Attachment 1

UES – Capital

Reliability Analysis and Recommendations 2015

Unitil Energy Systems - Capital

Reliability Study

2015

Prepared By:
Cyrus Esmaeili
Unitil Service Corp.
Oct 1, 2015

UES - Capital Reliability Analysis and Recommendations 2015

Oct 1, 2015

UES - Capital Reliability Analysis and Recommendations 2015

Oct 1, 2015

1. Executive Summary

The purpose of this document is to report on the overall reliability performance of the UES-Capital system January 1, 2014 through December 31, 2014. The scope of this report will also evaluate individual circuit reliability performance over the same time period. The outage data from the following storm has been excluded from these analyses: UES-CATO 11/26/2014 13:00 to 12/01/2014 19:30.

The following projects are proposed from the results of this study and are focused on improving the worst performing circuits as well as the overall UES-Capital system reliability. These recommendations are provided for consideration and will be further developed with the intention to be incorporated into the 2015 budget development process.

Circuit / Line / Substation	Proposed Project	Cost ($)
15W1	INSTALL A RECLOSING DEVICE TO PROTECT SHAKER RD	$9000
13W1	INSTALL COVERED WIRE ALONG KIMBALL POND RD	$23,000
4W4	INSTALL COVERED WIRE ALONG LAKEVIEW RD	$99,000
BOW JUNCITON	INSTALL AN AUTO TRANSFER SCHEME	$100,000
396 LINE	INSTALL AN AUTO SECTIONALIZING SCHEME	$40,000

Note: estimates do not include general construction overheads

2. Reliability Goals

The annual corporate system reliability goals for 2015 have been set at 180-160-139 SAIDI minutes. These were developed through benchmarking Unitil system performance with surrounding utilities.

Individual circuits will be analyzed based upon circuit SAIDI, SAIFI, and CAIDI. Analysis of individual circuits along with analysis of the entire Capital system is used to identify future capital improvement projects and/or operational enhancements which may be required in order to achieve and maintain these goals.

3. Outages by Cause

This section provides a breakdown of all outages by cause code experienced during 2014. Chart 1 lists the number of interruptions, and the percent of total interruptions, due to each cause. For clarity, only those causes occurring more than 5 times are labeled. Chart 2 details the percent of total customer-minutes of interruption due to each cause, only those causes contributing greater than 2% of the total are labeled.

UES - Capital Reliability Analysis and Recommendations 2015

Oct 1, 2015

Chart 1
Number of Interruptions by Cause

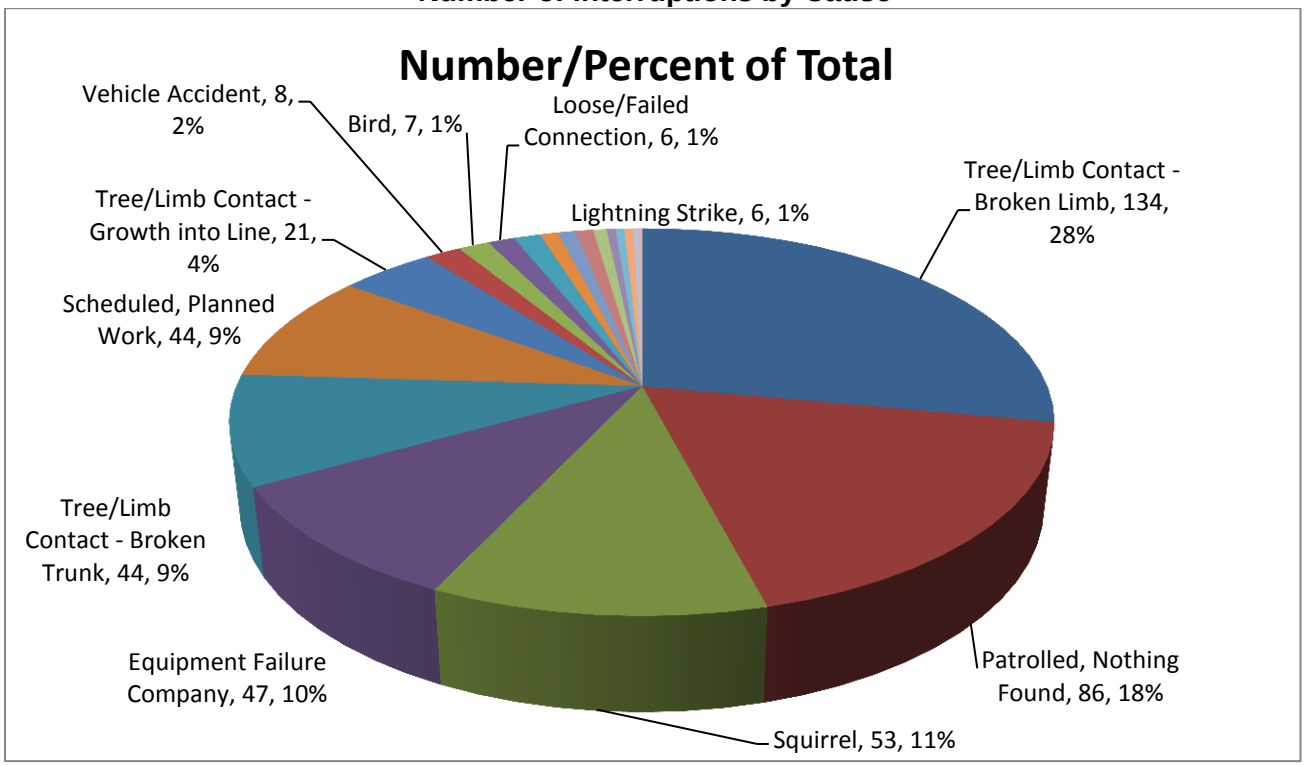
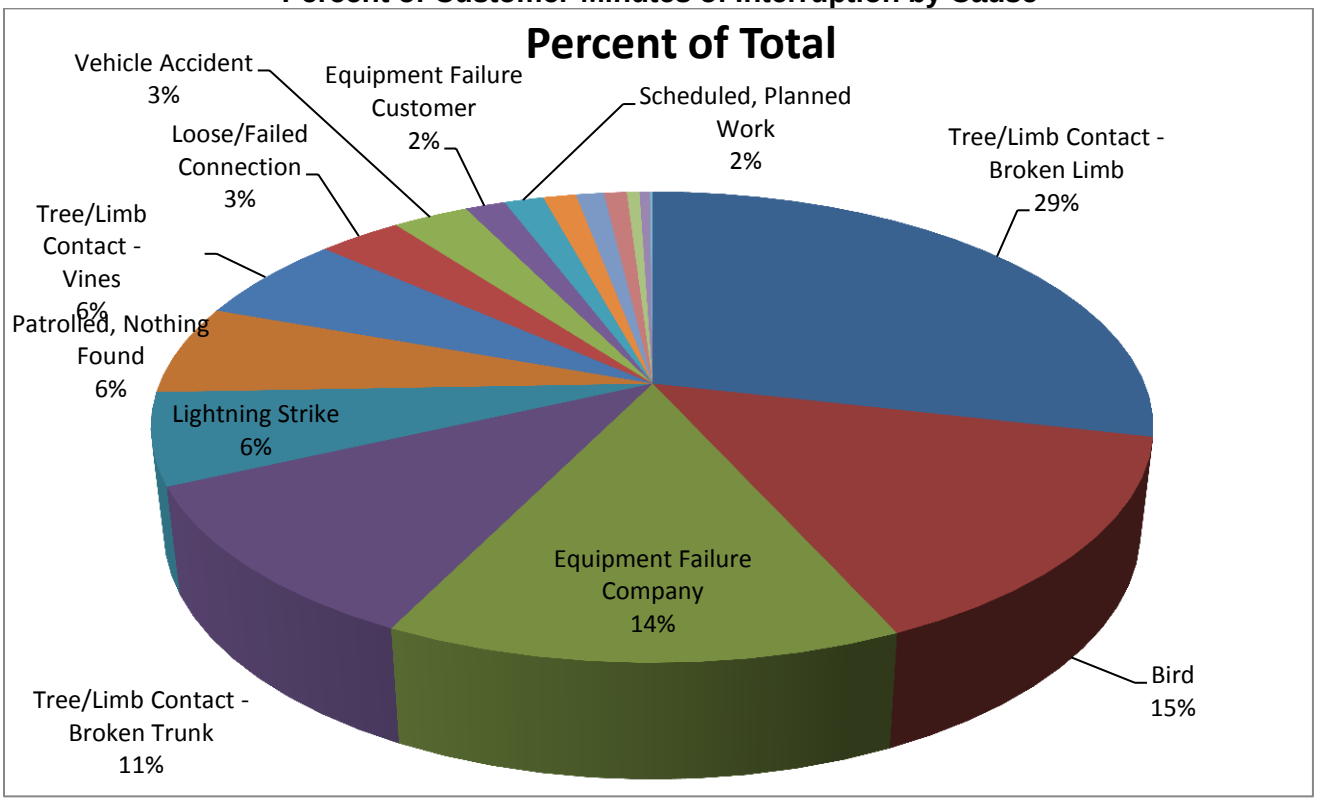


Chart 2
Percent of Customer-Minutes of Interruption by Cause



4. 10 Worst Distribution Outages

The ten worst distribution outages ranked by customer-minutes of interruption during the time period from January 1, 2014 through December 31, 2014 are summarized in Table 1 below.

Table 1
Worst Ten Distribution Outages

Circuit	Date/Cause	Customer Interruptions	Cust-Min of Interruption	SAIDI	SAIFI
22W3	1/4/2014 Loose/Failed Connection	906	99,931	3.34	0.030
8X3	11/2/2014 Tree/Limb Contact - Broken Limb	443	96,101	3.22	0.015
15W2	4/23/2014 Vehicle Accident	350	95,425	3.19	0.012
8X5	12/9/2014 Equipment Failure Company	855	77,956	2.61	0.029
13W2	7/28/2014 Tree/Limb Contact - Broken Limb	972	70,324	2.35	0.033
13W1	2/12/2014 Loose/Failed Connection	483	70,035	2.34	0.016
13W3	5/7/2014 Vehicle Accident	204	51,772	1.73	0.007
15W1	7/15/2014 Tree/Limb Contact - Broken Limb	256	47,501	1.59	0.009
7W3	9/7/2014 Patrolled, Nothing Found	898	46,831	1.57	0.030
8X3	6/25/2014 Tree/Limb Contact - Broken Trunk	332	43,131	1.44	0.011

Note: This table does not include substation, sub-transmission or scheduled planned work outages.

5. Sub-transmission Line and Substation Outages

This section describes the contribution of sub-transmission line and substation outages on the UES-Capital system from January 1, 2014 through December 31, 2014.

All substation and sub-transmission outages ranked by customer-minutes of interruption during the time period from January 1, 2014 through December 31, 2014 are summarized in Table 2 below.

Table 3 shows the circuits that have been affected by sub-transmission line outages. The table illustrates the contribution of customer minutes of interruption for each circuit affected by a sub-transmission outage.

Table 2
Sub-transmission and Substation Outages

Line/Substation	Date/Cause	Customer Interruptions	Cust-Min of Interruption	SAIDI	SAIFI
Line 396[1]	9/8/2014 Bird	11,910	1,003,440	33.58	0.399
Bow Junction Substation	4/19/2014 Equipment Failure Company - Transformer	5,129	480,605	16.08	0.172
Line 374[2]	9/13/2014 Tree/Limb Contact - Broken Trunk	5,909	446,659	14.95	0.198
Line 37	9/16/2014 Tree/Limb Contact - Vines	3,209	409,838	13.72	0.107
Line 35	7/16/2014 Lightning Strike	2,238	397,335	13.30	0.075
Line 33 (From Bow Junction)	7/2/2014 Tree/Limb Contact - Broken Limb	2,083	279,820	9.36	0.070
Line 374	2/13/2014 Equipment Failure Company - Insulator	3,056	189,460	6.34	0.102
Line 33 (From W. Concord)	7/5/2014 Patrolled, Nothing Found	1,197	143,524	4.80	0.040
Line 38[3]	1/10/2014 Equipment Failure Customer - Cable	873	100,056	3.35	0.029
Line 38	4/14/2014 Equipment Failure Company - Pole	1562	88,295	2.95	0.052
Line 38	9/3/2014 Operator Error/System Malfunction	689	42,316	1.42	0.023
Line 38[2]	1/10/2014 Equipment Failure Customer - Cable	687	7,534	0.25	0.023

[1] A fault on the 396 Line affected multiple sub transmission lines due to a protective device not operating. An investigation was completed and measures have been taken to prevent this situation from happing again.
[2] System was in an alternate configuration, thus the circuits affected had changed
[3] These outages are part of the same event, although the smaller of the two was about four hours after the first, which was required to reconnect the primary metered customer that caused the initial outage.

