIVER TAP	SPICKET RIVER	35.9	40.7	**18.6**	0.0	46%	**24.0**	0.0	59%	**25.3**	0.0	62%

Table 48 Alt #6 Supply Line Contingency Loading

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Alternative #7 Loading

Salem NH Feeder Analysis														
						2019			2022			2036		
Study Area	**Substation**	**Voltage (kV)**	**Feeder**	**SN Rating (Amps)**	**SE Rating (Amps)**	**Amps**	**N-1**	**%SN**	**Amps**	**N-1**	**%SN**	**Amps**	**N-1**	**%SN**
Salem NH	BARRON AVENUE 10	13.2	10L1	387	462	107	355	28%	268	310	51%	276	302	52%
Salem NH	BARRON AVENUE 10	13.2	10L2	526	578	268	310	51%	287	291	55%	295	283	56%
Salem NH	BARRON AVENUE 10	13.2	10L4	339	339	176	163	52%	181	397	34%	186	392	35%
Salem NH	OLDE TROLLEY 18	13.2	18L1	503	565	133	432	27%	217	348	43%	224	341	44%
Salem NH	OLDE TROLLEY 18	13.2	18L2	503	515	404	111	80%	291	224	58%	299	216	59%
Salem NH	OLDE TROLLEY 18	13.2	18L3	515	515	375	140	73%	341	174	66%	351	164	68%
Salem NH	OLDE TROLLEY 18	13.2	18L4	516	612	387	225	75%	284	328	55%	292	320	57%
Salem NH	PELHAM 14	13.2	14L4	530	589	44	545	8%	490	99	92%	504	85	95%
Salem NH	SALEM DEPOT 9	13.2	9L1	322	371	271	100	84%	297	281	56%	305	273	58%
Salem NH	SALEM DEPOT 9	13.2	9L2	322	371	224	147	70%	288	290	55%	297	281	57%
Salem NH	SALEM DEPOT 9	13.2	9L3	507	507	319	188	63%	391	187	74%	402	176	77%
Salem NH	SPICKET RIVER 13	13.2	13L1	515	515	326	189	63%	348	167	68%	358	157	70%
Salem NH	SPICKET RIVER 13	13.2	13L2	515	515	290	225	56%	310	205	60%	319	196	62%
Salem NH	SPICKET RIVER 13	13.2	13L3	522	522	442	80	85%	385	137	74%	396	126	76%
Salem NH	GOLDEN ROCK 19	13.2	19L4	530	589		589	0%	84	528	16%	86	526	16%
Salem NH	GOLDEN ROCK 19	13.2	19L6	530	589		589	0%	113	499	22%	116	496	22%
Salem NH	PELHAM 14	13.2	14L6	528	647		647	0%	326	321	62%	336	311	64%

Table 49 Alt #7 Feeder Normal Loading

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Salem NH Transformer Analysis

Study Area	Substation	Tranf. ID.	System Voltage (kV)		Maximum Nameplate Rating	Rating (MVA)		Projected Load								
								2019			2022			2036		
			From	To		SN	SE	MVA	N-1	% SN	MVA	N-1	% SN	MVA	N-1	% SN
Salem NH	GOLDEN ROCK 19	T1	115	23	50	78.7	91.6	56.9	34.7	72%	60.9	30.7	77%	62.7	28.9	80%
Salem NH	BARRON AVENUE 10	L1	23	13.2	7	9.4	10.9	2.4	8.5	26%	6.1	4.8	65%	6.3	6.7	50%
Salem NH	BARRON AVENUE 10	L2	23	13.2	7	13.6	14.2	6.1	8.1	45%	6.6	7.6	48%	6.8	7.4	50%
Salem NH	BARRON AVENUE 10	L4	23	13.2	7	9.1	10.3	4.0	6.3	44%	4.1	6.2	45%	4.3	8.7	34%
Salem NH	OLDE TROLLEY 18	L1	23	13.2	9.375	12.4	12.9	3.0	9.9	25%	5.0	7.9	40%	5.1	7.8	41%
Salem NH	OLDE TROLLEY 18	L2	23	13.2	9.375	12.4	12.9	9.2	3.7	75%	6.6	6.3	54%	6.8	6.1	55%
Salem NH	OLDE TROLLEY 18	L3	23	13.2	9.375	12.5	13	8.6	4.4	69%	7.8	5.2	62%	8.0	5.0	64%
Salem NH	OLDE TROLLEY 18	L4	23	13.2	9.375	12.5	13	8.8	4.2	71%	6.5	6.5	52%	6.7	6.3	53%
Salem NH	SALEM DEPOT 9	L1	23	13.2	7	7.36	10.1	6.2	3.9	84%	6.8	3.3	92%	7.0	6.0	56%
Salem NH	SALEM DEPOT 9	L2	23	13.2	7	7.36	9.2	5.1	4.1	70%	6.6	2.6	90%	6.8	6.2	54%
Salem NH	SALEM DEPOT 9	L3	23	13.2	9.375	11.6	11.6	7.3	4.3	63%	8.9	2.7	77%	9.2	2.4	79%
Salem NH	SPICKET RIVER 13	L1	23	13.2	9.375	14.4	14.4	7.5	6.9	52%	8.0	6.4	55%	8.2	6.2	57%
Salem NH	SPICKET RIVER 13	L2	23	13.2	9.375	13.9	14.4	6.6	7.8	48%	7.1	7.3	51%	7.3	7.1	52%
Salem NH	SPICKET RIVER 13	L3	23	13.2	9.375	13.9	14.4	10.1	4.3	73%	8.8	5.6	63%	9.1	5.3	65%
Salem NH	GOLDEN ROCK 19	T2	115	13.2	50	78.7	91.6	0.0	91.6	0%	4.5	87.1	6%	4.6	87.0	6%

Table 50 Alt #7 Transformer Normal Loading

Salem NH Supply Line Analysis

Study Area	Circuit	Voltage	Line Section		Rating (MVA)		Projected Load					
							2019		2022		2036	
			From	To	SN	SE	MVA	%SN	MVA	%SN	MVA	%SN
Salem NH	2352	23	Golden Rock	Barron Ave. Tap	54.8	65.4	30.9	56%	33.9	62%	34.9	64%
Salem NH	2352	23	Barron Ave. Tap	Olde Trolley Tap	56.4	72.5	30.9	55%	33.9	60%	34.9	62%
Salem NH	2352	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	12.3	39%	11.6	36%	12.0	38%
Salem NH	2352	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	18.6	69%	22.3	82%	23.0	85%
Salem NH	2393	23	Golden Rock	Barron Ave. Tap	54.8	65.4	26.0	47%	27.0	49%	27.8	51%
Salem NH	2393	23	Barron Ave. Tap	Olde Trolley Tap	45.2	58.2	17.4	38%	14.3	32%	14.7	33%
Salem NH	2393	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	17.4	55%	14.3	45%	14.7	46%
Salem NH	2393	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	0.0	0%	0.0	0%	0.0	0%
Methuen	2353	23	Meth Jnctn	Golden Rock	23.9	23.9	4.0	17%	0.0	0%	0.0	0%
Methuen	2376	23	Meth Jnctn	Golden Rock	23.9	23.9		0%		0%	0.0	0%
Methuen	2376	23	SPICKET RIVER TAP	SPICKET RIVER	35.9	40.7	24.2	67%	23.8	66%	25.2	70%

Table 51 Alt # 7 Supply Line Normal Loading

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Salem NH Transformer Contingency Analysis													
Study Area	Substation	Tranf. ID.	System Voltage (kV)		Maximum	Rating (MVA)		Projected Contingency					
								2019		2022		2036	
			From	To	Nameplate Rating	SN	SE	MVA	% SE	MVA	% SE	MVA	% SE
Salem NH	GOLDEN ROCK 19	T1	115	23	50	78.70	91.60	0.0	0%	0.0	0%	0.0	0%
Salem NH	BARRON AVENUE 10	L1	23	13.2	7	9.40	10.90	6.3	58%	8.4	65%	8.7	67%
Salem NH	BARRON AVENUE 10	L2	23	13.2	7	13.60	14.20	6.3	44%	8.4	59%	8.7	61%
Salem NH	BARRON AVENUE 10	L4	23	13.2	7	9.10	10.30	6.3	61%	8.4	65%	8.7	67%
Salem NH	OLDE TROLLEY 18	L1	23	13.2	9.375	12.40	12.90	9.9	77%	9.2	71%	9.5	73%
Salem NH	OLDE TROLLEY 18	L2	23	13.2	9.375	12.40	12.90	9.9	77%	9.2	71%	9.5	73%
Salem NH	OLDE TROLLEY 18	L3	23	13.2	9.375	12.50	13.00	9.9	76%	9.2	71%	9.5	73%
Salem NH	OLDE TROLLEY 18	L4	23	13.2	9.375	12.50	13.00	9.9	76%	9.2	71%	9.5	73%
Salem NH	SALEM DEPOT 9	L1	23	13.2	7	7.36	10.10	9.3	92%	11.2	86%	11.5	88%
Salem NH	SALEM DEPOT 9	L2	23	13.2	7	7.36	9.20	9.3	101%	11.2	86%	11.5	88%
Salem NH	SALEM DEPOT 9	L3	23	13.2	9.375	11.60	11.60	9.3	80%	11.2	96%	11.5	99%
Salem NH	SPICKET RIVER 13	L1	23	13.2	9.375	14.40	14.40	12.1	84%	11.9	83%	12.3	85%
Salem NH	SPICKET RIVER 13	L2	23	13.2	9.375	13.90	14.40	12.1	84%	11.9	83%	12.3	85%
Salem NH	SPICKET RIVER 13	L3	23	13.2	9.375	13.90	14.40	12.1	84%	11.9	83%	12.3	85%
Salem NH	GOLDEN ROCK 19	T2	115	13.2	50	78.70	91.60		0%		0%	0.0	0%

Table 52 Alt #7 Transformer Contingency Loading

Salem NH Supply Line Contingency Analysis															
Study Area	Circuit	Voltage (kV)	Line Section		Rating (MVA)		Projected Contingency								
							2019			2022			2036		
			From	To	SN	SE	MVA	Load > SE	% SE	MVA	Load > SE	% SE	MVA	Load > SE	% SE
Salem NH	2352	23	Golden Rock	Barron Ave. Tap	54.8	65.4	**48.3**	0.0	74%	**48.2**	0.0	74%	**49.6**	0.0	76%
Salem NH	2352	23	Barron Ave. Tap	Olde Trolley Tap	56.4	72.5	**48.3**	0.0	67%	**48.2**	0.0	67%	**49.6**	0.0	68%
Salem NH	2352	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	**29.7**	0.0	93%	**25.9**	0.0	81%	**26.7**	0.0	84%
Salem NH	2352	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	**18.6**	0.0	69%	**22.3**	0.0	82%	**23.0**	0.0	85%
Salem NH	2393	23	Golden Rock	Barron Ave. Tap	54.8	65.4	**56.9**	0.0	87%	**60.9**	0.0	93%	**62.7**	0.0	96%
Salem NH	2393	23	Barron Ave. Tap	Olde Trolley Tap	45.2	58.2	**56.9**	0.0	98%	**48.2**	0.0	83%	**49.6**	0.0	85%
Salem NH	2393	23	Olde Trolley Tap	Olde Trolley	31.9	31.9	**29.7**	0.0	93%	**25.9**	0.0	81%	**26.7**	0.0	84%
Salem NH	2393	23	Olde Trolley Tap	Salem Depot #9	27.1	27.1	**18.6**	0.0	69%	**22.3**	0.0	82%	**23.0**	0.0	85%
Methuen MA	2353	23	Meth Jnctn	Golden Rock	23.9	23.9	**30.9**	7.0	129%	**38.1**	14.2	159%	**40.2**	16.3	168%
Methuen MA	2376	23	Meth Jnctn	Golden Rock	23.9	23.9	**26.0**	2.1	109%	**27.0**	3.1	113%	**28.5**	4.6	119%
Methuen MA	2376	23	SPICKET RIVER TAP	SPICKET RIVER	35.9	40.7	**24.2**	0.0	59%	**23.8**	0.0	59%	**25.2**	0.0	62%

Table 53 Alt #7 Supply Line Contingency Loading

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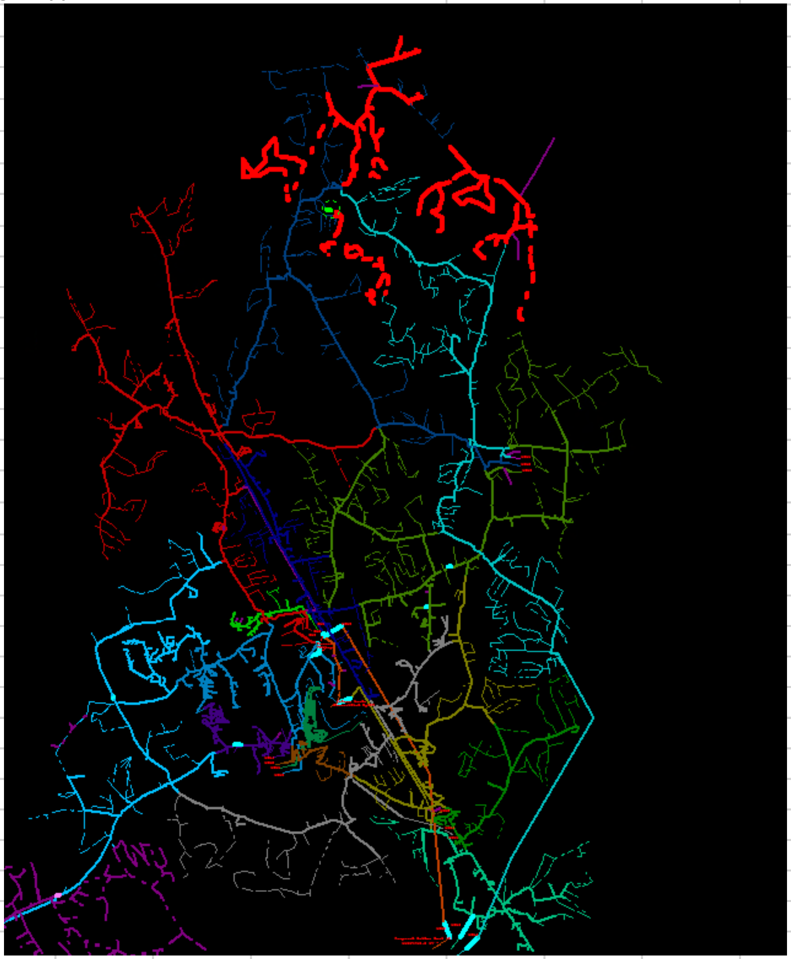
9.4 Appendix D – MWHr Summary

2022 Predicted Contingency N-1 Problems						
Plan	**180 MWhr Transformer Criteria Violations**		**120 MWhr Supply Line Criteria Violations**		**Feeders above 16 MWhr**	
	Description	**MWhr**	**Description**	**MWhr**	**Description**	**MWhr**
Base	Golden Rock T1 Outage	679	2393 Baron Ave Tap to Olde Trolley Tap	159	18L3	18
			G133 - 115kV Transmission Line	439	18L4	24
					9L1	24
					9L2	20
					9L3	23
					13L1	18
					13L2	20
					13L3	17
1	Golden Rock T1 Outage	254			9L2	16
2	Golden Rock T1 Outage	237			9L2	16
3	Golden Rock T1 Outage	352			9L2	16
4					9L2	16
5					21L10	19
					9L2	16
6					21L7	25
					21L8	23
7	Golden Rock T1 Outage	345			9L2	16
					14L4 / 14L6	52
					14L3 / 14L4 / 14L6	88

Table 54 2022 Predicted Contingency N-1 Problems

9.5 Appendix E – Spicket River Backup Analysis

Without Voltage Support (2019 Base Case w/ GR in service)



Eleven Operations

At 20 min per operation total restoration time = Three Hours and 40 Min

With Voltage Support (2019 Base Case w/ GR in service)

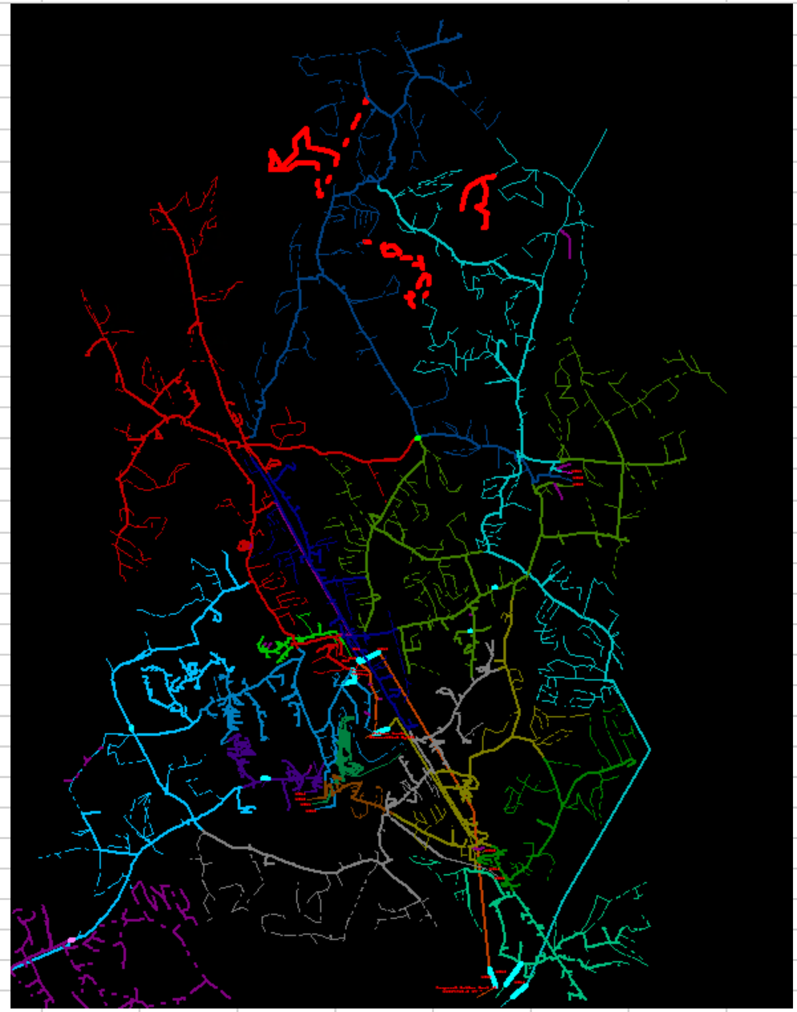


Figure 55: Voltage Performance during 13L1 contingency (low voltage <0.95 per-unit shown in red)

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9.6 Appendix F – 22.8 kV Voltage Analysis

		Voltage Issues	
Plan	Description	Summer Normal	Contingency
Alternative 1	Existing 23 kV system. 2.5 MW of generation available on each of the Salem Depot 9L3 and Barron Ave. 10L4 feeders during contingency conditions.	None	None
Alternative 2	Existing 23 kV system.	None	None
Alternative 3	Add 2-23/13 kV feeder positions at Salem Depot and one at Barron Ave. to the existing system.	Salem Depot 23 kV bus at .9375 per-unit. Olde Trolley 23 kV bus at .9471 per-unit.	Olde Trolley 23 kV bus at .87857 per-unit for 2352 and Golden Rock 115/23 kV transformer out-of-service.
			Salem Depot 23 kV bus at .8676 per-unit for 2352 and Golden Rock 115/23 kV transformer out-of-service.
Alternative 4	Add the second Golden Rock 115/23 kV transformer, one new 23 kV line, 2-23/13 kV feeder positions at Salem Depot and one at Barron Ave. to the existing system.	None	None
Alternative 5	Add the second Golden Rock 115/23 kV transformer, two new 23 kV lines and a new 23/13 kV Rockingham substation to the existing system.	None	Salem Depot 23 kV bus at .87524 per-unit for 2352 out-of-service. Rockingham 23 kV bus at .88188 per-unit for 2352 or second new line out-of-service.
Alternative 7	Existing 23 kV system. Added contingency of picking up the Pelham 14L4 and L6 feeders through ties to Olde Trolley and Barron Ave.	None	Olde Trolley 23 kV bus at .89932 per-unit for Golden Rock 115/23 kV transformer out-of-service.
			Salem Depot 23 kV bus at .89206 per-unit for Golden Rock 115/23 kV transformer out-of-service.
Base	Existing 23 kV system.	Olde Trolley 23 kV bus at .9411 per-unit and Salem Depot 23 kV bus at .9328 per-unit.	Olde Trolley 23 kV bus at .87171 per-unit for either 2352 or Golden Rock 115/23 kV transformer out-of-service.
			Salem Depot 23 kV bus at .86229 per-unit for either 2352 or Golden Rock 115/23 kV transformer out-of-service.

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9.7 Appendix G – Comparison of Plans – Cost vs Added Capacity

Alternative Plan	Total Cost ($M)	Spent to Date Towards Plan ($M)	MVA Capacity Provided		$ / MVA		Criteria Ranking
			Total	Firm	Total	Firm	
Alt Plan #1	**$11.41***	**$3.5**	88.7	10	$129	$1,141	**7**
Alt Plan #2	**$24.00**	**$3.5**	104.7	17.1	$229	$1,404	**4**
Alt Plan #3	**$35.31**	**$3.5**	146.9	60.3	$240	$586	**5**
Alt Plan #4	**$33.94**	**$0.0**	152.1	108.1	$223	$314	**3**
Alt Plan #5	**$33.15**	**$1.5**	152.1	93.7	$218	$354	**2**
Alt Plan #6	**$34.90**	**$5.0**	177.7	142.3	$196	$245	**1**
Alt Plan #7	**$25.01**	**$3.5**	116.68	29.1	$214	$859	**6**

* Does not include annual operating expenses for diesel generation, estimated to be $200,000 / year

Table 55 Comparison of Plans – Cost vs Added Capacity

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9.8 Appendix H – Comparable Past Studies to Salem

A. Mt Support Substation Expansion

a. Project Need

The main driver for the Mt Support Substation Expansion Project was load relief of forecasted overloads under normal and contingency conditions and voltage violations. With the contingency loss of the Mt Support transformer or Transmission line, the sub transmission system would result overloaded. Other feeders and transformers in the area were projected to violate the Distribution Planning Criteria for normal and contingency loading.

b. Selected Solution

To address the system deficiencies in the area, rather than expand or rely on the existing sub transmission system, the preferred solution included the extension of a new 115kV transmission line, the installation of a new 115/13.2kV transformer and the installation of two new 13.2kV distribution feeders.

B. Michael Ave Substation

a. Project Need

The main driver for the Michael Ave Project was to provide added capacity for the expansion of Whelen Engineering in Charlestown NH and to address the asset conditions at the Charlestown Substation. The issues experienced with the Charlestown substation were similar to those being experienced with Salem Depot and Barron Ave substations.

b. Selected Solution

To address the asset condition at the Charlestown Substation and provide added capacity to supply Whelen Engineering, the preferred solution included the installation of a new 115kV substation in Charlestown NH including a new 115/13kV transformer, a new 115kV transmission line and two new 13.2kV distribution feeders. The new Michael Ave substation allowed for the retirement of the Charlestown Substation and for the expansion of Whelen Engineering.

C. Pelham Substation Expansion

a. Project Need

The main driver for the Pelham Substation Expansion Project was load relief of forecasted overloads under normal and contingency conditions and to address the asset condition of the existing substation transformer. With the contingency loss of the Pelham transformer or Transmission line, the system lacked the necessary capacity to resolve Planning Criteria Violations for load at risk. Other feeders in the area were projected to violate the Distribution Planning Criteria for normal and contingency loading.

b. Selected Solution

To address the system deficiencies in the area, the preferred solution included the complete refurbishment of the Pelham substation including the extension of a new 115kV transmission line tap, the installation of a new 115/13.2kV transformer, the replacement of the existing 115/13.2kV transformer and the installation of two new 13.2kV distribution feeders.

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10.0 Annex List

Annex A - National Grid Internal Strategy Document Distribution Substation Transformers Revised Strategy – October 2009

Annex B – 10L1 Testing & Maintenance Report: United Power Group - August 2014

Annex C – 10L4 Testing & Maintenance Report: United Power Group - September 2014

Annex D – 9L3 Testing & Maintenance Report: United Power Group - August 2014

Annex E – 2020 Dissolved Gas Analysis: Weidmann

1. **Barron Ave 10L2 - Test Report #01-7334797-618125-00**
2. **Barron Ave 10L1 - Test Report #01-7334796-618125-00**
3. **Salem Depot 9L3 - Test Report #01-7334792-618125-00**
4. **Salem Depot 9L2 - Test Report #01-7334791-618125-00**

Annex F – Liberty Utilities Electrical Substation Clearances Standard - Doc. # ENG-SUB006 – August 2020

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Distribution Substation Transformers
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Distribution Substation Transformers Strategy Statement

The strategic aims for Distribution Substation Power Transformers are to:

- minimize random transformer failures
- ensure that the transformer population is capable of performing its function
- provide replacement for those units that are identified as more likely to fail.

A list of candidates for replacement on a per state basis can be found in the state specific section of this document. It should be noted that transformers suggested for replacement are evaluated in conjunction with substation reviews. This strategy is based on transformer condition and risk, and has been developed with significant input from subject matter experts, local operations colleagues and available historic and test results.

This strategy supports both reliability and a sustainable network by establishing a list of replacement candidates by state, applying an ongoing GE Type U replacement program, and employing a tactical application of Load Tap Changer (LTC) filtration and condition monitoring.

Amendments Record

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
	10/14/09	Revision	Eileen Duarte Distribution Asset Strategy	John Pettigrew Executive Vice President, Electric Distribution Operations
1	07/30/07	Initial Issue	Tony McGrail Substations O&M	John Pettigrew Executive Vice President, Electric Distribution Operations

Distribution Substation Transformers Strategy Justification

1.0 Purpose and Scope

This strategy sets forth a Distribution Substation Transformer program to allow National Grid to confidently rank it's substation transformers in terms of health, identify those transformers that are most critical to the system, and rank transformers in terms of risk so that the transformers are properly prioritized for asset replacement.

This strategy is consistent with the approach taken for our transmission assets and supports achieving the objective to improve reliability and meet service quality standards in all states in which National Grid operates. This strategy pertains to substation transformers described by FERC as distribution, which includes TxD, and DxD.

2.0 Background

Substation transformers are a critical asset class in the successful operation of the electrical distribution system. Consequently, we must endeavor to be proactive in our determination of the following:

- Transformer health through test and assessment
- Need for maintenance and content of the maintenance
- Spares and mobiles strategies
- System requirements and transformer capability
- Identification of 'at risk' units
- Identification of replacement candidates

Substation transformers have a number of characteristics that require close attention and supervision, such as:

- Transformers are usually very reliable (depending on size, configuration LTC's etc)
- Transformers have a long asset life expectancy
- Failures may cause significant interruptions
- Transformers are expensive
- Replacement is an involved procedure requiring coordination of many departments and issues
- Determining health and condition is a complex task
- Lead times for new transformers may be over a year
- Individual transformers of known manufacturer/design may be less reliable than others
- Safety and environmental concerns regarding large quantities of oil
- Replacement versus refurbish or repair decisions are complex
- Transformers have many sub-systems, including bushings, cooling, oil containment, tap changers, etc.

2.1 Substation Maintenance Standards

Transformer maintenance is covered under our substation maintenance standards and procedures. A list of substation maintenance documents can be found in SMS 400.00.1. There is no international standard that applies to transformer asset health. Work has been conducted to identify root cause analysis of failures at CIGRE, Doble Engineering, and HSB Insurance (1,2,3,4). These documents are referenced when transformer decisions are made at National Grid.

An oil sample is taken from our transformers on a one or two-year time-frame based on the size of the transformer as described in Substation Maintenance Standard (SMS) 402.02.1 and 402.01.1. Transformers rated 15 MVA and above are tested annually, and transformers rated between 2.5-14.9 MVA are tested on a 24 month interval (7, 8). The interval may change based on the results of the Dissolved Gas Analysis (DGA) or system incidents that indicate possible transformer health issues.

Transformers receive a bi-monthly Visual and Operational (V&O) inspection as part of the substation bi-monthly V&O. A severe trouble condition[1] problem is addressed immediately. Problems and discrepancies found are corrected, and problems and discrepancies not corrected are recorded on an inspection card and follow-up work is generated. This is in accordance with the SMS 400.06.1 [17].

In addition, Thermographic Inspections are performed on transformers as part of the annual substation Thermographic Inspection. A Thermographic Inspection Report is created for detected problems and follow-up work is scheduled. This is in accordance with the SMS 400.07.1 [18].

Specialized testing to ascertain transformer health in detail is performed on commissioning or after an incident (7, 8). These tests include power factor, capacitance, Sweep Frequency Response Analysis (SFRA) and other tests to gain information about the integrity of the transformer insulation and winding structure.

Transformers equipped with Load Tap Changers (LTC's) will receive a V&O inspection (six times a year), thermographic inspection (annually), and DGA sample on the LTC. Internal inspections are performed if the results of the inspections and/or the DGA sample indicates the need, or if the number of operations exceeds the ROP constant or the time interval limit has been reached. The timeframe for DGA samples and internal inspections are based on the manufacturer and type of LTC, which is listed in SMS 412.01.1[19].

Maintenance is performed on transformers as necessary based on the findings of the above mentioned inspections, oil analysis, testing and Company expert analysis and knowledge of the unit.

2.2 Data

The substation distribution transformer population consists of 1,471 operating units and 155 spares. This is based on an MVA rating up to 20 MVA. Of the 1,471 operating units and 155 spares listed in AIMMS, 1,078 units and 99 spares have associated age data.

The age profile for the operating distribution transformers are displayed in Figure 1. Fifty percent of the transformer population with a known age was manufactured prior to 1972, with the majority being between 35 and 60 years old. In addition, 5 % of the population is greater than 70 years old, while 10% are greater than 60

[1] Hazardous situation to system operation and/or National Grid employees or the public

years old. Twenty-seven percent of the transformer population is missing age data information. The transformer age profile on a per state basis can be found in the Appendix. After analyzing the age profile data on a per state basis, it is expected that the average age of the transformer population is actually higher than the average 29 years indicated and most likely closer to what is seen in Rhode Island, and average age of 36 years with only 7.6% of missing age data. The greater the percentage of missing age data, the younger the transformer population seems to be, indicating that the missing age data relates to older units.

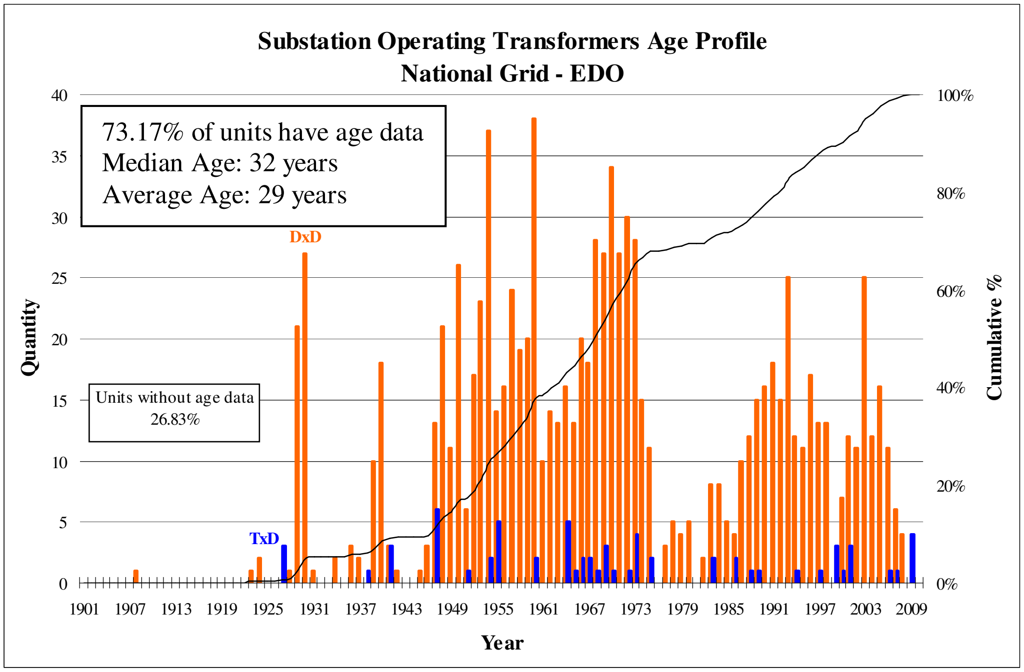

Figure 1. Distribution Transformer Age Profile

The age profile for the spare transformers is displayed in Figure 2. The average age of the spare fleet of transformers is 22 years. Fifty percent of the transformer population was manufactured prior to 1973, with the majority being between 35 and 54 years of age. In addition, 7 % of the population is greater than 63 years of age while 16% are greater than 52 years of age. Thirty-six percent of the transformer spare population is missing age data information.

The number of spares and age data, which was extracted from AIMMS, is presently under review. An initiative to determine the number of viable spares is underway, and CASCADE will be updated in 2010 in conjunction with the development of a transformer spares strategic approach.

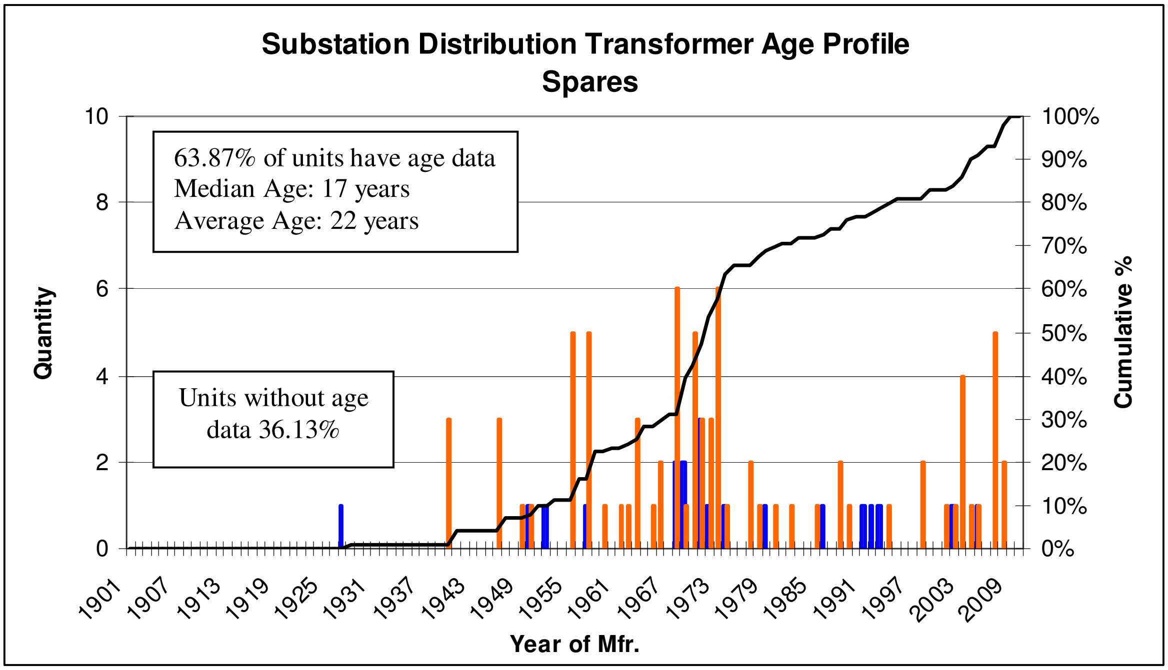

Figure 2: Distribution Transformer Age Profile Spares

The transformers MVA profile is shown in Figure 3 and indicates that 75% of the transformer population is 5 MVA or less, 91% is 7.5 MVA or less, and 98% is 20 MVA or less. DGA samples are typically taken on transformer banks rated 2.5 MVA or larger, equating to 0.833 MVA for single phase units in accordance with Substation Maintenance Standard 402.02.1 version 1.8.

