Attachment 1

UES – Capital

Reliability Study 2019

UES Capital

Reliability Study

2019

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Unitil Service Corp.

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Table of Contents

1 Executive Summary

The purpose of this document is to report on the overall reliability performance of the UES Capital system from January 1, 2018 through December 31, 2018. The scope of this report will also evaluate individual circuit reliability performance over the same time period. The outage data used in this report excludes the data in Section 5 (sub-transmission and substation outages), as well as outage data from IEEE Major Event Days (MEDs). UES-Capital MEDs are listed in the table below:

Date	Type of Event	Interruptions	Customer Interruptions	Cust-Min of Interruption
5/4/2018	Thunderstorm	33	3082	1,438,447
6/18/2018	Thunderstorm	27	11351	1,726,076

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 2020 budget development process.

Circuit / Line / Substation	Proposed Project	Cost ($)
15W1	Install Recloser on Mountain Rd	$32,401
8X3	Replace Hydraulic Recloser on Main St	$35,967
8X5	Install Recloser on Regional Dr	$34,531
6X3	Install Recloser on Pleasant St	$31,492
4W4	Install Recloser and Switches on Fisherville Rd	$85,802
Various	Fusesaver Installations	$143,506

Note: estimates do not include general construction overheads

UES Capital SAIDI was 127.48 minutes in 2018 after removing Major Event Days. The UES Capital target was 130 minutes. Charts 1, 2, and 3 below show UES Capital SAIDI, SAIFI, and CAIDI, respectively, over the past five years.