UES - Capital Reliability Analysis and Recommendations 2015

Oct 1, 2015

Table 3
Contribution of Sub-transmission and Substation Outages

Circuit	Substation / Transmission Line Outage	Cust-Min of Interruption	% of Total Circuit CMI	Circuit SAIDI Contribution	Number of Events
C13W1	Line 37	61,789	31%	127.66	1
C13W2	Line 37	124,173	50%	168.71	1
C13W3	Line 37	201,488	44%	127.85	1
C13X4	Line 37	128	33%	127.93	1
C14H1	Line 374 Line 396*	25,261	100%	271.62	3
C14H2	Line 374 Line 396*	181,927	99%	269.52	3
C14X3	Line 374 Line 396*	1,094	62%	182.35	3
C15H3	Line 35 Line 396*	4,243	100%	249.60	2
C15W1	Line 35 Line 396*	243,452	50%	250.21	2
C15W2	Line 35 Line 396*	87,247	31%	245.76	2
C16H1	Line 396*	22,903	72%	76.86	1
C16H3	Line 396*	47,552	100%	76.33	1
C16X4	Line 396*	43,710	86%	76.68	1
C16X5	Line 396*	78	9%	3.38	1
C16X6	Line 396*	77	100%	77.03	1
C17X1	Line 374 Line 396*	215	96%	1.90	2
C18W2	Line 374 Line 396*	178,888	55%	160.73	2
C1H1	Line 396*	24,486	100%	77.24	1
C1H2	Line 396*	19,943	100%	77.30	1
C1H3	Line 396*	46,099	65%	76.20	1
C1H4	Line 396*	3,850	100%	77.00	1
C1H5	Line 396*	5,390	100%	77.00	1
C1H6	Line 396*	25,641	87%	77.00	1
C1X7A	Line 396*	77	100%	77.00	1
C1X7P	Line 396*	613	75%	76.58	1
C21W1A	Line 396*	21,560	26%	76.73	1
C21W1P	Line 396*	31,745	61%	77.24	1
C22W1	Bow Junction Substation Line 33 Line 374	104,396	39%	209.63	3
C22W2	Bow Junction Substation Line 33 Line 374	8,836	41%	210.38	3
C22W3	Bow Junction Substation Line 33	324,787	28%	205.30	3

UES - Capital Reliability Analysis and Recommendations 2015

Oct 1, 2015

Circuit	Substation / Transmission Line Outage	Cust-Min of Interruption	% of Total Circuit CMI	Circuit SAIDI Contribution	Number of Events
	Line 374				
C24H1	Line 35 Line 38 Line 396*	171,333	95%	543.92	6
C24H2	Line 35 Line 38 Line 396*	203,884	100%	545.14	6
C2H1	Line 396*	34,632	100%	71.85	1
C2H2	Line 396*	76,248	92%	72.62	1
C2H4	Line 396*	6,768	100%	72.00	1
C33X2	Bow Junction Substation Line 33 Line 374	209	100%	209.18	2
C33X3	Bow Junction Substation Line 33 Line 396*	248	100%	247.50	3
C33X4	Bow Junction Substation Line 33 Line 396*	16,583	77%	247.50	3
C33X5	Bow Junction Substation Line 33 Line 396*	743	100%	247.50	3
C33X6	Bow Junction Substation Line 33 Line 396*	248	100%	247.50	3
C34X2	Line 396*	72	100%	72.00	1
C34X4	Line 396*	72	100%	72.00	1
C35X1	Line 35 Line 396*	2,505	31%	178.94	2
C35X2	Line 35 Line 396*	1,000	100%	249.88	2
C35X3	Line 35 Line 396*	250	100%	249.88	2
C35X4	Line 35 Line 396*	1,498	100%	249.73	2
C374X1	Line 374 Line 396*	3,002	100%	300.20	3
C375X1	Line 396*	466	100%	77.62	1
C37X1	Line 37	22,260	53%	127.20	1
C3H1	Line 374 Line 396*	169,056	94%	301.35	3
C3H2	Line 374 Line 396*	144,427	91%	282.64	3
C3H3	Line 374 Line 396*	32,469	99%	295.17	3
C6X3	Bow Junction Substation	266,697	76%	243.34	3

Circuit	Substation / Transmission Line Outage	Cust-Min of Interruption	% of Total Circuit CMI	Circuit SAIDI Contribution	Number of Events
	Line 33 Line 396*				
C7W3	Bow Junction Substation Line 374	261,461	66%	291.48	2
C7W4	Bow Junction Substation Line 374	211,553	90%	248.59	2
C7X1	Bow Junction Substation Line 374	41,772	94%	262.72	2

* A fault on the 396 Line affected multiple sub transmission lines due to a protective device not operating. An investigation was completed and measures have been taken to prevent this situation from happening again.

6. Worst Performing Circuits

This section compares the reliability of the worst performing circuits using various performance measures. All circuit reliability data presented in this section includes subtransmission or substation supply outages unless noted otherwise.

6.1. Worst Performing Circuits in Past Year

A summary of the worst performing circuits during the year of 2014 is included in the tables below. Table 4 shows the ten worst circuits ranked by the total number of Customer-Minutes of interruption. The SAIFI and CAIDI for each circuit are also listed in this table. Table 5 provides detail on the major causes of the outages affecting these circuits. Customer-minutes of interruption are given for the six most prevalent causes during 2014.

Circuits having one outage contributing to more than 75% of the Customer-Minutes of interruption of the circuit were excluded from this analysis.

Table 4
Worst Performing Circuits by Customer-Minutes

Circuit	No. of Customers Interruptions	Worst Event (% of CI)	Cust-Min of Interruption	Worst Event (% of CMI)	SAIDI	SAIFI	CAIDI
22W3	9,226	16.95%	1,154,184	40.33%	729.57	5.83	125.10
15W1	3,242	30.04%	486,372	35.66%	499.87	3.33	150.02
8X3	3,842	12.73%	470,761	20.41%	167.11	1.36	122.53
13W3	3,658	43.11%	455,916	44.19%	289.29	2.32	124.64
7W3	3,572	25.14%	398,770	42.55%	444.56	3.98	111.64
6X3	3,709	30.47%	349,127	38.66%	318.55	3.38	94.13
18W2	3,463	31.56%	324,955	37.67%	291.96	3.11	93.84
15W2	2,342	15.33%	282,163	33.82%	794.83	6.60	120.48
22W1	2,009	24.89%	266,112	56.60%	534.36	4.03	132.46
13W2	2,423	40.12%	247,111	50.25%	335.75	3.29	101.99

Note: all percentages and indices are calculated on a circuit basis

Table 5
Circuit Interruption Analysis by Cause

	Customer – Minutes of Interruption / # of Outages					
Circuit	**Animal Combined**	**Tree/Limb Contact - Broken Limb**	**Equipment Failure - Company**	**Tree/Limb Contact - Vines**	**Tree/Limb Contact - Broken Trunk**	**Patrolled, Nothing Found**
22W3	2,022 / 2	793,760 / 17	75,075 / 2	0 / 0	149,962 / 7	19,198 / 9
15W1	75,399 / 3	186,016 / 9	0 / 0	0 / 0	15,358 / 3	3,438 / 5
8X3	6,510 / 9	312,788 / 40	10,395 / 7	0 / 0	67,727 / 12	69,545 / 19
13W3	20,804 / 10	110,611 / 14	359 / 2	201,488 / 1	30,720 / 10	5,439 / 11
7W3	2,584 / 3	26,871 / 6	177,269 / 2	0 / 0	93,494 / 2	49,157 / 2
6X3	79,203 / 1	35,679 / 3	57,964 / 3	0 / 0	5,982 / 1	169,044 / 4
18W2	133,679 / 9	57,986 / 10	75,728 / 2	2,117 / 1	0 / 0	25,206 / 6
15W2	26,537 / 2	25,502 / 3	43,916 / 4	0 / 0	0 / 0	5,617 / 3
22W1	130 / 1	217,346 / 2	34,920 / 2	0 / 0	13,662 / 1	0 / 0
13W2	0 / 0	99,069 / 4	382 / 3	129,537 / 3	0 / 0	9,611 / 1

6.2. Worst Performing Circuits of the Past Five Years (2010 – 2014)

The annual performance of the ten worst circuits in terms of SAIDI and SAIFI for the past five years is shown in the tables below. Table 6 lists the ten worst circuits ranked by SAIDI performance. Table 7 lists the ten worst performing circuits ranked by SAIFI.

The data used in this analysis includes all system outages except those outages that occurred during the 2014 November 26 Cato Snowstorm, 2012 Hurricane Sandy, 2011 October Nor'easter, 2011 Hurricane Irene and 2010 Windstorm.

Table 6
Circuit SAIDI

Circuit Ranking	2014		2013		2012		2011		2010	
	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI
1	15W2	794.83	16H1	1524.26	13W2	817.42	13W1	887.09	8X3	1,037.0
2	22W3	729.57	375X1[1]	1018.00	13W1	425.04	13W2	835.67	211A	650.29
3	35X1	573.63	37X1	861.07	211P	381.91	37X1	797.25	13W1	648.23
4	24H1[2]	570.48	13W2	744.95	211A	270.00	13W3	660.07	13W2	487.15
5	24H2[2]	545.14	13W1	739.74	8X3	244.17	18W2	593.77	13W3	417.67
6	22W1	534.36	16X5	720.50	18W2	223.12	22W3	421.91	2H4	414.01
7	22W2	512.65	8X3	708.72	7W3	193.84	17X1	388.00	2H2	353.25
8	15W1	499.87	13W3	609.67	34X2	165.00	13X4	369.00	37X1	304.57
9	7W3	444.56	24H1	524.03	15W1	152.67	21W1A	361.90	3H2	298.00
10	38W	441.97	18W2	521.30	15W2	135.36	38W	359.61	18W2	293.13

Table 7
Circuit SAIFI

Circuit Ranking	2014		2013		2012		2011		2010	
	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI
1	24H1[2]	7.143	13W2	7.068	13W2	9.520	13W3	10.379	13W1	5.956
2	24H2[2]	6.987	16X5	5.500	13W1	4.858	13W2	8.942	8X3	5.847
3	15W2	6.597	37X1	5.412	21W1P	3.037	37X1	7.660	13W3	5.561
4	22W3	5.832	13W1	5.405	7W3	2.458	13W1	7.500	13W2	4.638
5	3H1[3]	4.251	22W3	4.849	18W2	2.386	22W3	6.440	37X1	4.391
6	22W1	4.034	4W3	4.574	6X3	2.283	38W	5.428	211A	4.365
7	38W	4.022	13W3	4.547	8X3	2.250	13X4	5.000	1H5	4.235
8	22W2	4.000	7W3	4.547	15W1	2.053	22W2	4.881	1H3	4.135
9	7W3	3.982	18W2	4.337	22W1	2.000	3H1	3.245	1H4	4.127
10	14X3	3.500	16H1	4.120	13W3	1.834	4X1	3.100	3H2	4.000

6.3. Improvements to Worst Performing Circuit (2013-2015)

Projects completed from 2013 to 2015 that are expected to improve the reliability of the worst performing circuits are included in table 8 below.

[1] Only two outages, one of which happened during a major event accounted for 97% of the Circuit SAIDI minutes
[2] 90% or more of the circuit SAIDI minutes are due to sub transmission outages. Refer to Table 8 for improvements completed on the 35 Line
[3] 90% or more of the circuit SAIDI minutes are due to sub transmission outages.