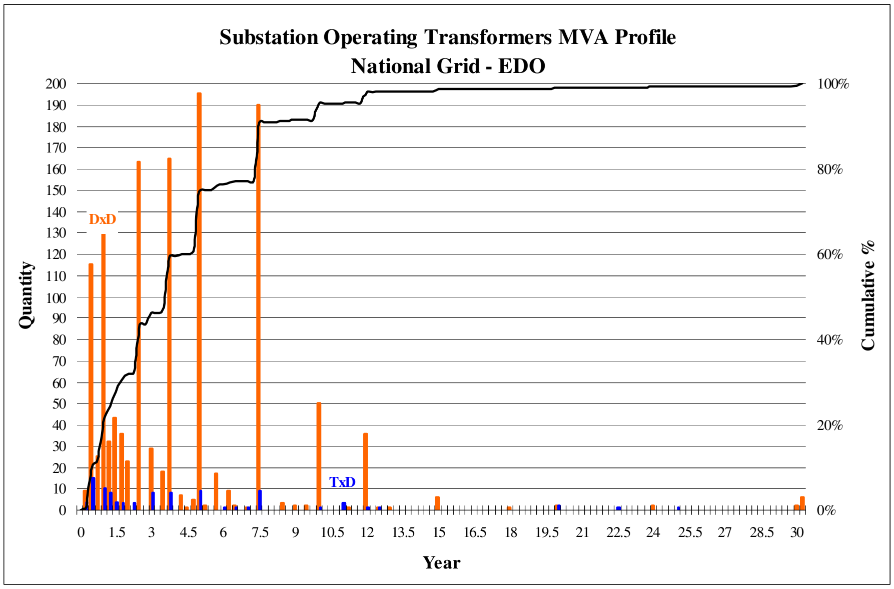

Figure 3. Distribution Transformer MVA Profile

2.3 Events

Over the last ten years there have been 47 transformers system wide that have failed due to various reasons. Figure 4 displays the number of failures on a per year basis.

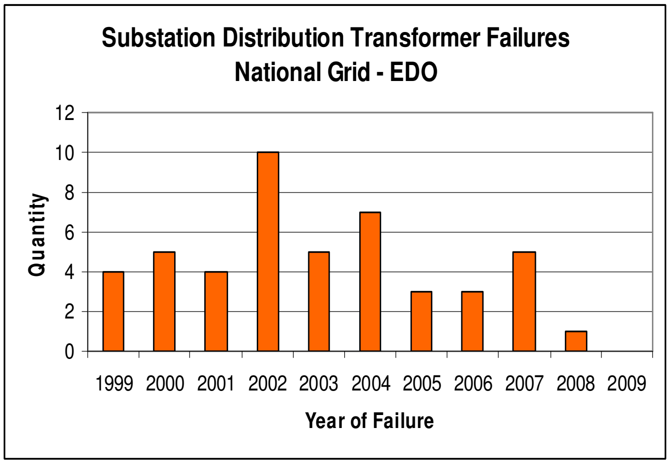

Figure 4. National Grid Transformer Failures

Based on the IDS and SIR data, over the last ten years there have been 212 events related to substation transformers. The most frequent listed failure reason extracted from this data is deteriorated equipment (79) followed by animals (32), overload (15), short circuit (14) and device failed (12). The number one cause of substation transformer failures is through faults. A healthy transformer is more likely able to withstand a thru fault than a unit that is deteriorated, aged or in poor electrical/mechanical condition.

Transformer failures are inevitable but we aim to minimize the likelihood of failures caused both by:

- Internal events – insulation failure, winding movement etc.
- External events – through faults, lightning, animal incursions etc.

Incipient internal events may be detected through Dissolved Gas Analysis (DGA), Visual & Operational Inspections (V&O), InfraRed inspections, PIW's or identified through engineering and industry knowledge. External events are addressed through application of lightning arresters, animal protection and pursuit of such activities as Feeder Hardening and Vegetation Management.

The failure rate for power transformers is approximately 0.5% per year with an average age at failure of between 30 and 35 years. Older units are not, *per se*, more likely to fail. However, they may be more susceptible due to accumulated effects of through faults and irreversible paper aging mechanisms. Transformer failures are captured by Substation O&M Services and the details distributed to key personnel in a bi-annual report. It is recommended that these failures be entered and maintained in Cascade in future.

2.4 Transformer Health and Risk Scores (THaRS)

In order to better manage the transformer fleet, we need to better understand the condition of all members of the fleet and their risks. This is not a simple matter and even the best managed fleet would still be prone to some random failures. The aim is to prevent as many failures as possible, reduce the exposure, and thus reduce impact to an acceptable level (1).

Transformers tend to be reliable (3), but the reliability is a function of faults seen, maintenance and the manufacture/design of the transformer. DGA alone is not sufficient to detect incipient faults, and the industry best practice is to expect that about 25% to 50% of imminent failures may be detected using DGA. To help better manage our transformer fleet and not rely on DGA alone, a scoring system based on condition and risk has been put in place to formulate a 'watch list' of transformers. This list will be closely monitored, and an action plan will be developed for each transformer on 'watch' to assist in preventing failures.

Distribution uses the work developed for transformer dissolved gas analysis (DGA) at National Grid UK as discussed at the Doble 2002 Client Conference (5). The technical discussion presented by John Lapworth, National Grid, UK discusses a method of using a DGA scoring system based on ratios of key gasses to identify transformers that may be at risk of poor condition. Certain key gasses and combinations of key gasses are indicators of particular problems within a transformer. The basic combustible gas results are combined to give a single DGA score for each transformer for each oil sample. This DGA score is the baseline for prioritizing our fleet of transformers.

DGA analysis is performed by engineers in each region. The DGA scoring system is a newly applied tool in National Grid that assists in the ranking process. In the UK for transmission transformers, generally with conservators[2] since they are free-breathing and key gasses are released into the atmosphere, a score of 60 is an indication of 'monitor' while a score of 100 is an 'alarm' situation. In the early days of analysis and review, it seems that with US distribution transformers, generally sealed[3], we can set the 'monitor' level to 100 and the 'alarm' level to 150. Key gasses remain contained within the transformer oil on sealed units, and therefore will have more combustible gasses present. This is, of course, a heuristic process but it can be validated by reviewing DGA results from known failed units. Failed units in the data set have an average DGA score in excess of 300, but as this was post fault, further analysis is necessary to gain the proper trend information.

Once the transformer population has received a DGA score, analysis with Subject Matter Experts (SME's) occurs to evaluate transformers with elevated scores or scores that have increased significantly since the previous analysis. This review, which includes review of other maintenance performed (V&O Inspection, Infrared survey, known problems such as through faults, field repairs, protective component issues, capacity issues), is conducted and the DGA rating is adjusted accordingly. After this review, the DGA score is converted to a DGA rating, which becomes part of the Transformer Health and Risk Score (THaRS) method used to prioritize transformers for replacement. A rating of 10 indicates a DGA score greater than 125, a rating of 5 indicates a DGA score between 76 and 125, and a DGA score less than 75 receives a rating of 1. However, these ratings are adjusted based on favorable or unfavorable comments from the SME's. For example, if a transformer's DGA score is greater than 125, but the SME's input is favorable (stable, transformer repaired, etc), then the score will be changed from a 10 to a 1.

[2] Conservator type transformers have free-breathing tanks and key gasses are released into the atmosphere.
[3] Sealed transformers have sealed tanks and key gasses remain within the transformer oil

In addition to the DGA rating, an MVA score is provided to each unit based on the formula (MVA+20)/20. Twenty MVA is used indicating the largest MVA for distribution class transformers. A larger unit is considered more critical than a smaller unit because typically it may carry more load, and is more costly to replace.

As displayed in Figure 1, National Grid has a large population of aging transformers. As the unit ages, the insulation condition deteriorates and therefore becomes more susceptible to failures. In addition, older units have more likely been exposed to through faults, thus further weakening the insulation integrity. Also, parts become obsolete and maintenance becomes costly. The health review includes an age score based on a life expectancy of 60 years, an age that we expect half of our transformers to reach. A transformer that is 60 years old would receive a score of 2, while a transformer that is new would receive a score of 1.

Transformers that contain 50 ppm or more of PCB are considered a hazardous waste and must be handled and disposed of in accordance with EP-1, Waste Management. Units that are known or expected to contain PCB in the insulating oil are an environmental and human health risk, and therefore are considered during this transformer health review. A transformer failure that contains 50 ppm or more of PCB in the oil is a contamination issue that requires an immediate and costly clean up. A score of 1.2 is given to those units containing PCB of 50 ppm or more, and a score of 1 to those units that are PCB free. Although PCB spills are serious, units containing PCB insulating oils can be mitigated by retro-filling with mineral oil.

Highly Utilized (HUtz) transformers are those transformers that have been identified to operate at 100% load or more during peak load periods. Although based on certain circumstances and the time of year, these transformers may or may not exceed 100% load. However, a transformer that is operated at its limit or above for long periods of time may result in a more rapid deterioration of condition than units operated below maximum load. In addition, since the capacity of these transformers has been exceeded, a future solution may be necessary in order to withstand the growth these transformers are serving. Therefore, a HUtz score has been incorporated into the health and risk review. If a transformer is operated above 100% load, the amount above 100% is added to 1.0. For example, a transformer that operates at 114% load will receive a HUtz score of 1.14.

The scores are applied to each transformer and a final transformer health and risk score (THaRS) is determined. The transformers are ranked in order of replacement priority based on the descending order of the final score. Further technical input from SME's is performed and the list is revised in light of their comments and experience. Table 1 describes the transformer health and risk scores.

THaRS is a simple but comprehensive method developed to initiate the replacement prioritization of the distribution substation transformer fleet. The scoring system is highly weighted on transformer condition with some risk incorporated into the analysis. Additionally, it should be noted that both O&M and the operations staff have provided comments and direction with regards to the history and capability of individual units, and assisted with the prioritization of the final list.

Condition Evaluation		Impact Evaluation			Risk Analysis
DGA	**Age**	**PCB**	**HUtz**	**MVA**	**THaRS**
10 >125 05>75<=125 01<=75	(60+Age)/60	1.2 = PCB 1.0 ≠ PCB	1.0 + percent overload	(20+MVA)/20	DGA*MVA*Age*PCB*HUtz
Comments from SME's are included in the score	Based on the life expectancy of 60 years			Based on largest unit being 20 MVA	

Table 1. Transformer Health and Risk Scores

Applying transformer health and risk scores allows us to provide a basic asset ranking. Future asset ranking methods will combine the methods discussed in this document along with the following:

- Design and manufacture information
- Station situation
- Oil quality
- Transformer winding type and LTC Type
- Capability of asset to perform required function
- Past performance, maintenance and costs
- Spare availability and mobile readiness
- Available through fault and interruption data

Transformer health and risk scores are not, by themselves, an indicator of a transformer problem. There is a need for more engineering judgment. For example, DGA results in NY tend to have higher hydrogen values than those from NE and the cause is related to the lab used; consequently they have a higher DGA score. Going forward, NY and NE will be using the same laboratory, and this ambiguity will be resolved.

The transformer health and risk score (THaRS) profile for National Grid's transformer fleet is displayed in Figure 6. The results represent the latest DGA records and PCB comments listed in AIMMS for all FERC coded TxD and DxD units rated greater than 0.5 MVA. The Highly Utilized Transformer List for Summer 2009 was used to determine the HUtz score (13).

Figure 5 shows how the scores are placed in good, fair and poor health and risk categories. There is some overlap, but when the score is above 10, the transformer warrants further investigation and is most likely on the 15 year replacement list. For example, if a transformer had a score of 6.5, the unit may either be considered good or fair. If a transformer received a score of 18, then the unit could be considered either fair or poor. Further analysis would be necessary in order to determine the outcome. A transformer with a score of 37 would be considered poor and a score of 3.3 would be considered good. In any event, a transformer with a score of 10 or higher warrants further investigation, and is most likely on the replacement list.

There were a total of 887 THaRS performed on National Grid's fleet of transformers; 323 performed on NE units and 524 performed on NY units. This does not correlate with the total number of operating transformers because either a DGA sample was not performed (units less than 2.5 MVA do not require DGA samples), or the MVA rating is 0.5 MVA or less.

The average THaRS of the National Grid fleet of operating transformers is 3.11, which indicates that the majority of the units are in good condition and pose little risk. In addition, 825 transformers have scores less than 10, of which 92.5% have scores less than 5. There is 1 transformer with a score greater than 40; 1 with a score between than 30 and 40; 10 with a score between than 20 and 30, and 62 with a score between than 10 and 20. From a population of 887 units scored, and noting that not all transformers are DGA sampled, 7% have a score greater than 10. All scores have been reviewed to ensure consistency of approach. It is recommended that those units (50) with scores in the fair-poor and poor categories have a mitigation plan in place in case of failure prior to replacement. Units with a score of 10 or higher (55 of the population) are placed on a watch list and monitored more closely; the watch list and associated action plans are in the process of being finalized and made generally available.

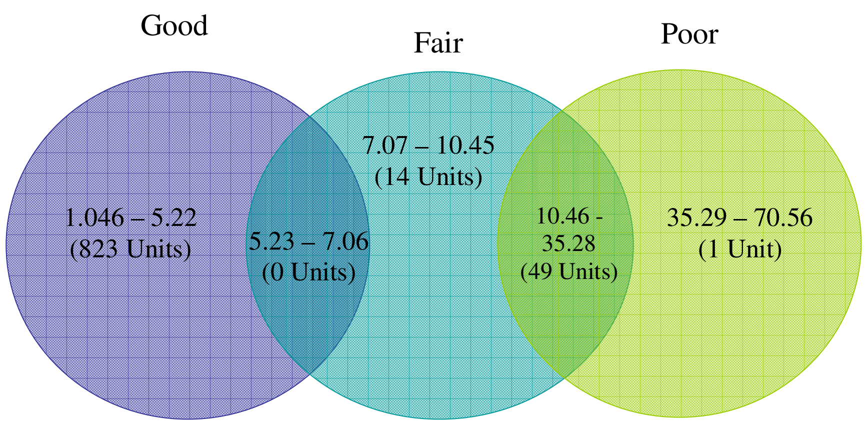

Figure 5 Transformer Health and Risk Scores (THaRS) Descriptors

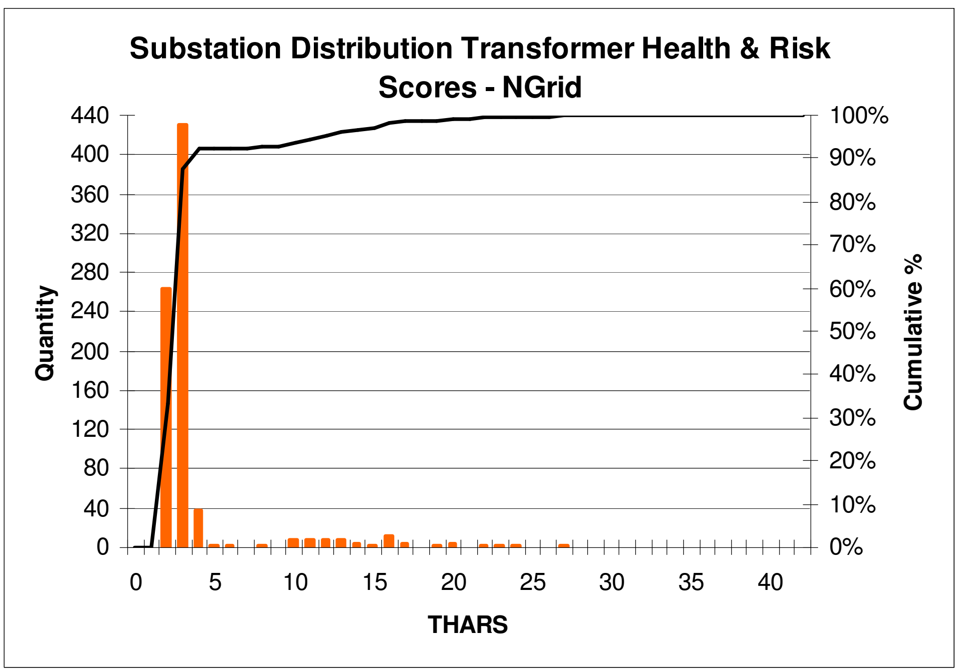

Figure 6. National Grid Transformer Health and Risk Score Profile

Asset Replacement: As the transformer population ages, replacement of both the oldest units and those most likely to fail should be considered. Older units tend to have insulation deterioration due to aging paper, and units most likely to fail may be those that have seen numerous faults.

The volume of transformers which are, in theory, required to be replaced annually is determined by analysis of the population of transformers in each state: by expecting the population to have an average life expectancy of 60 years, the volume required for replacement each year can be identified. However, this statistical analysis of the population does not identify individual units which are actual candidates for replacement. For example, New York's total MVA is 2590.63/60years = 43.18 MVA per year is suggested to be replaced.

The process continues by identifying the 'at risk' subpopulation of power transformers based on condition, and then identifying those with high Transformer Health and Risk Scores or with known and probable failure modes. This analysis is ongoing as the status of the transformer health and risk is in a constant state of flux. As of July 2009, there is a list of 80 transformers as candidates for replacement in the next 5 years. The list of replacement transformers can be found in the appendix under the appropriate state. The replacement candidates are listed in order of priority with the five-year candidates coded in orange. The preceding ten-year replacement list is coded in yellow. Each list generates replacement candidates for the next 15 years. It must be noted that this list is dynamic and updates to the lists are constantly ongoing due to changes in condition and risk. Therefore, the list projected in this strategy represents a snapshot in time and does not reflect the absolute list. This list is maintained by Asset Strategy and is communicated to Asset Planning. Although this list changes based on condition, transformers allocated for immediate replacement will not change. In addition, units that fail unexpectedly will be addressed immediately.

Type U Bushing Replacement: It is industry best practice to identify and replace those bushings that are GE Type U. These bushings have a known catastrophic failure mode, and are a risk to both safety and the system. The Substation Maintenance Standard, SMS 450.20.1 (10) discusses the replacement policy in detail.

LTC Filtration Systems: A tactical plan to apply LTC filtration systems to units requiring high maintenance and a risk of failure is ongoing. Units equipped with arcing-in-oil design type load tap changers, and elevated numbers of LTC operations are closely evaluated and considered candidates for installation of an LTC filtration system (11). Installation of LTC filtration systems will be installed when units come out of service for LTC maintenance per EOP SMP412.01.1 Load Tap Changer (12). The failure rate of transformers is strongly linked to tap changers, and the filtration unit helps keep the LTC clean, and extends the maintenance interval and the transformer life.

Condition Monitoring: Condition monitoring is applied on a case by case basis using an identified cost benefit. At present, National Grid may use additional condition monitoring to supplement our DGA where appropriate. This additional condition monitoring may comprise of oil analysis and partial discharge.

Surge Arrester Replacement: Presently, there is a substation Surge Arrester Strategy and an arrester replacement standard, SMS 419.15.2 Transformer Surge Arrester Replacement that addresses the replacement of any non-metal oxide (MOV) type arrester. This maintenance standard is an initiative to improve system reliability and transformer protection, and to reduce the likelihood of catastrophic arrester failures by implementing new protection technology.

3.0 Benefits

The risk of outages and catastrophic events will be reduced. All transformers will have an asset health (condition) score based on the following inputs:

- Available DGA, field diagnostic and test information
- Operational history, including load, faults, fault level and temperature data
- Particular manufacturer & design input
- Maintenance and inspection data
- Expected lifetime curve, including EOSU[4] and LOSU[5] where available
- Reliability Centered Maintenance (RCM) analysis of available failure data and incident data

All transformers will be assessed for criticality based on the consequence of failure or unavailability using the following inputs:

- Impact on CAIDI, SAIFI, SAIDI, CMI and CI statistics
- Input from system operation and system planning
- Availability of spares, mobile units and replacement complexity

All transformers will be ranked in terms of risk (consequence of criticality and health), and will be targeted for replacement based on risk and the constraints of the business.

As a result, the risk of outages, catastrophic events, and random failures will be reduced.

3.1 Safety & Environmental

Fewer transformer failures, removal of older units, and mitigation or removal of PCB contained units reduces the probability of an oil leak and oil containment issues.

3.2 Reliability

Risk to reliability will lessen as a result of fewer transformer interruptions related to the replaced units.

3.3 Regulatory

Potential improvements in SAIFI and SAIDI may be achieved.

3.4 Customers

Customer outages may be reduced. A customer outage may be substantial if a transformer fails. Transformer failures may affect numerous feeders resulting in a larger number of customers without power.

4.0 Estimated Costs

The costs indicated here are estimates that represent all aspects of a straightforward transformer replacement including engineering, foundation upgrades, purchase price, installation, commissioning and basic connections,

[4] Earliest Onset of Significant Unreliability
[5] Longest Onset of Significant Unreliability

but does not include changes to protection or significant infrastructure upgrades. The numbers given are for indication based on recent experiences and MVA of units.

For units rated 7.4 MVA and below, the estimated replacement cost is $900k per unit (average).
For units rated above 7.4 MVA, the estimated replacement cost is $1500k per unit (average).

There are 54 units on the five-year replacement list below 7.4 MVA, giving a total of $48.6M
There are 26 units on the five-year replacement list above 7.4 MVA, giving a total of $39.0M

This results in an overall estimated cost of $87.6M for 5 years, or $17.52M per annum. However, there is a lead time associated with these costs that skews the actual annual values.

The GE Type U bushings replacement initiative will continue to be applied in accordance with SMS 450.20.1.
The Surge Arrester replacement initiative will continue to be applied in accordance with SMS 419.15.2.

As discussed in Section 2.4, an LTC filtration system may be installed at an estimated cost of $25k per unit as needed.

Condition or partial discharge monitoring is a possibility, but unlikely on distribution equipment. It is considered a small capital item, and would be considered on an as needed basis.

5.0 Implementation

There should be an on-going state prioritized asset replacement plan based on condition and risk, and a tactical response program to install LTC filtration systems and condition or partial discharge monitoring as needed.

Continued review and revision of the replacement lists in each state will be performed in conjunction with SME's, Substations O&M staff and Operations staff so as to gather and reflect the latest data and information available for each transformer.

6.0 Risk Assessment

6.1 Safety & Environmental

Transformer failures may be both catastrophic and sudden. Distribution units may be smaller, but they are usually in closer proximity to residential areas. A catastrophic bushing or arrester failure has placed porcelain shards in neighboring fields, and the results of a transformer failure may cause oil contamination of the environment resulting in excessive clean-up costs.

6.2 Reliability

In most cases, a transformer failure will lead to power outages for customers. A transformer failure can take time to fix as the timing depends on many factors, including availability of spare transformers, mobile transformers or sourcing a replacement externally. In these cases, a transformer failure may have substantial impact.

6.3 Regulatory

The loss of a transformer may impact several regulatory targets. Although the number of substation events are low, they do contribute to SAIFI and SAIDI.

6.4 Customer

Customer outages may be substantial if a transformer fails. A transformer failure may affect numerous feeders resulting in a larger amount of customers without power.

7.0 Data Requirements

As National Grid evolves in the ability to manage the transformer fleet, our data requirements will grow.

7.1 Existing/Interim:

AIMMS, PIW's IDS

7.2 Proposed:

Cascade, EMS, PIW's, IDS

8.0 References

1. CIGRE failure study
2. Alan Wilson "Impact of technical condition on utilization of power transformers", Doble 2002
3. William Bartley, HSB, "Risk and Transformer Assessment", Doble HSB paper, 2004
4. Marsh, Keynote address, EuroDoble 2006
5. John Lapworth "A scoring system for integrating dissolved gas analysis results into a life management process for power transformers", Doble 2002
6. SMS 430.10.3 Transformer Oil In Service - Evaluation
7. SMS 402.01.1 Transformer 15 MVA and above
8. SMS 402.02.1 Transformer 2.5 to 14.9 MVA
9. Hartford Steam Boiler Insurance Company Asset Management Newsletter, July 2006
10. SMS 450.20.1 GE Type U Bushing Replacement
11. Falla, Dan, National Grid, Installation of LTC Oil Filtration Systems, August, 2007
12. SMS 412.01.1 Load Tap Changer
13. Highly Utilized Transformer List Summer 2009, National Grid
14. SMS 419.15.2 Transformer Surge Arrester Replacement
15. Jacques Afonso, Surge Arrester Strategy, January 8, 2009
16. Technical Evaluation of Proposed Capital Expenditure Program for NGC's 2006/07 Price Control Extension, Draft Final Report, July 2005, OFGEM
17. SMS 400.06.1 Visual and Operational (V&O) Inspection
18. SMS 400.07.1 Thermographic Inspection
19. EP-1; Waste Management
20. EPA 40 CFR Chapter 1, 761.125 Requirements for PCB Spill Cleanup

9.0 Massachusetts

There are 483 operating transformers in Massachusetts listed in AIMMS, with 85 spares. Of the 483 units, 269 received transformer health and risk scores. The total MVA population in Massachusetts is 2,572, and it is suggested that approximately 43 MVA be replaced per year to keep up with the aging population and to lessen the risk of failures.

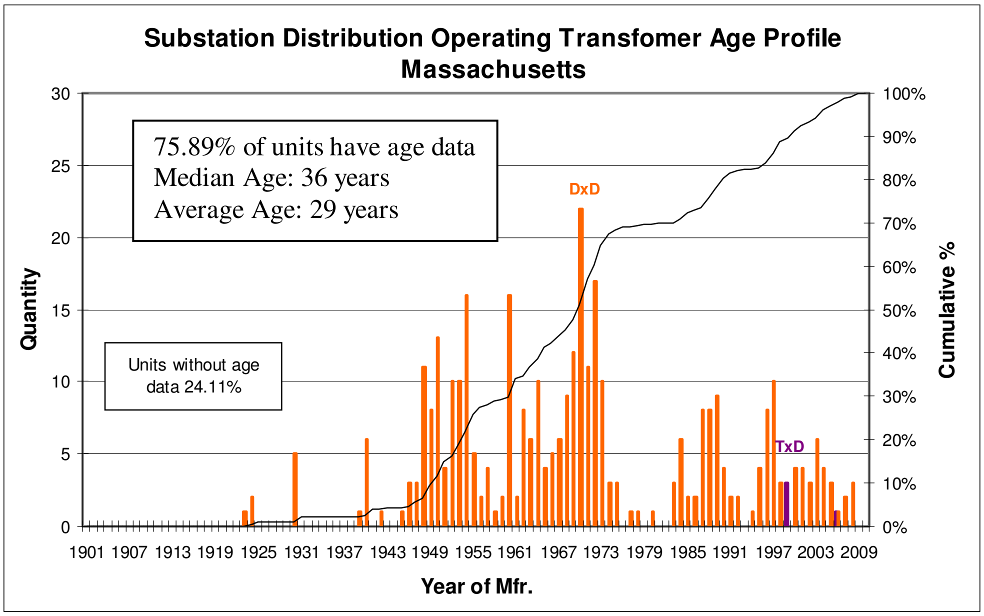

Figure 7. Substation Distribution Transformer Age Profile

Of the 483 operating transformers listed in AIMMS, 362 have age data, and therefore the average age is 29 years. This is similar to the total transformer population shown in Figure 1. The Massachusetts transformer age profile is displayed in Figure 7. Transformers without an age recorded tend to be older units.

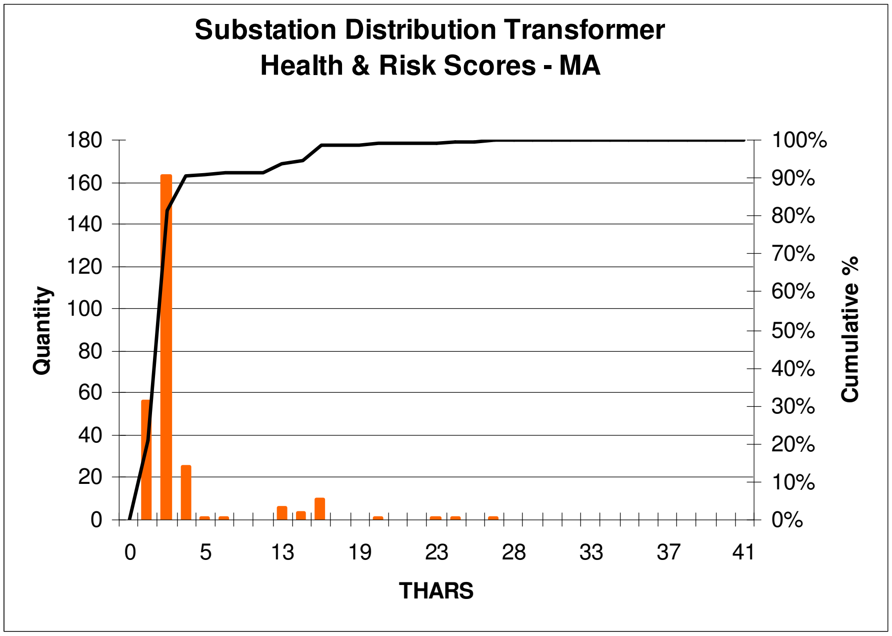

Figure 8. Transformer Health and Risk Scores for Massachusetts

In reference to Figure 8, 91% of the transformer health and risk scores for Massachusetts are 5 or below. This indicates that a large majority of the units in Massachusetts are in good condition and pose very little risk based on this health and risk scoring system. However, 5.2% of the population have scores 10 or greater, and 1% greater than 20. These units are on the 15 year replacement list found in Table 2. The THaRS number was excluded from the list because it is still in development, and it is our intention to improve on this prioritization tool.

The replacement candidates for Massachusetts are listed below in order of priority. The red coded unit(s) are already on the replacement list for FY10, the orange coated list is the replacement list for FY11 to FY14, and the yellow coded list is for the following 10 years. The number of units on the replacement list is based on the total population of transformer MVA divided by 60 years.