Chart 1: Annual Capital SAIDI

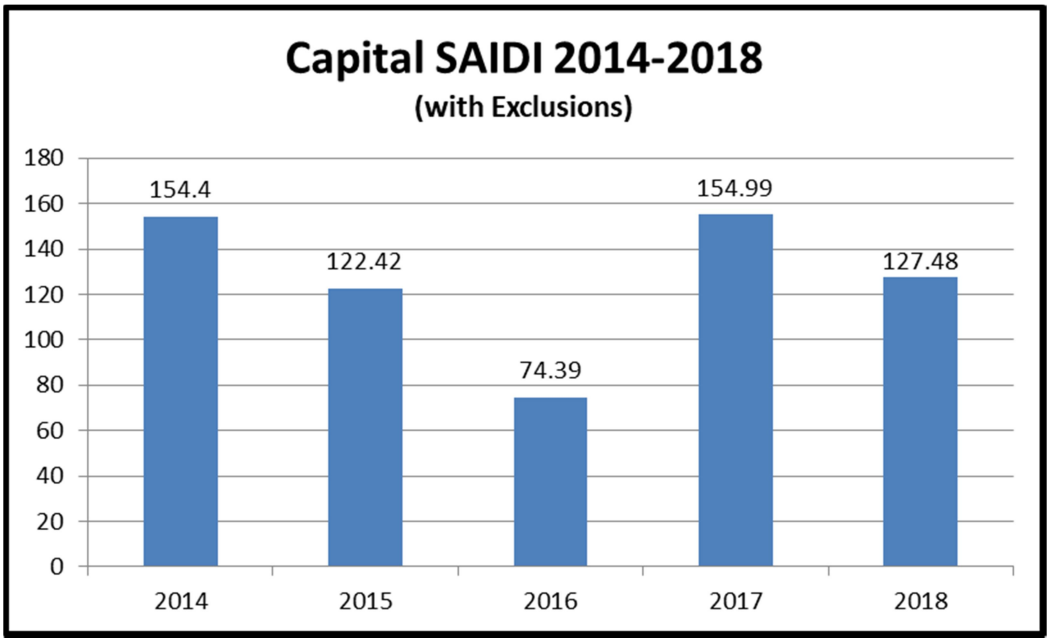


Chart 2: Annual Capital SAIFI

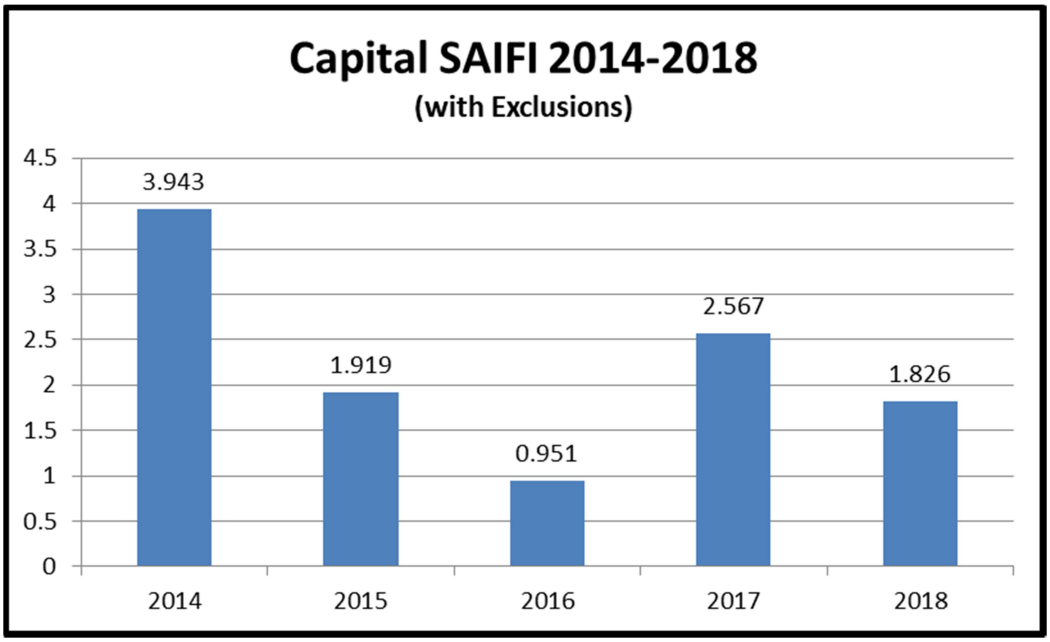
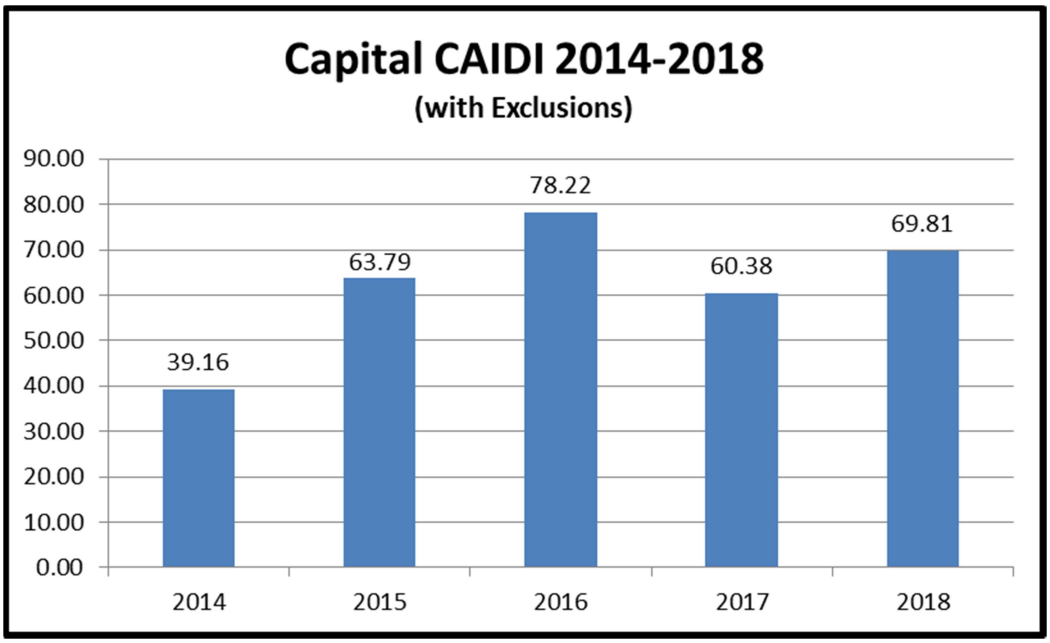