Table 8
Improvements to Worst Performing circuits

Circuits	Year of Completion	Project Description
37 Line[1]	2014	Cycle Pruning / New Construction on Failed Connection Pole / Replaced Insulators that are well known for Higher than normal failure rate
13W1	2013	Fuse Additions / Forestry Review / Mid Cycle Review / Storm Resiliency Pilot (SRP)
	2014	Cycle Pruning
	2015	Fuse Additions / Installed Animal Guards in problem areas
13W2	2013	Grey Spacer Cable Replacement
		Cycle Pruning
		Fuse Additions
	2015	Hazard Tree Mitigation
13W3	2013	Grey Spacer Cable Replacement
		Hazard Tree Mitigation
	2014	Hazard Tree Mitigation / Mid Cycle Review
13X4	2015	New Recloser Installation
15W1	2013	Fuse Addition
	2014	Forestry Review
	2015	Cycle Pruning / Hazard Tree Mitigation
15W2	2014	Fuse Additions
	2015	Cycle Pruning
18W2	2013	Hazard Tree Mitigation / SRP / Fuse Additions
	2014	Forestry Review / Installed Animal Guards in problem areas
	2015	Fuse Addition / Sectionalizer Installations / Forestry Review
33 Line[2]	2015	Install remote operation capability on switches and SCADA monitored Fault indicators
22W3	2013	Mid Cycle Review

[1] This work will improve reliability performance on circuits 13W1, 13W2 and 13W3.
[2] The 33 line project will improve reliability performance on circuits 22W1,22W2, 22W3 and 6X3

Circuits	Year of Completion	Project Description
	2014	Forestry Review / Installed Animal Guards in problem area
	2015	Cycle Pruning / Hazard Tree Mitigation / Installed Animal Guards in problem areas / Fuse savings implemented in problem areas
3H1	2015	Cycle Pruning
4W3	2015	Storm Resiliency Pilot (SRP)
6X3	2014	Hazard Tree Mitigation
	2015	All Mainline One Bolt Connectors Replaced / Installed Animal Guards in problem areas / Fuse Additions
7W3	2013	Storm Resiliency Pilot (SRP)
	2015	Cycle Pruning / Hazard Tree Mitigation
8X3	2015	Hazard Tree Mitigation / SRP / Mainline One Bolt Connectors Replaced / Replaced Insulators that are well known for Higher than normal failure rate / Fuse Addition / Install Reclosing Devices
38W[1]	2013	Reconfigured 38W Source Recloser
	2014	Cycle Pruning / Hazard Tree Mitigation / Mainline One Bolt Connectors Replaced
396 Line[2]	2014	Installed Animal Guards on 396J2 switch
35 Line[3]	2015	Replaced Insulators that are well known for Higher than normal failure rate

7. Tree Related Outages in the Past Year (1/1/14-12/31/14)

This section summarizes the worst ten performing circuits by tree related outages during 2014.

Table 9 shows the ten worst circuits ranked by the total number of Customer-Minutes of interruption caused by tree related faults on the circuit. The number of customer-interruptions and number of outages are also listed in this table. Circuits having less than three outages were excluded from this table.

All streets on the Capital System with three or more tree related outages are shown in Table 10 below. The table is sorted by number of outages and customer-minutes of interruption and does not include major events.

[1] The 38W line work will improve reliability performance on circuits 24H1 and 24H2
[2] Many circuits affected by this line, please reference table 3 for this list
[3] The 35 line work will improve reliability performance on circuits 35X1, 15W1, 15W2, 15H3, 38W, 24H1 and 24H2

Table 9
Worst Performing Circuits – Tree Related Outages

Circuit	Cust-Min of Interruption	Customer Interruptions	No. of interruptions
8X3[1]	382,577	2,964	54
22W3[1]	229,024	1,667	25
15W1[1]	209,638	949	13
13W3[1]	164,043	1,474	27
13W2[1]	104,433	1,220	6
4W3[1]	62,414	630	6
18W2[1]	60,103	593	11
6X3[1]	42,916	195	5
7W3[1]	31,746	456	8
13W1[1]	31,702	303	19

Table 10
Multiple Tree Related Outages by Street

Circuit	Street	# of Outages	Customer Interruptions	Customer Min. of Interruptions
8X3[1]	Dover Rd, Chichester/Epsom	5	370	46,934
15W1[1]	Mountain Rd, Concord	4	515	179,776
22W3[1]	Page Rd, Bow	4	1,031	85,875
8X3[1]	Horse Corner Rd, Chichester	4	314	29,138
13W3[1]	Battle St, Webster	4	153	28,615
13W1[1]	Borough Rd, Canterbury	4	86	9,107
8X3[1]	Main St, Chichester	3	967	139,186
18W2[1]	Twist Hill Rd, Dunbarton	3	159	19,835
13W3[1]	High St, Boscawen	3	503	18,641
13W3[1]	Warner Rd, Salisbury	3	107	17,211
22W3[1]	White Rock Hill Rd, Bow	3	92	10,990
15W1[1]	Oak Hill Rd, Concord/Loudon	3	175	9,941
13W1[1]	Hackleboro Rd, Canterbury	3	19	5,030
8X3[1]	Sanborn Hill Rd North, Epsom	3	27	2,970
8X3[1]	Old Mountain Rd, Epsom	3	3	1,091

8. Failed Equipment in the Past Year

This section is intended to clearly show all equipment failures throughout the year of 2014. Chart 3 shows all equipment failures throughout the study period. Chart 4 shows each equipment failure as a percentage of the total failures within this same study period. Chart 5 shows the top four types of failed equipment within the study period with five years of historical data.

[1] Tree trimming efforts have been or will be completed, refer to table 8 for details

Chart 3
Equipment Failure Analysis by Cause

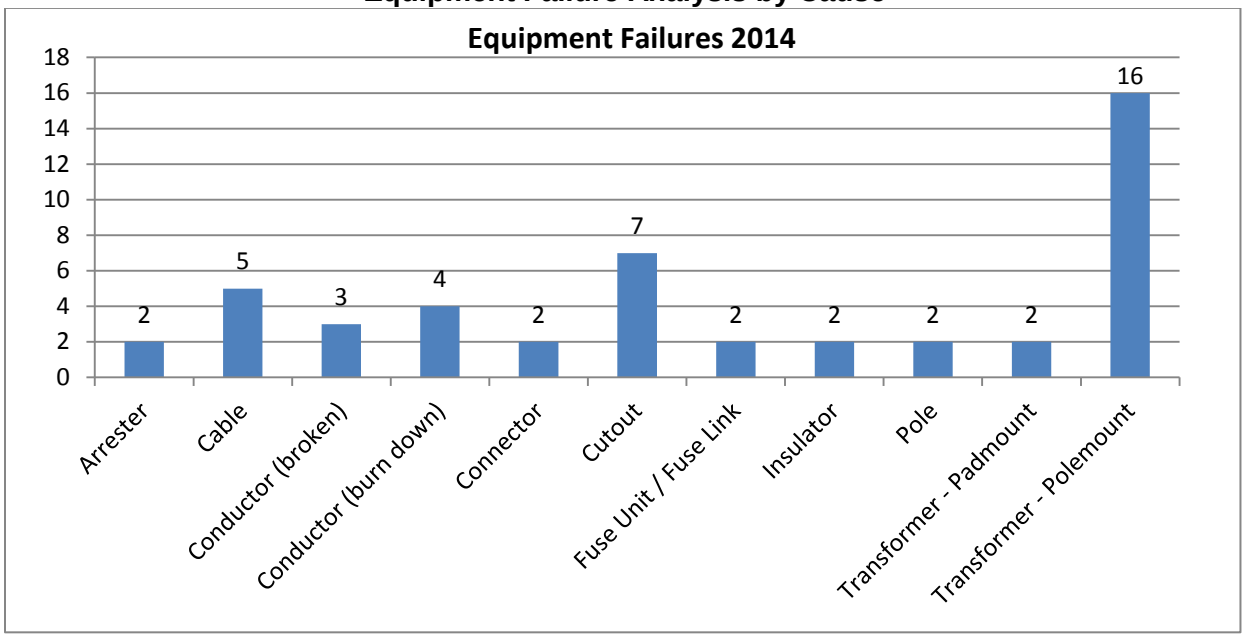
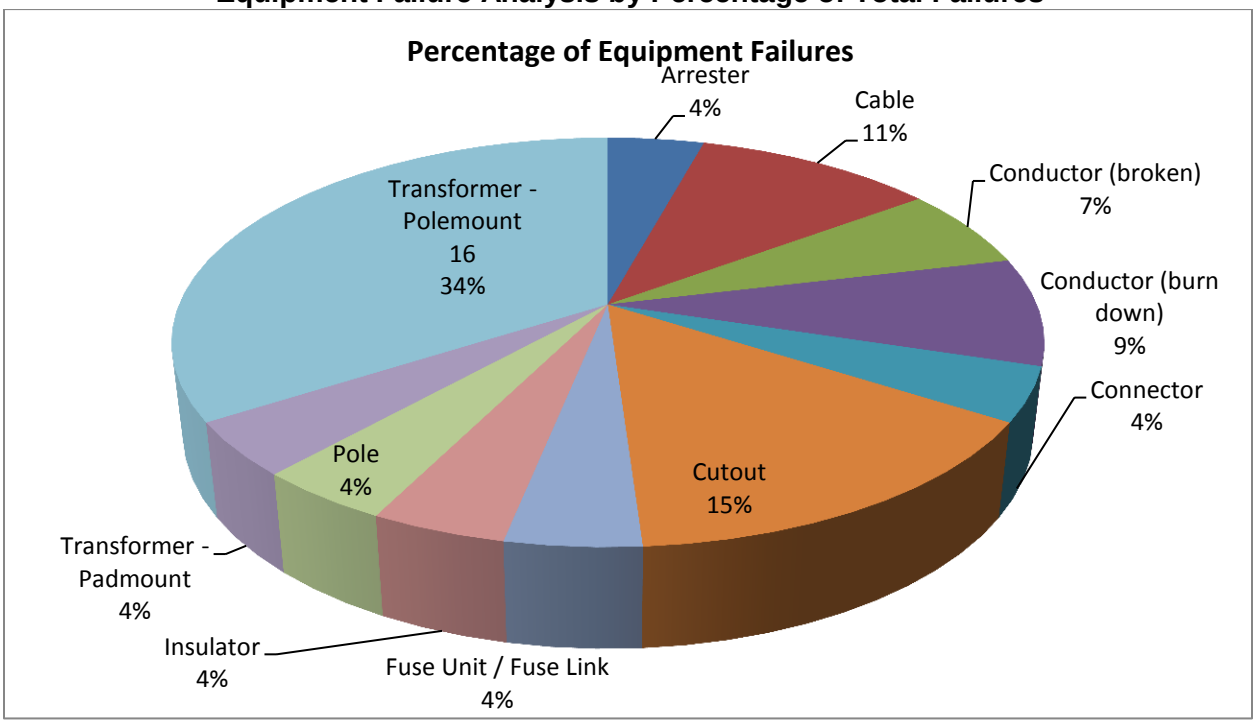