Represents those already on the list for replacement FY10
Represents replacement candidates for FY11-FY14 in order of priority.
Represent replacement candidates for FY15-FY25 in order of priority. Analysis based mostly on age then MVA for

MA - REPLACEMENT BASED ON 43 MVA PER YEAR **LAST DGA**

STA LOC	EQNUM	MVA	VOLT		AGE	ZHYDROGEN	ZMETHANE	ZCARBON_MONO	ZETHANE	ZETHYLENE	ZACETYLEN	ZCOMBUST_GAS
Salem 2 Valley St	20757	7	23		41	36	64	300	105	28	0	533
Tyngsboro 211	21601	6.25	23-13.2		37	855	53	344	3	701	2	1958
West Gloucester 28	23586	12.5	34.5-22.9		23	154	62	727	24	2	0	969
Rockport 40	23898	9.38	34.5-22.9		21	16	9	1140	2	46	0	1213
Vine 8	20363	3.75	13.8-4.33 kV		59	542	43	509	1	58	0	1153
Walnut Street 32	21112	10	24.6-4.16		62	32	8	158	8	6	0	212
Walnut Street 32	21111	10	24.6-4.16		62	18	6	90	8	4	0	126
Gloucester 24	20113	7.25	23-2.4		62	17	25	73	83	16	0	214
Melrose 4	20152	9.38	23-4.16		47	0	2	3	17	3	0	25
Melrose 4	20151	9.38	23-4.16		47	0	33	259	28	85	0	405
Water Street 31	21094	9.375	23.5-4.16 kV		52							
Salem 15	22955	1.5	13.2-2.3 kV	1	79							
Salem 15	22956	1.5	13.2-2.3 kV	1	79							
Salem 15	22957	1.5	13.2-2.3 kV	1	79							
Lawrence 2	20135	7.5	13.8-2.4		85	5	3	144	2	2	0	156
Lawrence 2	20136	7.5	13.8-2.4		85	0	1	90	1	3	0	95
Medford 9	20149	10	23.46-4		69	14	27	1130	0	36	0	1207
Medford 9	20150	10	23.46-4		59	27	30	1100	8	39	0	1204
Worthen Street 13	21899	7	13.8-13.2ZZ k'		36	29	145	567	110	126	0	
Plainville 3451	21545	6.25	22.9-13.8 kV		37	49	469	1980	398	273	0	
North Lawrence 6	20653	9.38	13.8-2.4 kV	7	59	8	5	184	1	39	0	237
Revere Beach 35	20250	9.38	22.9-4.16 kV		59	0	1	3	1	0	0	5
Bancroft Street 3	21756	6.25	13.2-2.4 kV	5	59	17	58	42	45	200	0	362
Faraday Street 11	20657	9.38	13.2-2.4 kV	7	58	6	5	23	5	1	0	40
Burrill 2	20065	3.65	13.8-4.36 kV		58	14	85	1100	34	34	0	1267
Quebec Street 17	20238	12.5	23.5-13.8 kV		57	5	21	10	153	9	0	198
Newburyport 36	21046	9.38	22.9-2.4 kV	7	57	185	9	151	10	3	0	358
Total MVA		**206.9**										
Glendal 6	20110	7.5	23-2.4		61	12	27	629	23	143	0	
Glendal 6												
Wollaston 2	20387	9.38	13.8-2.4		61	0	4	7	9	1	0	21
Revere 7	20248	9.38	23-2.4		?	0	10	38	13	25	0	86
Revere 7	20249	9.38	23-2.4		?	1	4	11	3	0	0	19
Newburyport 36	21047	9.38	22.9-2.4 kV	7	57	12	18	103	26	14	0	173
Amesbury 5	21003	9.38	22.3-2.4 kV	7	57	15	9	81	17	11	0	133
Water Street 31	21408	6.25	22-2.4 kV	5/6	57	0	10	20	11	70	0	111
Hudson 7	20132	3.75	13.8-4.36 kV		57	9	7	561	3	2	0	582
Salem 3 Boston St	20283	10	24.45-4.16		50	11	48	182	34	48	0	323
Salem 3 Boston St	20284	10	23-2.4 kV	7.5	61	18	6	161	0	3	0	188
Lawrence 1	20774	12.5	23.5-13.8 kV		56	36	64	300	105	28	0	533
Quebec Street 17	20237	12.5	23.5-13.8-4.16		56	7	1	29	1	2	0	40
Topsfield 26	23591	12.5	22.9-22.9 kV		?	14	17	625	5	1	0	662
Faraday Street 11	20658	9.38	13.2-2.4 kV	7	56	4	6	35	2	8	0	55
Dale Street 55	20581	7	22.9-13.2 kV		?	222	19	1070	3	49	0	1363
South Billerica 18	23115	7	22.9-13.8 kV		?	6	42	396	20	21	0	485
North Andover 7	~~20606~~	~~6.25~~	~~22.9-2.4 kV~~	~~5~~	~~56~~	14	7	168	14	15	0	218
Andover 3	20650	9.38	14.1-4.16 kV		55	63	13	169	13	9	0	267
Methuen 5	20720	9.38	22.9-4.16 kV		55	4	21	22	70	5	0	122
North Beverly 18	22539	9.38	22.9-4.16 kV		55	5	14	25	55	5	0	104

North Andover 7	20606	6.25	22.9-2.4 kV	5	56	14	7	168	14	15	0	218
Andover 3	20650	9.38	14.1-4.16 kV		55	63	13	169	13	9	0	267
Methuen 5	20720	9.38	22.9-4.16 kV		55	4	21	22	70	5	0	122
North Beverly 18	22539	9.38	22.9-4.16 kV		55	5	14	25	55	5	0	104
Andover 3	20651	9.38	14.1-4.16 kV		55	24	7	18	33	3	0	85
North Beverly 18	20183	9.38	22.9-4.16 kV		55	103	6	197	25	8	0	339
Methuen 5	20721	9.38	22.9-4.16 kV		55	0	16	24	30	3	0	73
Perry Street 3	20212	9.38	13.2-4.16 kV		55	0	2	47	1	17	0	67
Kent 13	20802	4.69	13.8-4.36 kV		55	35	65	390	104	16	0	610
Western 4	20380	3.75	13.8-4.36 kV		55	0	113	174	384	18	0	689
Perry Street 3	20213	9.38	13.2-4.16 kV		54	11	4	143	2	39	0	199
Atlantic 4	20003	6.25	13.8-4.16 kV		54	92	4	281	2	2	0	381
Lawrence 1	20134	9.38	13.8-2.3 kV	7	53	28	8	89	18	12	0	155
Humphrey 1	20133	6.25	13.8-4.36 kV		?	28	83	468	181	12	0	772
Beverly 12	20279	7	23-4.16 kV	5/	40	9	48	543	17	16	0	633
Sheffield 8	20273	7	23-13.8 kV	5/	40	68	48	325	124	13	0	578
West Methuen 63	23142	20	23-13.8 kV	1:	38	13	21	279	7	22	0	342
West Methuen 63	23263	20	23-13.8 kV	1:	38	19	30	150	29	4	0	232
North Lawrence 6	23316	20	23-13.2 kV	1:	36	20	20	326	13	21	0	400
Swampscott 22	23135	20	23-13.8 kV	1:	36	56	5	217	1	11	1	291
Risingdale 9	23580	20	23-23.8 kV	1:	35	10	11	85	4	13	0	123
Candle Street 101	24034	30	46-13.2 kV	3(	13	18	2	161	1	1	0	183
Candle Street 101	24041	30	46-13.2 kV	3(	13	2	3	47	1	1	0	54
Total MVA		**414.01**										

Table 2. Massachusetts Transformer Replacement List

In reference to Table 2, there are 27 transformers on the list for replacement over the next 5 years. One is to be replaced in FY10, which is excluded from the cost analysis. There is one single-phase bank that will be replaced with a 3-phase transformer. Therefore the cost is representative of replacing 24, 3-phase transformers. The cost of replacement is as follows:

Eight units at $900k per unit (average), $1.44M pa for 5 years
Sixteen units at $1.5M per unit (average), $4.8M pa for 5 years

10.0 New York

There are 807 operating transformers in New York listed in AIMMS, with 56 spares. Of the 807 units, 524 received transformer health and risk scores. The total MVA population in New York is 2,591, and it is suggested that approximately 43 MVA be replaced per year to keep up with the aging population and to lessen the risk of failures.

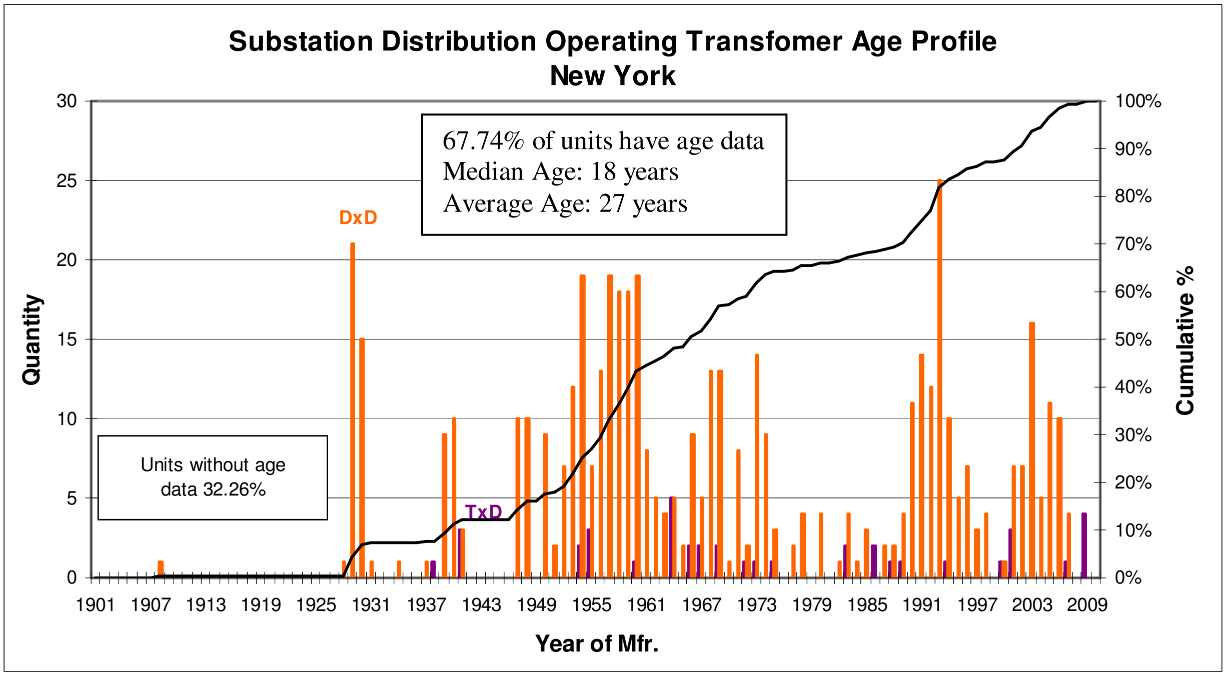

Figure 9. Distribution Transformer Age Profile

The available age data listed in AIMMS for New York results in an average age of 27 years, which is based on 547 units with age data. New York also has the largest amount of missing age data; this is not a significant issue as age may be inferred, if necessary, from related substation equipment and age is used as an indicator for condition rather than a driver for replacement. New York has 7 smaller units (less than 2.5 MVA) on the replacement list that may be best solved with a planning solution rather than replacement. The New York transformer age profile can be found in Figure 9.

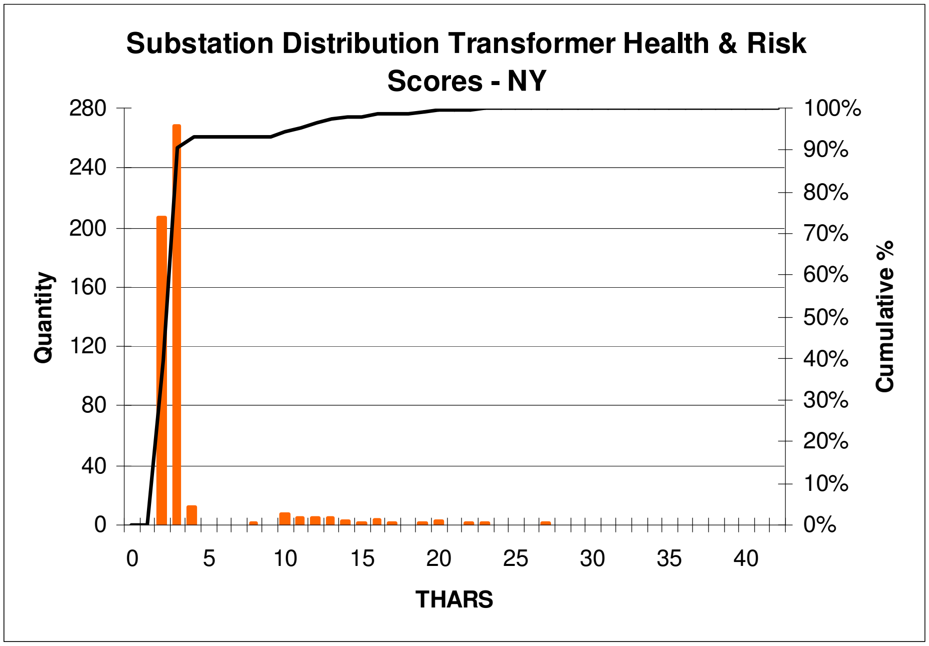

Figure 10. Transformer Health and Risk Scores for New York

In reference to Figure 10, 93% of the transformer health and risk scores for New York are below 5. This indicates that a large majority of the units in New York are in good condition and pose very little risk based on this health and risk scoring system. On the other hand, 7% of the population have scores greater than 10, and 1% greater than 20. These units are on the 15 year replacement list, which is attached below in Table 3.

						LAST DGA						
NY - REPLACEMENT BASED ON 43 MVA PER YEAR												
DIVISION	STA LOC	EQNUM	MVA	VOLT	AGE	ZHYDROGEN	ZMETHANE	ZCARBON_MON	ZETHANE	ZETHYLENE	ZACETYLENE	ZCOMBUST_GAS
NYCDSU	Fayetteville Station 18	222261	6.25	34.5-2.4 kV	52	25	211	108	333	929	0	1606
NYWDSU	French Creek Station	220472	3.75	34.5-13.8 k\	36	123	17	782	11	9	32	974
NYWDSU	Station 034	219590	2.5	23-4.16 kV 2	79	141	7	129	6	9	0	292
NYWDSU	Station 124 - Almeda	219384	3.75	34.5-4.16 k\		15	801	327	1483	2708	0	5334
NYWDSU	Station 124 - Almeda	219390	5.25	34.5-4.16 k\		4	140	184	315	61	0	704
NYWDSU	Station 124 - Almeda	219388	4.687	34.5-4.16 k\		20	80	269	120	39	0	528
NYWDSU	Station 124 - Almeda	219382	3.75	34.5-4.16 k\	?	12	137	93	508	36	0	786
NYWDSU	Avon Station 43	220403	3.75	34.5-4.8 kV	49	34	100	131	41	6	0	312
NYEDSU	Newtonville Station 30	221606	5.6	34.5-4.16 k\		108	65	84	41	107	0	405
NYWDSU	Station 056	219732	3.13	23-4.16 kV 2	53	304	13	378	13	21	0	729
NYWDSU	Oak Hill Station 62	220487	2.5	34.5-4.8 kV		261	7	540	5	26	0	839
NYEDSU	Chrisler Avenue Stati	221777	3	34.5-4.16 k\	?	9792	10	236	5	4	0	10047
NYWDSU	Station 038	219633	2.5	23-4.16 kV 2	79	13	4	110	18	8	0	153
NYCDSU	Mill Street Station 748	221188	6.25	23-4.8 kV 5/	54	16	45	270	77	6	0	414
NYEDSU	McCrea Street Statior	221950	3.75	34.5-4.8 kV	59	191	5	527	4	3	0	730
NYCDSU	Mill Street Station 748	221187	6.25	23-4.8 kV 5/	54	348	123	107	258	17	0	853
NYCDSU	Mill Street Station 748	221189	6.25	23-4.8 kV 5/	54	8	72	148	95	7	0	330
NYEDSU	Chrisler Avenue Stati	221776	3	34.5-4.16 k\	62	9	5	303	3	6	0	326
NYCDSU	Fisher Avenue Statior	220643	6.25	34.5-13.8 k\	39	0	1	28	1	2	0	32
NYCDSU	Rock City Station 623	222363	7	46-4.16 kV 5	55	81	636	125	776	1805	0	3423
NYEDSU	Summit Station 347	222446	10.5	69-4.8 kV 7.	40	46	39	140	28	68	0	321
NYWDSU	Golah Station	220370	7.5	69-34.5 kV 7	71	208	30	351	30	16	0	635
NYEDSU	Chestertown Station 4	222029	10.5	34.5-13.8 k\		19	169	126	316	378	0	1008
NYWDSU	Station 037	219618	2.5	23-4.16 kV 2	79	96	6	189	7	10	0	308
NYEDSU	Hoag Station 221	222408	0.7	34.5-4.8 kV	61	95	6	571	4	6	0	682
NYEDSU	Hoag Station 221	222407	0.7	34.5-4.8 kV	61	92	6	576	4	5	1	684
NYEDSU	Hoag Station 221	222409	0.7	34.5-4.8 kV	61	142	10	915	5	8	0	1080
NYCDSU	Westvale Station 133	210278	7.5	34.5-4.16 k\	49	38	3	167	2	8	2	220
NYCDSU	Galeville Station 213	220674	6.25	34.5-4.16 k\	51	228	35	677	101	17	0	1058
NYCDSU	Glenwood Station 227	220701	6.25	34.5-4.16 k\	49	21	267	322	390	1174	0	2174
NYEDSU	Colvin Avenue Statior	222411	6.25	34.5-4.16 k\		111	113	275	66	278	1	844
NYCDSU	Fabius Station 55	220852	0.83	34.5-4.8 kV	50	121	10	311	60	12	0	514
NYCDSU	Fabius Station 55	220851	0.83	34.5-4.8 kV	50	62	7	187	34	6	0	296
NYCDSU	Fabius Station 55	220853	0.83	34.5-4.8 kV	50	7	90	276	173	14	0	560
NYCDSU	Cuyler Station 24	222280	2	34.5-4.16 k\	80							
NYCDSU	Cuyler Station 24	222281	2	34.5-4.16 k\	80							
NYCDSU	Cuyler Station 24	222282	2	34.5-4.16 k\	80							
NYCDSU	Cuyler Station 24	222283	2	34.5-4.16 k\	80							
NYCDSU	Cuyler Station 24	222284	2	34.5-4.16 k\	80							
NYCDSU	Cuyler Station 24	222285	2	34.5-4.16 k\	80							
NYWDSU	Station 030	219562	3	23-4.16 kV 2	59	297	28	966	23	7	0	1321
NYWDSU	Machias Station 13	246649	3.75	34.5--4.8 kV		76	30	172	36	38	0	352
NYWDSU	Station 083 - Welch A	220250	3.5	12-4.16 kV 3		399	69	771	82	26	0	1347
NYWDSU	Station 057	222125	5.3	23-4.16 kV 3	36	94	6	452	7	4	0	563
NYWDSU	North Collins Station 9	222246	2.5	34.5-4.8 kV	46	123	212	193	359	50	0	937
NYWDSU	Station 025	219527	2.5	23-4.16 kV 2		7	4	136	6	5	6	164
NYWDSU	Station 029	219558	2.5	23-4.16 kV 2		43	6	104	6	8	0	167
NYWDSU	Station 027	219544	2.5	23-4.16 kV 2		29	5	73	6	11	0	124

NYWDSU	Station 045	219660	2.5	23-4.16 kV 2.5		87	8	306	149	14	0	564
NYCDSU	Roosevelt Road Temp	210109	1.667	23-4.8 kV 1.66		41	27	51	84	8	0	211
NYEDSU	Glens Falls Hospital S	222024	3.2	34.5-4.16 kV 2	35	101	40	236	75	39	0	491
	Total MVA		**195.094**									
NYCDSU	State Street Station 9	221400	3.75	23-4.8 kV 3/3.7	55	44	6	420	7	22	0	499
NYCDSU	Miller Street Station 1	220549	3.1	34.5-4.8	69	6	3	79	3	2	0	93
NYCDSU	Miller Street Station 1	220550	3.1	34.5-4.9	69	29	4	114	4	2	0	153
NYCDSU	Miller Street Station 1	220551	3.1	34.5-4.10	69	4	3	78	3	1	0	89
NYWDSU	Station 048	219683	4.687	23-4.16 kV 3.7	16	0	1	80	1	38	0	120
NYWDSU	Elm Street Station	219816	22.5	23 kV 22.5 MV	42	28	9	901	4	4	1	947
NYWDSU	Elm Street Station	219812	.15	23 kV .15 MVA	42	27	2	100	2	1	0	132
NYCDSU	Fayette Street Station	222295	12/16/20	34.5-4.16 kV 1	43	25	104	157	121	158	0	565
NYCDSU	Fayette Street Station	222293	12/16/20	34.5-4.16 kV 1	43	3	1	37	1	1	0	43
NYWDSU	Station 056	219734	2.5/3.1	23-4.16 kV 2.5	109	4	80	272	133	63	0	552
NYEDSU	Tibbits Avenue Station	221591	5/6.25	34.5-4.16 kV 5	55	119	5	341	4	2	0	471
NYEDSU	Scotia Station 255	221771	5/6.25	34.5-4.16 kV 5	54	68	3	311	0	1	0	383
NYWDSU	Station 051	219697	3	23-4.16 kV 2.5	70	45	21	684	11	8	0	769
NYEDSU	Partridge Street Static	221629	14	34.5-4.16 kV 1		0	32	462	39	12	0	545
NYEDSU	Partridge Street Static	221720	14	34.5-4.16 kV 1		0	27	423	27	12	0	489
NYCDSU	Conkling Station 652	221055	6.25	43.8/4.36 kV 5	53	84	73	260	186	15	0	618
NYCDSU	Park Street Station 14	220629	6.25	34.5-4.16 kV 5	53	46	19	338	11	1	0	415
NYEDSU	Karner Station 317	221618	6.25	34.5-4.16 kV 5	75	12	69	257	264	25	0	627
NYEDSU	Shore Road Station 2	221782	6.3	34.5-4.8 kV 5/6	52	104	4	392	1	2	0	503
NYEDSU	Selkirk Station 149	221523	9.4	34.5-13.8 kV 7	40	9	53	339	39	79	0	519
NYCDSU	Seventh North Street	220713	7	34.5-4.8 kV 5.6	48	2	77	113	122	7	0	321
NYEDSU	Saratoga Station 142	222469	6.3	34.5-4.16 kV 5	72	21	4	243	2	6	0	276
NYEDSU	Lynn Street Station 32	221923	6.25	34.5-4.16 kV 5	50	138	128	1205	130	19	0	1620
NYEDSU	Gloversville Station 72	222460	25	69-13.8 kV 15/	16	15	6	339	3	7	0	370
NYWDSU	Sheppard Road Static	220383	4.2	34.5-13.8 kV 3	36	101	52	454	47	32	0	686
NYEDSU	Delmar Station 279	221561	11	34.5-4.8 kV 5/6	49	79	74	826	87	24	1	1091
NYEDSU	Watt Street Station 38	222432	10.5	34.5-13.8 kV 7	38	60	157	648	194	32	0	1091
NYCDSU	Lenox Station 513	220983	6.25	13.2-4.16 kV 5		80	27	239	185	16	1	548
NYEDSU	Market Hill Station 32	221881	6.25	69-4.16 kV 5/6	45	35	28	613	14	7	0	697
NYEDSU	Newtonville Station 30	221605	6.25	34.5-13.8 kV 5		13	2	194	1	1	0	211
NYEDSU	Lansingburgh Station	221696	7.5	34.5-13.8 kV 7		140	104	709	126	28	0	1107
NYCDSU	State Street Station 9	221402	3.75	23-4.8 kV 3/3.7	55	148	237	737	1457	138	0	2717
NYWDSU	Station 043	219667	2.5	23-4.16 kV 2.5	80	0	3	82	2	1	0	88
NYCDSU	Homer Station 129	220606	3.13	34.5 -4.8 kV 2.	56	23	8	266	15	14	0	326
NYCDSU	Homer Station 129	220607	3.13	34.5-4.8 kV 2.5	56	14	5	180	5	5	0	209
NYCDSU	Homer Station 129	220605	3.13	34.5-4.8 kV 2.5	59	7	4	147	3	4	0	165
NYWDSU	Station 026	219537	5.25	23-4.16 kV 3.7		18	67	214	126	22	0	447
NYWDSU	Station 026	219533	5.25	23-4.16 kV 3.7		5	63	202	126	32	0	428
NYCDSU	West Herkimer Station	221098	7	46-13.8 kV 5/6	38	25	87	320	135	18	0	585
NYWDSU	Station 157	219450	5	23-4.16 kV 5 M		72	57	247	140	18	0	534
NYWDSU	Station 023	219511	2.5	23-4.16 kV 2.5	80	10	6	118	4	27	0	165
NYWDSU	Station 041	219643	2.5	23-4.16 kV 2.5	80	11	5	163	5	10	0	194
NYEDSU	Rensselaer Station 13	221721	10	34.5-13.8 kV 1		15	23	424	16	13	0	491
NYWDSU	Station 041	219647	2.5	23-4.16 kV 2.5	80	13	2	80	2	1	0	98
NYWDSU	Station 023	219512	2.5	23-4.16 kV 2.5	80	7	4	132	5	9	0	157
NYWDSU	Station 037	219620	2.5	23-4.16 kV 2.5	79	86	5	88	12	9	0	200
NYWDSU	Station 037	219614	2.5	23-4.16 kV 2.5	79	12	5	133	6	8	0	164
NYWDSU	Station 037	219619	2.5	23-4.16 kV 2.5	79	35	5	102	6	8	0	156

NYWDSU	Station 034	219594	2.5	23-4.16 kV 2.5	79	8	6	178	5	9	0	206
NYWDSU	Station 035	219604	2.5	23-4.16 kV 2.5	79	7	5	118	4	6	0	140
NYWDSU	Station 035	219603	2.5	23-4.16 kV 2.5	79	4	3	74	2	3	0	86
NYWDSU	Station 035	219598	2.5	23-4.16 kV 2.5	79	6	4	102	3	7	0	122
NYWDSU	Station 034	219595	2.5	23-4.16 kV 2.5	79	2	4	128	3	6	0	143
NYWDSU	Station 035	219602	2.5	23-4.16 kV 2.5	79	4	5	105	4	7	0	125
NYWDSU	Station 040	219635	4.8	23-4.16 kV 3.7		413	40	335	25	25	0	838
NYWDSU	Station 023	219513	2.5	23-4.16 kV 2.5	78	7	2	21	3	2	0	35
NYEDSU	Delmar Station 279	221560	6.25	34.5-4.8 kV 5/6	58	176	5	435	3	2	0	621
NYCDSU	Ash Street Station 22	220700	9.4	34.5-4.16 kV 7	45	30	50	115	121	34	0	350
NYCDSU	Ash Street Station 22	220698	9.4	34.5-4.16 kV 7	45	30	6	168	118	16	0	338
NYCDSU	Ash Street Station 22	220699	9.4	34.5-4.16 kV 7	45	34	8	203	119	19	1	384
NYCDSU	Mine Road Station 77	221262	9.4	34.5-23 kV 7.5	45	2	3	8	0	2	5	20
NYEDSU	Mayfield Station 356	221898	10.5	69-13.8 kV 7.5	41	16	83	192	168	15	0	474
NYCDSU	Antwerp Station 801	221209	3.75	23-4.8 kV 3.75	48	0	8	461	4	154	0	627
NYWDSU	Poland Station 66	220323	2.5	34.5-4.8 kV 2.5	54	1	102	304	211	100	1	719
NYEDSU	Schuylerville Station 3	222479	6.3	34.5-4.8 kV 5/6		26	4	567	2	60	0	659
NYWDSU	Greenhurst Station 60	220533	2.5	34.5-4.8 kV 2.5	53	25	7	216	24	13	0	285
NYCDSU	Constantia Station 19	220669	3.65	34.5-4.16 kV 3	69	9	8	442	5	4	0	468
NYCDSU	Clinton Station 604	221025	10.5	46-13.8 kV 7.5	40	150	8	247	9	8	0	422
NYEDSU	Emmet Street Station	221755	6.25	34.5-4.16 kV 3	55	141	6	354	4	2	0	507
NYWDSU	Sherman Station 54	220529	2.5	34.5-4.8 kV 2.5	51	0	14	236	7	3	0	260
NYWDSU	Station 067	219769	3.75	34.5-4.16 kV 3	?	25	5	197	68	16	1	312
NYWDSU	Station 160 - Summer	219456	3.75	23-4.16 kV 3.7	?	37	60	163	164	10	0	434
NYWDSU	Station 058	219737	4.69	34.5-4.16 kV 3	41	14	31	217	20	80	1	363
NYWDSU	Station 058	219735	4.69	34.5-4.16 kV 3	41	0	71	172	92	87	2	424
NYWDSU	Station 052	219708	3	23-4.16 kV 2.5	70	42	19	514	13	11	0	599
NYWDSU	Station 052	219706	3	23-4.16 kV 2.5	70	35	17	437	13	11	0	513
NYWDSU	Station 052	219710	3	23-4.16 kV 2.5	70	32	17	406	12	10	0	477
NYWDSU	Station 051	219701	3	23-4.16 kV 2.5	70	42	20	697	11	8	0	778
NYWDSU	Station 051	219699	3	23-4.16 kV 2.5	70	39	21	708	10	10	0	788
NYEDSU	Schoharie Station 234	221848	10.5	69-13.8 kV 7.5	38	26	32	127	78	38	0	301
NYEDSU	Brunswick Station 264	221556	10.5	34.5-13.8 kV 7	38	3	70	217	153	23	0	466
NYEDSU	Commerce Avenue S	221600	8.4	34.5-13.8 kV 7		0	1	60	1	1	0	63
NYWDSU	Station 027	219539	2.5	23-4.16 kV 2.5		9	8	75	14	12	0	118
NYWDSU	Station 067	219767	3.75	34.5-4.16 kV 3	42	33	39	112	22	11	2	219
NYWDSU	Station 038	219627	2.5	23-4.16 kV 2.5	79	8	5	147	6	8	0	174
NYWDSU	Station 038	219632	2.5	23-4.16 kV 2.5	79	6	5	129	5	10	0	155
NYWDSU	Station 038	219631	2.5	23-4.16 kV 2.5	79	2	3	92	2	2	0	101
NYCDSU	Fine Station 978	221424	1	34.5-4.8 kV 1 I	57							
NYCDSU	Moira Station 859	221293	3	34.5-4.8 kV 3/4	59	13	4	120	3	4	0	144
NYCDSU	Gabriels Station 835	221268	1.28	46-4.8 kV 1.28	?	4	1	52	1	1	0	59
	Total MVA		**424**									

NYEDSU	Commerce Avenue St	221600	8.4	34.5-13.8 kV 7		0	1	60	1	1	0	63
NYWDSU	Station 027	219539	2.5	23-4.16 kV 2.5		9	8	75	14	12	0	118
NYWDSU	Station 067	219767	3.75	34.5-4.16 kV 3	42	33	39	112	22	11	2	219
NYWDSU	Station 038	219627	2.5	23-4.16 kV 2.5	79	8	5	147	6	8	0	174
NYWDSU	Station 038	219632	2.5	23-4.16 kV 2.5	79	6	5	129	5	10	0	155
NYWDSU	Station 038	219631	2.5	23-4.16 kV 2.5	79	2	3	92	2	2	0	101
	Total MVA		**431**									

Table 3. New York Transformer Replacement List

In reference to Table 3, there are 51 transformers on the list for replacement over the next 5 years in New York. There are 4 single-phase banks that will be replaced with 3-phase transformers. Therefore the cost is representative of replacing 40, 3-phase transformers. The cost of replacement is as follows:

Thirty nine units at $900k per unit (average), $7.02M pa for 5 years
Four units at $1.5M per unit (average), $1.2M pa for 5 years

11.0 Rhode Island

There are 143 operating transformers in Rhode Island listed in AIMMS, with 12 spares. Of the 143 units, 79 received transformer health and risk scores. The total MVA population in Rhode Island is 983.94, and it is suggested that approximately 16 MVA be replaced per year to keep up with the aging population and to lessen the risk of failures.

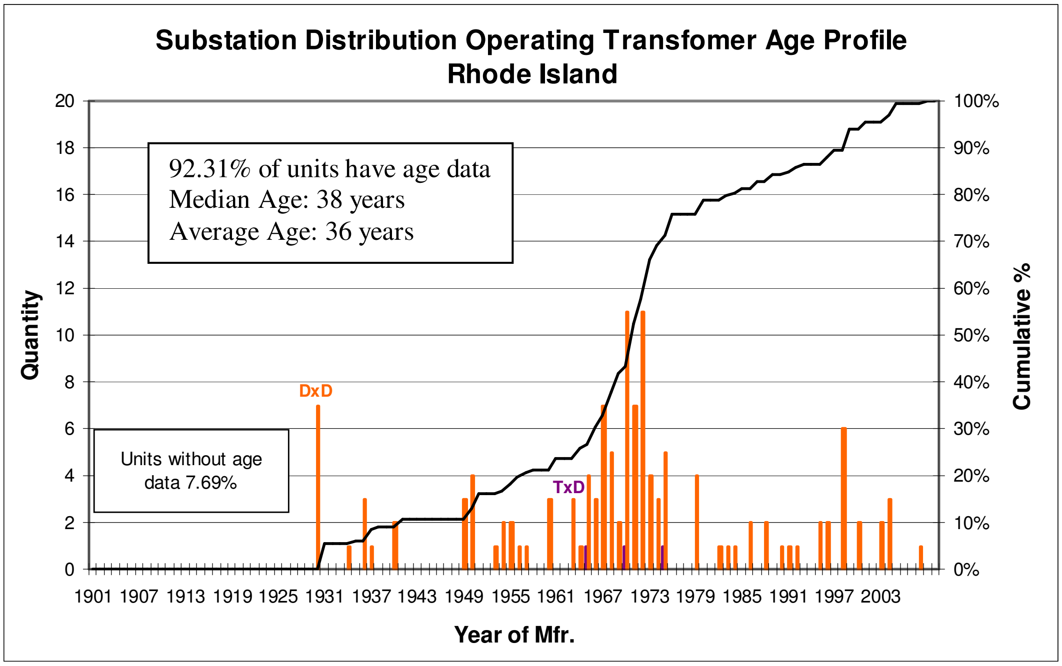

Figure 11. Distribution Transformer Age Profile

There are 132 units with age data in AIMMS for Rhode Island. Based on the available age data, the average RI transformer age is 36 years. Rhode Island has the oldest average age, but has the least amount of transformers with missing age data as a proportion of the population (7.69%). The Rhode Island transformer age profile can be found in Figure 11.

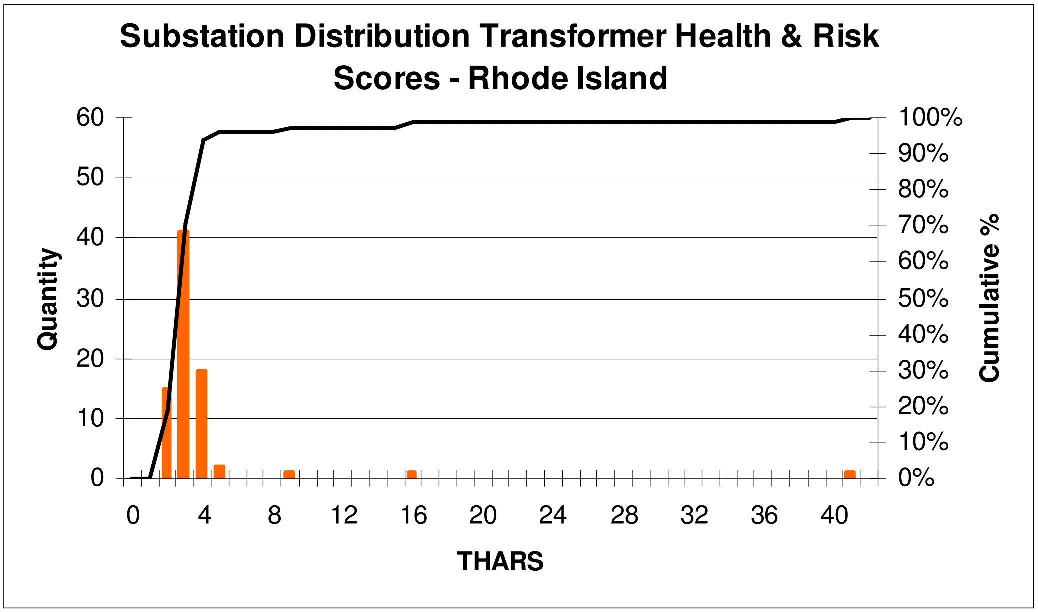

Figure 12. Transformer Health and Risk Scores for Rhode Island

In reference to Figure 12, 93.7% of the transformer health and risk scores for Rhode Island are 5.0 or below. This indicates that a large majority of the units in Rhode Island are in good condition and pose very little risk based on this health and risk scoring system. On the other hand, 2.5% of the population have scores greater than 10, and there is one unit with a score of 41. This unit is on the top of the Rhode Island replacement list. The attached list of replacement candidates for Rhode Island is listed below in Table 4.