Chart 3: Annual Capital CAIDI



2 Reliability Goals

The annual UES Capital system reliability goal for 2019 has been set at 147.45 SAIDI minutes. This was developed by calculating the contribution of UES Capital to the Unitil system performance using the past five year average. The contribution factor was then set against the 2019 Unitil System goal. The 2019 Unitil System goal was developed through benchmarking the Unitil system performance with nationwide utilities.

Individual circuits will be analyzed based upon circuit SAIDI, SAIFI, and CAIDI. Analysis of individual circuits along with analysis of the entire UES 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 2018. Charts 4, 5, and 6 show the number of interruptions, the number of customer interruptions, and total customer-minutes of interruptions due to each cause, respectively. Only the causes contributing 3% or greater of the total are labeled. Table 1 shows the number of interruptions for the top three trouble causes for the previous five years.

Chart 4: Number of Interruptions by Cause

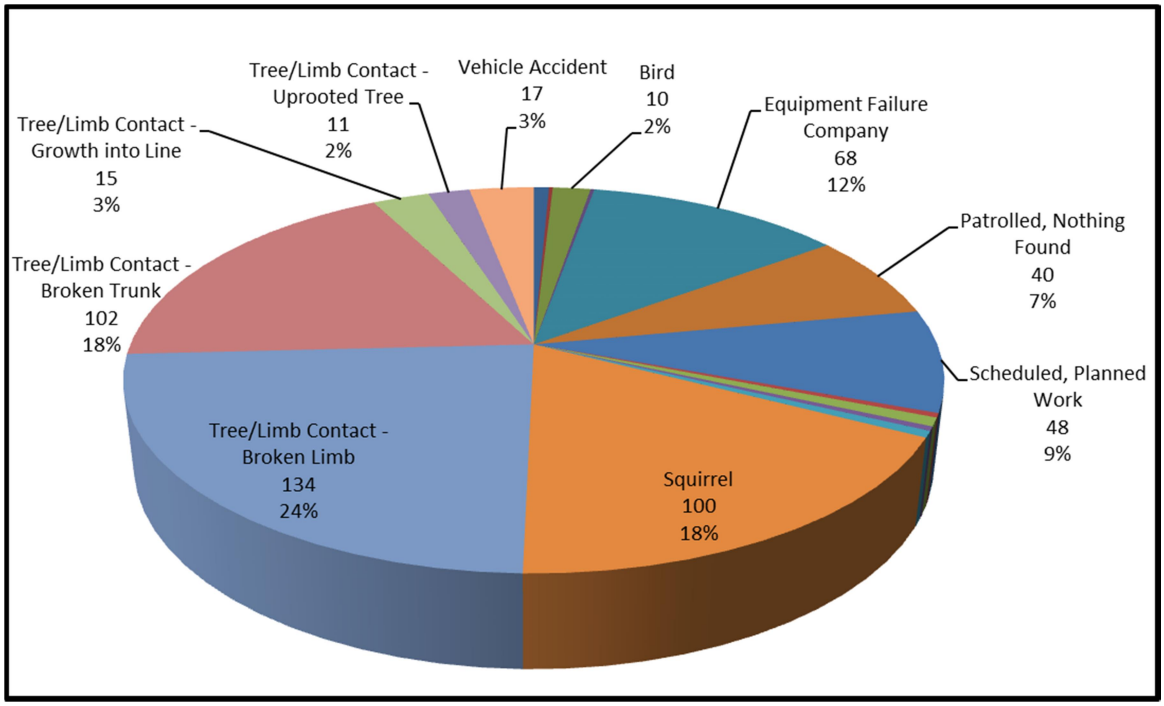


Chart 5: Number of Customer Interrupted by Cause

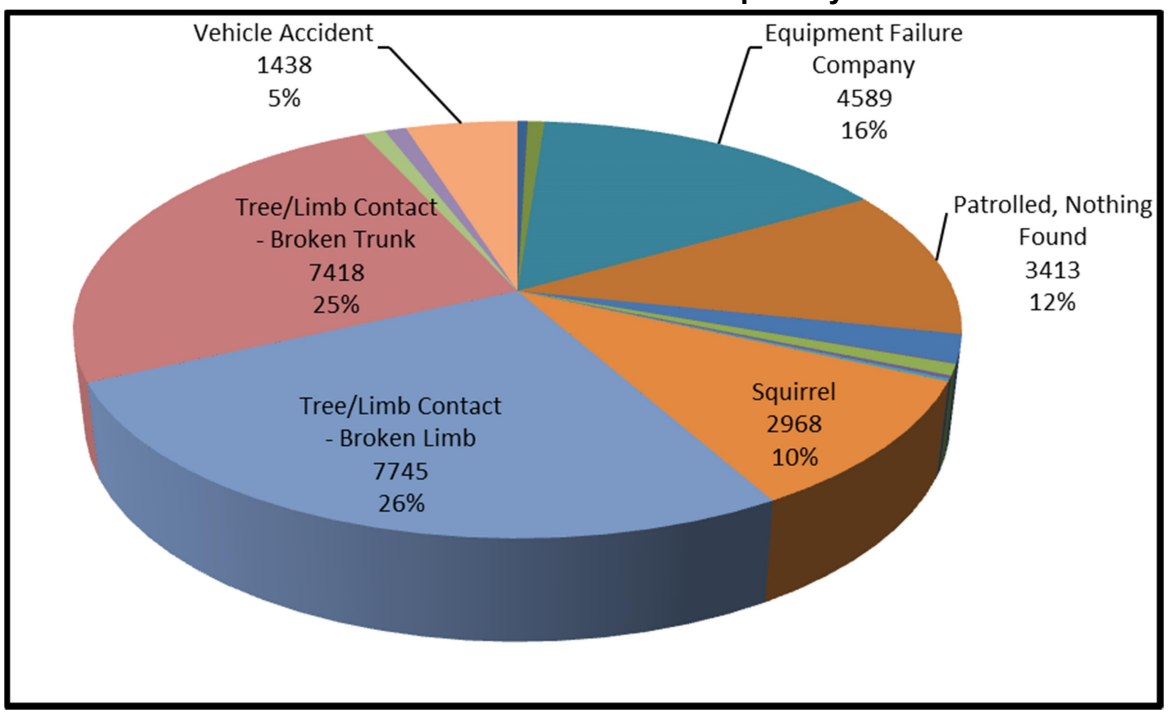


Chart 6: Percent of Customer-Minutes of Interruption by Cause

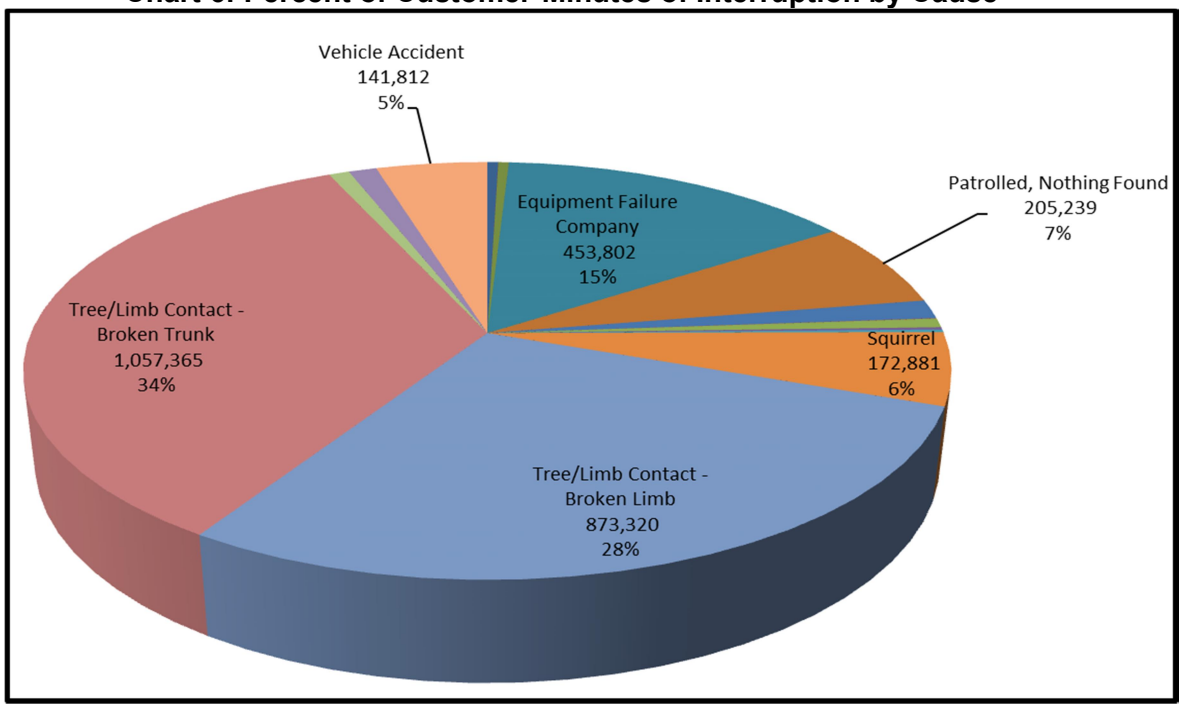


Table 1

Five-Year History of the Number of

Interruptions for the Worst Three Trouble Causes

Year	Tree/Limb Contact - Broken Limb	Tree/Limb Contact - Broken Trunk	Squirrel
2014	117	37	53
2015	134	44	53
2016	117	34	93
2017	86	37	112
2018	134	102	100

4 10 Worst Distribution Outages

The ten worst distribution outages ranked by customer-minutes of interruption during the time period from January 1, 2018 through December 31, 2018 are summarized in Table 2 below.

Table 2

Worst Ten Distribution Outages

Circuit	Description (Date/Cause)	No. of Customers Affected	No. of Customer Minutes	Capital SAIDI (min.)	Capital SAIFI
C13W3	11/10/2018 Tree/Limb Contact - Broken Trunk	1,615	155,709	5.13	0.053
C8X3	04/16/2018 Tree/Limb Contact - Broken Limb	1,139	140,192	4.62	0.038
C22W3	07/15/2018 Tree/Limb Contact - Broken Trunk	915	133,491	4.40	0.030
C13W3	07/10/2018 Tree/Limb Contact - Broken Trunk	401	92,484	3.05	0.013
C8X3	02/17/2018 Equipment Failure Company	892	70,914	2.34	0.029
C13W2	05/22/2018 Patrolled, Nothing Found	1,480	68,198	2.25	0.049
C38	07/21/2018 Equipment Failure Company	155	66,082	2.18	0.005
C13W2	07/10/2018 Tree/Limb Contact - Broken Limb	240	63,600	2.09	0.008
C13W3	01/23/2018 Tree/Limb Contact - Broken Limb	585	59,085	1.95	0.019
C15W2	12/17/2018 Tree/Limb Contact - Broken Trunk	251	57,547	1.90	0.008

Note: This table does not include outages that occurred at substations or on the subtransmission system, scheduled/planned work outages, or outages that occurred during excludable events.

5 Subtransmission and Substation Outages

This section describes the contribution of sub-transmission line and substation outages on the UES Capital system.