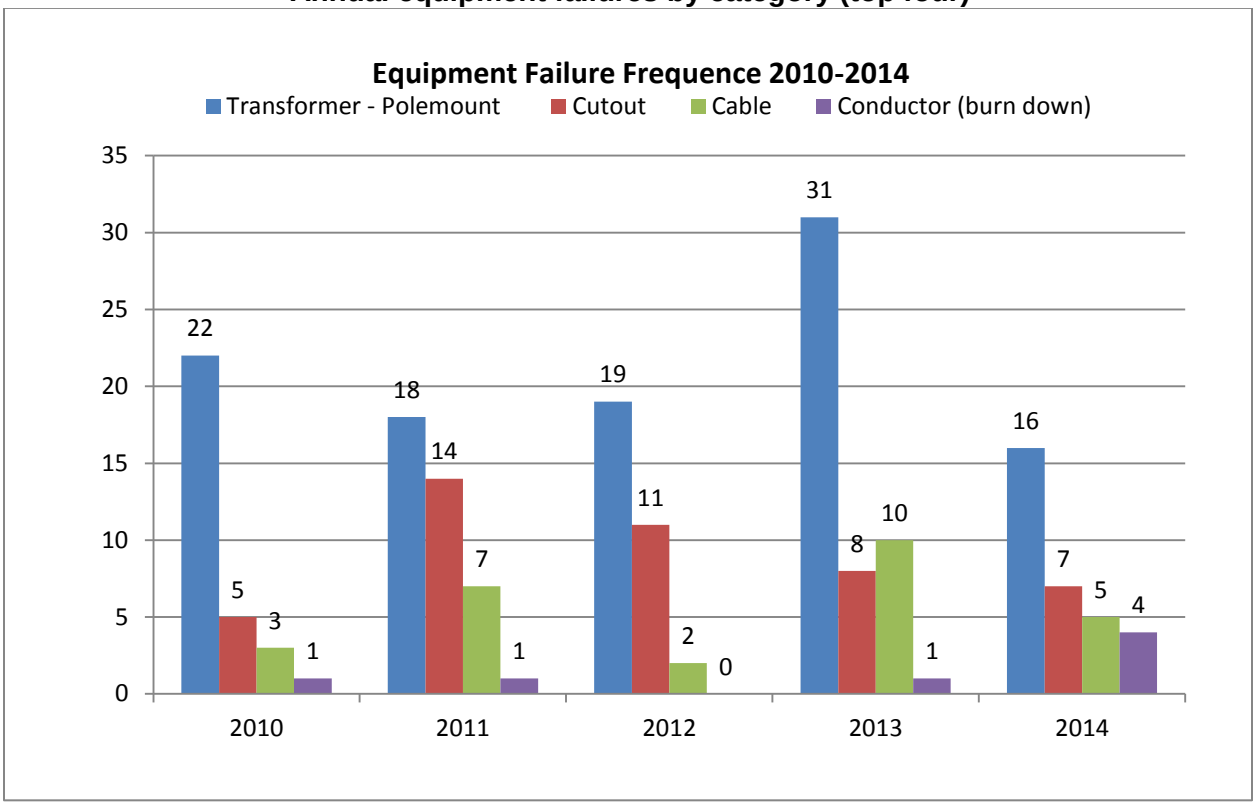
Chart 4
Equipment Failure Analysis by Percentage of Total Failures



UES - Capital Reliability Analysis and Recommendations 2015

Oct 1, 2015

Chart 5
Annual equipment failures by category (top four)



9. Multiple Device Operations in the Past Year (1/1/14-12/31/14)

Table 11 below is a summary of the devices that have operated three or more times in 2014. All exclusionary events are removed in this table.

Table 11
Multiple Device Operations

Circuit	Number of Operations	Device	Customer-Minutes	Customer-Interruptions
13W1[1,2]	6	Fuse, Pole 3, Hackleboro Rd, Canterbury	6,546.80	48
15W2[1]	5	Fuse, Pole 8, W. Portsmouth St, Concord	7,453.75	75
18W2[1,2]	5	Fuse, Pole 138-Z, Bow Bog Rd, Bow	7,384.65	105
22W3[1,2]	4	Fuse, Pole 1, Rocky Point Dr, Bow	102,111.70	385
4W4[1]	4	Recloser, Pole 1, Lake View Dr, Concord	24,565.31	147
15W1[1]	3	Fuse, Pole 5, Mountain Rd, Concord	183,646.07	582
18W2[1]	3	Fuse, Pole 211, Woodhill Rd, Bow	63,974.35	369
6X3[1]	3	Fuse, Pole 1, Currier Rd, Concord	53,780.17	210
8X3[1,2]	3	Fuse, Pole 26, New Orchard Rd, Epsom	40,718.13	201
8X3[1,2]	3	Fuse, Pole 54, Horse Corner Rd, Chichester	20,984.40	243
8X3[1]	3	Fuse, Pole 3, Canterbury Rd, Chichester	20,343.87	168
21W1P[2]	3	Fuse, Pole 12, Warren St, Concord	14,528.03	230
15W1[1]	3	Fuse, Pole 28, Oak Hill Rd, Concord	13,280.40	259
15W1[1]	3	Fuse, Pole 87, East Side Dr, Concord	13,107.90	181
18W2[1]	3	Fuse, Pole 34, Putney Rd, Bow	8,454.60	99
22W3[1]	3	Fuse, Pole 19, White Rock Hill Rd, Bow	8,215.00	144
13W1[1]	3	Fuse, Pole 50, Borough Rd, Canterbury	7,936.67	60
13W3[1]	3	Fuse, Pole 1, North Water St, Boscawen	5,582.70	84
8X3[1]	3	Fuse, Pole 1, Sanborn Hill Rd North, Epsom	2,969.55	27
8X3[1]	3	Fuse, Pole 2, Old Mountain Rd, Epsom	1,091.32	3

[1] Tree trimming efforts have been or will be completed by the end of 2015
[2] Reliability projects have been completed or will be completed by the end of 2015

10. Other Concerns

This section is intended to identify other reliability concerns that would not necessarily be identified from the analysis above.

10.1. Narrow subtransmission ROW expansion

The UES-Concord subtransmission system has some areas where the Right Of Way (ROW) is narrow, thus, even after pruning trees to the edge of the ROW we leave our system vulnerable to damage by falling trees. Historically, Unitil has experienced noticeably more outages, due to falling trees, on lines that are in narrow ROW in comparison to lines in larger ROW. Thus, Unitil has been working with land owners to allow tree removal outside of narrow ROW. If successful, this effort is expected to allow effective tree mitigation in the problem areas.

10.2. 13.8kV Underground Electric System Degradation

The 13.8kV underground electric system has been experiencing connector and conductor failures at an average rate of 0.8 per year for the last 5 years, but no failures in 2013 or 2014. This does not include scheduled replacement of hot terminations identified by inspection; hot terminations have been identified and replaced (without outage) in both 2013 and 2014. In 2015, a study on this system was completed. It identified age and use of 200A connectors may be a contributing factor to failures. Engineering and operations are evaluating underground design and material changes to address reliability concerns and future planning needs of this underground system.

10.3. Alternate Mainline for Large 34.5kV Circuits

Circuit 8X3 has the largest customer exposure on the capital system at 2,764 customers with an 11.5MVA peak, in 2014. This circuit has no alternate feeds to restore customers during mainline outages.

Building an alternate mainline to reduce customer exposure and allow an alternate feed during contingency scenarios is the ultimate goal for this area. Three alternatives where reviewed. One involved constructing a pole line outside of UES territory, one involved double circuiting, and the final involved rebuilding Horse Corner Rd. The Horse Corner Rd route is preferred because it will create an alternate pole line and does not involve joint construction with Eversource.

10.4. One Bolt Connector Replacement

One bolt connectors on primary conductor are required to be installed on stirrups, by existing construction standards. Surveys have found many one bolt connectors installed directly on primary conductor. It has been found that stranded conductor can become damaged by single bolt connectors directly connected, reducing the conductor’s thermal and mechanical strength. This damage has been found to be most drastic on 34.5kV energized conductor. Due to recent outages and noticeable damage found on 34.5kV circuits, it has become a priority to replace these connectors on 34.5kV energized mainline. Significant work was done in 2015 to mitigate this problem on circuits 6X3, 7X1, 8X5 and 8X3. Work is planned to continue on circuits 8X5 and 8X3 in 2016.

11. Recommended Reliability Improvement Projects

This following section describes recommendations on circuits, sub-transmission lines and substations to improve overall system reliability. The recommendations listed below will be compared to the other proposed reliability projects on a system-wide basis. A cost benefit analysis will determine the priority ranking of projects for the 2016 capital budget. All project costs are shown without general construction overheads

11.1. Circuit 15W1: Install a Reclosing Device to Protect Shaker Road

11.1.1. Identified Concerns

Shaker Road, phase B, has experienced three outages and Snow Pond Road has experienced one outage, in 2014. This recloser will prevent temporary faults from causing permanent outages for Shaker Road and provide fuse savings for Snow Pond Road.

11.1.2. Recommendations

Install a V4L hydraulic recloser with a 70A trip coil in the vicinity of pole 89-S, on phase B.

Estimated Project Cost (without construction overheads): $ 9,000
Estimated Annual Savings – Customer Minutes: 6,600, Customer Interruptions: 69
Customer Exposure: 88

11.2. Circuit 13W1: Install Covered Wire

11.2.1. Identified Concern

This area experienced one outage, in 2014, which was due to a failed connection on a # 6 CU single phase run. This conductor is at the tail end of the mainline circuit, is surrounded by large trees and causes circuit outages when failed.

11.2.2. Recommendation

Replace #6 Cu open wire with 1/0 ACSR Covered Wire, single phase, between poles 73 and 83 on Kimball Pond Road (1400 feet)

Estimated Project Cost: $23,000
Estimated Annual Savings – Customer Minutes of Interruption: 3,300, Customer Interruptions: 34
Customer Exposure: 482

11.3. Circuit 4W4: Install Covered Wire

11.3.1. Identified Concern

This area experienced three broken conductor outages, in 2014, which could be partially due to the # 6 CU conductor in this area.

11.3.2. Recommendation

Replace #6 Cu open wire with 1/0 ACSR Covered Wire, single phase, between poles 1 and 57 on Lakeview Drive (7000 feet)

Estimated Project Cost: $99,000

Estimated Annual Savings – Customer Minutes of Interruption: 1,500, Customer Interruptions: 16
Customer Exposure: 37

11.4. Bow Junction Substation: Install an Auto Transfer Scheme

11.4.1. Identified Concern

This area experienced one outage, in 2014, which was due to failed insulator. This project would automatically transfer Bow Junction Substation load to the 374 Line from Bridge Street Substation.

11.4.2. Recommendation

Install automation that will automatically cause the 374J3 switch to open and the 374J4 switch to close during an up line 374 Line outage.

Estimated Project Cost: $100,000
Estimated Annual Savings – Customer Minutes of Interruption: *84,000, Customer Interruptions: 1,400
Customer Exposure: 4029

*To estimate the outage duration for the calculation of these minutes, engineering judgment determined 60 minutes was a good average for time required to transfer Bow Junction Substation to an alternative source.

11.5. 374 Line: Install an Autosectionalizing Scheme

11.5.1. Identified Concern

Every time the 374 line from Bridge Street Substation sees a fault, circuit 18W2 and circuit 17X1loses power, which happened once in 2014. This scheme would isolate these circuits from a fault on the 374 Line from Bridge Street.

11.5.2. Recommendation

Install an autosectionalizing scheme on either the 396J2 or 396J1 switch. This scheme will cause the switch to open during the 396/0374 breakers reclosing cycle.

Estimated Project Cost: $40,000
Estimated Annual Savings – Customer Minutes of Interruption: 31,000, Customer Interruptions: 514
Customer Exposure: 1100

*To estimate the outage duration for the calculation of these minutes, engineering judgment determined 60 minutes was a good average for time required to manually patrol and switch into this configuration.

11.6. Miscellaneous Circuit Improvements to Reduce Recurring Outages

11.6.1. Identified Concerns & Recommendations

The following concerns were identified based on a review of Tables 10 & 11 of this report; Multiple Tree Related Outages by Street and Multiple Device Operations respectively.

Mid-Cycle Forestry Reviews

The areas identified below experienced three or more tree related outages in 2014. It is recommended that a forestry review of these areas be performed in 2016 in order to identify and address any mid-cycle growth or hazard tree problems.

- 13W1, Hackleboro Road, Canterbury
- 13W3, Park Street Area, Boscawen
- 13W1, Borough Road (after Pole 50), Canterbury
- 4W4, Lakeview Road, Concord
- 15W1, East Side Drive (from pole 87 going towards pole 61), Concord

Animal Guard Installation Recommendations

The area identified below experienced three or more patrolled nothing found / animal outages in 2014. It is recommended that an animal protection review is performed in 2016 in order to identify locations in which animal protection can prevent outages due to animals.

- 21W1P, Warren St and Rumford St, Concord

Reclosing Device Installation Recommendations

The areas identified below a number of outages that may have been prevented with a reclosing device. The installation of reclosing devices at these locations is recommended to improve reliability performance in these areas.