RI - REPLACEMENT BASED ON 16 MVA PER YEAR					LAST DGA						
STA LOC	EQNUM	MVA	VOLT	AGE	ZHYDROGEN	ZMETHANE	ZCARBON_MONOXI	ZETHANE	ZETHYLENE	ZACETYLENE	ZCOMBUST_GAS
Geneva 71	21233	9.38	23-4.16 kV 7	44							
Admiral Street 9	20652	15	22-11	79	2160	6	356	1	23	0	2546
Admiral Street 9	20659	15	22-11	79	44	6	467	3	18	0	538
South Street	20316	10	22-11	69	672	2	51	1	10	1	
Elmwood Gnd Bank -	24448	0.5	21.45-11	79							
Elmwood Gnd Bank -	24449	0.5	21.45-11	72							
Elmwood Gnd Bank -	24450	0.5	21.45-11	79							
Hunt River 40	23170	17.92	34.5	39	6	7	167	1	2	0	183
Hope 15	20794	6.25	21.9-7.2	?	14	2	93	0	3	0	112
Lakewood 57	22817	10.5	22.9-4.16	45	0	0	2	0	1	1	4
Vernon 23	24254	3.13	23-4.16	60	18	4	155	0	4	0	181
Total MVA		**79.3**									
Lafayette 30	20837	6.25	33.6-12.470Y	52	5	2	84	1	16	0	108
Toray Fan 87	23700	9.38	34.5-2.4	79	3	5	31	15	3	0	57
Harris Avenue 12	23244	9.38	23-4.16 kV 7	?	9	58	335	53	36	0	491
Knightsville 66	20882	9.38	22.9-4.16 kV	54	0	1	60	0	18	0	79
Knightsville 66	22811	9.38	22.9-4.16 kV	54	3	1	66	0	4	0	74
Toray Lumirror 88	23701	10.5	34.5-4.16 kV	49	5	39	206	23	44	0	317
West Greenville 45	20918	6.25	22.9-13.2 kV	49	0	9	289	0	20	0	318
Langworthy Corner 86	20222	7	33.6-12.470Y	46	82	17	819	5	47	0	970
Geneva 71	21232	9.38	22.9-4.16 kV	44	0	1	7	2	14	0	24
Lakewood 57	21351	10.5	22.9-4.16 kV	43	9	15	70	13	4	0	111
Coventry 54	20679	9.38	34.5-12.470Y	43	19	2	115	0	1	0	137
Auburn 73	21347	10.5	21.9-4.16 kV	42	5	10	122	6	3	0	146
Warwick 52	21036	10.5	22.9-13.2 kV	41	30	146	172	253	13	0	614
Warwick Mall 28	20498	6.25	22.9-13.2 kV	40	30	130	449	58	341	1	1009
Total MVA		**108.4**									

Table 4. Rhode Island Transformer Replacement List

In reference to Table 4, there are 11 transformers on the list for replacement over the next 5 years in Rhode Island. However, one is to be replaced in FY10, which is excluded from the cost analysis. There is one single-phase bank that will be replaced with a 3-phase transformer. Therefore the cost is representative of replacing 8, 3-phase transformers. The cost of replacement is as follows:

Three units at $900k per unit (average), $540k pa for 5 years
Five units at $1.5M per unit (average), $1.5M pa for 5 years

12.0 New Hampshire and Vermont

There are 44 operating transformers in New Hampshire and Vermont, with 2 spares. Of the 44 units, 15 received transformer health and risk scores. The replacement candidates in New Hampshire and Vermont were based on condition rather than total MVA due to the small quantity of units located in these states. There is one unit on the replacement list that is located in Vermont.

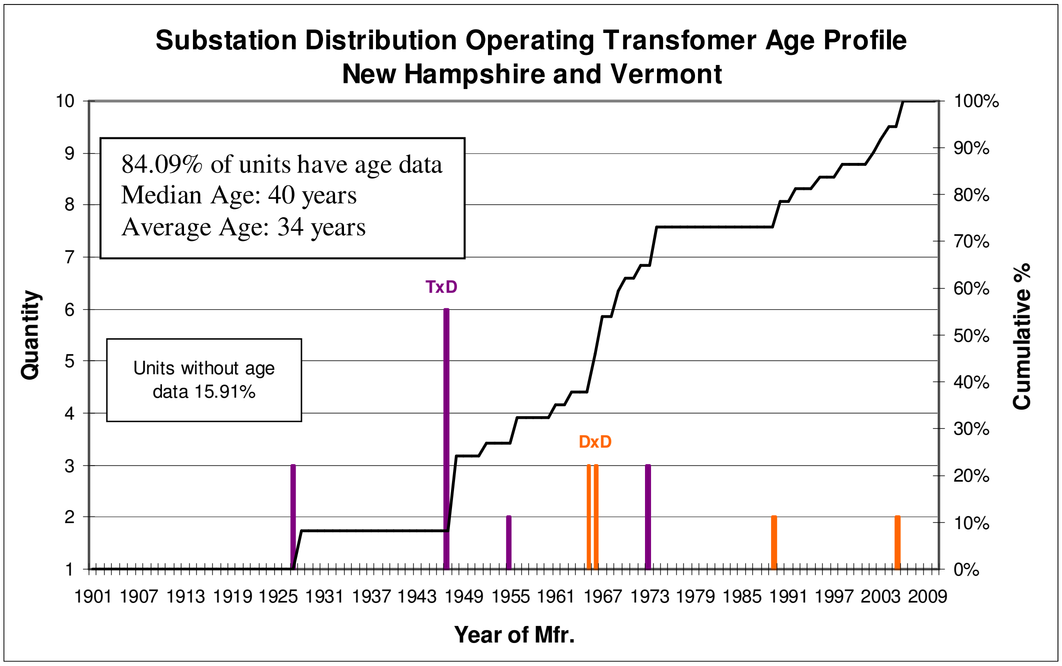

Figure 13. Distribution Transformer Age Profile

There are 37 units with age data in AIMMS for New Hampshire and Vermont. Based on the available age data, the average NH and VT transformer age is 34 years. NH and VT have the least amount of transformers with missing age data by actual count (7 units). The New Hampshire and Vermont transformer age profile is shown in Figure 13.

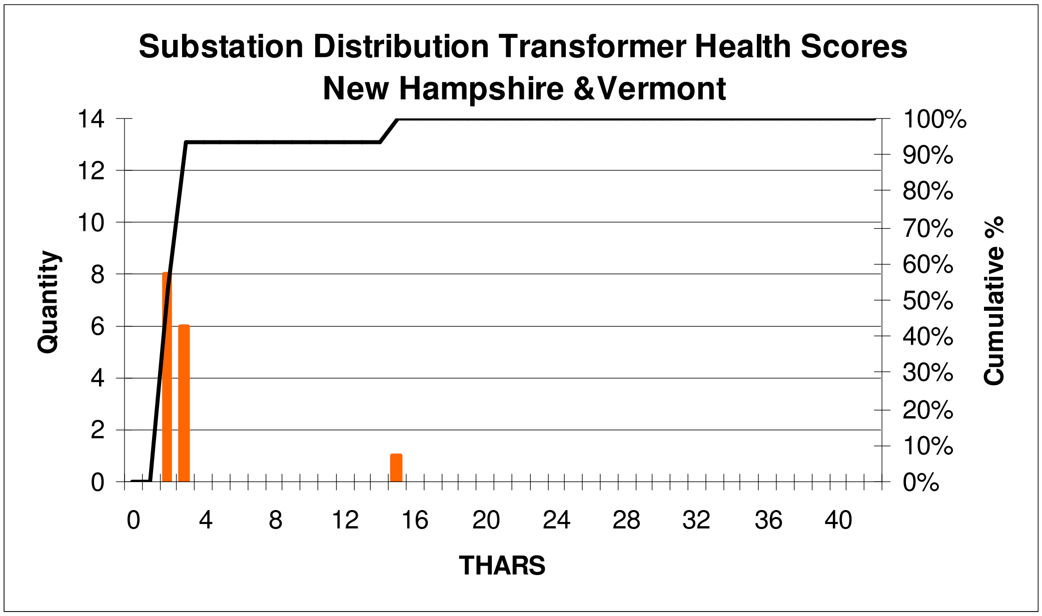

Figure 14. Transformer Health and Risk Scores for New Hampshire and Vermont

In reference to Figure 14, the majority of the transformer health and risk scores for New Hampshire and Vermont are 5.0 or below. This indicates that a most of the units in New Hampshire and Vermont are in good condition and pose very little risk based on this health and risk scoring system. There is 1 unit with a score of 15 and this unit is on the replacement list. The replacement candidates for New Hampshire and Vermont are listed below in Table 5 and Table 6.

NH - REPLACEMENT BASED ON CONDITION						LAST DGA						
DIVISION	STA LOC	EQNUM	MVA	VOLT	AGE	ZHYDROGEN	ZMETHANE	ZCARBON_MON	ZETHANE	ZETHYLENE	ZACETY	ZCOMBUST_GAS
NENG	Salem Depot 9	23068	7	22.9-13.2	?	565	264	1050	139	96	0	2114
NENG	Salem Depot 9	20402	7	22.9-13.2	41	104	17	1160	4	28	0	1313
NENG	Spicket River 13	23438	9.38	22.9-13.2 ZZ	?	129	71	508	40	104	0	852
NENG	Barron Avenue 10	20775	6.25	22.9-13.2	47	11	150	708	93	49	0	1011
	Total MVA		29.63									
NENG	Barron Avenue 10	21649	6.25	22.9-13.2 kV	38	11	150	708	93	49	0	1011
NENG	Charlestown 32	23604	6.25	45-13.2 kV 5/	36	30	29	736	5	63	0	863
NENG	Salem Depot 9	22772	9.38	22.9-13.2 ZZ k	20	70	39	573	17	3	0	702
	Total MVA		21.88									

Table 5. New Hampshire Transformer Replacement List

VT - REPLACEMENT BASED ON CONDITION												
DIVISION	STA LOC	EQNUM	MVA	VOLT	AGE	ZHYDROGEN	ZMETHANE	ZCARBON_MONOXIDE	ZETHANE	ZETHYLENE	ZACETYLENE	ZCOMBUST_GAS
NENG	Bridge Street 67	20062	3.75	6.9-4.8	49							

Table 6. Vermont Transformer Replacement List

In reference to Tables 5 and 6, there are 5 transformers on the list for replacement over the next 5 years in New Hampshire (4 units) and in Vermont (1 unit). The cost of replacement is as follows:

Four units at $900k per unit (average), $720k pa for 5 years
One unit at $1.5M per unit (average), $300k pa for 5 years

United Power Group, Inc.

Liberty Utilities
9 Lowell Road
Salem, NH 03079

Date. 8/27/14
Project No.

Project Location:

Barron Ave. Substation

Scope:

Perform testing & maintenance on the following equipment:
1. 10L1 Transformer
2. 10L1 Recloser and Form 3A Controller
3. 10L1 Voltage Regulators
4. Substation Perimeter Fence Grounding

Remarks:

1. Transformer 10L1's bushings are showing signs of deterioration. UPG would like to see past test data for the transformer. The transformer is over 40 years old. UPG recommends retesting the transformer in 1 year to see if the condition worsens.
2. Recloser 10L1 and form 3A controller test results are acceptable for service.
3. Voltage regulators 10L1 test results are acceptable for service.
4. UPG was asked to inspect the ground on the perimeter fence. It was discovered that most of the fence was ungrounded; a 2-point test was used to find this issue. UPG recommends adding grounds to the fence posts and adding a ground wire along the chain link.

Submitted by: James Fazio

United Power Group, Inc.

				Page No.	
Customer	Liberty Utilities	Date	8/26/2014	Project No.	
Address	Salem, NH	Air Temp.	25C	Rel. Humidity	32%
Owner	Liberty Utilities	Date Last Inspection		By Others	
Address	Salem, NH	Last Inspection Report No.			

Equipment Location: Barron Ave. Substation
Owner Identification: Transformer 10L1

Nameplate Information

Manufacturer	GE	KVA	5000/5600/7000	Phase	3	Cycle	60
Serial No.	F-959759	Type	Power	Form		Class	OA
Primary Voltage	13.2kV	Delta	Wye X	Rated Current	141	Amperes	
Secondary Voltage	7.62kV	Delta	Wye X	Rated Current	245	Amperes	
Coolant Oil	X	Askarel	Air	Nitrogen		Other	
Coolant Capacity - Units		Main Tank	690UG	LTC		Switch	
Temperature Rise		Date of Manufacture		Impedance	3.58%		
No Load Tap Changer Voltages	24100/23500/22900/22300/21700						

Gauges and Counters	Measured	Maximum	Reset	Trip	Alarm
Oil Temperature	40C	60C	X		
Wdg. Temperature			X		
Pressure	1+				
Oil Level	25C				

LTC	Measured	Max.	Min.
Tap	NA		
Counter	NA		

Visual Inspection			
Primary Connection	OK	Secondary Connections	OK
Tap Connections	OK	Leaks	NA
Gas Regulator	NA	Paint	OK
Infra-Red Inspection	NA	Grounds	OK

Fans and Controls	Oil Temp.	Wdg. Temp.	Manual	Auto	Lubrication Date
Stage 1	60C		X	X	
Stage 2					

Accessory Inspection	Alarm	Trip
Pressure Relief Device - Main Tank		
Pressure Relief Device - LTC		
Sudden Pressure Device		

Additional Tests

Remarks (1) Cooling fan is missing.

Submitted By JF

Transformer 10L1 – Doble Test

Company	UPG	**Serial Number**	F-959759
Location	Barron Ave. Substation	**Special ID**	Transformer - 10L1
Division	Liberty Utilities	**Circuit Designation**	
Manufacturer	GE	**Configuration**	Y-Y
Year Mfg.		**Tank Type**	OTHER
Mfr. Location	USA	**Coolant**	OIL
Phases	3	**Class**	OA/FA
Oil Volume	690 UG	**BIL**	110 kV
Weight	18600 LB	**Winding Config.**	Wye-Wye
kV	22.9, 7.62	**VA Rating**	, 5000, 5600, 7000 kVA
Note			

Test Date	8/26/2014	**Test Time**	7:54:38 AM	**Weather**	SUNNY
Air Temperature	23 °C	**Tank Temp.**	23°C	**RH.**	61 %
Tested by	JF/RB	**Work Order #**		**Last Test Date**	7/31/2014
Checked by		**Test Set Type**	M4K	**Retest Date**	
Checked Date		**Set Top S/N**		**Reason**	ROUTINE
Last Sheet #		**Set Bottom S/N**		**Travel Time**	
P.O. #		**Ins. Book #**		**Duration**	
Copies		**Sheet #**		**Crew Size**	2

Bushing Nameplate

Dsg	Serial	Mfr	Type	C1 %PF	C1 Cap	C2 %PF	C2 Cap	kV	Amps	Year
H2	1629051	GE	U	0.25	433			25	400	1967
H3	1629067	GE	U	0.31	446			25	400	1967
X1	1629055	GE	U	0.27	432			25	400	1967
X2	1629526	GE	U	0.27	439			25	400	1967
XO	1629093	GE	U	0.26	460			25	400	1967
X3	1629060	GE	U	0.27	431			25	400	1967
H1	1629061	GE	U	0.28	449			25	400	1967

Overall Tests

Meas.	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
CH + CHL	8.005	28.401	1.007		1.00	7533.6		
CH	8.004	28.362	1.002	0.35	1.00	7523.1	G	

Bushing C1

ID	Serial	NP %PF	NP Cap	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
H1	1629061	0.28	449	10.005	1.722	0.1360	0.79	1.00	456.73	D	
H2	1629051	0.25	433	10.005	1.642	0.0920	0.56	1.00	435.61	D	
H3	1629067	0.31	446	10.010	1.695	0.1050	0.62	1.00	449.49	D	
X1	1629055	0.27	432	10.006	1.630	0.0690	0.42	1.00	432.28	G	
X2	1629526	0.27	439	10.006	1.745	0.0530	0.30	1.00	462.82	D	
X3	1629060	0.27	431	10.005	1.758	0.0640	0.36	1.00	466.21	D	
XO	1629093	0.26	460	10.006	1.738	0.0540	0.31	1.00	460.91	G	

Insulation Resistance

Mfr.		Serial #		
Connection	**Volts**	**T1(Mohms)**	**T2(Mohms)**	**PI**
Hi / Lo to Earth	5000	9500	21000	2.2105

Exciting Current Tests

	Mfr.	Type	Steps	Boost %	Buck %	Position Found	Position Left	Oil Volume
De-Energized Tap Changer								
On-Load Tap Changer								

			H1 - H0			H2 - H0			H3 - H0				
DETC	**LTC**	**Test kV**	**mA**	**Watts**	**X**	**mA**	**Watts**	**X**	**mA**	**Watts**	**X**	IR_{auto}	IR_{man}
	3	8.045	113.84	949.85	L	74.934	657.28	L	114.32	956.31	L	G	

Turns Ratio (H-L) Tests

Mfr	Serial #	HV Winding	LV Winding
Connections	H1 - H0	H2 - H0	H3 - H0
	X1 - X0	X2 - X0	X3 - X0

Tap	Np Volt	Tap	Np Volt	Cal	Ratio 1	Ratio 2	Ratio 3	Min Lim	Max Lim	IR_{auto}	IR_{man}
3	13220		7620	1.735	1.732	1.737	1.734	1.726	1.744	G	

United Power Group, Inc.
VACUUM RECLOSER TEST AND INSPECTION REPORT

Page No. ____

Customer	Liberty Utilities	Date	8/26/2014	Project No.	
Address	Salem, NH	Air Temp.	88F	Rel. Humidity	38%
Owner	Liberty Utilities	Date Last Inspection			
Address	Salem, NH	Last Inspection Report No.			
Equipment Location	Barron Ave.				
Owner Identification	Recloser 10L1				

Breaker Nameplate Data:

Manufacturer	McGraw Edison	Type	VSA		
Serial No.	1896	Type Operating Mechanism	Coil Spring		
Amperes	800	Age		Interrupt. Rating	12kA
KV	15.5				

Adjustment Checks	Mfr's Rec.	As Found	As Left
Latch Wipe		X	X
Latch Clearance		X	X
Stop Clearance		X	X
Prop. Clearance		X	X
Phase Checked	A	B	C
Contact Gap	X	X	X
Contact Travel	X	X	X
Contact Wipe	X	X	X
Erosion Indicator	X	X	X

Phase Test Data	A	B	C
5 KV Bottle Megohms			
5 KV Open CB	B1	B3	B5
Megohms To Ground	100,000+	100,000+	100,000+
Bushings not under	B2	B4	B6
test were grounded.	100,000+	100,000+	100,000+
5 KV Closed CB	B1 & B2	B3 & B4	B5 & B6
Megohms To Ground	100,000+	100,000+	100,000+
K = *Number Entered Above X 1000*			
Closing/Opening Speed	Visual OK		
Contact Rest. Microhms	239	237	241

HIPOT Tests Microamps 1 Minute Test			
Phase tested	1	2	3
37.5 KV AC. Bottle Test	P	P	P
37.5 KV Closed CB Test	P	P	P
Bottle Test is a Go No Go Test (P = Pass) (F= Fail)			
Closed Test Energize a Phase & Grd. All Others			

Specified Tolerances (If Applicable)	
Latch Wipe	NA
Latch Clearance	NA
Stop Clearance	NA
Prop. Clearance	NA
Contact Gap	NA
Contact Travel	NA
Contact Wipe	NA
Erosion Indicator	NA

Inspection and Maintenance:

Checked Items:	Insp. Item	Found Dirty	Cleaned & Lubed	See Remarks
Vacuum Bottles	X			
Primary Stabs	X			
Ground Stab	X			
Structural Checks	X			
Mech. Conn.	X			
Charging Motor	X			
Closing Springs	X			
Opening Springs	X			
Operation Coils	X			
Auxiliary Devices	X			
Insulating Memb.	X			
Recloser Wiring	X			
Racking Device				
Heater & Lights	X			
Cubicle Wiring	X			
X = *Yes For This Entry*				
Counter Found	644			
Counter Left	670			

Remarks: Results are acceptable.

Submitted by: J Fazio

Equipment Used: DLRO, Megger, HIPOT

10L1 - Vacuum Recloser

Company	UPG	**Serial Number**	1896
Location	Barron Ave Substation	**Special ID**	Breaker 10L1
Division	Liberty Utility	**Circuit Designation**	
Manufacturer	MC-ED	**Type**	VSA
Yr. Manufactured		**Class**	
Mfr. Location	USA	**Mechanism Type**	
Interrupting Rating	12.0 kA	**Mechanism Design**	COIL SPRING
Weight		**BIL**	110 kV
Total Weight	525 LB	**Control Volts**	125
Counter		**Amps**	800
kV	15.5		
Note			

Test Date	8/26/2014	**Test Time**	11:05:30 AM	**Weather**	SUNNY
Air Temperature	35 °C	**Tank Temp.**	°C	**RH.**	34 %
Tested by	JF	**Work Order #**		**Last Test Date**	7/31/2014
Checked by		**Test Set Type**	M4K	**Retest Date**	
Checked Date		**Set Top S/N**		**Reason**	ROUTINE
Last Sheet #		**Set Bottom S/N**		**Travel Time**	
P.O. #		**Ins. Book #**		**Duration**	
Copies		**Sheet #**		**Crew Size**	

Overall Tests

Test Mode	Ph.	Test kV	mA	Watts	IR_{auto}	IR_{man}
GND	1	10.003	0.1820	0.0070	G	
GND	1	10.003	0.1750	0.0110	G	
GND	2	10.004	0.1900	0.0110	G	
GND	2	10.003	0.1840	0.0160	G	
GND	3	10.003	0.1920	0.0060	G	
GND	3	10.005	0.1760	0.0090	G	
UST	1	10.004	0.0370	0.0010	G	
UST	2	10.004	0.0390	0.0050	G	
UST	3	10.003	0.0380	0.0010	G	

Hot Collar Tests

Serial #	ID	Test Mode	Skirt #	Test kV	mA	Watts	IR_{auto}	IR_{man}
	1	GROUND	1	10.005	0.0610	0.0080	G	
	2	GROUND	1	10.007	0.0610	0.0050	G	
	3	GROUND	1	10.006	0.0660	0.0060	G	
	4	GROUND	1	10.006	0.0620	0.0060	G	
	5	GROUND	1	10.007	0.0650	0.0050	G	
	6	GROUND	1	10.007	0.0610	0.0050	G	

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PROTECTIVE RELAY TEST REPORT

		Page No.	
Customer	Liberty Utilities	Date	8/26/14
		Proj. No.	
Address	Salem, NH	Air Temp.	88F
		Rel. Hum.	35%
Owner	Liberty Utilities	Date Last Inspection	By Others
Address	Salem, NH	Last Inspection Report No.	
Equipment Location	Barron Ave. Substation		
Owner Identification	10L1 Recloser		

Circuit Identification 10L1 C.T.Ratio 1000/1 P.T.Ratio

Visual Inspection					Routine Maintenance					
Cover Gasket		X			Glass Cleaned		X			Mfr: Cooper
Glass		X			Case Cleaned		X			Type Ph: Form 3A
Foreign Material		X			Relay Cleaned		X			Cat No:
Moisture		X			Connections Tight		X			Tap Range Ph:
Spiral Spring					Taps Tightened					Tap Range Grd:
Bearing Condition					Contacts Cleaned					Inst. Range Ph:
Bearing End-Play					Insulation Resistance		X			Inst Range Grd:
Disc Clearance					Trip Circuit		X			Use: 51P/51G/79
Rust		X								S/N =

Remarks: Results are acceptable.

Relay Settings

	Reclosing			Inst. Element Setting		Tap Setting		Curve Setting				Time Dial Setting			
	1st	2nd	3rd	50P-1	50G-1	51P	51G	50P-1	50G-1	51P	51G	51P Fast	51G Fast	51P	51G
Specified	5	15	LO			560A	200A					A	1	D	3
As Found	5	15	LO			560A	200A					A	1	D	3
As Left	5	15	LO			560A	200A					A	1	D	3

Test Operations - As Found - Time in Seconds

		Time Element P. U.		Current Voltage Time			Inst. Element Current/Voltage		Targets		Reclosing			
	Zero Set	Tap 1	Tap 2	P. U. X	Tap 1 X2	Tap 2 X4	Pick Up	Delay	LED	Reset	1st	2nd	3rd	4th
A Phase		0.588			1.16	0.254			X	X				
B Phase		0.586			1.13	0.247			X	X	5	15	LO	
C Phase		0.587			1.15	0.248			X	X				
GRD		0.203			6.26	2.36			X	X				

Test Operations - As Left - Time in Seconds

		Time Element P. U.		Current Voltage Time			Inst. Element Current/Voltage		Targets		Reclosing			
	Zero Set	Tap 1	Tap 2	P. U. X	Tap 1 X2	Tap 2 X4	Pick Up	Delay	LED	Reset	1st	2nd	3rd	4th
A Phase		0.588			1.16	0.254			X	X				
B Phase		0.586			1.13	0.247			X	X	5	15	LO	
C Phase		0.587			1.15	0.248			X	X				
GRD		0.203			6.26	2.36			X	X				

Submitted By JF Equipment Used Doble 2253

10L1 - A Phase Voltage Regulator

Company	UPG	**Serial Number**	M168839 PVC
Location	Barron Ave. Substation	**Special ID**	10L1Regulators
Division	Liberty Utilities	**Circuit Designation**	A Phase
Manufacturer	GE	**Type**	VR-1
Yr. Manufactured	2000	**Class**	OA
Mfr. Location	USA		
Tank Type	N2 BLANKETED	**Coolant**	OIL
Phases	1	**BIL**	95 kV
Weight	2790 LB	**Oil Volume**	95 UG
kV	7.96	**Amps**	313
Impedance	%	**VA Rating**	250 kVA
Catalog #		**LTC Counter**	98624
Design	Step	**Ctrl Wire Diameter**	
Catalog/Style		**Crew Size**	
Note			

Test Date	8/27/2014	**Test Time**	7:35:00 AM	**Weather**	SUNNY
Air Temperature	24 °C	**Tank Temp.**	24°C	**RH.**	59 %
Tested by		**Work Order #**		**Last Test Date**	8/1/2014
Checked by		**Test Set Type**	M4K	**Retest Date**	
Checked Date		**Set Top S/N**		**Reason**	ROUTINE
Last Sheet #		**Set Bottom S/N**		**Travel Time**	
P.O. #		**Ins. Book #**		**Duration**	
Copies		**Sheet #**		**Crew Size**	

Overall Tests

Meas.	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
CH	8.003	15.928	3.775	2.37	1.00	4223.8	G	

Hot Collar Tests

Serial #	ID	Test Mode	Skirt #	Test kV	mA	Watts	IR_{auto}	IR_{man}
	S	GROUND	3	10.012	0.0690	0.0240	G	
	L	GROUND	3	10.014	0.0690	0.0310	G	
	SL	GROUND	3	10.012	0.0650	0.0210	G	

Insulation Resistance

Mfr.:	AVO	Serial #:				
kV	**Connection**	**T1(Mohms)**	**T2(Mohms)**	**PI**	**IR_{auto}**	**IR_{man}**
5000	Src/Load to Earth	3200	6100	1.9062	G	

Exciting Current Tests

	Mfr.	Type	Steps	Position Found	Position Left
De-Energized Tap Changer					
On-Load Tap Changer					

	Connections	SA - SL		SB - SL		SC - SL			
LTC	**Test kV**	**mA**	**Watts**	**mA**	**Watts**	**mA**	**Watts**	**IR_{auto}**	**IR_{man}**
1L	2.500	504.32	792.04						
N	2.500	852.15	856.43						
1R	2.501	501.95	824.77						
2R	2.500	851.27	871.76						
3R	2.501	502.12	816.97						
4R	2.502	852.36	900.32						
5R	2.502	849.18	922.24						
6R	2.502	852.70	905.43						
7R	2.500	502.95	820.01						
8R	2.502	853.18	907.52						
9R	2.503	504.92	847.34						
10R	2.500	853.11	891.57						
11R	2.500	503.78	824.60						
12R	2.503	853.83	919.61						
13R	2.500	850.87	902.72						
14R	2.501	853.13	902.59						
15R	2.499	504.35	819.84						
16R	2.501	853.06	893.12						

10L1 – B Phase Voltage Regulator

Company	UPG	**Serial Number**	M168838 PVC
Location	Barron Ave. Substation	**Special ID**	10L1Regulators
Division	Liberty Utilities	**Circuit Designation**	B Phase
Manufacturer	GE	**Type**	VR-1
Yr. Manufactured	2000	**Class**	OA
Mfr. Location	USA		
Tank Type	N2 BLANKETED	**Coolant**	OIL
Phases	1	**BIL**	95 kV
Weight	2790 LB	**Oil Volume**	95 UG
kV	7.96	**Amps**	313
Impedance	%	**VA Rating**	250 kVA
Catalog #		**LTC Counter**	98624
Design	Step	**Ctrl Wire Diameter**	
Catalog/Style		**Crew Size**	
Note			

Test Date	8/27/2014	**Test Time**	7:35:00 AM	**Weather**	SUNNY
Air Temperature	24 °C	**Tank Temp.**	24°C	**RH.**	59 %
Tested by	JF	**Work Order #**		**Last Test Date**	8/1/2014
Checked by		**Test Set Type**	M4K	**Retest Date**	
Checked Date		**Set Top S/N**		**Reason**	ROUTINE
Last Sheet #		**Set Bottom S/N**		**Travel Time**	
P.O. #		**Ins. Book #**		**Duration**	
Copies		**Sheet #**		**Crew Size**	

Overall Tests

Meas.	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
CH	8.009	15.110	2.741	1.81	1.00	4007.2	G	

Hot Collar Tests

Serial #	ID	Test Mode	Skirt #	Test kV	mA	Watts	IR_{auto}	IR_{man}
	S	GROUND	3	10.011	0.0720	0.0260	G	
	L	GROUND	3	10.014	0.0660	0.0310	G	
	SL	GROUND	3	10.012	0.0660	0.0300	G	

Insulation Resistance

Mfr.:	AVO	Serial #:				
kV	**Connection**	**T1(Mohms)**	**T2(Mohms)**	**PI**	**IR_{auto}**	**IR_{man}**
5000	Src/Load to Earth	8600	13400	1.5581	G	

Exciting Current Tests

	Mfr.	Type	Steps	Position Found	Position Left
De-Energized Tap Changer					
On-Load Tap Changer					

	Connections	SA - SL		SB - SL		SC - SL			
LTC	**Test kV**	**mA**	**Watts**	**mA**	**Watts**	**mA**	**Watts**	**IR_{auto}**	**IR_{man}**
1L	2.501	513.71	784.42						
N	2.502	863.16	883.66						
1R	2.500	510.79	801.35						
2R	2.502	862.19	889.40						
3R	2.503	512.35	835.33						
4R	2.500	862.91	869.66						
5R	2.501	859.01	897.53						
6R	2.502	862.84	899.14						
7R	2.504	513.60	845.59						
8R	2.501	863.50	895.13						
9R	2.500	512.98	813.39						
10R	2.502	863.31	897.76						
11R	2.500	513.21	813.64						
12R	2.501	863.61	889.59						
13R	2.501	862.06	910.00						
14R	2.502	863.77	912.19						
15R	2.500	514.03	816.40						
16R	2.502	863.93	902.15						

10L1 – C Phase Voltage Regulator

Company	UPG	**Serial Number**	M168837 PVC
Location	Barron Ave. Substation	**Special ID**	10L1Regulators
Division	Liberty Utilities	**Circuit Designation**	C Phase
Manufacturer	GE	**Type**	VR-1
Yr. Manufactured	2000	**Class**	OA
Mfr. Location	USA		
Tank Type	N2 BLANKETED	**Coolant**	OIL
Phases	1	**BIL**	95 kV
Weight	2790 LB	**Oil Volume**	95 UG
kV	7.96	**Amps**	313
Impedance	%	**VA Rating**	250 kVA
Catalog #		**LTC Counter**	98624
Design	Step	**Ctrl Wire Diameter**	
Catalog/Style		**Crew Size**	
Note			

Test Date	8/27/2014	**Test Time**	7:46:31 AM	**Weather**	SUNNY
Air Temperature	23 °C	**Tank Temp.**	23°C	**RH.**	59 %
Tested by		**Work Order #**		**Last Test Date**	8/27/2014
Checked by		**Test Set Type**	M4K	**Retest Date**	
Checked Date		**Set Top S/N**		**Reason**	ROUTINE
Last Sheet #		**Set Bottom S/N**		**Travel Time**	
P.O. #		**Ins. Book #**		**Duration**	
Copies		**Sheet #**		**Crew Size**	

Overall Tests

Meas.	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
CH	8.004	16.483	4.126	2.50	1.00	4371.0	G	

Hot Collar Tests

Serial #	ID	Test Mode	Skirt #	Test kV	mA	Watts	IR_{auto}	IR_{man}
	S	GROUND	3	10.011	0.0730	0.0380	G	
	L	GROUND	3	10.014	0.0680	0.0280	G	
	SL	GROUND	3	10.010	0.0640	0.0360	G	

Insulation Resistance

Mfr.:	AVO	Serial #:				
kV	**Connection**	**T1(Mohms)**	**T2(Mohms)**	**PI**	**IR_{auto}**	**IR_{man}**
5000	Src/Load to Earth	4890	7220	1.4765		G

Exciting Current Tests

	Mfr.	Type	Steps	Position Found	Position Left
De-Energized Tap Changer					
On-Load Tap Changer					

	Connections	SA - SL		SB - SL		SC - SL			
LTC	**Test kV**	**mA**	**Watts**	**mA**	**Watts**	**mA**	**Watts**	**IR_{auto}**	**IR_{man}**
1L	2.515	531.36	845.75						
N	2.509	892.74	923.63						
1R	2.500	526.14	787.71						
2R	2.502	888.78	876.65						
3R	2.500	526.26	789.59						
4R	2.500	888.19	853.04						
5R	2.500	884.38	874.44						
6R	2.503	889.94	893.95						
7R	2.501	527.56	807.78						
8R	2.501	889.12	867.20						
9R	2.500	527.55	792.53						
10R	2.502	889.62	882.03						
11R	2.501	528.06	807.26						
12R	2.501	889.55	872.37						
13R	2.500	887.03	870.17						
14R	2.500	889.19	852.58						
15R	2.501	528.70	807.44						
16R	2.500	889.34	853.53						

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				Page No.	
Customer	Liberty Utilities	Date	8/27/2014	Proj. No.	
Address	Salem, NH	Air Temp.	85F	Rel. Hum.	54%
Owner	Liberty Utilities	Date Last Inspection	By Others		
Address	Salem, NH	Last Inspection Report No.			

Equipment Location: Barron Ave.
Owner Identification: 10L1

Manuf.	GE	Type	VR1	Test Set#	TTR-JF
Gallons	95	Oil Levels	OK	KVA	250

Nameplate Voltage	7960
Line to Line Voltage	
Percent Regulation	5/8%

Ser # A	M168839 PVC
Ser # B	M168838 PVC
Ser # C	M168837 PVC

Doble Factor	Power Results
Test KV	8
Position	N

Tap Position	Tap Voltage	TTR Ratio	TTR MEASURED VALUES: S-SL A / L-SL A	S-SL B / L-SL B	S-SL C / L-SL C
16R	8756	0.909	0.904	0.906	0.906
15R	8706	0.914	0.912	0.912	0.912
14R	8657	0.920	0.917	0.917	0.917
13R	8607	0.925	0.923	0.923	0.923
12R	8557	0.930	0.929	0.929	0.929
11R	8507	0.936	0.934	0.934	0.934
10R	8458	0.941	0.941	0.941	0.941
9R	8408	0.947	0.946	0.946	0.946
8R	8358	0.952	0.951	0.951	0.951
7R	8308	0.958	0.957	0.957	0.957
6R	8259	0.964	0.962	0.962	0.962
5R	8209	0.970	0.969	0.969	0.969
4R	8159	0.976	0.976	0.976	0.976
3R	8109	0.982	0.982	0.982	0.982
2R	8060	0.988	0.988	0.988	0.988
1R	8010	0.994	0.994	0.994	0.994
N	7960	1.000	1.000	1.000	1.000
1L	7910	1.006	1.006	1.006	1.006
2L	7861	1.013	1.013	1.013	1.013
3L	7811	1.019	1.019	1.019	1.019
4L	7761	1.026	1.025	1.025	1.025
5L	7711	1.032	1.033	1.033	1.033
6L	7662	1.039	1.041	1.041	1.041
7L	7612	1.046	1.047	1.047	1.047
8L	7562	1.053	1.054	1.054	1.054
9L	7512	1.060	1.061	1.061	1.061
10L	7463	1.067	1.068	1.068	1.068
11L	7413	1.074	1.075	1.075	1.075
12L	7363	1.081	1.082	1.082	1.082
13L	7313	1.088	1.091	1.091	1.091
14L	7264	1.096	1.099	1.099	1.099
15L	7214	1.103	1.107	1.107	1.107
16L	7164	1.111	1.115	1.115	1.115

Remarks: Regulator test results are acceptable.