All substation and sub-transmission outages ranked by customer-minutes of interruption during the time period from January 1, 2018 through December 31, 2018 are summarized in Table 3 below.

Table 4 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 24% of the total customer-minutes of interruption for UES Capital.

Table 3

Subtransmission and Substation Outages

Trouble Location	Description (Date/Cause)	No. Customers Affected	No. of Customer Minutes	UES CAPITAL SAIDI (min)	UES Capital SAIFI	No. Times on List (past 4 yrs)
Line 38	12/17/2018 Tree/Limb Contact - Broken Limb	1,804	253,850	8.39	0.059	4
Line 34	11/06/2018 Tree/Limb Contact - Uprooted Tree	1,715	246,325	8.11	0.056	2
Line 35	02/16/2018 Equipment Failure Company	1,279	122,558	4.04	0.042	1
Line 34	07/04/2018 Tree/Limb Contact - Broken Trunk	1,710	90,674	2.99	0.056	2
Line 36	02/16/2018 Equipment Failure Company	10	410	0.01	0.000	0

Table 4

Contribution of Subtransmission and Substation Outages

Circuit	Trouble Location	Customer-Minutes of Interruption	% of Total Circuit Minutes	Circuit SAIDI Contribution	Number of Events
C2H4	Line 33 / Line 34	43,483	90%	836.21	2
C2H1	Line 33 / Line 34	69,631	100%	144.76	1
C33X4	Line 33 / Line 34	9,536	99%	146.71	2
C2H2	Line 33 / Line 34	211,208	88%	198.69	2
C33X5	Line 33 / Line 34	447	100%	149.00	2
C33X3	Line 33 / Line 34	149	100%	149.00	2
C33X6	Line 33 / Line 34	149	73%	3.73	2
C34X2	Line 33 / Line 34	2,025	100%	225.00	2
C34X4	Line 33 / Line 34	372	100%	371.80	2
C1X7P	Line 1X7P	349	100%	43.57	1
C21W1P	Line 1X7P	18,656	82%	43.49	3
C35X2	Line 36 / Line 35	644	100%	161.00	2
C35X3	Line 36 / Line 35	805	100%	161.00	2
C35X4	Line 36 / Line 35	161	100%	161.00	2
C15W2	Line 35	23,940	21%	72.33	1
C15W1	Line 35	94,145	74%	94.90	1
C15H3	Line 35	1,425	100%	95.00	1
C35X1	Line 35	1,848	100%	123.20	1

*Note that 2H1 and 2H4 were tied during some of the outages, which effects their event totals.

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 sub-transmission or substation supply outages unless noted otherwise.

6.1 Worst Performing Circuits in Past Year (1/1/18 – 12/31/18)

A summary of the worst performing circuits during the time period between January 1, 2018 and December 31, 2018 is included in the tables below.

Table 5 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 6 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 during 2018.

Circuits having one outage contributing more than 80% of the Customer-Minutes of interruption were excluded from this analysis.

Table 5

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
C13W3	8,906	18%	857,816	18%	532.47	5.528	96.32
C8X3	4,223	27%	470,644	30%	164.27	1.474	111.45
C22W3	4,679	34%	387,272	34%	242.20	2.926	82.77
C13W2	3,881	38%	359,001	19%	327.56	3.541	92.50

C38	754	21%	142,781	46%	128.52	0.679	189.37
C7W3	1,248	14%	129,571	27%	142.86	1.376	103.82
C4W3	1,541	30%	116,834	29%	73.62	0.971	75.82
C18W2	1,061	20%	97,330	16%	83.62	0.912	91.73
C15W2	517	49%	88,754	65%	268.14	1.562	171.67
C13W1	801	16%	75,936	13%	155.29	1.638	94.80