- 8X3, New Orchard Road, Epsom
- 18W2, Bow Bog Road, Bow

12. Conclusion

During 2014, the Capital System has been greatly affected by interruptions on the sub transmission system. Although the most common cause among sub transmission outages is company equipment failure, there are no patterns to be recognized at this time and previous years do not present the same results. Tree related outages still present the largest problem, compared to other causes. Although compared to previous years, the worst performing circuits have seen a dramatic decrease in Customer Minutes of Interruption from tree related outages. Enhanced tree trimming efforts are still being implemented, which is expected to improve reliability for most of the worst performing circuits identified in this study.

Recommendations developed from this study are mainly focused on improving reliability of the sub transmission system because two thirds of the customer minutes in 2014 where due to sub transmission outages. At least one project is expected to be completed in 2015 that will improve the reliability of the sub transmission system. In addition, new ideas and solutions to reliability problems are always being explored in an attempt to provide the most reliable service possible.

Attachment 2

UES - Seacoast

Reliability Analysis and Recommendations 2015

Unitil Energy Systems – Seacoast

Reliability Study
2015

Prepared By:

Jake Dusling
Unitil Service Corp.

September 21, 2015

1 Executive Summary

The purpose of this document is to report on the overall reliability performance of the UES-Seacoast system from January 1, 2014 through December 31, 2014. The scope of this report will also evaluate individual circuit reliability performance over the same time period.

The following projects are proposed from the results of this study and are focused on improving the worst performing circuits as well as the overall UES-Seacoast system reliability. These recommendations are provided for consideration and will be further developed with the intention to be incorporated into the 2016 budget development process.

Circuit / Line / Substation	Proposed Project	Cost ($)
47X1	Install Devices and Implement a "Pulsefinding" Scheme	$300,000
18X1	Install Recloser on Mary Batchelder Road	$55,000
13W2	Replace V4L Reclosers and Relocate Downline	$170,000
3347 Line Tap	Recloser Replacements	$125,000
22X1	Relocate Main Line to Route 111	$825,000
19X2/11X2	Distribution Automation Scheme with Portsmouth Ave	$175,000
3343/3354 and 3351/3362 Lines	Installation of Motor Operated Switches with SCADA Control	$190,000

Note: estimates do not include general construction overheads

2 Reliability Goals

The annual corporate system reliability goals and UES-Seacoast reliability goals have been at 191-156-121 SAIDI minutes and 208-165-123, respectively. These were developed through benchmarking Unitil system performance with surrounding utilities.

Individual circuits will be analyzed based upon circuit SAIDI, SAIFI, and CAIDI. Analysis of individual circuits along with analysis of the entire Seacoast system is used to identify future capital improvement projects and/or operational enhancements which may be required in order to achieve and maintain these goals.

3 Outages by Cause

This section provides a breakdown of all outages by cause code experienced during 2014. Chart 1 lists the number of interruptions due to each cause. For clarity, only those causes occurring more than 10 times are labeled. Chart 2 details the percent of total customer-minutes of interruption due to each cause. Only those causes contributing greater than 2% of the total are labeled.

Chart 1
Number of Interruptions by Cause

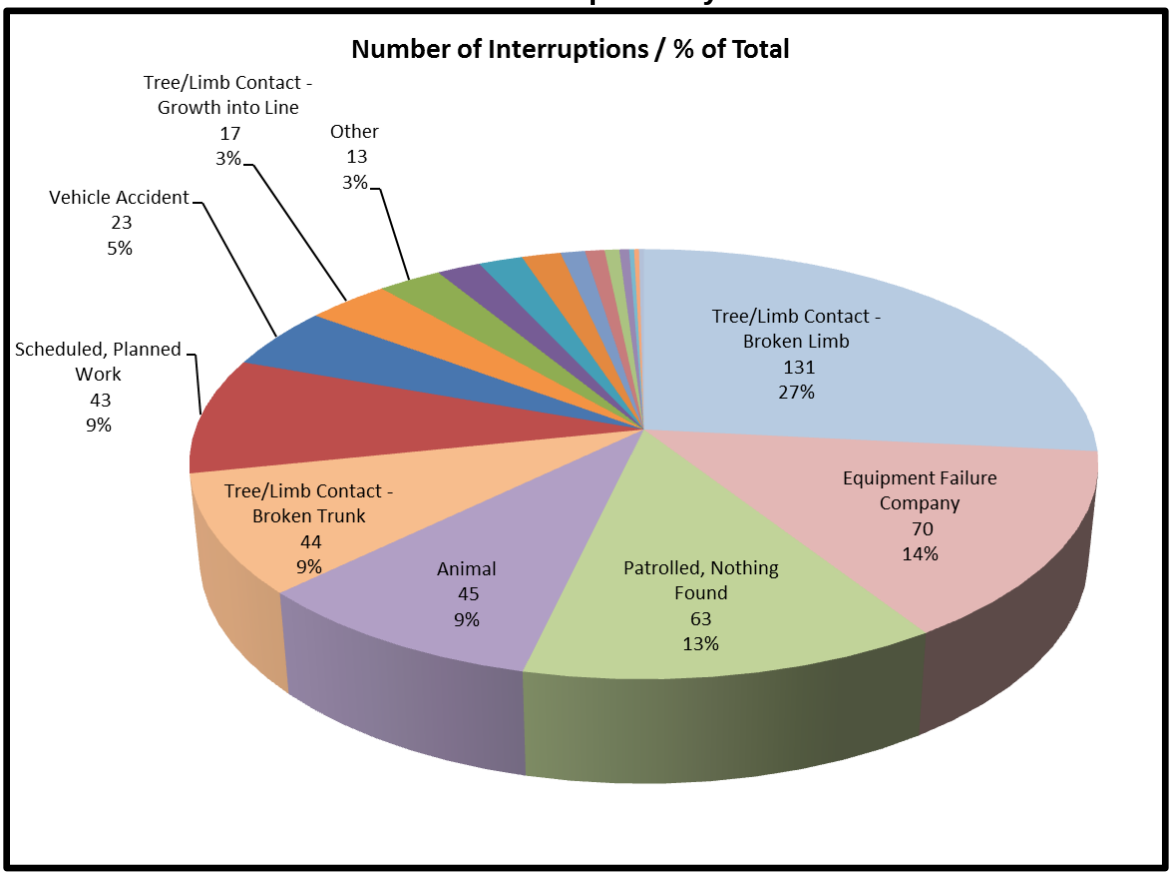
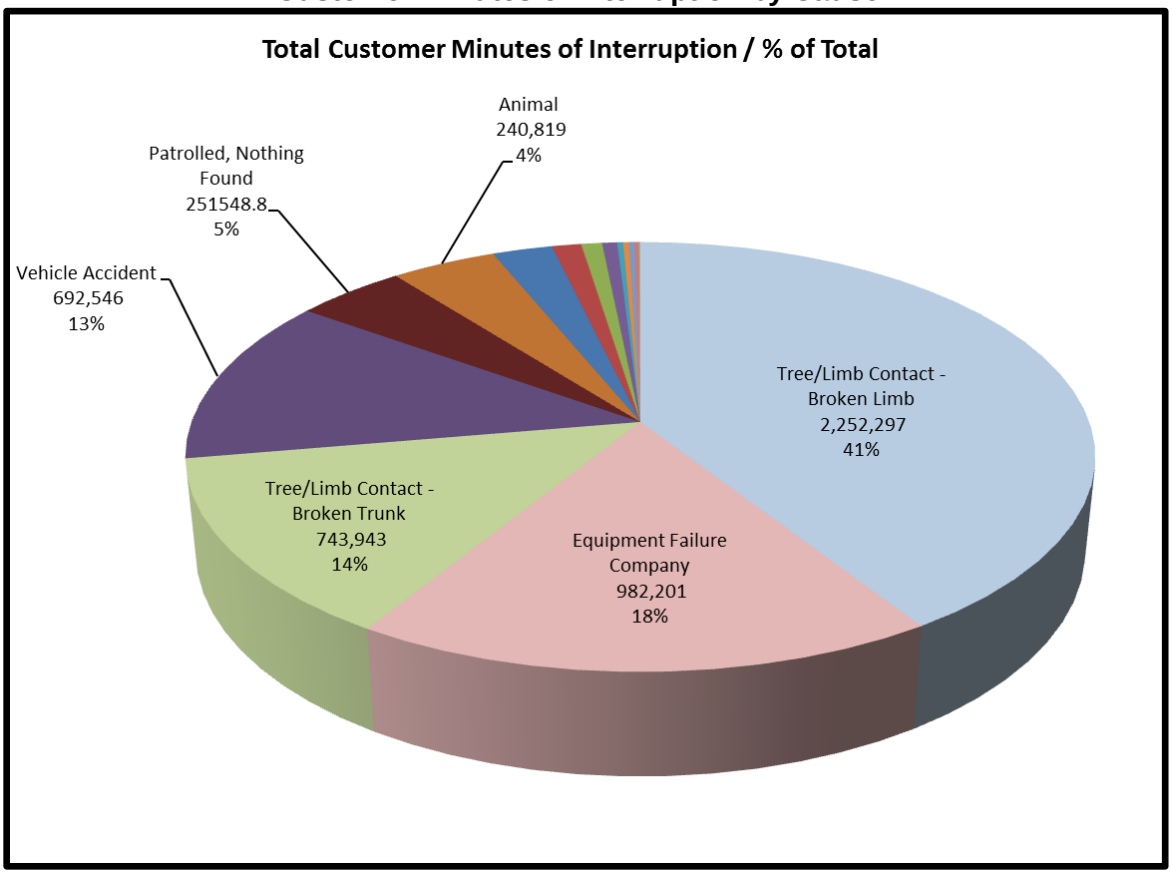


Chart 2
Customer-Minutes of Interruption by Cause



4 10 Worst Distribution Outages

The ten worst distribution outages ranked by customer-minutes of interruption during the time period from January 1, 2014 through December 31, 2014 are summarized in Table 1 below.

Table 1
Worst Ten Distribution Outages

Circuit	Description (Date/Cause)	No. of Customers Affected	No. of Customer Minutes	UES Seacoast SAIDI (min.)	UES Seacoast SAIFI
19X3	7/3/14 Tree/Limb Contact – Broken Limb	3,175	634,732	13.8	0.069
54X1	2/2/14 Vehicle Accident	1,442	381,510	8.29	0.031
43X1	8/1/14 Tree/Limb Contact – Broken Limb	1,861	231,167	5.03	0.040
18X1	10/22/14 Tree/Limb Contact – Broken Trunk	707	217,803	4.74	0.015
6W1	4/20/14 Tree/Limb Contact – Broken Limb	875	179,242	3.90	0.019
51X1	7/3/14 Tree/Limb Contact – Broken Limb	2,075	160,922	3.50	0.045
21W1	10/29/14 Vehicle Accident	1,365	159,599	3.47	0.030
7X2	10/22/14 Tree/Limb Contact – Broken Trunk	1,084	98,079	2.13	0.024
22X1	8/13/14 Tree/Limb Contact – Broken Trunk	2,068	93,060	2.02	0.045
15X1	2/19/14 Tree/Limb Contact – Broken Limb	664	68,447	1.49	0.014

Note: This table does not include outages that occurred at substations, on the sub-transmission system or during snowstorm CATO.

5 Sub-transmission and Substation Outages

This section describes the contribution of sub-transmission line and substation outages on the UES-Seacoast system from January 1, 2014 through December 31, 2014.

All substation and subtransmission outages ranked by customer-minutes of interruption during the time period from January 1, 2014 through December 31, 2014 are summarized in Table 2 below.

Table 3 shows the circuits that have been affected by sub-transmission line and substation outages. The table illustrates the contribution of customer-minutes of interruption for each circuit affected.

In aggregate, sub-transmission line and substation outages accounted for 19% of the total customer-minutes of interruption for UES-Seacoast.