United Power Group, Inc.

Liberty Utilities
9 Lowell Road
Salem, NH 03079

Date. 9/18/14
Project No.

Project Location:

Barron Ave. Substation

Scope:

Perform testing & maintenance on the following equipment:
1. 10L4 Transformer
2. 10L4 Recloser and Form 6 Controller
3. 10L4 Voltage Regulators

Remarks:

1. Transformer 10L4's X1 and X2 bushings are showing signs of deterioration. UPG would like to see past test data for the transformer. There is also signs of oil leaking around the bottom valve. A closer look will be taken when the oil sample is extracted.
2. Recloser 10L4 and form 6 controller test results are acceptable for service.
3. Voltage regulators 10L4 test results are acceptable for service.

Submitted by: James Fazio

Transformer 10L4 – Doble Test

Company	UPG	**Serial Number**	G-853504
Location	Barron Ave. Substation	**Special ID**	Transformer - 10L4
Division	Liberty Utilities	**Circuit Designation**	
Manufacturer	GE	**Configuration**	Y-Y
Year Mfg.		**Tank Type**	OTHER
Mfr. Location	USA	**Coolant**	OIL
Phases	3	**Class**	OA/FA
Oil Volume	1010 UG	**BIL**	110 kV
Weight	35700 LB	**Winding Config.**	Wye-Wye
kV	22.9, 7.97	**VA Rating**	, , 5000, 6250 kVA
Note			

Test Date	9/17/2014	**Test Time**	9:31:01 AM	**Weather**	
Air Temperature	22 °C	**Tank Temp.**	°C	**RH.**	40 %
Tested by	JF/MH	**Work Order #**		**Last Test Date**	8/26/2014
Checked by		**Test Set Type**	M4K	**Retest Date**	
Checked Date		**Set Top S/N**		**Reason**	ROUTINE
Last Sheet #		**Set Bottom S/N**		**Travel Time**	
P.O. #		**Ins. Book #**		**Duration**	
Copies		**Sheet #**		**Crew Size**	

Bushing Nameplate

Dsg	Serial	Mfr	Type	C1 %PF	C1 Cap	C2 %PF	C2 Cap	kV	Amps	Year
H2	8T01120505	A-BB	O+C	0.36	535	0.30	431	25	400	1998
H3	8T01120509	A-BB	O+C	0.37	530	0.33	425	25	400	1998
X1	1715668	GE	U	0.30	444			16	400	1971
X2	1715669	GE	U	0.31	446			16	400	1971
XO	1715667	GE	U	0.32	447			16	400	1971
X3	1583864	GE	U	0.28	439			16	400	1965
H1	8T01120504	A-BB	O+C	0.36	533	0.42	430	25	400	1998

Overall Tests

Meas.	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
CH + CHL	8.001	31.693	1.101		1.00	8406.7		
CH	8.001	31.689	1.102	0.35	1.00	8405.6	G	

Bushing C1

ID	Serial	NP %PF	NP Cap	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
H1	8T01120504	0.36	533	10.002	2.016	0.0790	0.39	1.00	534.65	G	
H2	8T01120505	0.36	535	10.002	1.923	0.0710	0.37	1.00	537.03	G	
H3	8T01120509	0.37	530	10.002	1.905	0.0740	0.39	1.00	531.98	G	
X1	1715668	0.30	444	8.001	1.684	0.1120	0.67	1.00	446.74	D	
X2	1715669	0.31	446	8.002	1.598	0.0950	0.59	1.00	446.09	D	
X3	1583864	0.28	439	8.001	1.577	0.0550	0.35	1.00	440.27	G	
XO	1715667	0.32	447	8.002	1.598	0.0570	0.36	1.00	446.19	G	

Bushing C2

ID	Serial #	NP %PF	NP Cap	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
H1	8T01120504	0.42	430	0.5000	1.568	0.0480	0.31	1.00	437.81	G	
H2	8T01120505	0.30	431	0.5000	1.566	0.0360	0.23	1.00	437.33	G	
H3	8T01120509	0.33	425	0.5000	1.553	0.0350	0.23	1.00	433.74	G	

Insulation Resistance

Mfr.		Serial #	

Connection	Volts	T1(Mohms)	T2(Mohms)	PI
Hi to Lo/Earth	5000	4900	11900	2.4286

Exciting Current Tests

	Mfr.	Type	Steps	Boost %	Buck %	Position Found	Position Left	Oil Volume
De-Energized Tap Changer								
On-Load Tap Changer								

			H1 - H0			H2 - H0			H3 - H0				
DETC	LTC	Test kV	mA	Watts	X	mA	Watts	X	mA	Watts	X	IR_{auto}	IR_{man}
	3	8.024	122.55	1051.2	L	83.382	736.15	L	118.43	1032.3	L	G	

Turns Ratio (H-L) Tests

Mfr	Serial #	HV Winding	LV Winding
		L-N	L-N
Connections	**H1 - H0**	**H2 - H0**	**H3 - H0**
	X1 - X0	**X2 - X0**	**X3 - X0**

Tap	Np Volt	Tap	Np Volt	Cal	Ratio 1	Ratio 2	Ratio 3	Min Lim	Max Lim	IR_{auto}	IR_{man}
2	13570		7970	1.703	1.745	1.745	1.744				G

United Power Group, Inc.

		Page No.	
Customer	Liberty Utilities	Date 9/17/2014	Project No.
Address	Salem, NH	Air Temp. 14C	Rel. Humidity 37%
Owner	Liberty Utilities	Date Last Inspection	By Others
Address	Salem, NH	Last Inspection Report No.	

Equipment Location: Barron Ave. Substation
Owner Identification: Transformer 10L4

Nameplate Information

Manufacturer	GE	KVA	5000/6250	Phase	3	Cycle	60
Serial No.	G-853504	Type	Power	Form		Class	OA
Primary Voltage	13.57kV	Delta	Wye X	Rated Current	123	Amperes	
Secondary Voltage	7.97kV	Delta	Wye X	Rated Current	209	Amperes	
Coolant Oil	X	Askarel	Air	Nitrogen		Other	
Coolant Capacity - Units		Main Tank	1010UG	LTC		Switch	
Temperature Rise		Date of Manufacture		Impedance	3.21%		
No Load Tap Changer Voltages	24100/23500/22900/22300/21700						

Gauges and Counters	Measured	Maximum	Reset	Trip	Alarm
Oil Temperature	25C	60C	X		
Wdg. Temperature			X		
Pressure	1+				
Oil Level	25C				

LTC	Measured	Max.	Min.
Tap	NA		
Counter	NA		

Visual Inspection			
Primary Connection	OK	Secondary Connections	OK
Tap Connections	OK	Leaks	Bottom Valve
Gas Regulator	NA	Paint	OK
Infra-Red Inspection	NA	Grounds	OK

Fans and Controls	Oil Temp.	Wdg. Temp.	Manual	Auto	Lubrication Date
Stage 1	60C		X	X	
Stage 2					

Accessory Inspection	Alarm	Trip
Pressure Relief Device - Main Tank		
Pressure Relief Device - LTC		
Sudden Pressure Device		

Additional Tests

Remarks: Oil leak on bottom valve.

Submitted By: JF

10L4 - Vacuum Recloser

Company	UPG	**Serial Number**	CP571172094
Location	Barron Ave Substation	**Special ID**	Breaker 10L4
Division	Liberty Utility	**Circuit Designation**	
Manufacturer	KYLE	**Type**	OTHER
Yr. Manufactured		**Class**	
Mfr. Location	USA	**Mechanism Type**	
Interrupting Rating	12.0 kA	**Mechanism Design**	COIL SPRING
Weight		**BIL**	110 kV
Total Weight	525 LB	**Control Volts**	125
Counter		**Amps**	800
kV	15.5		
Note			

Test Date	9/17/2014	**Test Time**	12:36:43 PM	**Weather**	
Air Temperature	26 °C	**Tank Temp.**	°C	**RH.**	26 %
Tested by		**Work Order #**		**Last Test Date**	8/26/2014
Checked by		**Test Set Type**	M4K	**Retest Date**	
Checked Date		**Set Top S/N**		**Reason**	ROUTINE
Last Sheet #		**Set Bottom S/N**		**Travel Time**	
P.O. #		**Ins. Book #**		**Duration**	
Copies		**Sheet #**		**Crew Size**	

Overall Tests

Test Mode	Ph.	Test kV	mA	Watts	IR_{auto}	IR_{man}
GND	1	10.002	0.2240	0.0030		G
GND	1	9.306	0.2010	0.0080		G
GND	2	10.002	0.2230	0.0030		G
GND	2	10.002	0.2060	0.0090		G
GND	3	10.002	0.2230	0.0020		G
GND	3	10.001	0.2000	0.0080		G
UST	1	10.001	0.0490	0.0000		G
UST	2	10.001	0.0490	0.0000		G
UST	3	10.002	0.0490	0.0000		G

Hot Collar Tests

Serial #	ID	Test Mode	Skirt #	Test kV	mA	Watts	IR_{auto}	IR_{man}
	1	GROUND	1	10.007	0.0730	0.0140	G	
	2	GROUND	1	10.008	0.0780	0.0150	G	
	3	GROUND	1	10.007	0.0770	0.0100	G	
	4	GROUND	1	10.008	0.0720	0.0150	G	
	5	GROUND	1	10.007	0.0640	0.0170	G	
	6	GROUND	1	10.007	0.0730	0.0130	G	

United Power Group, Inc.

VACUUM RECLOSER TEST AND INSPECTION REPORT

				Page No.	
Customer	Liberty Utilities	Date	9/17/2014	Project No.	
Address	Salem, NH	Air Temp.	70F	Rel. Humidity	38%
Owner	Liberty Utilities	Date Last Inspection			
Address	Salem, NH	Last Inspection Report No.			
Equipment Location	Barron Ave.				
Owner Identification	Recloser 10L4				

Breaker Nameplate Data:

Manufacturer	Kyle	Type	VSA-12		
Serial No.	CP571172094	Type Operating Mechanism	Coil Spring		
Amperes	800	Age			
Interrupt. Rating	12kA	KV	15.5		

Adjustment Checks	Mfr's Rec.	As Found	As Left
Latch Wipe		X	X
Latch Clearance		X	X
Stop Clearance		X	X
Prop. Clearance		X	X
Phase Checked	A	B	C
Contact Gap	X	X	X
Contact Travel	X	X	X
Contact Wipe	X	X	X
Erosion Indicator	X	X	X

Phase Test Data	A	B	C
5 KV Bottle Megohms			
5 KV Open CB	B1	B3	B5
Megohms To Ground	100,000+	100,000+	100,000+
Bushings not under	B2	B4	B6
test were grounded.	100,000+	100,000+	100,000+
5 KV Closed CB	B1 & B2	B3 & B4	B5 & B6
Megohms To Ground	100,000+	100,000+	100,000+
K = *Number Entered Above X 1000*			
Closing/Opening Speed	Visual OK		
Contact Rest. Microhms	169	166	168

HIPOT Tests Microamps 1 Minute Test			
Phase tested	1	2	3
37.5 KV AC. Bottle Test	P	P	P
37.5 KV Closed CB Test	P	P	P
Bottle Test is a Go No Go Test (P = Pass) (F= Fail)			
Closed Test Energize a Phase & Grd. All Others			

Specified Tolerances (If Applicable)	
Latch Wipe	NA
Latch Clearance	NA
Stop Clearance	NA
Prop. Clearance	NA
Contact Gap	NA
Contact Travel	NA
Contact Wipe	NA
Erosion Indicator	NA

Inspection and Maintenance:

Checked Items:	Insp. Item	Found Dirty	Cleaned & Lubed	See Remarks
Vacuum Bottles	X			
Primary Stabs	X			
Ground Stab	X			
Structural Checks	X			
Mech. Conn.	X			
Charging Motor	X			
Closing Springs	X			
Opening Springs	X			
Operation Coils	X			
Auxiliary Devices	X			
Insulating Memb.	X			
Recloser Wiring	X			
Racking Device				
Heater & Lights	X			
Cubicle Wiring	X			
X = *Yes For This Entry*				
Counter Found	58			
Counter Left	74			

Remarks: Results are acceptable.

Submitted by: J Fazio

Equipment Used: DLRO, Megger, HIPOT

United Power Group, Inc.

PROTECTIVE RELAY TEST REPORT

		Page No.	
Customer	Liberty Utilities	Date	9/17/14
		Proj. No.	
Address	Salem, NH	Air Temp.	70F
		Rel. Hum.	30%
Owner	Liberty Utilities	Date Last Inspection	By Others
Address	Salem, NH	Last Inspection Report No.	
Equipment Location	Barron Ave. Substation		
Owner Identification	10L4 Recloser		

Circuit Identification 10L4 C.T.Ratio 1000/1 P.T.Ratio

Visual Inspection					Routine Maintenance					
Cover Gasket		X			Glass Cleaned		X			Mfr: Cooper
Glass		X			Case Cleaned		X			Type Ph: Form F6
Foreign Material		X			Relay Cleaned		X			Cat No:
Moisture		X			Connections Tight		X			Tap Range Ph: 5-3200A
Spiral Spring					Taps Tightened					Tap Range Grd: 2-1600A
Bearing Condition					Contacts Cleaned					Inst. Range Ph:
Bearing End-Play					Insulation Resistance		X			Inst Range Grd:
Disc Clearance					Trip Circuit		X			Use: 51P/51G/79
Rust		X								S/N =

Remarks: Results are acceptable.

Relay Settings

	Reclosing			Inst. Element Setting		Tap Setting		Curve Setting				Time Dial Setting			
	1st	2nd	3rd	50P-1	50G-1	51P	51G	50P-1	50G-1	51P	51G	50P-1	50G-1	51P	51G
Specified	5	5	LO			720A	280A							133	140
As Found	5	5	LO			720A	280A							133	140
As Left	5	5	LO			720A	280A							133	140

Test Operations - As Found - Time in Seconds

		Time Element P. U.		Current Voltage Time			Inst. Element Current/Voltage		Targets		Reclosing			
	Zero Set	Tap 1	Tap 2	P. U. X	Tap 1 X3	Tap 2 X5	Pick Up	Delay	LED	Reset	1st	2nd	3rd	4th
A Phase		0.723			1.35	0.528			X	X				
B Phase		0.725			1.36	0.524			X	X	5	5	LO	
C Phase		0.726			1.35	0.529			X	X				
GRD		0.284			3.30	1.89			X	X	5	5	LO	

Test Operations - As Left - Time in Seconds

		Time Element P. U.		Current Voltage Time			Inst. Element Current/Voltage		Targets		Reclosing			
	Zero Set	Tap 1	Tap 2	P. U. X	Tap 1 X3	Tap 2 X5	Pick Up	Delay	LED	Reset	1st	2nd	3rd	4th
A Phase		0.723			1.35	0.528			X	X				
B Phase		0.725			1.36	0.524			X	X	5	5	LO	
C Phase		0.726			1.35	0.529			X	X				
GRD		0.284			3.30	1.89			X	X	5	5	LO	

Submitted By JF Equipment Used Doble 2253

10L4 - A Phase Voltage Regulator

Company	UPG	**Serial Number**	M044407PFN
Location	Barron Ave. Substation	**Special ID**	10L4 Regulators
Division	Liberty Utilities	**Circuit Designation**	A Phase
Manufacturer	GE	**Type**	ML-32
Yr. Manufactured	1986	**Class**	OA
Mfr. Location	USA		
Tank Type	N2 BLANKETED	**Coolant**	OIL
Phases	1	**BIL**	95 kV
Weight	2790 LB	**Oil Volume**	95 UG
kV	7.96	**Amps**	313
Impedance	%	**VA Rating**	250 kVA
Catalog #		**LTC Counter**	258007
Design	Step	**Ctrl Wire Diameter**	
Catalog/Style		**Crew Size**	
Note			

Test Date	9/18/2014	**Test Time**	8:33:18 AM	**Weather**	SUNNY
Air Temperature	16 °C	**Tank Temp.**	°C	**RH.**	60 %
Tested by	JF	**Work Order #**		**Last Test Date**	8/27/2014
Checked by		**Test Set Type**	M4K	**Retest Date**	
Checked Date		**Set Top S/N**		**Reason**	ROUTINE
Last Sheet #		**Set Bottom S/N**		**Travel Time**	
P.O. #		**Ins. Book #**		**Duration**	
Copies		**Sheet #**		**Crew Size**	

Overall Tests

Meas.	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
CH	8.001	11.093	1.172	1.06	1.00	2942.4	G	

Hot Collar Tests

Serial #	ID	Test Mode	Skirt #	Test kV	mA	Watts	IR_{auto}	IR_{man}
	S	GROUND	3	10.013	0.0670	0.0130	G	
	L	GROUND	3	10.014	0.0680	0.0130	G	
	SL	GROUND	3	10.013	0.0610	0.0100	G	

Insulation Resistance

Mfr.:	AV0	Serial #:				
kV	**Connection**	**T1(Mohms)**	**T2(Mohms)**	**PI**	**IR_{auto}**	**IR_{man}**
5000	Src/Load to Earth	14500	26700	1.8414	G	

Exciting Current Tests

	Mfr.	Type	Steps	Position Found	Position Left
De-Energized Tap Changer					
On-Load Tap Changer					

	Connections	SA - SL		SB - SL		SC - SL			
LTC	**Test kV**	**mA**	**Watts**	**mA**	**Watts**	**mA**	**Watts**	**IR_{auto}**	**IR_{man}**
1L	2.500	402.14	1045.1						
N	2.499	1377.1	1286.8						
1R	2.500	401.39	1046.8						
2R	2.498	1376.7	1285.4						
3R	2.500	805.25	1161.8						
4R	2.499	1376.9	1286.7						
5R	2.500	401.82	1046.7						
6R	2.500	1376.4	1286.3						
7R	2.499	805.09	1162.6						
8R	2.499	1376.5	1286.8						
9R	2.500	402.09	1048.4						
10R	2.499	1376.4	1287.5						
11R	2.499	805.57	1164.9						
12R	2.499	1376.5	1288.1						
13R	2.500	402.34	1050.6						
14R	2.499	1377.4	1289.6						
15R	2.500	805.67	1169.1						
16R	2.499	1376.7	1290.4						

10L4 – B Phase Voltage Regulator

Company	UPG	**Serial Number**	M046769PCP
Location	Barron Ave. Substation	**Special ID**	10L4 Regulators
Division	Liberty Utilities	**Circuit Designation**	B Phase
Manufacturer	GE	**Type**	MLT-32
Yr. Manufactured	1986	**Class**	OA
Mfr. Location	USA		
Tank Type	N2 BLANKETED	**Coolant**	OIL
Phases	1	**BIL**	95 kV
Weight	2790 LB	**Oil Volume**	95 UG
kV	7.96	**Amps**	313
Impedance	%	**VA Rating**	250 kVA
Catalog #		**LTC Counter**	533046
Design	Step	**Ctrl Wire Diameter**	
Catalog/Style		**Crew Size**	
Note			

Test Date	9/18/2014	**Test Time**	8:54:10 AM	**Weather**	SUNNY
Air Temperature	17 °C	**Tank Temp.**	°C	**RH.**	55 %
Tested by	JF	**Work Order #**		**Last Test Date**	8/27/2014
Checked by		**Test Set Type**	M4K	**Retest Date**	
Checked Date		**Set Top S/N**		**Reason**	ROUTINE
Last Sheet #		**Set Bottom S/N**		**Travel Time**	
P.O. #		**Ins. Book #**		**Duration**	
Copies		**Sheet #**		**Crew Size**	

Overall Tests

Meas.	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
CH	8.001	12.151	2.242	1.85	1.00	3222.6	G	

Hot Collar Tests

Serial #	ID	Test Mode	Skirt #	Test kV	mA	Watts	IR_{auto}	IR_{man}
	S	GROUND	3	10.011	0.0680	0.0100	G	
	L	GROUND	3	10.015	0.0720	0.0100	G	
	SL	GROUND	3	10.012	0.0590	0.0150	G	

Insulation Resistance

Mfr.:	AV0	Serial #:				
kV	**Connection**	**T1(Mohms)**	**T2(Mohms)**	**PI**	**IR_{auto}**	**IR_{man}**
5000	Src/Load to Earth	6320	14500	2.2943		

Exciting Current Tests

	Mfr.	Type	Steps	Position Found	Position Left
De-Energized Tap Changer					
On-Load Tap Changer					

	Connections	SA - SL		SB - SL		SC - SL			
LTC	**Test kV**	**mA**	**Watts**	**mA**	**Watts**	**mA**	**Watts**	**IR_{auto}**	**IR_{man}**
1L	2.500	380.98	1048.9						
N	2.500	1287.6	1303.2						
1R	2.500	380.11	1046.7						
2R	2.500	1287.2	1303.8						
3R	2.500	754.57	1166.3						
4R	2.500	1287.6	1304.0						
5R	2.500	380.64	1045.7						
6R	2.500	1288.2	1305.0						
7R	2.500	755.29	1167.3						
8R	2.500	1287.8	1306.0						
9R	2.500	381.08	1048.7						
10R	2.500	1288.2	1307.2						
11R	2.499	755.66	1170.6						
12R	2.499	1288.2	1308.5						
13R	2.500	381.37	1051.2						
14R	2.500	1288.6	1310.5						
15R	2.499	756.11	1176.7						
16R	2.500	1288.8	1314.2						

10L4 – C Phase Voltage Regulator

Company	UPG	**Serial Number**	M044399PFN
Location	Barron Ave. Substation	**Special ID**	10L4 Regulators
Division	Liberty Utilities	**Circuit Designation**	C Phase
Manufacturer	GE	**Type**	ML-32
Yr. Manufactured	1986	**Class**	OA
Mfr. Location	USA		
Tank Type	N2 BLANKETED	**Coolant**	OIL
Phases	1	**BIL**	95 kV
Weight	2790 LB	**Oil Volume**	95 UG
kV	7.96	**Amps**	313
Impedance	%	**VA Rating**	250 kVA
Catalog #		**LTC Counter**	426012
Design	Step	**Ctrl Wire Diameter**	
Catalog/Style		**Crew Size**	
Note			

Test Date	9/18/2014	**Test Time**	9:20:05 AM	**Weather**	SUNNY
Air Temperature	19 °C	**Tank Temp.**	°C	**RH.**	47 %
Tested by	JF	**Work Order #**		**Last Test Date**	8/27/2014
Checked by		**Test Set Type**	M4K	**Retest Date**	
Checked Date		**Set Top S/N**		**Reason**	ROUTINE
Last Sheet #		**Set Bottom S/N**		**Travel Time**	
P.O. #		**Ins. Book #**		**Duration**	
Copies		**Sheet #**		**Crew Size**	

Overall Tests

Meas.	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
CH	8.001	12.102	2.191	1.81	1.00	3209.6	G	

Hot Collar Tests

Serial #	ID	Test Mode	Skirt #	Test kV	mA	Watts	IR_{auto}	IR_{man}
	S	GROUND	3	10.011	0.0650	0.0060	G	
	L	GROUND	3	10.015	0.0670	0.0080	G	
	SL	GROUND	3	10.012	0.0580	0.0050	G	

Insulation Resistance

Mfr.:	AVO	Serial #:				
kV	**Connection**	**T1(Mohms)**	**T2(Mohms)**	**PI**	**IR_{auto}**	**IR_{man}**
5000	Src/Load to Earth	12700	27800	2.189		

Exciting Current Tests

	Mfr.	Type	Steps	Position Found	Position Left
De-Energized Tap Changer					
On-Load Tap Changer					

	Connections	SA - SL		SB - SL		SC - SL			
LTC	**Test kV**	**mA**	**Watts**	**mA**	**Watts**	**mA**	**Watts**	**IR_{auto}**	**IR_{man}**
1L	2.501	411.41	1059.7						
N	2.500	1376.3	1303.3						
1R	2.500	410.61	1059.3						
2R	2.499	1376.3	1303.8						
3R	2.500	810.33	1176.6						
4R	2.500	1376.6	1303.8						
5R	2.500	411.25	1059.1						
6R	2.500	1376.6	1303.1						
7R	2.500	810.99	1176.9						
8R	2.499	1377.0	1303.9						
9R	2.499	411.57	1060.8						
10R	2.500	1376.6	1304.1						
11R	2.500	810.99	1179.2						
12R	2.500	1376.7	1305.7						
13R	2.500	411.88	1063.7						
14R	2.500	1376.8	1307.3						
15R	2.499	811.02	1183.2						
16R	2.500	1376.6	1308.5						

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				Page No.	
Customer	Liberty Utilities	Date	9/18/2014	Proj. No.	
Address	Salem, NH	Air Temp.	55F	Rel. Hum.	37%
Owner	Liberty Utilities	Date Last Inspection	By Others		
Address	Salem, NH	Last Inspection Report No.			

Equipment Location: Barron Ave.
Owner Identification: 10L4 Regulators

Manuf.	GE	Type	VR1	Test Set#	TTR-JF
Gallons	95	Oil Levels	OK	KVA	250

Nameplate Voltage	7960
Line to Line Voltage	
Percent Regulation	5/8%

Ser # A	M044407PFN
Ser # B	M046769PCP
Ser # C	M044399PFN

Doble Factor	Power Results
Test KV	8
Position	N

Tap Position	Tap Voltage	TTR Ratio	TTR MEASURED VALUES:		
			S-SL A	S-SL B	S-SL C
			L-SL A	L-SL B	L-SL C
16R	8756	0.909	0.904	0.905	0.905
15R	8706	0.914	0.912	0.912	0.912
14R	8657	0.920	0.917	0.918	0.917
13R	8607	0.925	0.925	0.921	0.923
12R	8557	0.930	0.929	0.928	0.929
11R	8507	0.936	0.934	0.933	0.933
10R	8458	0.941	0.941	0.941	0.939
9R	8408	0.947	0.945	0.946	0.946
8R	8358	0.952	0.951	0.952	0.951
7R	8308	0.958	0.957	0.956	0.957
6R	8259	0.964	0.964	0.962	0.963
5R	8209	0.970	0.969	0.968	0.969
4R	8159	0.976	0.975	0.976	0.976
3R	8109	0.982	0.982	0.982	0.981
2R	8060	0.988	0.987	0.989	0.988
1R	8010	0.994	0.994	0.995	0.994
N	7960	1.000	1.000	1.001	1.000
1L	7910	1.006	1.007	1.007	1.006
2L	7861	1.013	1.013	1.013	1.013
3L	7811	1.019	1.02	1.019	1.019
4L	7761	1.026	1.025	1.024	1.025
5L	7711	1.032	1.032	1.034	1.033
6L	7662	1.039	1.041	1.041	1.042
7L	7612	1.046	1.047	1.047	1.048
8L	7562	1.053	1.055	1.055	1.054
9L	7512	1.060	1.061	1.061	1.062
10L	7463	1.067	1.069	1.068	1.068
11L	7413	1.074	1.076	1.076	1.075
12L	7363	1.081	1.083	1.082	1.082
13L	7313	1.088	1.092	1.092	1.093
14L	7264	1.096	1.099	1.101	1.099
15L	7214	1.103	1.109	1.107	1.107
16L	7164	1.111	1.117	1.116	1.115

Remarks: Regulator test results are acceptable.

United Power Group, Inc.

Liberty Utilities
9 Lowell Road
Salem, NH 03079

Date. 8/1/14
Project No.

Project Location:

Salem Depot Substation

Scope:

Perform testing & maintenance on the following equipment:
1. Transformer 9T3
2. Transformer 9L1T
3. 9L3 Recloser and Form 6 Controller
4. 9L3 Voltage Regulators

Remarks:

1. Transformer 9T3's H3 bushing is showing signs of deterioration; the bushing's power factor value has doubled and needs to be replaced. The oil temperature and tank pressure gauges are in poor condition. UPG also recommends replacing both gauges.
2. Transformer 9L1T test results are acceptable for service.
3. Recloser 9L3 and form 6 controller test results are acceptable for service.
4. Voltage regulator 9L3 "A phase" stopped operating on the 15L tap. It was discovered that the limit switch located in the regulator tap indication gauge was misaligned. Adjustments were made and the regulator operated correctly. All other test results are acceptable.

Submitted by: James Fazio

9T3- Two-winding Transformer

Company	UPG	**Serial Number**	M 160691
Location	Salem Depot Substation	**Special ID**	Transformer - 9T3
Division	Liberty Utilities	**Circuit Designation**	
Manufacturer	GE	**Configuration**	D-ZZY
Year Mfg.		**Tank Type**	OTHER
Mfr. Location	USA	**Coolant**	OIL
Phases	3	**Class**	OA/FA
Oil Volume	1250 UG	**BIL**	110 kV
Weight	43400 LB	**Winding Config.**	Delta-Wye
kV	22.9, 7.62	**VA Rating**	, , 7500, 9375 kVA
Note			

Test Date	7/31/2014	**Test Time**	11:27:29 AM	**Weather**	SUNNY
Air Temperature	31 °C	**Tank Temp.**	31°C	**RH.**	32 %
Tested by	JF/RB	**Work Order #**		**Last Test Date**	7/31/2014
Checked by		**Test Set Type**	M4K	**Retest Date**	
Checked Date		**Set Top S/N**		**Reason**	TROUBLE
Last Sheet #		**Set Bottom S/N**		**Travel Time**	
P.O. #		**Ins. Book #**		**Duration**	
Copies		**Sheet #**		**Crew Size**	2

Bushing Nameplate

Dsg	Serial	Mfr	Type	C1 %PF	C1 Cap	C2 %PF	C2 Cap	kV	Amps	Year
H1	3745150989	W	0C	0.33	583			25	400	1989
H2	3745151089	W	0C	0.32	592			25	400	1989
H3	3740560189	W	0C	0.31	600			25	400	1989
X1	3745151189	W	0C	0.34	563			25	400	1989
X2	3745150289	W	0C	0.33	593			25	400	1989
X0	3745150389	W	0C	0.32	588			25	400	1989
X3	3745150189	W	0C	0.31	600			25	400	1989

Overall Tests

Meas.	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
CH + CHL	10.004	45.326	1.337		1.00	12023.0		
CH	10.003	15.242	0.5490	0.36	1.00	4043.0	G	
CHL(UST)	10.003	30.074	0.7620	0.25	1.00	7977.4	G	
CHL		30.084	0.788	0.26	1.00	7980.000	G	
CL + CHL	8.003	64.041	1.742		1.00	16987.3		
CL	8.003	33.959	0.9870	0.29	1.00	9007.8	G	
CHL(UST)	8.003	30.073	0.7580	0.25	1.00	7977.0	G	
CHL		30.082	0.755	0.25	1.00	7979.500	G	
CH'		8.756	0.270	0.31	1.00	2263.540		
CL'		25.306	0.666	0.26	1.00	6684.280		

Bushing C1

ID	Serial	NP %PF	NP Cap	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
H1	3745150989	0.33	583	10.002	2.091	0.0730	0.35	1.00	583.83	G	
H2	3745151089	0.32	592	10.003	2.122	0.0680	0.32	1.00	592.63	G	
H3	3740560189	0.31	600	10.010	2.273	0.1380	0.61	1.00	603.00	D	
XO	3745150389	0.32	588	8.004	2.218	0.0820	0.37	1.00	588.27	G	
X1	3745151189	0.34	563	8.007	2.232	0.0850	0.38	1.00	592.17	G	
X2	3745150289	0.33	593	8.004	2.023	0.0720	0.36	1.00	564.80	G	
X3	3745150289-	0.33	593	8.004	2.180	0.0820	0.38	1.00	578.28	G	

Insulation Resistance

Mfr.	AVO	Serial #	

Connection	Volts	T1(Mohms)	T2(Mohms)	PI
Hi to Earth Guard Lo	5000	17800	20700	1.162
Lo to Earth Guard Hi	5000	14400	34400	2.388
Hi to Lo Guard Earth	5000	15200	45700	3.006

Exciting Current Tests

	Mfr.	Type	Steps	Boost %	Buck %	Position Found	Position Left	Oil Volume
De-Energized Tap Changer								
On-Load Tap Changer								

			H1 - H3			H2 - H1			H3 - H2				
DETC	LTC	Test kV	mA	Watts	X	mA	Watts	X	mA	Watts	X	IR_{auto}	IR_{man}
	3	8.028	55.290	421.21	L	22.841	175.63	L	60.242	448.31	L	G	

Turns Ratio (H-L) Tests

Mfr	Serial #	HV Winding	LV Winding
		L-L	L-N
Connections	H1 - H0	H2 - H0	H3 - H0
	X1 - X0	X2 - X0	X3 - X0

Tap	Np Volt	Tap	Np Volt	Cal	Ratio 1	Ratio 2	Ratio 3	Min Lim	Max Lim	IR_{auto}	IR_{man}
3	22900		7620	3.005	3.001	2.999	3.002	2.990	3.020	G	

United Power Group, Inc.

				Page No.	
Customer	Liberty Utilities	Date	7/31/2014	Project No.	
Address	Salem, NH	Air Temp.	25C	Rel. Humidity	32%
Owner	Liberty Utilities	Date Last Inspection		By Others	
Address	Salem, NH	Last Inspection Report No.			