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

Table 6

Circuit Interruption Analysis by Cause

Circuit	Customer – Minutes of Interruption / # of Outages					
	Tree/Limb Contact - Broken Trunk	**Tree/Limb Contact - Broken Limb**	**Equipment Failure Company**	**Patrolled, Nothing Found**	**Vehicle Accident**	**Squirrel**
C13W3	490,316 / 29	218,235 / 37	2,483/ 6	54,908 / 10	29,058 / 4	12,812 / 13
C8X3	69,595 / 20	244,196 / 33	94,108/ 12	14,261 / 7	411 / 1	29,420 / 24
C22W3	245,240 / 9	79,321 / 16	22,258 / 9	9,999 / 3	0 / 0	7,452 / 9
C13W2	73,965 / 12	184,454 / 10	4,375 / 2	68,312 / 2	0 / 0	8,176 / 4
C38	1,408 / 2	1,602 / 2	131,284 / 6	7,065 / 1	0 / 0	0 / 0
C7W3	17,177 / 4	25,329 / 4	18,643 / 4	335 / 1	59,533 / 2	7,280 / 4
C4W3	0 / 0	17,452 / 4	40,990 / 4	68 / 1	36,204 / 4	14,067 / 4
C18W2	50,273 / 8	12,296 / 5	135 / 1	1,192 / 1	0 / 0	33,056 / 13

C15W2	57,546 / 1	3,296 / 1	4,017 / 2	0 / 0	0 / 0	7,292 / 4
C13W1	25,406 / 9	18,208 / 7	1450 / 3	7,839 / 4	13,955 / 2	2,764 / 6

6.2 Worst Performing Circuits of the Past Five Years (2014 – 2018)

The annual performance of the ten worst circuits in terms of circuit SAIDI and SAIFI for each of the past five years is shown in the tables below. Table 7 lists the ten worst performing circuits ranked by SAIDI and Table 8 lists the ten worst performing circuits ranked by SAIFI. Table 9 lists the ten worst performing circuits ranked by SAIDI and SAIFI over the past five years.

The data used in this analysis includes all system outages except those outages that occurred during the 2016 July Wind/Thunder storm, 2014 November Cato Snowstorm, 2017 March Windstorm, 2017 October Tropical Storm, 2018 May Windstorm, and 2018 June Thunderstorm.

The data used in this analysis includes all distribution circuits except those that do not have an interrupting device, e.g. fuse or recloser, at their tap location.

Table 7

Circuit SAIDI

Circuit Ranking (1 = worst)	2018		2017		2016		2015		2014	
	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI
1	C13W3	532.47	C13W2	577.74	C21W1A	892.82	C21W1A	803.71	C15W2	794.83
2	C13W2	327.55	C18W2	560.64	C7W3	272.49	C34X2	399.45	C22W3	729.57
3	C15W2	268.13	C13W1	555.75	C34X2	244.80	C13W3	357.44	C35X1	573.63
4	C22W3	242.19	C13W3	496.50	C37X1	176.22	C375X1	318.05	C24H1	570.48
5	C21W1A	166.73	C396X2	454.70	C18W2	155.42	C14H2	288.10	C24H2	545.14
6	C8X3	164.27	C17X1	410.37	C15W1	147.96	C16X4	281.37	C22W1	534.36
7	C13W1	155.28	C16H3	403.03	C4X1	146.38	C16H1	281.30	C22W2	512.65
8	C7W3	142.85	C8X3	326.03	C13W1	140.76	C7W3	281.18	C15W1	499.87
9	C38	128.51	C33X4	246.98	C22W3	136.51	C16H3	280.82	C7W3	444.56
10	C2H4	87.84	C8H2	246.67	C13W3	117.09	C16X5	280.05	C38W	441.97