Table 2
Sub-transmission and Substation Outages

Trouble Location	Description (Date/Cause)	No. of Customers Affected	No. of Customer Minutes	UES Seacoast SAIDI (min.)	UES Seacoast SAIFI
Exeter Sw/S	3/30/14 Equipment Failure Company – Arrester	10,300	767,800	16.69	0.224
3343 Line	6/18/14 Operator Error / System Malfunction	3,284	130,833	2.84	0.071
Dow's Hill S/S	7/11/14 Squirrel	547	88,284	1.92	0.012
3351 Line	11/18/14 Tree/Limb Contact Broken Limb	2,311	79,685	1.73	0.051
3352 Line	11/26/14 Tree/Limb Contact – Broken Limb	4,677	196,961	4.28	0.102
3343 Line	11/26/14 Tree/Limb Contact – Broken Limb	3,088	447,763	9.74	0.067

Table 3
Contribution of Sub-transmission and Substation Outages

Number of events	Circuit	Trouble Location	Customer-Minutes of Interruption	% of Total Circuit Minutes	Circuit SAIDI Contribution
3	20H1	Dow's Hill S/S Exeter Sw/S 3351 Line	103,296	77.8%	233.31
2	1H3	Exeter Sw/S 3352 Line	106,450	49.4%	200.69
2	1H4	Exeter Sw/S 3352 Line	96,058	99.6%	199.15
2	19H1	Exeter Sw/S 3352 Line	29,640	79.1%	182.40
2	19X2	Exeter Sw/S 3352 Line	85,895	96.1%	159.88
2	19X3	Exeter Sw/S 3352 Line	563,093	30.5%	177.38
2	51X1	Exeter Sw/S 3351 Line	99,965	17.8%	52.91
2	27X1	3343 Line (2)	117,018	69.6%	155.47
2	27X2	3343 Line (2)	48,105	69.8%	115.25
2	28X1	3343 Line (2)	94,553	89.7%	189.39
2	43X1	3343 Line (2)	318,921	33.4%	171.59
1	11X2	Exeter Sw/S	15,226	10.2%	15.59
1	47X1	Exeter Sw/S	22,874	9.9%	15.46
1	11X1	Exeter Sw/S	10,235	8.5%	16.13

6 Worst Performing Circuits

This section compares the reliability of the worst performing circuits using various performance measures. All circuit reliability data presented in this section includes subtransmission or substation supply outages unless noted otherwise.

6.1 Worst Performing Circuits in Past Year (1/1/14 – 12/31/14)

A summary of the worst performing circuits during the time period between January 1, 2014 and December 31, 2014 is included in the tables below.

Table 4 shows the ten worst performing circuits ranked by the total number of customer-minutes of interruption. The SAIFI and CAIDI for each circuit are also listed in this table.

Table 5 provides detail on the major causes of the outages on each of these circuits. Customer-minutes of interruption are given for the six most prevalent causes[1].

Circuits having one outage contributing more than 75% of the customer-minutes of interruptions were excluded from this analysis.

Table 4
Worst Performing Circuits Ranked by Customer-Minutes

Circuit	Customer Interruptions	Worst Event (% of CI)	Cust-Min of Interruption	Worst Event (% of CMI)	SAIDI	SAIFI	CAIDI
19X3	10,227	31.0%	1,844,551	34.4%	581.05	3.22	180.36
43X1	7,674	24.3%	953,763	46.4%	513.14	4.13	124.29
22X1	5,152	40.1%	712,991	33.4%	345.20	2.49	138.39
54X1	2,815	51.2%	693,162	55.0%	479.86	1.95	246.24
51X1	7,221	28.7%	561,412	38.4%	297.15	3.82	77.75
6W1	2,830	30.9%	481,745	37.2%	550.41	3.23	170.23
18X1	5,027	35.2%	464,682	46.9%	262.63	2.84	92.44
6W2	4,209	38.2%	301,017	35.4%	336.08	4.70	71.52
21W1	3,633	37.6%	246,118	64.8%	180.63	2.67	67.75
21W2	1,402	29.5%	235,674	38.1%	170.25	1.01	168.10

Note: all percentages and indices are calculated on a circuit basis

[1] Six most prevalent causes determined from UES-Seacoast system wide data, not individual circuit data.

Table 5
Circuit Interruption Analysis by Cause

Circuit	Customer – Minutes of Interruption / # of Outages					
	Tree/Limb Contact – Broken Limb	Equipment Failure Company	Tree/Limb Contact – Broken Trunk	Vehicle Accident	Patrolled, Nothing Found	Squirrel
19X3	1,346,588 / 18	460,268 / 9	2,086 / 1	24,490 / 1	910 / 1	110 / 1
43X1	843,913 / 15	240 / 1	5,043 / 3	350 / 1	24,531 / 3	99 / 1
22X1	522,311 / 30	11,530 / 6	144,725 / 6	0 / 0	2,448 / 5	0 / 0
54X1	280,171 / 14	4,874 / 3	1,446 / 1	381,510 / 1	2,959 / 5	0 / 0
51X1	470,658 / 14	28,523 / 2	18,960 / 1	12,581 / 2	4,672 / 1	19,941 / 7
6W1	272,858 / 11	23,050 / 2	137,401 / 7	19,862 / 1	13,207 / 5	4,756 / 1
18X1	96,400 / 5	24,760 / 4	250,088 / 3	25,279 / 2	42,048 / 1	17,809 / 2
6W2	242,635 / 20	13,218 / 1	30,092 / 1	0 / 0	12,964 / 1	1,212 / 1
21W1	50,140 / 6	706 / 1	6,981 / 2	159,599 / 1	2,059 / 2	17,249 / 3
21W2	196,748 / 8	3,774 / 4	203 / 1	0 / 0	0 / 0	2,587 / 1

6.2 Worst Performing Circuits of the Past Five Years (2010 – 2014)

The annual performance of the ten worst circuits in terms of SAIDI and SAIFI for each of the past five years is shown in the tables below. Table 6 lists the ten worst performing circuits ranked by SAIDI and Table 7 lists the ten worst performing circuits ranked by SAIFI.

The data used in this analysis includes all system outages except those outages that occurred during the 3342/3353 Line Outage in 2014, Hurricane Sandy in 2012, the 2011 October Nor'easter, Hurricane Irene in 2011 and the 2010 Wind Storm.

Table 6
Circuit SAIDI

Circuit Ranking (1 = worst)	2014		2013		2012		2011		2010	
	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI
1	19X3	581.05	6W1	384.28	56X2	590.69	13W2	698.61	51X1	582.06
2	6W1	550.41	27X1	300.82	13W2	556.17	54X1	557.90	3H2	575.51
3	43X1	513.14	47X1	275.19	13W1	383.59	17W2	429.40	22X1	518.07
4	54X1	479.86	18X1	255.15	2X2	376.99	22X1	407.92	59X1	509.53
5	1H3	406.51	21W1	242.80	58X1	339.87	17W1	381.20	15X1	387.88
6	22X1	345.20	13W2	212.92	7X2	317.63	46X1	372.37	23X1	378.56
7	6W2	336.08	59X1	197.65	47X1	297.13	13W1	275.45	17W2	361.53
8	20H1	299.78	22X1	136.57	43X1	296.43	21W2	239.71	58X1	308.72
9	51X1	297.15	15X1	128.33	23X1	292.58	11W1	226.92	46X1	306.30
10	18X1	262.63	43X1	122.34	15X1	263.38	7X2	213.44	21W1	291.33

Table 7
Circuit SAIFI

Circuit Ranking (1 = worst)	2013		2012		2011		2010		2009	
	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI
1	6W2	4.70	18X1	3.40	56X2	7.39	54X1	5.25	51X1	6.65
2	20H1	4.36	21W1	3.25	13W2	5.77	22X1	4.93	3H2	6.01
3	43X1	4.13	27X1	2.98	23X1	5.69	13W2	4.53	22X1	5.21
4	51X1	3.82	6W1	2.95	43X1	4.22	13W1	2.81	15X1	4.38
5	6W1	3.23	47X1	2.55	6W1	4.06	7X2	2.48	23X1	3.77
6	19X3	3.22	13W2	2.48	13W1	3.92	11W1	2.42	59X1	3.43
7	18X1	2.84	43X1	2.42	15X1	3.89	47X1	1.99	11W1	3.29
8	21W1	2.67	7X2	1.98	59X1	3.64	18X1	1.94	13W2	3.21
9	47X1	2.67	56X1	1.96	21W1	3.20	21W2	1.93	28X1	3.07
10	11X1	2.64	54X1	1.91	58X1	3.13	6W1	1.77	20H1	3.01

6.3 System Reliability Improvements (2013 and 2014)

Vegetation management projects completed in 2014 and 2015 that are expected to improve the reliability of the 2014 worst performing circuits are included in table 8 below. Table 9 below details electric system upgrades that are scheduled to be completed in 2015 or were completed in 2014 that were performed to improve system reliability.

Table 8
Vegetation Management Projects on Worst Performing Circuits

Circuit(s)	Year of Completion	Project Description
19X3	2014	Storm Resiliency pruning
		Planned Mid-Cycle pruning
43X1	2014	Storm Resiliency pruning
22X1	2015	Planned Cycle Pruning
		Hazard tree mitigation
	2014	Storm Resiliency pruning
54X1	2015	Planned Cycle Pruning
		Hazard tree mitigation
6W1	2015	Planned Cycle Pruning
		Hazard tree mitigation
	2014	Planned Mid-Cycle pruning
		Hazard tree mitigation
18X1	2014	Planned Cycle Pruning
6W2	2015	Planned Cycle Pruning
		Hazard tree mitigation
	2014	Planned Mid-Cycle pruning
		Hazard tree mitigation
21W1	2015	Planned Cycle pruning (Carryover from 2014)
		Hazard tree mitigation (Carryover from 2014)
	2014	Planned Cycle Pruning
		Hazard tree mitigation
21W2	2014	Planned Cycle Pruning

Circuit(s)	Year of Completion	Project Description
1H3	2015	Planned Cycle Pruning
20H1	2015	Planned Mid-Cycle pruning
47X1	2014	Planned Cycle Pruning
		Hazard tree mitigation
11X1	2015	Planned Mid-Cycle pruning

Table 9
Electric System Improvements Performed to Improve Reliability

Circuit(s)	Year of Completion	Project Description	Justification
54X1	2015	Recloser additions to split circuit 54X1 into two circuits, 54X1 and 54X1	2015 DRB Project
		Replace 54J54X1 and 43J54X1 switches with motor operated switches and connect to SCADA at New Boston Road Tap	2015 DRB Project
6W1, 6W2	2015	Replace J654 and J643 switches with motor operated switches and connect to SCADA at East Kingston substation	2015 DRB Project
13W1	2015	Install fuses – Upper Rd, Middle Rd, and Lower Rd	Multiple device operation pole 7 Danville Rd, Plaistow
13X3	2015	Upgraded fuse size, replaced insulators and upgraded overloaded transformer	Multiple device operation pole 19 Kingston Rd, Plaistow
7W1	2014	Install cone style animal guards and replace transformer wire taps with covered tap wire	Multiple device operation pole 1 Cross Beach Rd, Seabrook
		Install cone style animal guards and replace transformer wire taps with covered tap wire	Multiple device operation pole 20 Route 286, Seabrook

7 Tree Related Outages in Past Year (1/1/14 – 12/31/14)

This section summarizes the worst performing circuits by tree related outages during the time period between January 1, 2014 and December 31, 2014.

Table 10 shows these circuits ranked by the total number of customer-minutes of interruption. The number of customer-interruptions and number of outages are also listed in this table. Circuits having two or less tree related outages were excluded from this table.

All streets on the Seacoast system with three or more tree related outage are shown in table 11 below. The table is sorted by number of outages and customer-minutes of interruption.

Table 10
Worst Performing Circuits – Tree Related Outages

Circuit	Customer-Minutes of Interruption	Number of Customers Interrupted	No. of Interruptions
19X3[1]	751,819	6,614	21
22X1[1]	688,690	5,032	40
6W1[1]	420,710	2,474	19
51X1[2]	418,394	2,842	17
43X1[1]	412,556	4,005	22
18X1[1]	347,507	2,298	9
54X1[1,3]	288,788	765	16
6W2[1]	273,623	3,626	22
21W2[1]	225,174	1,312	11
13W2[2]	196,941	798	14

Table 11
Tree Related Outages by Street

Circuit	Street	# Outages	Customer-Minutes of Interruption	No. of Customer Interruptions
6W2[1]	South Rd, East Kingston / South Hampton	4	161,634	1,184
22X1[1]	Main St, Danville	4	128,683	1,437
6W2[1]	North Rd, Kingston	3	24,092	220
19X3[1]	Linden St, Exeter	3	45,247	122
58X1[2]	Sawyer Ave, Atkinson	3	29,323	57
19X3[1]	Brentwood Rd, Exeter	3	2,574	39
21W2[1]	Maple Ave, Atkinson	3	384	3
23X1[2]	Woodman Rd, South Hampton	3	290	5

[1] Pruning is planned or has been completed on this circuit (refer to table 8 for details)
[2] Refer to section 11 for recommendations in this area.
[3] Projects that are planned or have been completed on this circuit (refer to table 9 for details)

8 Failed Equipment

This section is intended to clearly show all equipment failures throughout the study period from January 1, 2014 through December 31, 2014. Chart 2 shows all equipment failures throughout the study period. Chart 3 shows each equipment failure as a percentage of the total failures within this same study period. The number of equipment failures in each of the top four categories of failed equipment for the past five years are shown below in Chart 4.