Equipment Location: Salem Depot Substation
Owner Identification: 9T3

Nameplate Information

Manufacturer	GE	KVA	7500/9375	Phase	3	Cycle	60
Serial No.	M 160691	Type	Power	Form		Class	OA/FA
Primary Voltage	22.9kV	Delta X	Wye	Rated Current	236	Amperes	
Secondary Voltage	7.62kV	Delta	Wye X	Rated Current	410	Amperes	
Coolant Oil	X	Askarel		Air		Nitrogen	Other
Coolant Capacity - Units		Main Tank	1250UG	LTC		Switch	
Temperature Rise		Date of Manufacture		Impedance	7.37%		
No Load Tap Changer Voltages	24100/23500/22900/22300/21700						

Gauges and Counters	Measured	Maximum	Reset	Trip	Alarm
Oil Temperature	40C	110C	X		
Wdg. Temperature	30C	70C	X		
Pressure	1+				
Oil Level	25C				

LTC	Measured	Max.	Min.
Tap	NA		
Counter	NA		

Visual Inspection			
Primary Connection	OK	Secondary Connections	OK
Tap Connections	OK	Leaks	NA
Gas Regulator	NA	Paint	OK
Infra-Red Inspection	NA	Grounds	OK

Fans and Controls	Oil Temp.	Wdg. Temp.	Manual	Auto	Lubrication Date
Stage 1	80C		OK	OK	
Stage 2					

Accessory Inspection	Alarm	Trip
Pressure Relief Device - Main Tank		
Pressure Relief Device - LTC		
Sudden Pressure Device		

Additional Tests

Remarks: Oil temp and tank pressure gauges needs to be replaced.

Submitted By: JF

9L1T- Auto Transformer

Company	UPG	**Serial Number**	965618C
Location	Salem Depot Substation	**Special ID**	Transformer - 9L1T
Division	Liberty Utilities	**Circuit Designation**	
Manufacturer	GE	**Configuration**	Y-Y
Year Mfg.		**Tank Type**	OTHER
Mfr. Location	USA	**Coolant**	OIL
Phases	3	**Class**	OA/FA
Oil Volume	690 UG	**BIL**	150 kV
Weight	18600 LB	**Winding Config.**	Wye-Wye
kV	22.9, 13.8	**VA Rating**	5000,6250,7000 kVA
Note			

Test Date	7/31/2014	**Test Time**	8:45:13 AM	**Weather**	SUNNY
Air Temperature	25 °C	**Tank Temp.**	30°C	**RH.**	45 %
Tested by	JF/RB	**Work Order #**		**Last Test Date**	
Checked by		**Test Set Type**	M4K	**Retest Date**	
Checked Date		**Set Top S/N**		**Reason**	ROUTINE
Last Sheet #		**Set Bottom S/N**		**Travel Time**	
P.O. #		**Ins. Book #**		**Duration**	
Copies		**Sheet #**		**Crew Size**	2

Bushing Nameplate

Dsg	Serial	Mfr	Type	C1 %PF	C1 Cap	C2 %PF	C2 Cap	kV	Amps	Year
X1	1ZUA7CJ2679303	A-BB	O+C	0.26	489	0.15	647	25	400	2008
X2	1ZUA7CJ2679307	A-BB	O+C	0.25	491	0.19	671	25	400	2008
X3	0S23105550	A-BB	O+C	0.29	515	0.27	411	25	400	2000
X0	1ZUA7CJ2679302	A-BB	O+C	0.25	488	0.17	623	25	400	2008
H1	0S23105539	A-BB	O+C	0.25	489	0.25	423	25	400	2000
H2	1ZUA7CJ2679310	A-BB	O+C	0.25	497	0.24	875	25	400	2008
H3	1ZUA7CJ2679305	A-BB	O+C	0.25	489	0.16	725	25	400	2008

Overall Tests

Meas.	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
CH + CHL	8.004	28.796	0.9190		1.00	7638.3		
CH	8.003	28.791	0.9240	0.32	1.00	7637.0		G

Bushing C1

ID	Serial	NP %PF	NP Cap	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
H1	0S23105539	0.25	489	8.002	1.838	0.0580	0.32	1.00	487.61	G	
H2	1ZUA7CJ2679310	0.25	497	8.006	1.872	0.0460	0.25	1.00	496.65	G	
H3	1ZUA7CJ2679305	0.25	489	8.004	1.838	0.0440	0.24	1.00	487.43	G	
X0	1ZUA7CJ2679302	0.25	488	8.004	1.832	0.0430	0.23	1.00	485.94	G	
X1	1ZUA7CJ2679303	0.26	489	8.004	1.840	0.0440	0.24	1.00	488.07	G	
X2	1ZUA7CJ2679307	0.25	491	8.004	1.849	0.0440	0.24	1.00	490.53	G	
X3	0S23105550	0.29	515	8.004	1.926	0.0630	0.33	1.00	510.89	G	

Bushing C2

ID	Serial #	NP %PF	NP Cap	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
H1	0S23105539	0.25	423	0.4990	1.618	0.0190	0.12	1.00	429.10	G	
H2	1ZUA7CJ2679310	0.24	875	0.4990	3.310	0.0770	0.23	1.00	877.87	G	
H3	1ZUA7CJ2679305	0.16	725	0.4990	2.751	0.0520	0.19	1.00	729.70	G	
X1	1ZUA7CJ2679303	0.15	647	0.4990	2.452	0.0420	0.17	1.00	650.38	G	
X2	1ZUA7CJ2679307	0.19	671	0.4990	2.543	0.0420	0.17	1.00	674.46	G	
X3	0S23105550	0.27	411	0.5000	1.569	0.0400	0.25	1.00	416.25	G	
X0	1ZUA7CJ2679302	0.17	623	0.4990	2.356	0.0350	0.15	1.00	624.95	G	

Insulation Resistance

Mfr.	AVO	Serial #	

Connection	Volts	T1(Mohms)	T2(Mohms)	PI
Hi to Earth Guard Lo		2480	3360	1.35

Exciting Current Tests

	Mfr.	Type	Steps	Boost %	Buck %	Position Found	Position Left	Oil Volume
De-Energized Tap Changer								
On-Load Tap Changer								

			H1 - H0			H2 - H0			H3 - H0				
DETC	LTC	Test kV	mA	Watts	X	mA	Watts	X	mA	Watts	X	IR_{auto}	IR_{man}
	3	5.008	126.53	1067.1	L	92.078	770.76	L	126.49	1067.6	L	G	

Turns Ratio (H-L) Tests

Mfr	Serial #	HV Winding	LV Winding
		L-N	L-N
Connections	H1 - H0	H2 - H0	H3 - H0
	X1 - X0	X2 - X0	X3 - X0

Tap	Np Volt	Tap	Np Volt	Cal	Ratio 1	Ratio 2	Ratio 3	Min Lim	Max Lim	IR_{auto}	IR_{man}
3	13220		7620	1.735	1.7339	1.7339	1.7342	1.726	1.744	G	

United Power Group, Inc.

				Page No.	
Customer	Liberty Utilities	Date	7/31/2014	Project No.	
Address	Salem, NH	Air Temp.	25C	Rel. Humidity	32%
Owner	Liberty Utilities	Date Last Inspection		By Others	
Address	Salem, NH	Last Inspection Report No.			

Equipment Location: Salem Depot Substation
Owner Identification: 9L1T

Nameplate Information

Manufacturer	GE	KVA	5000/6250/7000	Phase	3	Cycle	60
Serial No.	965618C	Type	Auto	Form		Class	OA/FA
Primary Voltage	22.9kV	Delta		Wye	X	Rated Current	176 Amperes
Secondary Voltage	7.62kV	Delta		Wye	X	Rated Current	306 Amperes
Coolant Oil	X	Askarel		Air		Nitrogen	Other
Coolant Capacity - Units		Main Tank	690UG	LTC		Switch	
Temperature Rise		Date of Manufacture		Impedance	3.46%		
No Load Tap Changer Voltages	24100/23500/22900/22300/21700						

Gauges and Counters	Measured	Maximum	Reset	Trip	Alarm
Oil Temperature	30C	30C			
Wdg. Temperature	30C	30C			
Pressure					
Oil Level	25C				

LTC	Measured	Max.	Min.
Tap	NA		
Counter	NA		

Visual Inspection			
Primary Connection	OK	Secondary Connections	OK
Tap Connections	OK	Leaks	NA
Gas Regulator	NA	Paint	OK
Infra-Red Inspection	NA	Grounds	OK

Fans and Controls	Oil Temp.	Wdg. Temp.	Manual	Auto	Lubrication Date
Stage 1					
Stage 2					

Accessory Inspection	Alarm	Trip
Pressure Relief Device - Main Tank		
Pressure Relief Device - LTC		
Sudden Pressure Device		

Additional Tests

Remarks Transformer tested OK.

Submitted By JF

9L3 - Vacuum Recloser

Company	UPG	**Serial Number**	CP571029803
Location	Salem Depot	**Special ID**	Recloser 9L3
Division	Liberty Utility	**Circuit Designation**	
Manufacturer	CPS	**Type**	VSA
Yr. Manufactured	2006	**Class**	
Mfr. Location	USA	**Mechanism Type**	
Interrupting Rating	12.0 kA	**Mechanism Design**	COIL SPRING
Weight		**BIL**	110 kV
Total Weight	525 LB	**Control Volts**	125
Counter	124	**Amps**	800
kV	15.5		
Note			

Test Date	7/31/2014	**Test Time**	2:06:19 PM	**Weather**	SUNNY
Air Temperature	31 °C	**Tank Temp.**		**RH.**	34 %
Tested by	JF	**Work Order #**		**Last Test Date**	
Checked by		**Test Set Type**	M4K	**Retest Date**	
Checked Date		**Set Top S/N**		**Reason**	ROUTINE
Last Sheet #		**Set Bottom S/N**		**Travel Time**	
P.O. #		**Ins. Book #**		**Duration**	
Copies		**Sheet #**		**Crew Size**	

Overall Tests

Test Mode	Ph.	Test kV	mA	Watts	IR_{auto}	IR_{man}
GND	1	10.007	0.2210	0.0180		G
GND	1	10.005	0.2080	0.0220		G
GND	2	10.004	0.2210	0.0270		G
GND	2	10.004	0.2120	0.0250		G
GND	3	10.004	0.2210	0.0150		G
GND	3	10.004	0.2080	0.0340		G
UST	1	10.007	0.0500	0.0010		G
UST	2	10.003	0.0480	0.0000		G
UST	3	10.004	0.0490	0.0010		G

Hot Collar Tests

Serial #	ID	Test Mode	Skirt #	Test kV	mA	Watts	IR_{auto}	IR_{man}
	1	GROUND	1	10.004	0.0720	0.0290	G	
	2	GROUND	1	10.005	0.0740	0.0200	G	
	3	GROUND	1	10.004	0.0710	0.0130	G	
	4	GROUND	1	10.004	0.0730	0.0130	G	
	5	GROUND	1	10.004	0.0740	0.0120	G	
	6	GROUND	1	10.004	0.0810	0.0270	G	

United Power Group, Inc.
VACUUM RECLOSER TEST AND INSPECTION REPORT

				Page No.	4
Customer	Liberty Utilities	Date	6/10/2011	Project No.	U061118
Address	Salem, NH	Air Temp.	77F	Rel. Humidity	42%
Owner	Liberty Utilities	Date Last Inspection	New		
Address	Salem, NH	Last Inspection Report No.			
Equipment Location	Salem Depot				
Owner Identification	Recloser 9L3				

Breaker Nameplate Data:

Manufacturer	Cooper	Type	VSA12		
Serial No.	CP571029803	Type Operating Mechanism	Coil Spring		
Amperes	800	Age 2006	Interrupt. Rating 12kA	KV	15.5

Adjustment Checks	Mfr's Rec.	As Found	As Left
Latch Wipe		X	X
Latch Clearance		X	X
Stop Clearance		X	X
Prop. Clearance		X	X
Phase Checked	A	B	C
Contact Gap	X	X	X
Contact Travel	X	X	X
Contact Wipe	X	X	X
Erosion Indicator	X	X	X

Specified Tolerances (If Applicable)	
Latch Wipe	NA
Latch Clearance	NA
Stop Clearance	NA
Prop. Clearance	NA
Contact Gap	NA
Contact Travel	NA
Contact Wipe	NA
Erosion Indicator	NA

Phase Test Data	A	B	C
5 KV Bottle Megohms			
5 KV Open CB	B1	B3	B5
Megohms To Ground	100,000+	100,000+	100,000+
Bushings not under	B2	B4	B6
test were grounded.	100,000+	100,000+	100,000+
5 KV Closed CB	B1 & B2	B3 & B4	B5 & B6
Megohms To Ground	100,000+	100,000+	100,000+
K = *Number Entered Above X 1000*			
Closing/Opening Speed	Visual OK		
Contact Rest. Microhms	180	192	181

HIPOT Tests Microamps 1 Minute Test			
Phase tested	1	2	3
37.5 KV AC. Bottle Test	P	P	P
37.5 KV Closed CB Test	P	P	P
Bottle Test is a Go No Go Test (P = Pass) (F= Fail)			
Closed Test Energize a Phase & Grd. All Others			

Inspection and Maintenance:

Checked Items:	Insp. Item	Found Dirty	Cleaned & Lubed	See Remarks
Vacuum Bottles	X			
Primary Stabs	X			
Ground Stab	X			
Structural Checks	X			
Mech. Conn.	X			
Charging Motor	X			
Closing Springs	X			
Opening Springs	X			
Operation Coils	X			
Auxiliary Devices	X			
Insulating Memb.	X			
Recloser Wiring	X			
Racking Device				
Heater & Lights	X			
Cubicle Wiring	X			
X = *Yes For This Entry*				
Counter Found	140			
Counter Left	163			

Remarks: Results are acceptable.

Submitted by: J Fazio

Equipment Used: DLRO, Megger, HIPOT

United Power Group, Inc.

PROTECTIVE RELAY TEST REPORT

				Page No.	
Customer	Liberty Utilities	Date	8/1/14	Proj. No.	
Address	Salem, NH	Air Temp.	80F	Rel. Hum.	35%
Owner	Liberty Utilities	Date Last Inspection	By Others		
Address	Salem, NH	Last Inspection Report No.			
Equipment Location	Salem Depot Substation				
Owner Identification	9L3 Recloser				

Circuit Identification	9L3	C.T.Ratio	1000/1	P.T.Ratio	

Visual Inspection					Routine Maintenance					
Cover Gasket		X			Glass Cleaned		X			Mfr: Cooper
Glass		X			Case Cleaned		X			Type Ph: Form F6
Foreign Material		X			Relay Cleaned		X			Cat No:
Moisture		X			Connections Tight		X			Tap Range Ph: 5-3200A
Spiral Spring					Taps Tightened					Tap Range Grd: 2-1600A
Bearing Condition					Contacts Cleaned					Inst. Range Ph:
Bearing End-Play					Insulation Resistance		X			Inst Range Grd:
Disc Clearance					Trip Circuit		X			Use: 51P/51G/79
Rust		X								S/N =

Remarks: Results are acceptable.

Relay Settings

	Reclosing			Inst. Element Setting		Tap Setting		Curve Setting				Time Dial Setting			
	1st	2nd	3rd	50P-1	50G-1	51P	51G	50P-1	50G-1	51P	51G	50P-1	50G-1	51P	51G
Specified	5	10	LO			600A	240A							132	IEC VI
As Found	5	10	LO			600A	240A							132	IEC VI
As Left	5	10	LO			600A	240A							132	IEC VI

Test Operations - As Found - Time in Seconds

		Time Element P. U.		Current Voltage Time			Inst. Element Current/Voltage		Targets		Reclosing			
	Zero Set	Tap 1	Tap 2	P. U. X	Tap 1 X2	Tap 2 X4	Pick Up	Delay	LED	Reset	1st	2nd	3rd	4th
A Phase		0.600			13.6	3.91			X	X				
B Phase		0.600			13.5	3.90			X	X	5	10	LO	
C Phase		0.600			13.6	3.90			X	X				
GRD		0.241			2.54	.564			X	X				

Test Operations - As Left - Time in Seconds

		Time Element P. U.		Current Voltage Time			Inst. Element Current/Voltage		Targets		Reclosing			
	Zero Set	Tap 1	Tap 2	P. U. X	Tap 1 X2	Tap 2 X4	Pick Up	Delay	LED	Reset	1st	2nd	3rd	4th
A Phase		0.600			13.6	3.91			X	X				
B Phase		0.600			13.5	3.90			X	X	5	10	LO	
C Phase		0.600			13.6	3.90			X	X				
GRD		0.241			2.54	.564			X	X				

Submitted By JF Equipment Used Doble 2253

9L3 - Voltage Regulator "A Phase"

Company	UPG	**Serial Number**	Q557660-TSR
Location	Salem Depot Substation	**Special ID**	9L3 Regulators
Division	Liberty Utilities	**Circuit Designation**	A Phase
Manufacturer	GE	**Type**	VR-1
Yr. Manufactured	2000	**Class**	OA
Mfr. Location	USA		
Tank Type	N2 BLANKETED	**Coolant**	OIL
Phases	1	**BIL**	95 kV
Weight	3079 LB	**Oil Volume**	112 UG
kV	7.96	**Amps**	418
Impedance	%	**VA Rating**	333 kVA
Catalog #		**LTC Counter**	186279
Design	Step	**Ctrl Wire Diameter**	
Catalog/Style		**Crew Size**	
Note			

Test Date	8/1/2014	**Test Time**	7:29:06 AM	**Weather**	SUNNY
Air Temperature	23 °C	**Tank Temp.**	23°C	**RH.**	62 %
Tested by	jf	**Work Order #**		**Last Test Date**	
Checked by		**Test Set Type**	M4K	**Retest Date**	
Checked Date		**Set Top S/N**		**Reason**	ROUTINE
Last Sheet #		**Set Bottom S/N**		**Travel Time**	
P.O. #		**Ins. Book #**		**Duration**	
Copies		**Sheet #**		**Crew Size**	1

Overall Tests

Meas.	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
CH	8.004	19.973	2.052	1.03	1.00	5297.7	G	

Hot Collar Tests

Serial #	ID	Test Mode	Skirt #	Test kV	mA	Watts	IR_{auto}	IR_{man}
	S	GROUND	2	10.004	0.0770	0.0530	G	
	L	GROUND	2	10.006	0.0790	0.0510	G	
	SL	GROUND	2	10.004	0.0580	0.0470	G	

Insulation Resistance

Mfr.:	AVO	Serial #:				
kV	Connection	T1(Mohms)	T2(Mohms)	PI	IR_{auto}	IR_{man}
5000	Src/Load to Earth	5600	26000	4.6429		G

Exciting Current Tests

	Mfr.	Type	Steps	Position Found	Position Left
De-Energized Tap Changer					
On-Load Tap Changer					

	Connections	SA - SL		SB - SL		SC - SL			
LTC	Test kV	mA	Watts	mA	Watts	mA	Watts	IR_{auto}	IR_{man}
1R	2.500	1144.1	1010.4						
N	2.500	1151.7	984.34						
1L	2.500	685.37	892.26						
2L	2.501	1150.8	1011.6						
3L	2.503	684.84	912.81						
4L	2.500	1151.2	989.06						
5L	2.502	685.01	907.98						
6L	2.502	1151.5	1015.2						
7L	2.503	1148.7	1028.0						
8L	2.500	1151.3	998.78						
9L	2.503	1147.7	1046.1						
10L	2.507	1151.4	1037.8						
11L	2.501	1146.2	1017.6						
12L	2.500	1150.0	999.93						
13L	2.501	682.53	896.33						
14L	2.500	1150.4	991.85						
15L	2.501	682.36	895.51						
16L	2.502	1150.2	1012.6						

9L3 - Voltage Regulator "B Phase"

Company	UPG	**Serial Number**	Q557658-TSR
Location	Salem Depot Substation	**Special ID**	9L3 Regulators
Division	Liberty Utilities	**Circuit Designation**	B Phase
Manufacturer	GE	**Type**	VR-1
Yr. Manufactured	2000	**Class**	OA
Mfr. Location	USA		
Tank Type	N2 BLANKETED	**Coolant**	OIL
Phases	1	**BIL**	95 kV
Weight	3079 LB	**Oil Volume**	112 UG
kV	7.96	**Amps**	418
Impedance	%	**VA Rating**	333 kVA
Catalog #		**LTC Counter**	186279
Design	Step	**Ctrl Wire Diameter**	
Catalog/Style		**Crew Size**	
Note			

Test Date	8/1/2014	**Test Time**	10:17:53 AM	**Weather**	SUNNY
Air Temperature	25 °C	**Tank Temp.**	25°C	**RH.**	55 %
Tested by	JF	**Work Order #**		**Last Test Date**	8/1/2014
Checked by		**Test Set Type**	M4K	**Retest Date**	
Checked Date		**Set Top S/N**		**Reason**	ROUTINE
Last Sheet #		**Set Bottom S/N**		**Travel Time**	
P.O. #		**Ins. Book #**		**Duration**	
Copies		**Sheet #**		**Crew Size**	1

Overall Tests

Meas.	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
CH	8.004	20.432	1.814	0.89	1.00	5419.5	G	

Hot Collar Tests

Serial #	ID	Test Mode	Skirt #	Test kV	mA	Watts	IR_{auto}	IR_{man}
	S	GROUND	2	10.005	0.0680	0.0310	G	
	L	GROUND	2	10.008	0.0710	0.0300	G	
	SL	GROUND	2	10.007	0.0690	0.0280	G	

Insulation Resistance

Mfr.:	AVO	Serial #:				
kV	**Connection**	**T1(Mohms)**	**T2(Mohms)**	**PI**	**IR_{auto}**	**IR_{man}**
5000	Src/Load to Earth	12300	34200	2.7805		

Exciting Current Tests

	Mfr.	Type	Steps	Position Found	Position Left
De-Energized Tap Changer					
On-Load Tap Changer					

	Connections	SA - SL		SB - SL		SC - SL			
LTC	**Test kV**	**mA**	**Watts**	**mA**	**Watts**	**mA**	**Watts**	**IR_{auto}**	**IR_{man}**
1R	2.505	1165.1	1059.9						
N	2.502	1170.9	1004.2						
1L	2.501	695.86	925.58						
2L	2.504	1171.3	1042.6						
3L	2.500	695.31	915.41						
4L	2.499	1170.3	997.49						
5L	2.502	695.67	921.06						
6L	2.501	1170.9	1017.4						
7L	2.499	1167.3	1021.4						
8L	2.505	1171.5	1035.8						
9L	2.500	1166.0	1029.8						
10L	2.499	1169.8	1005.1						
11L	2.503	1165.7	1036.7						
12L	2.502	1170.1	1013.2						
13L	2.500	692.89	903.68						
14L	2.503	1169.7	1024.3						
15L	2.501	693.18	910.64						
16L	2.503	1169.6	1022.6						

9L3 - Voltage Regulator "C Phase"

Company	UPG	**Serial Number**	Q557659-TSR
Location	Salem Depot Substation	**Special ID**	9L3 Regulators
Division	Liberty Utilities	**Circuit Designation**	C Phase
Manufacturer	GE	**Type**	VR-1
Yr. Manufactured	2000	**Class**	OA
Mfr. Location	USA		
Tank Type	N2 BLANKETED	**Coolant**	OIL
Phases	1	**BIL**	95 kV
Weight	3079 LB	**Oil Volume**	112 UG
kV	7.96	**Amps**	418
Impedance	%	**VA Rating**	333 kVA
Catalog #		**LTC Counter**	186279
Design	Step	**Ctrl Wire Diameter**	
Catalog/Style		**Crew Size**	
Note			

Test Date	8/1/2014	**Test Time**	11:11:19 AM	**Weather**	SUNNY
Air Temperature	29 °C	**Tank Temp.**	29°C	**RH.**	46 %
Tested by	JF	**Work Order #**		**Last Test Date**	8/1/2014
Checked by		**Test Set Type**	M4K	**Retest Date**	
Checked Date		**Set Top S/N**		**Reason**	ROUTINE
Last Sheet #		**Set Bottom S/N**		**Travel Time**	
P.O. #		**Ins. Book #**		**Duration**	
Copies		**Sheet #**		**Crew Size**	1

Overall Tests

Meas.	Test kV	mA	Watts	%PF corr	Corr Fctr	Cap(pF)	IR_{auto}	IR_{man}
CH	8.004	21.188	2.491	1.18	1.00	5619.8	G	

Hot Collar Tests

Serial #	ID	Test Mode	Skirt #	Test kV	mA	Watts	IR_{auto}	IR_{man}
	S	GROUND	2	10.005	0.077	0.054	G	
	L	GROUND	2	10.008	0.068	0.051	G	
	SL	GROUND	2	10.007	0.055	0.044	G	

Insulation Resistance

Mfr.:	AVO	Serial #:				
kV	**Connection**	**T1(Mohms)**	**T2(Mohms)**	**PI**	**IR_{auto}**	**IR_{man}**
5000	Src/Load to Earth	5800	9700	1.6724		

Exciting Current Tests

	Mfr.	Type	Steps	Position Found	Position Left
De-Energized Tap Changer					
On-Load Tap Changer					

	Connections	SA - SL		SB - SL		SC - SL			
LTC	**Test kV**	**mA**	**Watts**	**mA**	**Watts**	**mA**	**Watts**	**IR_{auto}**	**IR_{man}**
1R	2.504	1141.3	1008.0						
N	2.501	1149.3	987.89						
1L	2.502	683.01	894.75						
2L	2.506	1150.6	1017.4						
3L	2.501	682.80	890.91						
4L	2.499	1148.8	971.44						
5L	2.502	682.90	895.02						
6L	2.506	1150.1	1018.0						
7L	2.499	1145.5	996.83						
8L	2.500	1148.4	969.91						
9L	2.500	1144.8	1002.6						
10L	2.500	1147.8	972.31						
11L	2.503	1144.9	1016.2						
12L	2.501	1148.8	984.69						
13L	2.502	681.13	888.42						
14L	2.502	1148.5	992.23						
15L	2.501	680.04	881.51						
16L	2.503	1148.8	998.48						

United Power Group, Inc.

				Page No.	
Customer	Liberty Utilities	Date	8/1/2014	Proj. No.	
Address	Salem, NH	Air Temp.	68F	Rel. Hum.	34%
Owner	Liberty Utilities	Date Last Inspection	By Others		
Address	Salem, NH	Last Inspection Report No.			

Equipment Location: Salem Depot
Owner Identification: 9L3 Regulator Bank

Manuf.	GE	Type	VR1	Test Set#	TTR-JF
Gallons	112	Oil Levels	OK	KVA	333

Nameplate Voltage	7960	Ser # A	Q557660 - TSR
Line to Line Voltage		Ser # B	Q557658 - TSR
Percent Regulation	5/8%	Ser # C	Q557659 - TSR

Doble Factor	Power Results
Test KV	8
Position	N

Tap Position	Tap Voltage	TTR Ratio	TTR MEASURED VALUES: S-SL A / L-SL A	S-SL B / L-SL B	S-SL C / L-SL C
16R	8756	0.909	0.906	0.906	0.906
15R	8706	0.914	0.911	0.911	0.911
14R	8657	0.920	0.915	0.915	0.915
13R	8607	0.925	0.921	0.921	0.921
12R	8557	0.930	0.926	0.926	0.926
11R	8507	0.936	0.932	0.932	0.932
10R	8458	0.941	0.937	0.937	0.937
9R	8408	0.947	0.944	0.944	0.944
8R	8358	0.952	0.951	0.951	0.951
7R	8308	0.958	0.957	0.957	0.957
6R	8259	0.964	0.963	0.963	0.963
5R	8209	0.970	0.969	0.969	0.969
4R	8159	0.976	0.975	0.975	0.975
3R	8109	0.982	0.981	0.981	0.981
2R	8060	0.988	0.985	0.985	0.985
1R	8010	0.994	0.995	0.995	0.995
N	7960	1.000	1.000	1.000	1.000
1L	7910	1.006	1.006	1.006	1.006
2L	7861	1.013	1.013	1.013	1.013
3L	7811	1.019	1.017	1.017	1.017
4L	7761	1.026	1.024	1.024	1.024
5L	7711	1.032	1.031	1.031	1.031
6L	7662	1.039	1.037	1.037	1.037
7L	7612	1.046	1.044	1.044	1.044
8L	7562	1.053	1.053	1.053	1.053
9L	7512	1.060	1.061	1.062	1.061
10L	7463	1.067	1.067	1.067	1.067
11L	7413	1.074	1.075	1.075	1.075
12L	7363	1.081	1.083	1.083	1.083
13L	7313	1.088	1.091	1.091	1.091
14L	7264	1.096	1.097	1.097	1.097
15L	7214	1.103	1.105	1.105	1.105
16L	7164	1.111	1.112	1.112	1.112

Remarks: Regulator test results are acceptable.

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TEST REPORT
01-7334797-618125-00

Liberty Utilities		**Serial#:**	HA08863002	**Mfr:**	ABB	**Control#:**	7334797
		Location:	BARRON AVENUE 10	**kV:**	22.9	**Order#:**	618125
		Equipment:	TRANSFORMER	**kVA:**	9375	**Account:**	110710
LONDONDERRY, NH 03053 US		**Compartment:**	MAIN(BOTTOM)	**Year Mf'd:**	2002	**Received:**	04/28/2020
ATTN: MARIO BARONE		**Breathing:**	SEAL	**Syringe ID:**	55005286	**Reported:**	05/12/2020
PO#: PO000016751		**Bank:**	**Phase:**	**Bottle ID:**			
Project ID:		**Fluid:** MIN	**USGal:** 1323	**Sampled By:**			
Customer ID: REF# 024304							

	Lab Control Number:	7334797	7044984	7035705[7]
	Date Sampled:	11/21/2019	06/14/2017	12/17/2014
	Order Number:	618125	541715	539662
	Oil Temp:		45	50
Dissolved Gas Analysis (DGA)	**Hydrogen (H2) (µL/L):**	<2	347	<2
ASTM	**Methane (CH4) (µL/L):**	17	17	16
D-3612[1]	**Ethane (C2H6) (µL/L):**	7	6	4
	Ethylene (C2H4) (µL/L):	1	1	<1
	Acetylene (C2H2) (µL/L):	<1	<1	<1
	Carbon Monoxide (CO) (µL/L):	**474**	**531**	**431**
	Carbon Dioxide (CO2) (µL/L):	1425	1681	1320
	Nitrogen (N2) (µL/L):	60545	74393	98100
	Oxygen (O2) (µL/L):	2263	2549	14600
	Total Dissolved Gas (TDG) (µL/L):	64732	79525	114471
	Total Dissolved Combustible Gas (TDCG) (µL/L):	499	**902**	451
	Equivalent TCG (%):	0.5603	1.2905	0.2979

DGA Diagnostics	**DGA Keys Gas / Interpretive Method: PER IEEE C57.104-2008** (most recent sample)	Hydrogen within condition 1 limits (100 µL/L). Methane within condition 1 limits (120 µL/L). Ethane within condition 1 limits (65 µL/L). Ethylene within condition 1 limits (50 µL/L). Acetylene within condition 1 limits (1 µL/L). Carbon Monoxide: Condition 2 Indications of overheated cellulose insulation (350 µL/L). Carbon Dioxide within condition 1 limits (2500 µL/L). TDCG within condition 1 limits (720 µL/L).
	DGA TDCG Rate Interpretive Method: PER IEEE C57.104-2008 (two most recent sample)	Retest Annually. 1-Continue normal operation.
	DGA Cellulose (Paper) Insulation:	CO2/CO Ratio is only applicable when CO2 greater than 5000 and CO greater than 500.
	Weidmann DGA Condition Code:	NORMAL
	Weidmann Recommended Action:	Continue normal operation. Resample for testing within one year.

Comment:

General Oil Quality (GOQ)					
ASTM D-1533[1]	**Moisture in Oil**	**(mg/kg):**	5	12	5
ASTM D-971[1]	**Interfacial Tension**	**(mN/m):**	33.85	38.17	36.0
ASTM D-974[1]	**Acid Number**	**(mg KOH/g):**	0.004	0.014	0.005
ASTM D-1500[1]	**Color Number**	**(ASTM):**	L1.0	L1.0	1
ASTM D-1524[1]	**Visual Exam.**	**(Relative):**	PASS	PASS	PASS
			CLR&BRIGHT	CLR&BRIGHT	CLR&BRIGHT
ASTM D-1524[1]	**Sediment Exam.**	**(Relative):**	LIGHT	TRACE	
ASTM D-877[1]	**Dielectric Breakdown**	**(kV):**	47	54	52
ASTM D-1816	**Dielectric Breakdown 1 mm**	**(kV °C):**		34 (25°C)	23 (50°C)
ASTM D-924[1]	**Power Factor @ 25°C (Routine)**	**(%):**	0.057	0.099	0.056
ASTM D-924	**Power Factor @ 100°C (Routine)**	**(%):**			1.052
ASTM D-1298	**Density @15°C**	**(g/mL):**			0.891

Notations: 1. Analysis is ISO/IEC 17025:2017 accredited, ANAB Accredited Certificate Number L2303.02 2. This test is conducted by a subcontracted laboratory. 3. Subcontracted laboratory has received ISO Standard 17025 accreditation for this test. 5. This test is conducted by Weidmann Laboratory other than Primary Lab. 6. Weidmann Laboratory has received ISO Standard 17025 accreditation for this test. 7. Imported Sample: WEIDMANN Electrical Technology accepts no responsibility for these results; accreditation status does not apply to these results. 8. Imported Equipment 10. mg/kg , µg/g, µg/mL, µL/L = ppm, µg/L = ppb, mN/m = dynes/cm, mm²/s = cSt

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TEST REPORT
01-7334797-618125-00

Liberty Utilities	**Serial#:** HA08863002	**Mfr:** ABB	**Control#:** 7334797
	Location: BARRON AVENUE 10	**kV:** 22.9	**Order#:** 618125
	Equipment: TRANSFORMER	**kVA:** 9375	**Account:** 110710
LONDONDERRY, NH 03053 US	**Compartment:** MAIN(BOTTOM)	**Year Mf'd:** 2002	**Received:** 04/28/2020
ATTN: MARIO BARONE	**Breathing:** SEAL	**Syringe ID:** 55005286	**Reported:** 05/12/2020
PO#: PO000016751	**Bank:** **Phase:**	**Bottle ID:**	
Project ID:	**Fluid:** MIN **USGal:** 1323	**Sampled By:**	
Customer ID: REF# 024304			

		Lab Control Number:	7334797	7044984	7035705[7]	
		Date Sampled:	11/21/2019	06/14/2017	12/17/2014	
		Order Number:	618125	541715	539662	
		Oil Temp:		45	50	
ASTM D-4052	**Density @15°C**	**(g/mL):**			0.891	
ASTM D-445	**Viscosity @40°C**	**(mm²/s):**			8.93	
ASTM D-2668[5, 6]	**Oxidation Inhibitor**	**(wt. %)**	0.187	0.183	0.251	

GOQ Diagnostics	**Moisture in Oil:**	Acceptable for in-service oil (35 mg/kg max).
PER IEEE C57.106-2015	**Interfacial Tension:**	Acceptable for in-service oil (25 mN/m min).
(most recent sample)	**Acid Number:**	Acceptable for in-service oil (0.2 mg KOH/g max).
	Color Number and Visual:	Diagnostic not applicable. Diagnostic not applicable.
	Dielectric Breakdown ASTM D-877:	Diagnostic not applicable.
	Power Factor @ 25°C (Routine):	Acceptable for in-service oil (0.5% max).
	Oxidation Inhibitor:	Exceeds limit for in-service oil Type I (0.0% min and 0.08% max). Acceptable for in-service oil type II (0.08% min and 0.3% max).