Chart 2
Equipment Failure Analysis by Cause

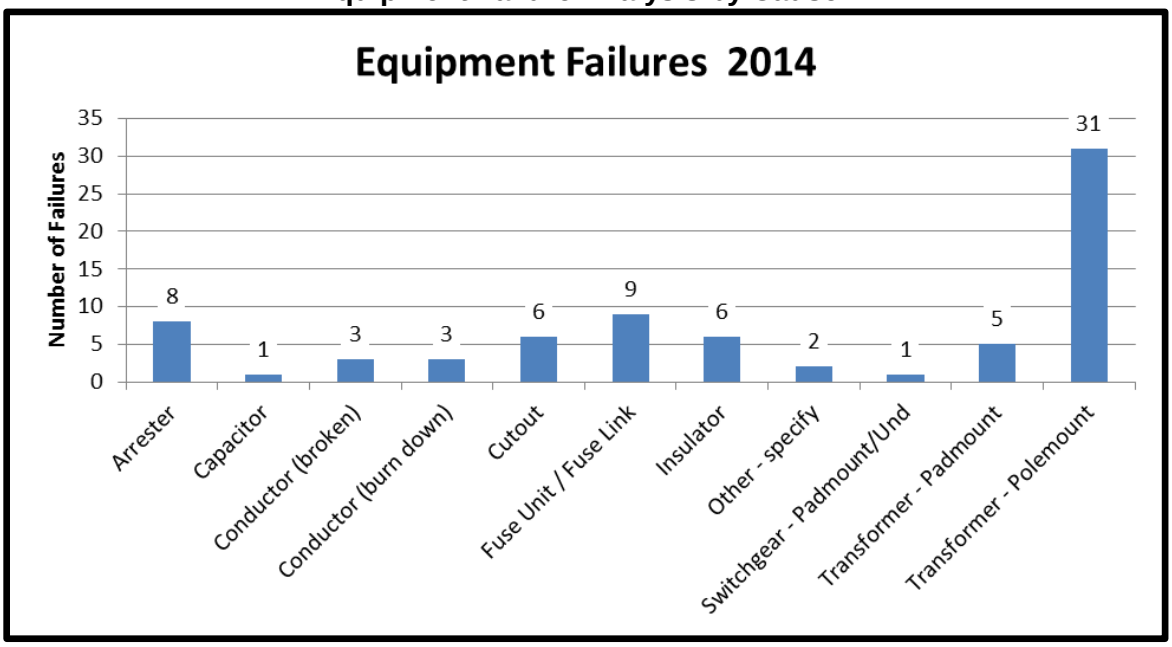


Chart 3
Equipment Failure Analysis by Percentage of Total Failures

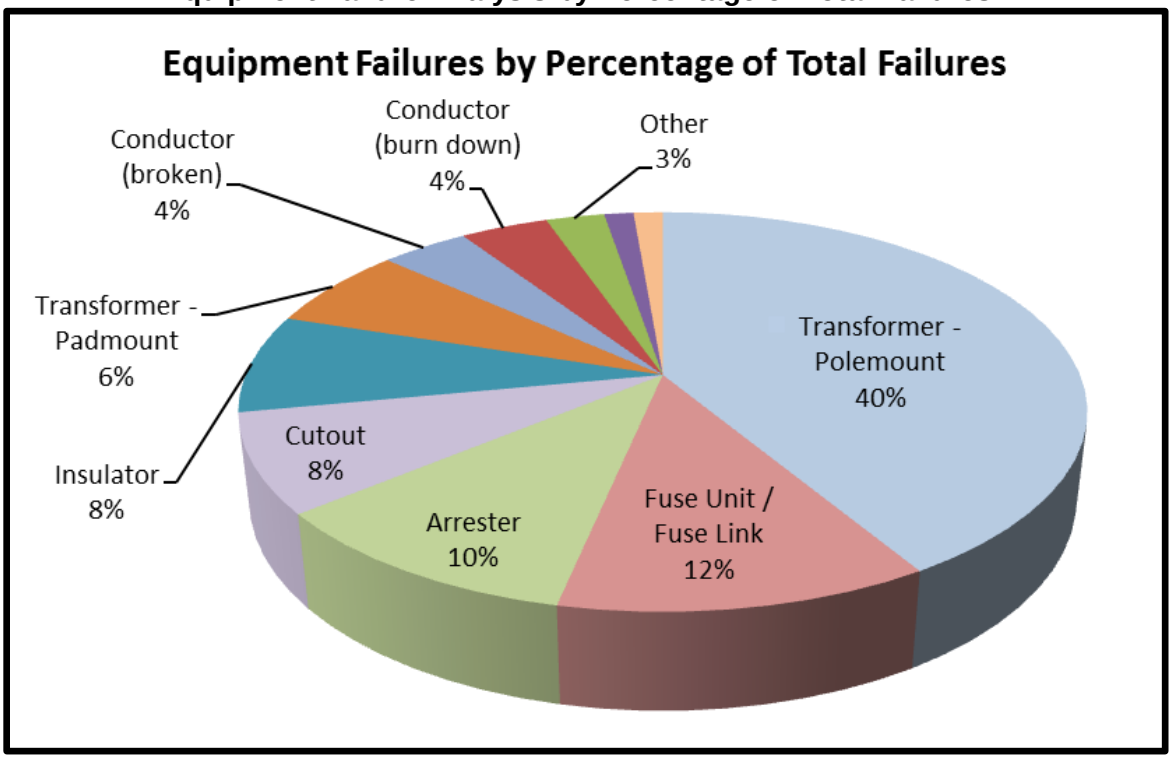
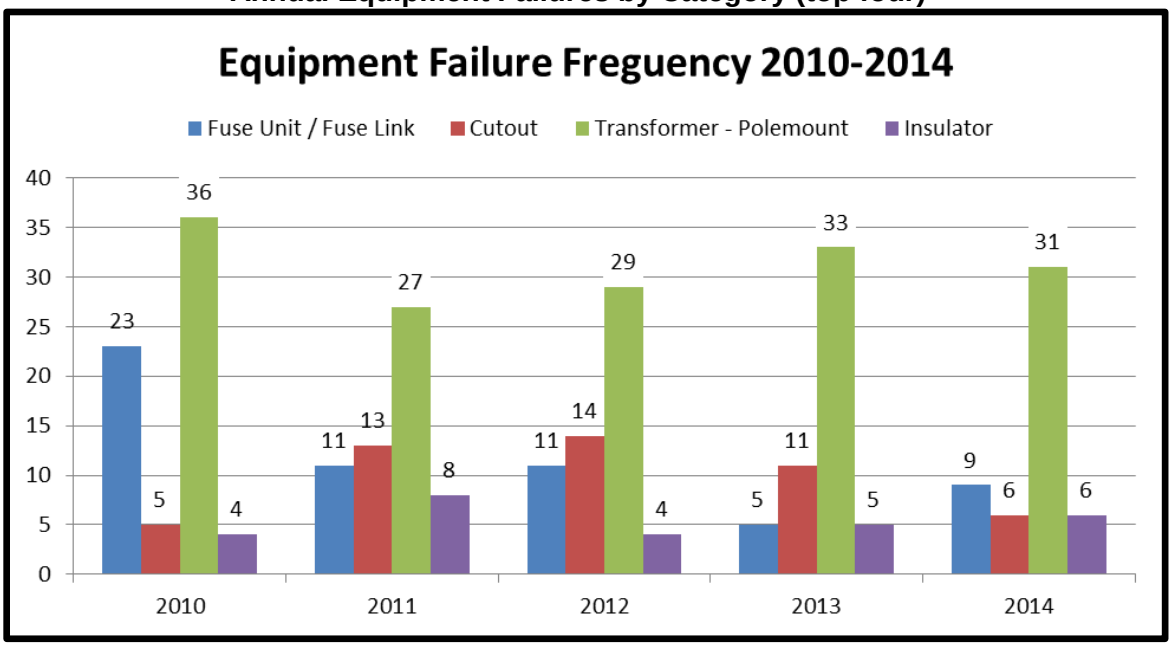


Chart 4
Annual Equipment Failures by Category (top four)



9 Multiple Device Operations in Past Year (1/1/14 – 12/31/14)

A summary of the devices that have operated three or more times from January 1, 2014 to December 31, 2014 are included in table 12 below.

Table 12
Multiple Device Operations

Circuit	Number of Operations	Device	Customer-Minutes	Customer-Interruptions
13X3[1,2]	6	Fuse – Pole 55/19 Kingston Rd, Plaistow	7,120	66
6W1[2]	4	Recloser – Pole 23/2 South Rd, East Kingston	150,639	1,024
7W1[1]	4	Fuse – Pole 128/1 Cross Beach Rd, Seabrook	17,855	100
18X1[2,3]	3	Fuse – Pole 172/1 Mary Batchelder Rd, Hampton	305,586	1,904
22X1[2]	3	Fuse – Pole 27/9 Kingston Rd, Danville	139,711	1,667
11X1[4]	3	Fuse – Pole 69/1 Patriots Rd, Stratham	33,594	375
58X1[3]	3	Fuse – Pole 76/1 Sawyer Ave, Atkinson	29,038	39
6W2[2]	3	Fuse – Pole 93/33 North Rd, Kingston	17,799	123
7W1[1]	3	Fuse – Pole 134/20 Route 286, Seabrook	12,666	150
13W1[1]	3	Fuse – Pole 25/7 Danville Rd, Plaistow	12,357	351

[1] Projects that are planned or have been completed on this circuit (refer to table 9 for details).
[2] Pruning is planned or has been completed on this circuit (refer to table 8 for details).
[3] Refer to section 11 for recommendations in the area.
[4] Operations performed a detailed review of the area and observed good tree clearance and animal guards installed on all transformers.

10 Other Concerns

This section is intended to identify other reliability concerns that would not be identified from the analyses above.

10.1 Recloser Replacements

Power factor testing has identified that the solid dielectric material used for the poles on a specific type/vintage recloser degrades over time leading to premature failure. In follow up discussions with the manufacturer, they acknowledged that the solid dielectric material used for the recloser poles could prematurely degrade resulting in a dielectric failure.

Unitil has experienced two (UES-Seacoast and FG&E) failures of this type/vintage of recloser in 2011 and removed two others from service due to the appearance of tracking.

Based on this information, a multi-year replacement program began in 2013 to replace all reclosers of this vintage. There are currently four of these reclosers in service on the UES-Seacoast system two at Wolf Hill, which are scheduled to be replaced in 2015 and two at the 3347 Line tap.

It is recommended that this program continue in 2016.

10.2 Subtransmission Lines Across Salt Marsh

The 3348 line experienced one outage in 2012 caused by a failed insulator and has been damaged several times during major events in the past, causing outages to the customers on all the distribution circuits (2H1, 2X3, 3H1, 3H2, 3H3, 7W1 and 7X2) supplied by the 3348, 3350 and 3353 lines distribution . The 3348 line is constructed through salt marsh, making it very difficult to access and repair.

In 2012, during a wind and snow event, both the 3342 and 3353 lines were damaged resulting in an outage to the Hampton Beach area that lasted nearly thirteen hours. These lines being constructed through the salt march made them difficult to patrol and inaccessible to repair without a boat. There is a multi-stage project that began in 2014 to relocate these lines closer to the road.

The 3350 line is also constructed through salt marsh. This line has the same access concerns as the 3348, 3342 and 3353 lines in the past. The 3350 line is a radial line that supplies Seabrook substation, if damaged load may need to be left out of service until repairs are made.

Additionally the 3348/3350 tap structure was damaged during Hurricane Sandy in 2012, requiring the 3348 and 3350 lines to remain out of service for several weeks until repairs were made. During the time of year the damaged occurred the load normally supplied by the 3350 line was restored via distribution ties. During summer peak conditions the distribution circuits in the area do not have the capacity to restore all load for this type of event.

In 2014, Unitil began investigating the possibility of acquiring land rights that would accommodate relocating the 3348 and 3350 lines to the railroad right-of-way that runs from Hampton S/S to Route 286 in Seabrook in the future. This investigatory effort will continue in 2015.

Reclosers are scheduled to be placed in service at Hampton substation in 2015 to reduce the impact of 3348, 3350, 3342 and 3353 line faults.

10.3 3347 Line

The 3347 line has been damaged by trees during major events in the past, causing outages to customers served by Guinea Road tap, Portsmouth Ave substation and Osram/Sylvania until repairs are made.

The installation of reclosers at Portsmouth Ave Substation and the replacement of the 19X2 relay at Exeter Switching were completed in 2013. These upgrades allow all customers served from Portsmouth Ave substation to be restored via distribution ties for the loss of the 3347 Line. Guinea Road tap and Osram/Sylvania load will remain out of service until repairs are made.

11 Recommendations

This following section describes recommendations on circuits, sub-transmission lines and substations to improve overall system reliability. The recommendations listed below will be compared to the other proposed reliability projects on a system-wide basis. A cost benefit analysis will determine the priority ranking of projects for the 2016 capital budget. All project costs are shown without general construction overheads.

11.1 Miscellaneous Circuit Improvements to Reduce Recurring Outages

11.1.1 Identified Concerns & Recommendations

The following concerns were identified based on a review of Tables 10 and 11 of this report; Multiple Tree Related Outages by Street and Multiple Device Operations respectively.

Mid-Cycle Forestry Review

The areas identified below experienced three or more tree related outages in 2014. It is recommended that a forestry review of these areas be performed in 2016 in order to identify and address any mid-cycle growth or hazard tree problems.

- 58X1, Sawyer Ave, Atkinson
- 23X1, Woodman Rd, South Hampton

11.2 Circuit 47X1 – Install Devices and Implement a "Pulsefinding" Scheme

11.2.1 Identified Concerns

Circuit 47X1 is routinely one of the worst performing circuits on the UES-Seacoast system. It has been on the worst performing SAIDI and SAIFI lists two of the past five years .

Additionally, 47X1 is served from the 3347 line which is a radial subtransmission line that typically is damaged during major events.

11.2.2 Recommendation

This project will consist of installing multiple S&C Intellirupters at strategic locations along circuit 47X1 and implementing a "pulsefinding" scheme.

"Pulsefinding" is a technique that allows devices with the same overcurrent protection settings to be used in series without the installation of device-to-device communications. At this time S&C Intellirupters are the only device with this capability.

After the devices are installed and programmed the 47X1 recloser and all series Intellirupters will trip in response to a downstream fault. The 47X1 recloser will reclose and stay closed if the fault is no longer present. The first downstream Intellirupter, upon sensing the return of voltage, pulsecloses (pulsecloses are too short to initiate a time-overcurrent trip of the recloser) and the Intellirupter will close if the fault is no longer present. This continues with each Intellirupter until the fault is isolated or the circuit is fully restored.

Additionally, a new normally open Intellirupter will be installed at the 51X1/47X1 tie. Upon loss of voltage this Intellirupter will pulseclose and stay closed if now fault is detected. The pulse closing scheme would then continue to the new Intellirupter until the faulted section is left out of service or circuit 47X1 is restored in its entirety from circuit 51X1. This portion of the scheme needs to be reviewed in additional detail to determine its feasibility.

This project will act as a pilot installation for this technology and if successful there are several other large circuits in Unitil's territory that could greatly benefit from pulseclosing.

- Estimated annual customer-minutes savings = 115,814
- Estimated annual customer-interruption savings = 1,206

Estimated Project Cost: $300,000 (4 Locations @ $75,000 per location)

11.3 Circuit 18X1 – Install Recloser on Mary Batchelder Road

11.3.1 Identified Concerns

Circuit 18X1 was one of the worst performing circuits in 2014 and has been on the worst performing SAIFI circuit list three of the last five years.

Additionally, the 175 QA at pole 1 Mary Batchelder Road operated three times in 2014.

11.3.2 Recommendation

This project will consist of replacing the 175 QA fuses at pole 1 Mary Batchelder Road with an electronically controlled recloser. The 175QA fuses will be relocated to the vicinity of pole 2 Towle Farm Road.

The new recloser will benefit approximately 700 customers and the new fuse location is expected save approximately 325 customer interruptions per year.

- Estimated annual customer-minutes savings = 30,994
- Estimated annual customer-interruption savings = 323

Estimated Project Cost: $55,000

11.4 Circuit 13W2 – Replace V4L Reclosers and Relocate Downline

11.4.1 Identified Concerns

Circuit 13W2 is typically one of the worst performing circuits on the UES-Seacoast system. It has been on the worst performing SAIFI four of the past five years and has been on the worst performing SAIDI list three of the last five years.

11.4.2 Recommendation

This project will consist of replacing the two existing sets of 140A V4L reclosers on circuit 13W2 with electronically controlled reclosers. This will allow the existing reclosers to be relocated to Peaslee Crossing Road and Thornell Road. Two additional sets of 100A V4L reclosers will be installed on Highland Street and Pond Street. The existing 13W2 recloser control at Timberlane substation will most likely need to be replaced to accommodate this project.

The new reclosers will benefit approximately 1,100 customers.

- Estimated annual customer-minutes savings = 34,200
- Estimated annual customer-interruption savings = 356

Estimated Project Cost: $150,000

11.5 Recloser Replacements

11.5.1 Identified Concerns

Unitil has experienced premature failures of a specific type/vintage of recloser due to insulation breakdown of the poles.

This will be the final year of a multi-year project to replace the reclosers of the identified type/vintage.

11.5.2 Recommendation

This project will consist of replacing the remaining two reclosers on the UES-Seacoast system.

- Two (2) at 3347 Line Tap

Below is a summary of the reliability benefit for this project:

Recloser	Customers of Exposure
3347A	5,350
3347B	7,900

- Estimated annual customer-minutes savings = 110,088
- Estimated annual customer-interruption savings = 1,147

Estimated Project Cost: $125,000

11.6 Circuit 22X1 – Relocate Main Line to Route 111

11.6.1 Identified Concerns

Circuit 22X1 was one of the worst performing circuits in 2014 and has been on the worst performing SAIDI circuit list four of the last five years.

Additionally, the existing main line along Kingston Road and Pleasant Street typically sustain significant damage during major storms, requiring lengthy repairs to energize the mainline of 22X1.

11.6.2 Recommendation

This project will consist of building approximately 2.25 miles of new three-phase open wire construction along Route 111 from Mill Road to the Danville Tie. Route 111 is a major state road-way with very little tree exposure.

Once complete, the new main line of 22X1 will run along Route 111. Kingston/Danville Road will become protected laterals off the new mainline.

This project is expected to save approximately 1,900 customer interruptions per event for faults on Danville Road t. This will also reduce damage to the mainline of 22X1 during major events.

This project is being designed in 2015 and is currently budgeted for construction in 2016.

- Estimated annual customer-minutes savings = 287,266
- Estimated annual customer-interruption savings = 2,992

Estimated Project Cost: $825,000

11.7 Circuit 19X2 – Distribution Automation Scheme with Portsmouth Ave

11.7.1 Identified Concerns

On average one subtransmission outage per year causes an outage to Portsmouth Ave substation or Exeter Switching Station.

Additionally, Portsmouth Ave substation is supplied from the 3347 line, which is a radial line that typically experiences damage during major events.

11.7.2 Recommendation

This project will consist of replacing the 11X2J19X2 tie switch with a recloser and the installation communication infrastructure between the new recloser, the 19X2 recloser at Exeter Switching and Portsmouth Ave substation.

A distribution automation scheme will be implemented that will restore the 1,617 customers on circuits 11X1 and 11X2 via circuit 19X2 for the loss of the 3347 line. Additionally, for a fault on the 3352 or 3362 line the 538 customers supplied by circuit 19X2 will automatically be restored via circuit 11X2.

- Estimated annual customer-minutes savings = 71,149
- Estimated annual customer-interruption savings = 0

Estimated Project Cost: $175,000

11.8 Installation of Motor Operated Switches at Substations and Subtransmission Taps

11.8.1 Summary

Unitil acquired twenty-three motor operated switches and two additional motor operators in 2014. It was determined that some or all of these switches would be used to replace the existing manually operated switches that connect substations and distribution taps to the UES-Seacoast subtransmission system.

Reference the document titled Motor Operated Switch Installation – Project Justification, dated February 24th, 2015 for additional information.

11.8.2 Switches Proposed for Replacement – 2016

Based on the project justification document referenced above the following switches are proposed for replacement in 2016.

Location	Switches to be Replaced	Cost (w/o OH's)	Special Details
Willow Road Tap	54J43X1 43J43X1	$30,000	Pre-Existing SCADA Site
Shaw's Hill Tap	54J27 43J27	$30,000	Pre-Existing SCADA Site
Munt Hill Tap	54J28 43J28	$30,000	Pre-Existing SCADA Site
Winnicutt Road Tap	62J51X1 51J51X1	$50,000	SCADA Installation Required
Dow's Hill S/S	J2062 J2051	$50,000	SCADA Installation Required
Total	**10 Switches**	**$190,000**	

12 Conclusion

The UES-Seacoast system has been greatly affected by outages involving tree contact and equipment failures A more aggressive tree trimming program began in 2011 and has started to reduce the number and impact of tree related outages.

In 2012 three circuits on the UES-Seacoast benefited from a storm resiliency pruning pilot, which consisted of ground to sky trimming and hazard tree removal. Due to the success of this pilot, three additional UES-Seacoast circuits had storm resiliency pruning performed in 2014.

The recommendations in this report are aimed at reducing the duration and customer impact of outages, improving the reliability of the subtransmission system and mitigating damage to distribution mainlines and subtransmission lines during major events. This report is also intended to assist Unitil Forestry in identifying areas of the system that are being frequently affected by tree related outages to allow proactive measure to be taken.

Attachment 3

REP Project Listing

2015 Actual Expenditures

REP Project Spending 2015

Attachment 3

Budget Number	Auth #	Description	Budget Amount	Installation Costs	Cost of Removal	Salvage	Retirements	Total Project Spending	Comments
DPBC01	C-150126	UES Capital - Distribution Pole Replacement	$ 603,930.00	$ 634,963.46	$39,413.11	($278.13)	$ 23,180.07	$ 674,098.44	Closed 12/31/2015
DPBE01	E-151009	UES Seacoast - Distirbution Pole Replacment	$ 635,292.00	$ 608,086.24	$28,695.84	($828.71)	$ 32,283.67	$ 635,953.37	Closed 12/31/2015
DRBC05	C-150157	Install Fuse Saver device on Pole #130 Bow Bog and P#28 New Orchard Rd.	$ 9,200.00	$ 9,473.51				$ 9,473.51	Complete 11/24/2015
			$ 1,248,422.00	$ 1,252,523.21	$ 68,108.95	$ (1,106.84)	$ 55,463.74	$ 1,319,525.32	
DRBC07	C-150168	Reliability improvments on 24.5kV Main lines and Sub-Trans lines	$ 91,800.00					$ 68,858.71	Not complete
DRBE04	E-151043	New Boston Road Tap - Install Reclosers	$ 302,000.00					$ 214,552.55	Not complete
DRBE05	E-151056	Replace manually switches with automated switches, Lines 3343 and 3354	$ 285,000.00					$ 174,058.24	To be carried over to 2016
DRBE09	E-151058	Install SCADA Operated Air Breaks on 3362 & 3351 lines,@ Dows Hill S/S	$ 150,000.00					$ 142,328.52	To be carried over to 2016
			$ 828,800.00					$ 599,798.02	
		Total Spending						$ 1,919,323.34	
DPCE02	E-151029	Replace 03341 and 3352 reclosers at Wolf Hill	$ 64,446.00						Authorization never approved