Comment:

Furanic Compound	**2-Furaldehyde (µg/L):**	< 10	< 10	
ASTM D-5837[5]	**5-Hydroxy-methyl-furaldehyde (µg/L):**	< 10	< 10	
	2-Acetylfuran (µg/L):	< 10	< 10	
	5-Methyl-2-furaldehyde (µg/L):	< 10	< 10	
	2-Furyl alcohol (µg/L):	< 10	< 10	

Furanic Compound Diagnostics (most recent sample):

New insulation with a high degree of mechanical strength will typically have a Degree of Polymerization (DP) of 1000-1300. "Middle Aged" paper is approximately 500 and paper with less than 250 is in its "Old Age." Severely degraded insulation with a DP of 150 or less will have very little mechanical strength and may result in a transformer failure. The above estimations are based on a study by Chendong of GSU transformers filled with mineral oil.

Estimated Average Degree of Polymerization (DP): >1003

Estimated Operating Age of the Equipment: <1.0

Notations:

Comment:

PCB	**Concentration (mg/kg):**	< 1.0 mg/kg	< 1.0 mg/kg	
mod EPA Method 8082a[5, 6]	**PCB Type (Arocolor):**	ND	ND	
	Reporting Limit:	1	1	

Comment:

End of Test Report

Authorized By:

ERIC MCANANY
CHEMIST

Notations: 1. Analysis is ISO/IEC 17025:2017 accredited, ANAB Accredited Certificate Number L2303.02 2. This test is conducted by a subcontracted laboratory. 3. Subcontracted laboratory has received ISO Standard 17025 accreditation for this test. 5. This test is conducted by Weidmann Laboratory other than Primary Lab. 6. Weidmann Laboratory has received ISO Standard 17025 accreditation for this test. 7. Imported Sample: WEIDMANN Electrical Technology accepts no responsibility for these results; accreditation status does not apply to these results. 8. Imported Equipment 10. mg/kg , µg/g, µg/mL, µL/L = ppm, µg/L = ppb, mN/m = dynes/cm, mm²/s = cSt

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TEST REPORT
01-7334796-618125-00

Liberty Utilities	**Serial#:** F959759	**Mfr:** GENERAL ELECTRIC	**Control#:** 7334796
	Location: BARRON AVENUE 10	**kV:** 22.9	**Order#:** 618125
	Equipment: TRANSFORMER	**kVA:** 7000	**Account:** 110710
LONDONDERRY, NH 03053 US	**Compartment:** MAIN(BOTTOM)	**Year Mf'd:** 1970	**Received:** 04/28/2020
ATTN: MARIO BARONE	**Breathing:** SEAL	**Syringe ID:** 53004958	**Reported:** 05/12/2020
PO#: PO000016751	**Bank:** **Phase:**	**Bottle ID:**	
Project ID:	**Fluid:** MIN **USGal:** 739	**Sampled By:**	
Customer ID: REF# 023486			

	Lab Control Number:	7334796	7044991	7035681[7]	7035704[7]	7035682[7]
	Date Sampled:	11/21/2019	06/14/2017	01/11/2016	01/17/2014	01/17/2014
	Order Number:	618125	541715	539638	539661	539639
	Oil Temp:		65	60	60	60
Dissolved Gas Analysis (DGA)	**Hydrogen (H2) (µL/L):**	31	37	36	53	53
ASTM	**Methane (CH4) (µL/L):**	8	8	10	11	11
D-3612[1]	**Ethane (C2H6) (µL/L):**	3	3	2	2	2
	Ethylene (C2H4) (µL/L):	1	1	1	1	1
	Acetylene (C2H2) (µL/L):	<1	<1	<1	<1	<1
	Carbon Monoxide (CO) (µL/L):	**390**	**435**	**439**	**585**	**585**
	Carbon Dioxide (CO2) (µL/L):	**3476**	**3966**	**4600**	**5220**	**5220**
	Nitrogen (N2) (µL/L):	54119	64457	68900	77200	77200
	Oxygen (O2) (µL/L):	15897	21425	22700	20900	20900
	Total Dissolved Gas (TDG) (µL/L):	73925	90332	96688	103972	103972
	Total Dissolved Combustible Gas (TDCG) (µL/L):	433	484	488	652	652
	Equivalent TCG (%):	0.5356	0.4982	0.4686	0.5812	0.5812

DGA Diagnostics	**DGA Keys Gas / Interpretive Method: PER IEEE C57.104-2008** (most recent sample)	Hydrogen within condition 1 limits (100 µL/L). Methane within condition 1 limits (120 µL/L). Ethane within condition 1 limits (65 µL/L). Ethylene within condition 1 limits (50 µL/L). Acetylene within condition 1 limits (1 µL/L). Carbon Monoxide: Condition 2 Indications of overheated cellulose insulation (350 µL/L). Carbon Dioxide: Condition 2 Indications of overheated cellulose insulation (2500 µL/L). TDCG within condition 1 limits (720 µL/L).
	DGA TDCG Rate Interpretive Method: PER IEEE C57.104-2008 (two most recent sample)	Retest Annually. 1-Continue normal operation.
	DGA Cellulose (Paper) Insulation:	CO2/CO Ratio is only applicable when CO2 greater than 5000 and CO greater than 500.
	Weidmann DGA Condition Code:	NORMAL
	Weidmann Recommended Action:	Continue normal operation. Resample for testing within one year.

Comment:

General Oil Quality (GOQ)								
ASTM D-1533[1]	**Moisture in Oil**	**(mg/kg):**	9	16	10	9	9
ASTM D-971[1]	**Interfacial Tension**	**(mN/m):**	40.15	37.72	41.0	42.0	42.0
ASTM D-974[1]	**Acid Number**	**(mg KOH/g):**	0.007	0.022	0.005	0.005	0.005
ASTM D-1500[1]	**Color Number**	**(ASTM):**	L1.5	L1.0	1.5	1.5	1.5
ASTM D-1524[1]	**Visual Exam.**	**(Relative):**	PASS	PASS	PASS	PASS	PASS
			CLR&BRIGHT	CLR&BRIGHT	CLR&BRIGHT	CLR&BRIGHT	CLR&BRIGHT
ASTM D-1524[1]	**Sediment Exam.**	**(Relative):**	TRACE	TRACE			
ASTM D-877[1]	**Dielectric Breakdown**	**(kV):**	51	47	62	59	59
ASTM D-1816	**Dielectric Breakdown 1 mm**	**(kV °C):**		30 (27°C)	37 (60°C)	36 (60°C)	36 (60°C)
ASTM D-924[1]	**Power Factor @ 25°C (Routine)**	**(%):**	0.006	0.016	0.002	0.002	0.002
ASTM D-924	**Power Factor @ 100°C (Routine)**	**(%):**			0.014	0.412	0.412

Notations: 1. Analysis is ISO/IEC 17025:2017 accredited, ANAB Accredited Certificate Number L2303.02 2. This test is conducted by a subcontracted laboratory. 3. Subcontracted laboratory has received ISO Standard 17025 accreditation for this test. 5. This test is conducted by Weidmann Laboratory other than Primary Lab. 6. Weidmann Laboratory has received ISO Standard 17025 accreditation for this test. 7. Imported Sample: WEIDMANN Electrical Technology accepts no responsibility for these results; accreditation status does not apply to these results. 8. Imported Equipment 10. mg/kg , µg/g, µg/mL, µL/L = ppm, µg/L = ppb, mN/m = dynes/cm, mm²/s = cSt

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TEST REPORT
01-7334796-618125-00

Liberty Utilities	**Serial#:** F959759	**Mfr:** GENERAL ELECTRIC	**Control#:** 7334796
	Location: BARRON AVENUE 10	**kV:** 22.9	**Order#:** 618125
	Equipment: TRANSFORMER	**kVA:** 7000	**Account:** 110710
LONDONDERRY, NH 03053 US	**Compartment:** MAIN(BOTTOM)	**Year Mf'd:** 1970	**Received:** 04/28/2020
ATTN: MARIO BARONE	**Breathing:** SEAL	**Syringe ID:** 53004958	**Reported:** 05/12/2020
PO#: PO000016751	**Bank:** **Phase:**	**Bottle ID:**	
Project ID:	**Fluid:** MIN **USGal:** 739	**Sampled By:**	
Customer ID: REF# 023486			

		Lab Control Number:	7334796	7044991	7035681[7]	7035704[7]	7035682[7]
		Date Sampled:	11/21/2019	06/14/2017	01/11/2016	01/17/2014	01/17/2014
		Order Number:	618125	541715	539638	539661	539639
		Oil Temp:		65	60	60	60
ASTM D-1298	**Density @15°C**	**(g/mL):**			0.896	0.896	0.896
ASTM D-4052	**Density @15°C**	**(g/mL):**			0.896	0.896	0.896
ASTM D-445	**Viscosity @40°C**	**(mm²/s):**			10.05	10.02	10.02
ASTM D-2668[5, 6]	**Oxidation Inhibitor**	**(wt. %)**	0.173	0.179	0.235	0.237	0.237

GOQ Diagnostics	**Moisture in Oil:**	Acceptable for in-service oil (35 mg/kg max).
PER IEEE C57.106-2015	**Interfacial Tension:**	Acceptable for in-service oil (25 mN/m min).
(most recent sample)	**Acid Number:**	Acceptable for in-service oil (0.2 mg KOH/g max).
	Color Number and Visual:	Diagnostic not applicable. Diagnostic not applicable.
	Dielectric Breakdown ASTM D-877:	Diagnostic not applicable.
	Power Factor @ 25°C (Routine):	Acceptable for in-service oil (0.5% max).
	Oxidation Inhibitor:	Exceeds limit for in-service oil Type I (0.0% min and 0.08% max). Acceptable for in-service oil type II (0.08% min and 0.3% max).

Comment:

Furanic Compound	**2-Furaldehyde (µg/L):**	59	69
ASTM D-5837[5]	**5-Hydroxy-methyl-furaldehyde (µg/L):**	< 10	< 10
	2-Acetylfuran (µg/L):	< 10	< 10
	5-Methyl-2-furaldehyde (µg/L):	13	< 10
	2-Furyl alcohol (µg/L):	< 10	< 10

Furanic Compound Diagnostics (most recent sample):

New insulation with a high degree of mechanical strength will typically have a Degree of Polymerization (DP) of 1000-1300. "Middle Aged" paper is approximately 500 and paper with less than 250 is in its "Old Age." Severely degraded insulation with a DP of 150 or less will have very little mechanical strength and may result in a transformer failure. The above estimations are based on a study by Chendong of GSU transformers filled with mineral oil.

Estimated Average Degree of Polymerization (DP): 784

Estimated Operating Age of the Equipment: 10.3

Notations:

Comment:

PCB	**Concentration (mg/kg):**	6.79 mg/kg	4.23 mg/kg
mod EPA Method 8082a[5, 6]	**PCB Type (Arocolor):**	1242	1242
	Reporting Limit:	1	1

Comment:

End of Test Report

Authorized By:

ERIC MCANANY
CHEMIST

Notations: 1. Analysis is ISO/IEC 17025:2017 accredited, ANAB Accredited Certificate Number L2303.02 2. This test is conducted by a subcontracted laboratory. 3. Subcontracted laboratory has received ISO Standard 17025 accreditation for this test. 5. This test is conducted by Weidmann Laboratory other than Primary Lab. 6. Weidmann Laboratory has received ISO Standard 17025 accreditation for this test. 7. Imported Sample: WEIDMANN Electrical Technology accepts no responsibility for these results; accreditation status does not apply to these results. 8. Imported Equipment 10. mg/kg , µg/g, µg/mL, µL/L = ppm, µg/L = ppb, mN/m = dynes/cm, mm²/s = cSt

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TEST REPORT
01-7334792-618125-00

Liberty Utilities	**Serial#:** M160691	**Mfr:** GENERAL ELECTRIC	**Control#:** 7334792
	Location: SALEM DEPOT #9	**kV:** 23	**Order#:** 618125
	Equipment: TRANSFORMER	**kVA:** 9300	**Account:** 110710
LONDONDERRY, NH 03053 US	**Compartment:** MAIN(BOTTOM)	**Year Mf'd:** 1989	**Received:** 04/28/2020
ATTN: MARIO BARONE	**Breathing:** SEAL	**Syringe ID:** 3001645	**Reported:** 05/12/2020
PO#: PO000016751	**Bank:** **Phase:**	**Bottle ID:**	
Project ID:	**Fluid:** MIN **USGal:** 1250	**Sampled By:**	
Customer ID: REF# 022772			

	Lab Control Number:	7334792	7044980	7035699[7]	7035709[7]	7035700[7]
	Date Sampled:	11/21/2019	06/14/2017	09/01/2016	12/16/2014	12/16/2014
	Order Number:	618125	541715	539656	539666	539657
	Oil Temp:		55	90	80	80
Dissolved Gas Analysis (DGA)	**Hydrogen (H2) (µL/L):**	40	51	50	50	50
ASTM	**Methane (CH4) (µL/L):**	55	56	54	51	51
D-3612[1]	**Ethane (C2H6) (µL/L):**	56	44	48	39	39
	Ethylene (C2H4) (µL/L):	4	4	4	4	4
	Acetylene (C2H2) (µL/L):	<1	<1	<1	<1	<1
	Carbon Monoxide (CO) (µL/L):	**459**	**495**	**477**	**447**	**447**
	Carbon Dioxide (CO2) (µL/L):	**13496**	**14360**	**14800**	**14200**	**14200**
	Nitrogen (N2) (µL/L):	64658	80509	89000	83300	83300
	Oxygen (O2) (µL/L):	<500	1194	4950	6500	6500
	Total Dissolved Gas (TDG) (µL/L):	79090	96713	109383	104591	104591
	Total Dissolved Combustible Gas (TDCG) (µL/L):	614	650	633	591	591
	Equivalent TCG (%):	0.6293	0.5587	0.4794	0.4804	0.4804

DGA Diagnostics	**DGA Keys Gas / Interpretive Method: PER IEEE C57.104-2008** (most recent sample)	Hydrogen within condition 1 limits (100 µL/L). Methane within condition 1 limits (120 µL/L). Ethane within condition 1 limits (65 µL/L). Ethylene within condition 1 limits (50 µL/L). Acetylene within condition 1 limits (1 µL/L). Carbon Monoxide: Condition 2 Indications of overheated cellulose insulation (350 µL/L). Carbon Dioxide: Condition 4 Severe Indications of overheated cellulose insulation (10000 µL/L). TDCG within condition 1 limits (720 µL/L).
	DGA TDCG Rate Interpretive Method: PER IEEE C57.104-2008 (two most recent sample)	Retest Annually. 1-Continue normal operation.
	DGA Cellulose (Paper) Insulation:	CO2/CO Ratio is only applicable when CO2 greater than 5000 and CO greater than 500.
	Weidmann DGA Condition Code:	CAUTION
	Weidmann Recommended Action:	Resample within 6 months for testing.

Comment:

General Oil Quality (GOQ)							
ASTM D-1533[1]	**Moisture in Oil**	**(mg/kg):**	10	23	58	6	6
ASTM D-971[1]	**Interfacial Tension**	**(mN/m):**	37.99	37.82	35.0	38.0	38.0
ASTM D-974[1]	**Acid Number**	**(mg KOH/g):**	0.007	0.016	0.005	0.005	0.005
ASTM D-1500[1]	**Color Number**	**(ASTM):**	L0.5	L0.5	0.5	0.5	0.5
ASTM D-1524[1]	**Visual Exam.**	**(Relative):**	PASS	PASS	PASS	PASS	PASS
			CLR&BRIGHT	CLR&BRIGHT	CLR&BRIGHT	CLR&BRIGHT	CLR&BRIGHT
ASTM D-1524[1]	**Sediment Exam.**	**(Relative):**	TRACE	TRACE			
ASTM D-877[1]	**Dielectric Breakdown**	**(kV):**	47	51	55	63	63
ASTM D-1816	**Dielectric Breakdown 1 mm**	**(kV °C):**		25 (24°C)	42 (90°C)	39 (80°C)	39 (80°C)
ASTM D-924[1]	**Power Factor @ 25°C (Routine)**	**(%):**	0.006	0.018	0.008	0.005	0.005

Notations: 1. Analysis is ISO/IEC 17025:2017 accredited, ANAB Accredited Certificate Number L2303.02 2. This test is conducted by a subcontracted laboratory. 3. Subcontracted laboratory has received ISO Standard 17025 accreditation for this test. 5. This test is conducted by Weidmann Laboratory other than Primary Lab. 6. Weidmann Laboratory has received ISO Standard 17025 accreditation for this test. 7. Imported Sample: WEIDMANN Electrical Technology accepts no responsibility for these results; accreditation status does not apply to these results. 8. Imported Equipment 10. mg/kg , µg/g, µg/mL, µL/L = ppm, µg/L = ppb, mN/m = dynes/cm, mm²/s = cSt

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TEST REPORT
01-7334792-618125-00

Liberty Utilities	**Serial#:** M160691	**Mfr:** GENERAL ELECTRIC	**Control#:** 7334792
	Location: SALEM DEPOT #9	**kV:** 23	**Order#:** 618125
	Equipment: TRANSFORMER	**kVA:** 9300	**Account:** 110710
LONDONDERRY, NH 03053 US	**Compartment:** MAIN(BOTTOM)	**Year Mf'd:** 1989	**Received:** 04/28/2020
ATTN: MARIO BARONE	**Breathing:** SEAL	**Syringe ID:** 3001645	**Reported:** 05/12/2020
PO#: PO000016751	**Bank:** **Phase:**	**Bottle ID:**	
Project ID:	**Fluid:** MIN **USGal:** 1250	**Sampled By:**	
Customer ID: REF# 022772			

		Lab Control Number:	7334792	7044980	7035699[7]	7035709[7]	7035700[7]
		Date Sampled:	11/21/2019	06/14/2017	09/01/2016	12/16/2014	12/16/2014
		Order Number:	618125	541715	539656	539666	539657
		Oil Temp:		55	90	80	80
ASTM D-924	**Power Factor @ 100°C (Routine)**	**(%):**			0.340	0.324	0.324
ASTM D-1298	**Density @15°C**	**(g/mL):**			0.874	0.873	0.873
ASTM D-4052	**Density @15°C**	**(g/mL):**			0.874	0.873	0.873
ASTM D-445	**Viscosity @40°C**	**(mm²/s):**			8.52	8.46	8.46
ASTM D-2668[5, 6]	**Oxidation Inhibitor**	**(wt. %)**	**0.045**	0.033	0.059	0.069	0.069

GOQ Diagnostics	**Moisture in Oil:**	Acceptable for in-service oil (35 mg/kg max).
PER IEEE C57.106-2015	**Interfacial Tension:**	Acceptable for in-service oil (25 mN/m min).
(most recent sample)	**Acid Number:**	Acceptable for in-service oil (0.2 mg KOH/g max).
	Color Number and Visual:	Diagnostic not applicable. Diagnostic not applicable.
	Dielectric Breakdown ASTM D-877:	Diagnostic not applicable.
	Power Factor @ 25°C (Routine):	Acceptable for in-service oil (0.5% max).
	Oxidation Inhibitor:	Acceptable for in-service oil Type I (0.0% min and 0.08% max). Exceeds limit for in-service oil type II (0.08% min and 0.3% max).

Comment:

Furanic Compound	**2-Furaldehyde (µg/L):**	10	< 10
ASTM D-5837[5]	**5-Hydroxy-methyl-furaldehyde (µg/L):**	< 10	< 10
	2-Acetylfuran (µg/L):	< 10	< 10
	5-Methyl-2-furaldehyde (µg/L):	< 10	< 10
	2-Furyl alcohol (µg/L):	< 10	< 10

Furanic Compound Diagnostics (most recent sample):

New insulation with a high degree of mechanical strength will typically have a Degree of Polymerization (DP) of 1000-1300. "Middle Aged" paper is approximately 500 and paper with less than 250 is in its "Old Age." Severely degraded insulation with a DP of 150 or less will have very little mechanical strength and may result in a transformer failure. The above estimations are based on a study by Chendong of GSU transformers filled with mineral oil.

Estimated Average Degree of Polymerization (DP): 1001

Estimated Operating Age of the Equipment: <1.0

Notations:

Comment:

PCB	**Concentration (mg/kg):**	< 1.0 mg/kg	< 1.0 mg/kg
mod EPA Method 8082a[5, 6]	**PCB Type (Arocolor):**	ND	ND
	Reporting Limit:	1	1

Comment:

End of Test Report

Authorized By: [signature]

ERIC MCANANY
CHEMIST

Notations: 1. Analysis is ISO/IEC 17025:2017 accredited, ANAB Accredited Certificate Number L2303.02 2. This test is conducted by a subcontracted laboratory. 3. Subcontracted laboratory has received ISO Standard 17025 accreditation for this test. 5. This test is conducted by Weidmann Laboratory other than Primary Lab. 6. Weidmann Laboratory has received ISO Standard 17025 accreditation for this test. 7. Imported Sample: WEIDMANN Electrical Technology accepts no responsibility for these results; accreditation status does not apply to these results. 8. Imported Equipment 10. mg/kg , µg/g, µg/mL, µL/L = ppm, µg/L = ppb, mN/m = dynes/cm, mm²/s = cSt

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TEST REPORT
01-7334791-618125-00

Liberty Utilities	**Serial#:** G859810A	**Mfr:** GENERAL ELECTRIC	**Control#:** 7334791
	Location: SALEM DEPOT 9	**kV:** 22.9	**Order#:** 618125
	Equipment: TRANSFORMER	**kVA:** 7000	**Account:** 110710
LONDONDERRY, NH 03053 US	**Compartment:** MAIN(BOTTOM)	**Year Mf'd:**	**Received:** 04/28/2020
ATTN: MARIO BARONE	**Breathing:** SEAL	**Syringe ID:** 53005817	**Reported:** 05/12/2020
PO#: PO000016751	**Bank:** **Phase:**	**Bottle ID:**	
Project ID:	**Fluid:** MIN **USGal:** 1010	**Sampled By:**	
Customer ID: REF# 023068			

	Lab Control Number:	7334791	7044979	7035697[7]	7035708[7]	7035698[7]
	Date Sampled:	11/21/2019	06/14/2017	09/01/2016	12/16/2014	12/16/2014
	Order Number:	618125	541715	539654	539665	539655
	Oil Temp:		56	60	60	60
Dissolved Gas Analysis (DGA)	**Hydrogen (H2) (µL/L):**	**469**	**488**	**226**	**649**	**649**
ASTM	**Methane (CH4) (µL/L):**	**307**	**355**	**299**	**373**	**373**
D-3612[1]	**Ethane (C2H6) (µL/L):**	**194**	**175**	**194**	**183**	**183**
	Ethylene (C2H4) (µL/L):	**111**	**121**	**122**	**136**	**136**
	Acetylene (C2H2) (µL/L):	<1	<1	<1	<1	<1
	Carbon Monoxide (CO) (µL/L):	**1164**	**1293**	**773**	**1320**	**1320**
	Carbon Dioxide (CO2) (µL/L):	**18354**	**19237**	**19400**	**17200**	**17200**
	Nitrogen (N2) (µL/L):	61883	78625	76300	72700	72700
	Oxygen (O2) (µL/L):	585	1295	14100	3950	3950
	Total Dissolved Gas (TDG) (µL/L):	83067	101589	111414	96511	96511
	Total Dissolved Combustible Gas (TDCG) (µL/L):	**2245**	**2432**	**1614**	**2661**	**2661**
	Equivalent TCG (%):	2.6607	2.2693	1.195	2.783	2.783

DGA Diagnostics	**DGA Keys Gas / Interpretive Method: PER IEEE C57.104-2008** (most recent sample)	Hydrogen: Condition 2 Indications of partial discharge activity (100 µL/L). Methane: Condition 2 Indications of overheated (>150°C) oil (120 µL/L). Ethane: Condition 4 Indications of severely overheated (>250°C) oil (150 µL/L). Ethylene: Condition 3 Indications of significantly overheated (>350°C) oil (100 µL/L). Acetylene within condition 1 limits (1 µL/L). Carbon Monoxide: Condition 3 Indications of significantly overheated cellulose insulation (570 µL/L). Carbon Dioxide: Condition 4 Severe Indications of overheated cellulose insulation (10000 µL/L). TDCG: Condition 3 Levels indicate a high level of decomposition. Faults are probably present (1920 µL/L).
	DGA TDCG Rate Interpretive Method: PER IEEE C57.104-2008 (two most recent sample)	Retest Monthly. Exercise extreme caution. Analyze for individual gases. Plan outage. Advise manufacturer.
	DGA Cellulose (Paper) Insulation:	CO2/CO >= 10: Indication of thermal decomposition of cellulose insulation.
	Weidmann DGA Condition Code:	CAUTION
	Weidmann Recommended Action:	Resample within 6 months for testing.

Comment:

General Oil Quality (GOQ)							
ASTM D-1533[1]	**Moisture in Oil**	**(mg/kg):**	19	91	<2	4	4
ASTM D-971[1]	**Interfacial Tension**	**(mN/m):**	38.6	37.21	37.0	39.0	39.0
ASTM D-974[1]	**Acid Number**	**(mg KOH/g):**	0.009	0.021	0.005	0.005	0.005
ASTM D-1500[1]	**Color Number**	**(ASTM):**	L1.5	L1.0	1.5	1.5	1.5
ASTM D-1524[1]	**Visual Exam.**	**(Relative):**	PASS CLR&BRIGHT	PASS CLR&BRIGHT	PASS CLR&BRIGHT	PASS CLR&BRIGHT	PASS CLR&BRIGHT
ASTM D-1524[1]	**Sediment Exam.**	**(Relative):**	ND	ND			
ASTM D-877[1]	**Dielectric Breakdown**	**(kV):**	48	48	65	61	61

Notations: 1. Analysis is ISO/IEC 17025:2017 accredited, ANAB Accredited Certificate Number L2303.02 2. This test is conducted by a subcontracted laboratory. 3. Subcontracted laboratory has received ISO Standard 17025 accreditation for this test. 5. This test is conducted by Weidmann Laboratory other than Primary Lab. 6. Weidmann Laboratory has received ISO Standard 17025 accreditation for this test. 7. Imported Sample: WEIDMANN Electrical Technology accepts no responsibility for these results; accreditation status does not apply to these results. 8. Imported Equipment 10. mg/kg , µg/g, µg/mL, µL/L = ppm, µg/L = ppb, mN/m = dynes/cm, mm²/s = cSt

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TEST REPORT
01-7334791-618125-00

Liberty Utilities	**Serial#:** G859810A	**Mfr:** GENERAL ELECTRIC	**Control#:** 7334791
	Location: SALEM DEPOT 9	**kV:** 22.9	**Order#:** 618125
	Equipment: TRANSFORMER	**kVA:** 7000	**Account:** 110710
LONDONDERRY, NH 03053 US	**Compartment:** MAIN(BOTTOM)	**Year Mf'd:**	**Received:** 04/28/2020
ATTN: MARIO BARONE	**Breathing:** SEAL	**Syringe ID:** 53005817	**Reported:** 05/12/2020
PO#: PO000016751	**Bank: Phase:**	**Bottle ID:**	
Project ID:	**Fluid:** MIN **USGal:** 1010	**Sampled By:**	
Customer ID: REF# 023068			

		Lab Control Number:	7334791	7044979	7035697[7]	7035708[7]	7035698[7]
		Date Sampled:	11/21/2019	06/14/2017	09/01/2016	12/16/2014	12/16/2014
		Order Number:	618125	541715	539654	539665	539655
		Oil Temp:		56	60	60	60
ASTM D-1816	**Dielectric Breakdown 1 mm**	**(kV °C):**		27 (25°C)	40 (60°C)	42 (60°C)	42 (60°C)
ASTM D-924[1]	**Power Factor @ 25°C (Routine)**	**(%):**	0.007	0.021	0.006	0.004	0.004
ASTM D-924	**Power Factor @ 100°C (Routine)**	**(%):**			0.195	0.238	0.238
ASTM D-1298	**Density @15°C**	**(g/mL):**			0.887	0.887	0.887
ASTM D-4052	**Density @15°C**	**(g/mL):**			0.887	0.887	0.887
ASTM D-445	**Viscosity @40°C**	**(mm²/s):**			9.34	9.31	9.31
ASTM D-2668[5, 6]	**Oxidation Inhibitor**	**(wt. %)**	**0.068**	0.066	0.095	0.098	0.098

GOQ Diagnostics	**Moisture in Oil:**	Acceptable for in-service oil (35 mg/kg max).
PER IEEE C57.106-2015	**Interfacial Tension:**	Acceptable for in-service oil (25 mN/m min).
(most recent sample)	**Acid Number:**	Acceptable for in-service oil (0.2 mg KOH/g max).
	Color Number and Visual:	Diagnostic not applicable. Diagnostic not applicable.
	Dielectric Breakdown ASTM D-877:	Diagnostic not applicable.
	Power Factor @ 25°C (Routine):	Acceptable for in-service oil (0.5% max).
	Oxidation Inhibitor:	Acceptable for in-service oil Type I (0.0% min and 0.08% max). Exceeds limit for in-service oil type II (0.08% min and 0.3% max).

Comment:

Furanic Compound	**2-Furaldehyde (µg/L):**	41	38
ASTM D-5837[5]	**5-Hydroxy-methyl-furaldehyde (µg/L):**	< 10	< 10
	2-Acetylfuran (µg/L):	< 10	< 10
	5-Methyl-2-furaldehyde (µg/L):	38	28
	2-Furyl alcohol (µg/L):	< 10	< 10

Furanic Compound Diagnostics (most recent sample):

New insulation with a high degree of mechanical strength will typically have a Degree of Polymerization (DP) of 1000-1300. "Middle Aged" paper is approximately 500 and paper with less than 250 is in its "Old Age." Severely degraded insulation with a DP of 150 or less will have very little mechanical strength and may result in a transformer failure. The above estimations are based on a study by Chendong of GSU transformers filled with mineral oil.

Estimated Average Degree of Polymerization (DP): 828

Estimated Operating Age of the Equipment: 7.6

Notations:

Comment:

PCB	**Concentration (mg/kg):**	268.13 mg/kg	265.02 mg/kg
mod EPA Method 8082a[5, 6]	**PCB Type (Arocolor):**	1260/54/42	1260/54/42
	Reporting Limit:	1	1

Comment:

End of Test Report

Authorized By: [signature]

ERIC MCANANY
CHEMIST

Notations: 1. Analysis is ISO/IEC 17025:2017 accredited, ANAB Accredited Certificate Number L2303.02 2. This test is conducted by a subcontracted laboratory. 3. Subcontracted laboratory has received ISO Standard 17025 accreditation for this test. 5. This test is conducted by Weidmann Laboratory other than Primary Lab. 6. Weidmann Laboratory has received ISO Standard 17025 accreditation for this test. 7. Imported Sample: WEIDMANN Electrical Technology accepts no responsibility for these results; accreditation status does not apply to these results. 8. Imported Equipment 10. mg/kg , µg/g, µg/mL, µL/L = ppm, µg/L = ppb, mN/m = dynes/cm, mm²/s = cSt

INTRODUCTION

An initial step in the engineering and design of any electric station is the selection of suitable electrical clearances. Design clearances and spacing of energized and grounded parts are established for two purposes, to assure the proper operation of the substation and to assure the safety of the public and personnel working in and around the substation bus and equipment.

PURPOSE

The purpose of this standard is to provide the design requirements for electrical clearances and spacing for outdoor substations.

ACCOUNTABILITY

Not Applicable

COORDINATION

Not Applicable

REFERENCES

IEEE Paper T-72-131-6 “Minimum Line-To-Ground Electrical Clearances for EHV Substations Based on Switching Surge Requirements” by IEEE Working Group 59.1, IEEE Transactions on Power Apparatus and Systems, Volume 91, 1972, pages 1924-1930.

IEEE Paper 31-TP-66-16, “Minimum Phase to Phase Electrical Clearances for Substations Based on Switching Surges and Lightning Surges”, T. Udo, IEEE Power Transactions on Power Apparatus and Systems, Volume 85, 1966, pages 838-845

IEEE Paper 31 TP 66-106 “Series Gaps in Air Break Switches”, P. Mayo, IEEE Transactions on Power Apparatus and Systems, Volume PAS-66, No. 4, April 1967, pages 428-438.

LU-ENG-SUB005 Animal Deterrents in Electric Substations

DEFINITIONS

See Section 3.0

TRAINING

Not Applicable

DOCUMENT CONTENTS

Table of Contents

1.0 OPERATING REQUIREMENTS

1.1 The proper operation of the substation is addressed by establishing clearances and spacing that coordinate with the design insulation level of the substation. Minimum electrical clearances in air-insulated substations have a direct correlation with the insulation levels.

1.1.1 For voltages up to 115kV, clearances are generally selected based on BIL.

1.1.2 At 230 kV, clearances are generally dictated by BIL, but could also be dictated by switching surge.

1.1.3 For EHV (345kV and above), clearances are generally dictated by switching surge withstand requirements. Table 8.3 provides typical insulation levels for substation equipment.

1.2 The potential for hazards and personal injury is greatly increased as the proximity of personnel to electrical equipment decreases. Consequently, safety clearances are established to minimize the possibility of accidental human contact with live parts. Guards shall be provided around all live parts operating above 300V phase-to-phase without adequate insulating covering, unless the location of the live parts gives a sufficient safety clearance zone.

1.3 Working clearances around electrical equipment are designed to provide safe access to personnel working in the substation. The safe distances required for normal operation and maintenance work are specified in:

1.3.1 Table 2A-D Minimum Approach Distances of this standard

1.3.2 Section 5 Substations of Liberty's Employee Safety & Health Handbook.

2.0 CODES & STANDARDS

2.1 This standard is based on the following:

2.1.1 ANSI C2-2007, National Electrical Safety Code (NESC)

2.1.2 ANSI C37.06-2000, "AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis-Preferred Ratings and Related Required Capabilities"

2.1.3 ANSI C37.32-2002, "American National Standard for Switchgear - High Voltage Air Switches, Bus Supports, and Switch Accessories - Schedules of Preferred Ratings, Manufacturing Specifications, and Application Guide"

2.1.4 ANSI C84.1-2006, "Electrical Power Systems and Equipment - Voltage Ratings (60 Hz)"

2.1.5 IEEE C57.12.00-2006, IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers, 2.1.6 IEEE C62.22-1996, “Guide for the Application of Metal-Oxide Surge Arresters for Alternating-Current Systems”.

2.1.7 IEEE Std. 1313.1-1996, “IEEE Standard for Insulation Coordination - Definitions, Principles, and Rules”

2.1.8 IEEE Std. 1313.2-1999, “IEEE Guide for the Application of Insulation Coordination”

2.1.9 IEEE Std. 1427-2006, “IEEE Guide for Recommended Electrical Clearances and Insulation Levels in Air-Insulated Electrical Power Substations”

2.1.10 Liberty Employee Health & Safety Handbook

2.1.11 NEMA Standards Publication No. SG-6-2000, “Power Switching Equipment”

2.1.12 NESC 2017 – “National Electric Safety Code”

2.1.13 OSHA Standard 29CFR1910.269, “Working on Exposed Energized Parts”

3.0 EXPLANATION OF TERMS

3.1 Air Switch: A switching device designed to close and open one or more electric circuits by means of guided separable contacts that separate in air.

3.2 BIL: Commonly referred to as “Basic Impulse Level” or “Basic Insulation Level.” The BIL value is a reference insulation value expressed in terms of the crest value of a standard lightning impulse.

3.3 BSL: The reference insulation level expressed in terms of the crest value of a standard switching impulse.

3.4 Centerline-to-Centerline Spacing of Buses: A distance that is measured from the centerline of one bus/conductor to the centerline of another bus/conductor

3.5 Clearance between Live Parts: A distance that is measured from surface to surface of two electrically connected parts having voltages different from that of the ground.

3.6 Clearances: The clear distance measured between two objects measured surface to surface.

3.7 Double-Break Switch: A switch that opens a conductor of a circuit at two points.

3.8 Equipment Internal & External BIL/BSL: The internal insulation level of equipment such as transformers vs. the external insulation level of the substation

3.9 Horn-Gap Switches: A switch provided with arcing horns.

3.10 Insulation Coordination: The process of bringing the insulation strengths of electrical equipment and buses into the proper relationship with expected overvoltages and with the characteristics of the insulating media and surge protective devices, to obtain an acceptable risk of failure.

3.11 Maintenance Clearances: Clearance values designed to provide adequate distances during the maintenance of electrical equipment

3.12 Maximum System Voltage: The highest voltage at which a system is designed to operate.

3.13 Minimum clearances: The shortest distance measured between any energized parts.

3.14 Nominal System Voltage: The nominal value assigned to a system for the purpose of conveniently designating its voltage class. The actual operating voltage of a system may vary above and below the nominal value.

3.15 Phase to Grade: The shortest distance between any energized part and finished grade, that is the surface beneath a person's feet or beneath a vehicle's tires.

3.16 Phase to Ground: The shortest distance between any energized part(s) and the adjacent grounded part(s).

3.17 Phase to Phase: The shortest distance between any energized parts where the parts are different phases, including phases of different voltages.

3.18 Recommended Clearance: The clearance value in accordance with all applicable codes that have been obtained through years of successful experience.

3.19 Safe Working Clearances: Clearance values designed to ensure the safety of personnel working about electrical equipment.

3.20 Side Break Switch: A switch in which the travel of the blade is in a plane parallel to the base of the switch.

3.21 Spacing: The clear distance measured between two objects measured center to center.

3.22 Surge Arrester: Electrical device designed to protect electrical systems and equipment from overvoltages and from transient overvoltages that appear on the system.

3.23 Vertical Break Switch: A switch in which the travel of the blade is in a plane perpendicular to the plane of the mounting base. The blade in the closed position is parallel to the mounting base.

4.0 ELECTRICAL CLEARANCES AND SPACING FOR OUTDOOR STATIONS

4.1 Table 8.1 provides Liberty's design requirements for electrical clearances and spacing for outdoor substations. These values are based on a combination of code requirements and Liberty's operating experience and preferred practices. It lists the phase-to-ground and phase-to-phase clearance values as well as phase-to-phase spacing. Figure 8.1 provides a visual aid of various electrical clearance values that may be used in a substation. Liberty Preferred Clearances and Spacing are presented in Section 7.0.

4.2 When Preferred and Minimum values are listed for the same attribute in Table 8.1, the preferred value should be used for design. The Minimum values listed are based on the minimum requirements of ANSI C37.32. The minimum values are to be used only in evaluating existing stations, or in the design of new stations where space is very limited and the more generous preferred value cannot be accommodated.

4.3 The phase-to-ground and phase-to-phase clearances listed in ANSI C37.32 are generally more conservative than those of IEEE 1427. Historically ANSI C37.32 has been used as the governing code for electrical clearances and is reflected in Liberty current practices. For that reason the more conservative values of Liberty Preferred Practices, ANSI C37.32 and IEEE 1427 are used in Table 8.1 except as noted.

4.4 Liberty tries to design the appearance of its substations to be pleasing to the eye. As such one goal is to keep the station bus spacing as uniform as possible. The phase spacing for a voltage level should be as uniform as possible. The phase spacing for a voltage level should be used through-out the entire station. Based solely on the phase spacing tables in this document you could have three different phase spacings for one voltage level given by dimensions A, B and F in Clearance Figure 8.1. When determining the phase spacing pick the largest dimension necessary for the type of switches to be used and use that dimension for all of the bus spacing at that voltage level.

5.0 SAFETY CLEARANCES

5.1 NESC Rules

5.1.1 These clearances are for personnel safety and are based on NESC requirements and Liberty's preferred practices. The following NESC rules are used for the basis of this Section:

a. Rule 110 “General Requirements”

b. Rule 124 “Guarding Live Parts”

c. Rule 232 “Vertical Clearances of Wires, Conductors, Cables, and Equipment Above Ground, Roadway, Rail or Water Surfaces”

d. Rule 234 “Clearances of Wires, Conductors, Cables and Equipment from Buildings, Bridges, Rail Cars, Swimming Pools and other Installations”

e. Rule 441 “Energized Conductors or Parts”

5.2 Design Factors

5.2.1 Factors that are considered in establishing substation safety clearance requirements include the following:

a. Clearances from earth, taking into account a number of factors such as voltage class, height of a person, depth of snow where applicable, height of footings, etc.

b. Clearances to vehicles, taking into account the height of typical maintenance vehicles, and the height of floats and trucks that are used for the transportation of major equipment.

c. Clearances to fences.

5.3 Design Safety Clearances

5.3.1 Table 8.1 also provides Liberty design “Safety Clearances” from energized parts to personnel, roadways, control house roofs, railroads, vehicles, and fences within the substation and to buildings on the property line. Figures 8.1, 8.2, 8.3, 8.4 and 8.5 assist in interpreting the values presented in Table 8.1. Personnel clearance values presented in Table 8.1 are also applicable to personnel working in indoor areas of the substation. Liberty Preferred Clearances and Spacing are presented in Section 7.0.

5.3.2 The derivation/source of these clearances is as follows:

a. NESC Part 2, Rule 232C1a - For the minimum clearance from energized conductor to roadways/other land traverse by vehicles. Clearance values for cables (lines/strain bus) are derived from Rule 232B1 (H) and for Rigid Bus from Rule 232B2 (J).

b. NESC Part 1, Rule 110A2 - For the minimum safety clearance to station fence (S). This table presents the minimum values required by code.

c. NESC Part 1, Rule 124A1 - For the minimum horizontal clearance from unguarded live parts (E) and minimum vertical clearance from unguarded live parts to grade (D).

d. NESC Part 1 Rule 124C3 - For the minimum horizontal clearance from guard to live parts.

e. NESC Part 2, Rule 234C1 - For the minimum clearance from conductors to the roof of the substation control house (K) or the side wall of buildings (M).

f. NESC Part 4, Rule 441A1 - For the minimum approach distance to energized conductors. These distances are more conservative than those shown in Table R-6 of OSHA 29CFR1910.269, "Working on Exposed Energized Parts".

g. NESC Part 2, Rules 232B1 and 232C1a - For the minimum clearance from overhead conductors to railroad tracks within the substation site (L).

5.4 Working Clearances Around Equipment

5.4.1 Working clearances around electrical equipment are designed to provide safe access to personnel working in the substation. The safe distances required for normal operation and maintenance work are specified in:

a. Table 2A - D Minimum Approach Distances of this standard

b. Section 5 Substations of Liberty's Employee Health & Safety Handbook.

6.0 ELECTRICAL CLEARANCES AND SPACING FOR INDOOR FACILITIES

6.1 Table 8.2 provides electrical clearance for bare conductors for indoor substation facilities. It lists the phase-to-ground and phase-to-phase minimum and recommended clearance values. When both values are shown, the clearance used should be as near the recommended as practical. Figure 8.1 provides a visual aid of various electrical clearance values that may be used in a substation.

6.2 This section present the values based on the codes cited in Table 8.2. Liberty Preferred Clearances and Spacing are presented in Section 7.0.

7.0 LIBERTY PREFERRED CLEARANCE AND SPACING

7.1 Sections 4.0, 5.0 and 6.0 present spacing and clearances based primarily on code minimum requirements. Liberty, though years of design and operational experience has established preferred values of design clearances and spacing. These preferred values are discussed below.

7.1.1 Clearances to Fences

a. Figure 8.3 provides the Liberty preferred clearances to substation fences and should be used for new designs for conductors leaving the station.

b. Figure 8.4 provide the Liberty preferred clearance to substation fences and should be used for new designs for conductors not leaving the station.

7.1.2 Preferred Spacing, Bus Heights and Clearances

a. Table 8.1 provides the Liberty preferred spacing, bus height and clearances and should be used for new designs.

8.0 TABLES AND FIGURES

8.1 Safety Clearances to Fences, Property Lines and Buildings

8.1.1 The permitted or intended use of the property immediately outside the fence or property line may not be known at the time of original design. Therefore proper safety clearances should be incorporated in the design to allow for the most liberal potential use of adjacent area.

8.1.2 Figure 8.3 illustrates the safety clearance to substation fences for conductors leaving the station.

a. Dimension H is the Minimum Vertical Clearance to Unguarded Live Parts for Vehicular Traffic from Table 8.1.

b. Dimension D is the Minimum Vertical Clearance to Unguarded Live Parts for Personnel on Foot, from Table 8.1.

c. Dimension S is the Minimum Clearance of Live Parts to Substation Fences from Table 8.1

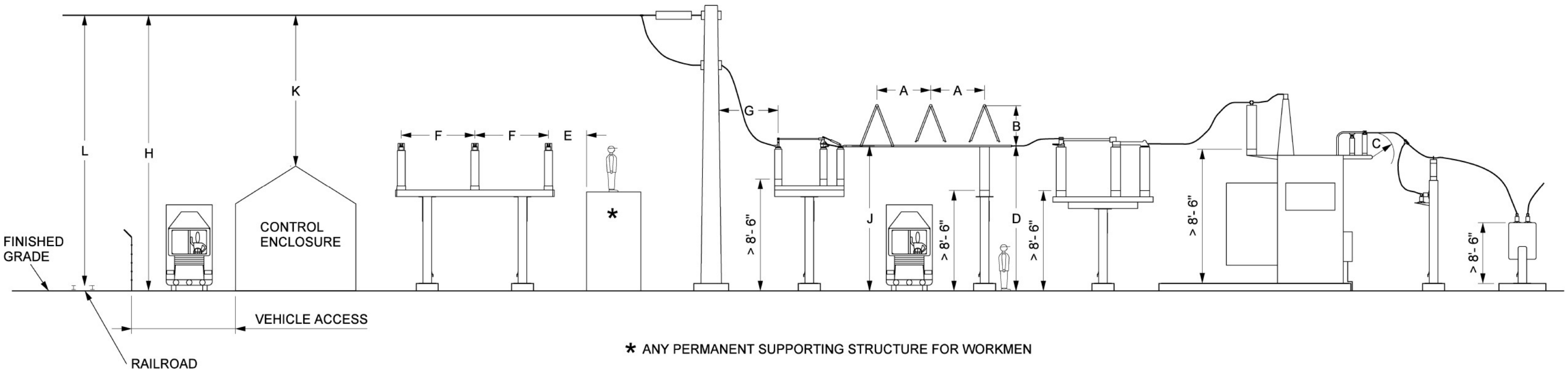
8.1.3 The Safety Clearance boundary is located by constructing an arc with Radius S from a point on the substation fence a height of H-S above grade, such that the arc is tangent to the horizontal line defined by Dimension H and intersects the horizontal line defined by Dimension D. All live parts are to be located beyond this Safety Clearance boundary as shown in Figure 8.3. If the center of the arc is above the horizontal line defined by D, (i.e., H-S > D), then after a 90 degree sweep of the arc a vertical line is drawn tangent to the arc and intersecting the horizontal line defined by D

8.1.4 Figure 8.4 illustrates the safety clearance to substation fences for conductors not leaving the station. The minimum safety clearance zone for substation fences is located by constructing an arc with radius S from a point on the fence 5'-0" above grade, such that the arc intersects the horizontal line defined by Dimension D.

8.1.5 Fences or walls when installed as barriers for unauthorized personnel shall be located such that exposed live parts are outside the safety zone. However, when a fence, partition, or wall with no openings through which sticks or other objects can be inserted is utilized, live parts may be installed within the safety clearance zone, if they are below the horizontal line projected from the top of the fence or wall.

8.1.6 Figure 8.5 illustrates the minimum clearance per NESC 234c1 of conductor in a substation to a building on the property line or that may be built on the property line.

Figure 8.1 - Application Guideline



This Applications Diagram's Sole Purpose is to illustrate the Application of the Various Electrical Clearances for Outdoor Structures.

It Does Not Necessarily Represent Standard Structures or Electrical Arrangements

Whenever a Foundation is Large enough for a Workman to Stand on Without Conscious Effort, the Minimum and Recommended Clearances Shall Be from the Top of the Foundation and Not Finished Grade.

A Recommended Centerline to Centerline Spacing of Bus
B Clearance between Live Parts.
C Clearance from Live Parts to Ground
D Minimum Vertical Clearance to Unguarded Live Parts Accessible Only to Personnel on Foot
E Minimum Horizontal Clearance to Unguarded Live Parts from Any Permanent Supporting Structure for Workmen
F Phase-to-Phase Spacing for Switches-
G Phase-to-Ground Spacing for Horn Gap Switches
H Minimum Vertical Clearance to Unguarded Wire and Conductor Live Parts Accessible to Vehicular Traffic.
J Minimum Vertical Clearance to Unguarded Rigid Bus Live Parts for Vehicular Traffic
K Minimum Vertical Clearance of Overhead Conductors to Control Enclosure Roofs
L Minimum Vertical Clearance of Overhead Conductors to Railroad Tracks

Table 8.1 - Outdoor Phase Spacing Bus Heights and Clearances

Preferred Nominal System Voltage (kV)		2.4 4.26 4.8 7.2	12 13.2 13.8	23	34.5	46	69	115	138	230			345	
BIL (kV)		95	110	150	200	250	350	550	650	750	900	1050	1175	1300
Maximum Voltage Rating (kV)		8.25	15.5	25.8	38.0	48.3	72.5	121	145	242			372	
Center-to-Center Spacing (A)	Bus, Vertical Break Switches, Double Side Break Switches	2' - 0"	3' - 0"			4' - 0"	5' - 0"	8' - 0"		9' - 0"	11' - 0"	13' - 4"	16' - 0"	
	Side Break Switches	2' - 6"	2' - 6"	3' - 0"	4' - 0"	4' - 0"	6' - 0"	9' - 0"	11' - 0"	13' - 0"	16' - 0"	18' - 0"	NYE	
Clearance Between Live Parts (B)	Minimum per ANSI C37.32	0' - 7"	1' - 0"	1' - 3"	1' - 6"	1' - 9"	2' - 7'	4' - 5"	5' - 3"	6' - 0"	7' - 5"	8' - 9"	8' - 0" (2)	
	Preferred	1' - 0"	1' - 6'	2' - 0"	2' - 6"	3' - 0"	4' - 0"	6' - 0"	7' - 0"	8' - 0"	10' - 0"	11' - 0"	13' - 6"	
	Minimum for Animal Deterrent (4)	See LU-ENG-SUB005 Animal Deterrents in Electric Substations												
Clearance From Live Parts to Ground (C)	Minimum per ANSI C37.32	0' - 6"	0' - 8" (1)	0' - 11" (1)	1' - 3" (1)	1' - 7" (1)	2' - 1'	3' - 6"	4' - 2"	4' - 10"	5' - 11"	6' - 11"	7' - 10"	8' - 8"
	Preferred	0' - 8"	0' - 10"	1' - 0"	1' - 3"	1' - 7"	2' - 5"	3' - 11"	4' - 5"	5' - 2"	6' - 4"	7' - 7'	8' - 2"	9' - 4"
	Minimum for Animal Deterrent (4)	See LU-ENG-SUB005 Animal Deterrents in Electric Substations												
Clearance from Unguarded Live Parts	(D) Vertical (3)	9' - 0"		10' - 0"			11' - 0"	12' - 0"	13' - 0"	14' - 0"	15' - 0"	16' - 0"	17' - 9"	
	(E) Horizontal	3' - 4"	3' - 6"	3' - 9"	4' - 0"	4' - 4"	4' - 11"	6' - 1"	6' - 8"	7' - 4"	9' - 4"	10' - 0"	12' - 3"	
Spacing of Horn-Gap Switches without Arc Extinguishing Devices (5)	(F) Phase-to-Phase	3' - 0"		4' - 0"	5' - 0"	6' - 0"	7' - 0"	10' - 0"	12' - 0"	14' - 0"	16' - 0"	18' - 0"	19' - 0"	20' - 0"
	(G) Phase-to-Ground	2' - 0"		2' - 6"	3' - 0"	3' - 9"	4' - 3"	6' - 0"	7' - 6"	9' - 0"	10' - 0"	11' - 0"	12' - 0"	

(Continued)

<table>
<tr><th colspan="2">Preferred Nominal System Voltage (kV)</th><th>2.4
4.26
4.8
7.2</th><th>12
13.2
13.8</th><th>23</th><th>34.5</th><th>46</th><th>69</th><th>115</th><th>138</th><th>230</th><th>345</th></tr>
<tr><td rowspan="2">Vertical Clearances from Conductors to Roads/Land Traversed by Vehicles</td><td>(H) Line/Strain Bus</td><td colspan="2">22’ - 0”</td><td colspan="3">25’ - 0”</td><td colspan="3">30’ - 0”</td><td>34’ - 0”</td><td>37’ - 0”</td></tr>
<tr><td>(J) Rigid Bus</td><td colspan="5">20’ - 0”</td><td>20’ - 6”</td><td colspan="2">21’ - 6”</td><td>23’ - 6”</td><td>26’ - 0”</td></tr>
<tr><td colspan="2">Vertical Clearances Overhead Conductors to Control House Roof (K)</td><td colspan="4">12’ - 6”</td><td>12’ - 9”</td><td>13’ - 2”</td><td>14’ - 2”</td><td>14” - 7”</td><td>16’ - 6”</td><td>19’ - 0”</td></tr>
<tr><td colspan="2">Vertical Clearances Overhead Conductors to Railroad Tracks (L)</td><td colspan="4">26’ - 6”</td><td>26’ - 9”</td><td>27’ - 2”</td><td>28’ - 1”</td><td>28’ - 7”</td><td>30’ - 6”</td><td>33’ - 0”</td></tr>
<tr><td colspan="2">Horizontal Clearance of Conductor to Buildings (M)</td><td colspan="4">7’ - 6”</td><td>7’ - 8”</td><td>8’ - 2”</td><td>9’ - 0”</td><td>9’ - 6”</td><td>11’ - 3”</td><td>13’ - 6”</td></tr>
<tr><td colspan="2">Clearance to Fence(6) (S)</td><td colspan="4">11’ - 0”</td><td colspan="2">12’ - 0“</td><td colspan="2">14’ - 0”</td><td>16’ - 5”</td><td>18’ - 4”</td></tr>
<tr><td colspan="2">Approach Distance to Energized Conductors (Phase-to-Ground) - Qualified Employee</td><td colspan="2">2’ - 2”</td><td>3’ - 0”</td><td>3’ - 0”</td><td colspan="2">4’ - 0”</td><td>5’ - 0”</td><td>6’ - 0”</td><td>7’ - 0”</td><td>9’ - 0”</td></tr>
<tr><td colspan="2">Approach Distance to Energized Conductors (Phase-to-Ground) - Non-Qualified Employee(OSHA)</td><td colspan="5">10’ - 0”</td><td>10’ - 8”</td><td>12’ - 4”</td><td>13’ - 0”</td><td>16’ - 0”</td><td>20’ - 0”</td></tr>
</table>

Notes for Table 8.1

Letter in ( ) refers to attributes in Figures 8.1, 8.2, 8.3, 8.4 and 8.5
Electrical clearances values based on ANSI C37.32 and EEEE 1427 and Liberty Preferred Practices
Safety clearances based on NESC 2017 and Liberty Preferred Practices
NYE indicates values not yet established in either C37.32 or IEEE 1427
(1) - Entries from IEEE 1427 that exceed the requirements of ANCI C37.32
(2) - Entries based on IEEE 1427 for 2.5 per unit switching surge factor (BSL 760 kV) to qualify Liberty practices that are less than ANSI C37.32
(3) - A minimum of 8’ - 6” shall be maintained to the bottom of porcelain or other parts of indeterminate potential
(4) - At voltages of 34.5 kV and less, if the phase to phase spacing and/or clearance to ground is less than that required for animal deterrents then animal guards should be installed on the bus.
(5) - This spacing may be reduced as long as the minimum clearance between live parts is maintained.
(6) - The values of S in the table meet or exceed the Minimum Clearances to Fences in accordance with NESC Table 110-1

Figure 8.2 - Clearance From Live Parts

Figure 8.2 should be used in conjunction with Table 8.1 to obtain the indicated horizontal and vertical clearances**.**

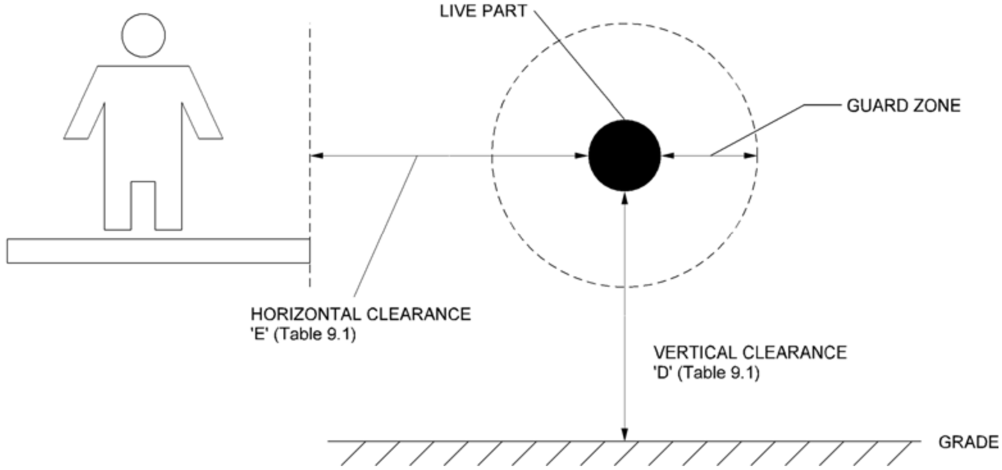


Figure 8.3 - Safety Clearance to Substation Fences for Conductors Leaving the Station

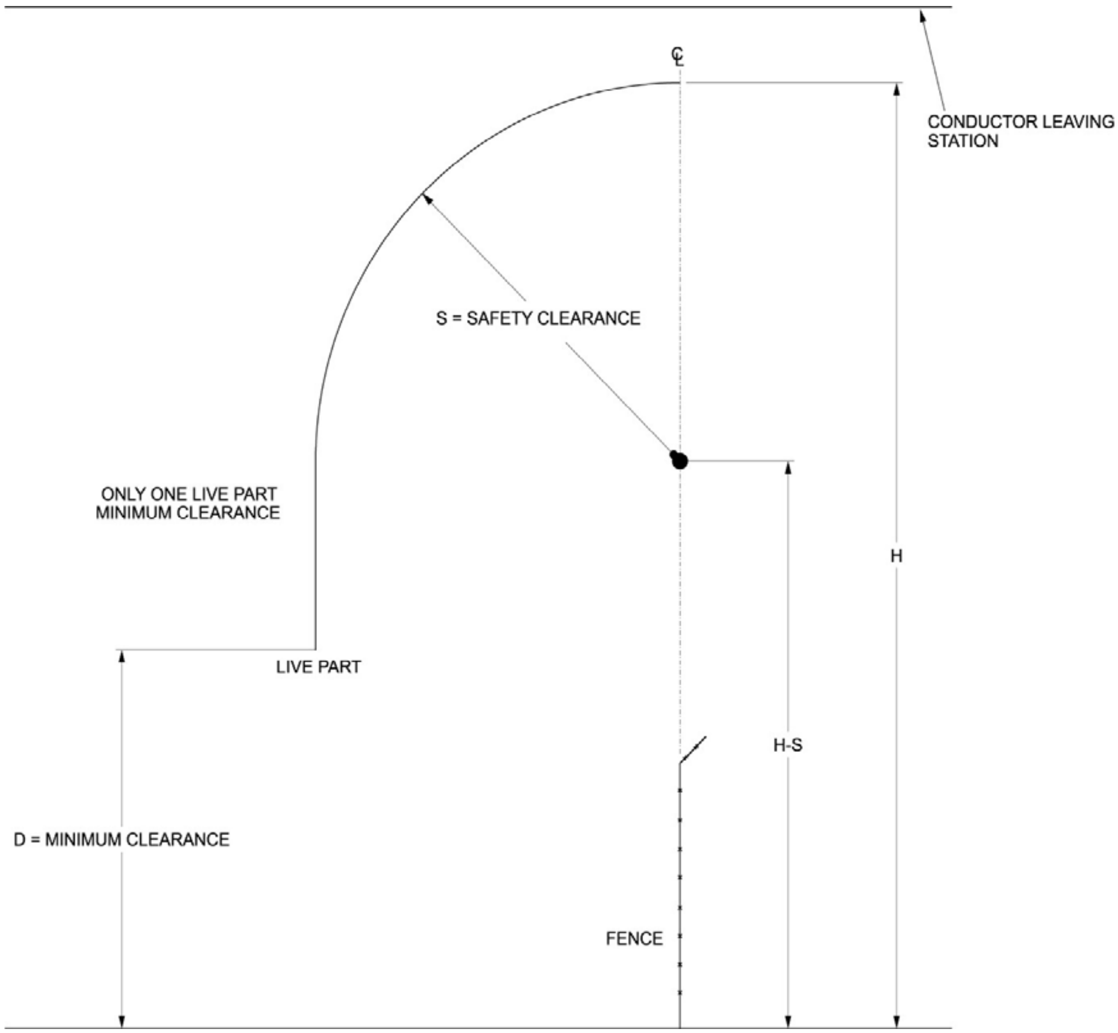


Figure 8.4 - Safety Clearance to Substation Fences for Conductors Not Leaving the Station

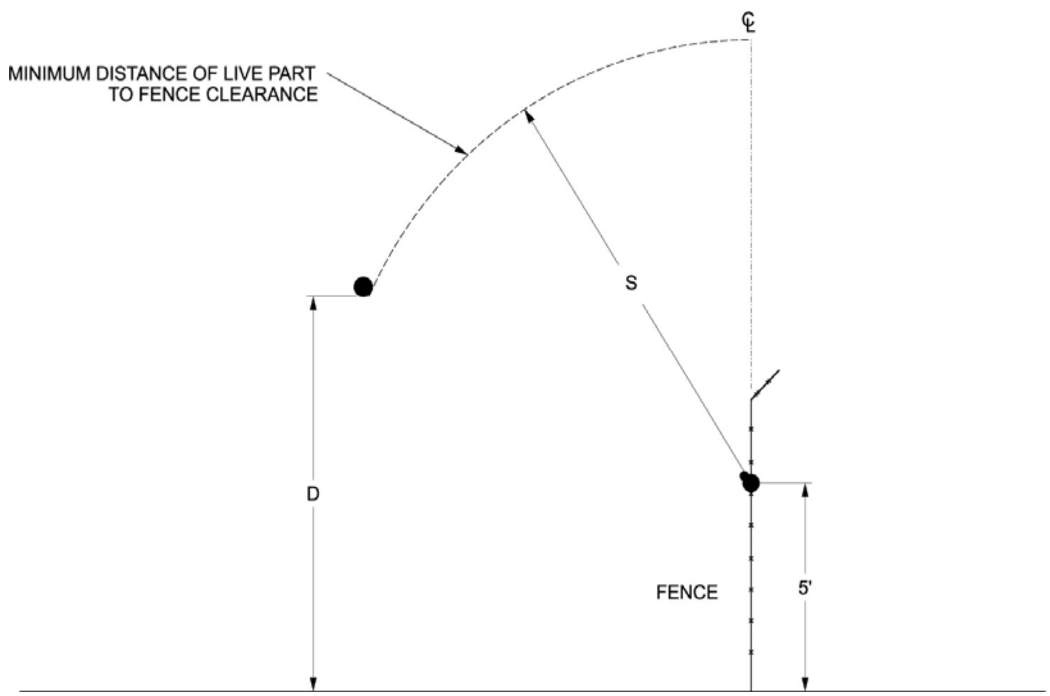


Figure 8.5 - Safety Clearance to Building on Property Line for Conductors Not Leaving Station

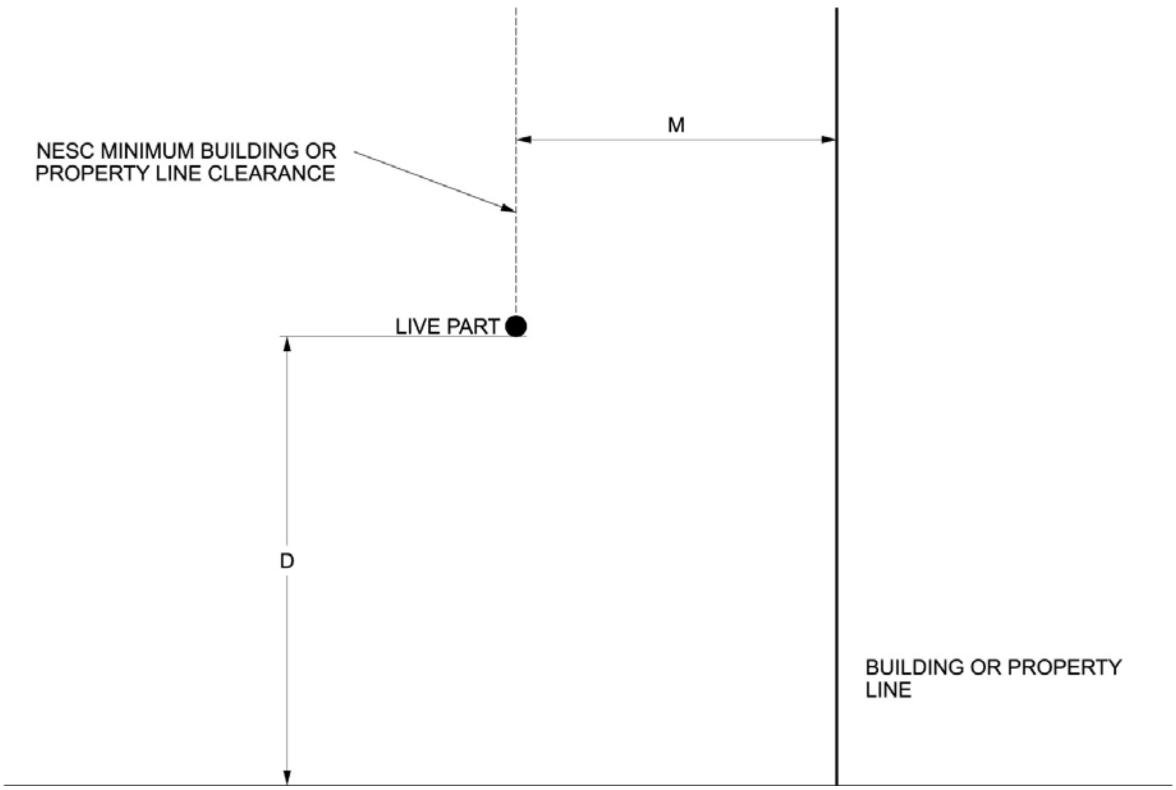


Table 8.2 - Indoor Phase Spacing and Clearances for Bare Conductors

kV Class		7.5	15	23	34.5
BIL (kV Crest)[1]		60	110	125	150
Rated Maximum Voltage		2400 V 4160 V 4800 V	8320 V 12 kV 13.2 kV 13.8 kV	23 kV	34.5 kV 38 kV
Spacing of Buses	Rec. [5]	12”	18”	20”	24”
	Min. [5]	9”	12”	14”	18”
Clearance Between Live Parts	Rec. [5]	8”	14”	16”	20”
	Min. [2]	4 ½”	9”	13”	18”
Clearance From Live Parts to Ground	Rec. [5]	6”	10”	18”	24”
	Min. [3]	4 ½”	8”	11”	15”
Minimum Clearance to Unguarded Live Parts	Vert. [4]	8’ - 10”	9’ - 0”	9’ - 1”	9’ - 3”
	Horz. [4]	3’ - 4”	3’ - 6”	3’ - 7”	3’ - 9”

Notes for Table 8.1

1. Based on ANSI C37.32 Table 12
2. Based on ANSI C37.32 Table 14
3. Based on IEEE 1427 Table 3
4. Based on NESC Table 124-1
5. Based on Liberty Preferred Practices
6. Any reduction in clearances or spacing of conductors allowed by covering them is determined by a number of factors (material used, conductor shape, installation geometry, thickness of the covering, etc.) and can only be established by test for specific cases. Covered conductors shall be treated as bare conductors for clearance and spacing purposes unless otherwise established by vendor’s guideline or testing specific to the covering used.

Table 8.3 - Electrical Power Equipment BIL Ratings (kV)

Max. System Voltage (kV)	High Voltage Circuit Breakers (ANSI C37.06)			Air Switches (ANSI C37.32)		Transformers (IEEE C57.12.00)	
	Indoor Oil	Indoor Oil-less	Outdoor Table 4	Indoor Table 12	Outdoor Table 6	Power Table 3	Distribution Table 3
4.76	60	60		60		60/75	60
8.25	75	95		75	95	75/95	75
15	95	95	110	95/110	110	95/110	95
25.8	125		150	125	150	150	125
38	150	150	200	150	200	200	150
48.3			250		250	200/250	200/250
72.5			350		350	250/350	250/350
121			550		550	350/450/550	
145			650		650	450/550/650	
242			900		900/1050	650/750/825/900	
372			1300		1050/1300	900/1050/1175	

9.0 REVISION HISTORY

Date	Rev #	Description	Lead/Author
08/01/2020	1.0	Initial Version of Liberty Utilities document. Updated from National Grid document to be NH Specific.	Robert J Johnson