Table 8

Circuit SAIFI

Circuit Ranking (1 = worst)	2017		2016		2015		2014		2013	
	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI
1	C2H4	10.981	C13W2	6.694	C21W1A	3.993	C21W1A	6.356	C24H1	7.143
2	C13W3	5.528	C13W1	5.818	C37X1	2.418	C16X4	5.023	C24H2	6.987
3	C13W2	3.541	C13W3	5.267	C18W2	1.995	C16H1	5.020	C15W2	6.597
4	C22W3	2.926	C16H3	4.693	C15W1	1.938	C16X5	5.000	C22W3	5.832
5	C8X5	1.795	C18W2	4.131	C13W1	1.785	C16X6	5.000	C3H1	4.251
6	C13W1	1.638	C8H2	3.122	C1X7P	1.778	C375X1	5.000	C22W1	4.034
7	C15W2	1.562	C8X3	3.108	C4X1	1.738	C16H3	4.998	C38W	4.022
8	C8X3	1.474	C17X1	3.000	C22W3	1.509	C7W3	4.850	C22W2	4.000
9	C7W3	1.376	C396X2	3.000	C7W3	1.396	C13W3	4.567	C7W3	3.982
10	C21W1A	1.239	C37X1	2.770	C13W3	1.348	C18W2	4.127	C14X3	3.500

Table 9

Worst Performing Circuit past Five Years

SAIDI			SAIFI		
Circuit Ranking	**Circuit**	**# Appearances**	**Circuit Ranking**	**Circuit**	**# Appearances**
1	C13W3	4	**1**	C21W1A	3
2	C21W1A	3	**2**	C13W1	3
3	C13W2	2	**3**	C13W3	4
4	C15W2	2	**4**	C13W2	2
5	C22W3	3	**5**	C22W3	3
6	C34X2	2	**6**	C18W2	3
7	C7W3	4	**7**	C15W2	2
8	C13W1	3	**8**	C16H3	2
9	C18W2	2	**9**	C24H1	1
10	C15W1	2	**10**	C2H4	1

6.3 System Reliability Improvements (2018 and 2019)

Vegetation management projects completed in 2018 or planned for 2019 that are expected to improve the reliability of the 2018 worst performing circuits are included in table 10 below. Table 11 below details electric system upgrades that are scheduled to be completed in 2019, or were completed in 2018, that were performed to improve system reliability.

Table 10

Vegetation Management Projects on Worst Performing Circuits

Circuit(s)	Year of Completion	Project Description
C13W3	2018	Planned Cycle Pruning
C13W2	2018	Planned Cycle Pruning & Hazard Tree Mitigation
C38	2019	Planned Cycle Pruning
C7W3	2018	Planned Hazard Tree Mitigation / Mid-Cycle Pruning
C4W3	2018 / 2019	Planned Reliability Analysis / Planned Mid-Cycle Pruning
C18W2	2019	Planned Mid-Cycle Pruning
C15W2	2018	Planned Mid-Cycle Pruning & Hazard Tree Mitigation
C13W1	2018 / 2019	Planned Reliability Analysis / Planned Cycle Pruning

Table 11

Electric System Improvements Performed to Improve Reliability

Circuit(s)	Year of Completion	Project Description
18W2	2018	Microprocessor Controlled Recloser Installation
13W3	2018	Sectionalizer Replacement (increased zone of protection)

Circuit(s)	Year of Completion	Project Description
8X3	2018	Fusesaver Installation
18W2	2019	Microprocessor Controlled Recloser Installation
18W2	2019	Fusesaver Installation
13W3	2019	Hydraulic Recloser Replacement (for coordination)
VARIOUS	2019	Porcelain Cutout Replacements
8X3 and 8X5	2019	New Circuit Tie
38	2019	UG Cable Injection
16H3	2019	UG Cable Injection
2H2	2019	Spacer Cable Replacement
1H2 and 1H3	2019	Replace Switchgear and add Tie
VARIOUS	2019	Animal Guard Installation
396X1	2019	Microprocessor Controlled Recloser Installation

7 Tree Related Outages in Past Year (1/1/18 – 12/31/18)

This section summarizes the worst performing circuits by tree related outage during the time period between January 1, 2018 and December 31, 2018.

Table 12 shows the ten worst 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.

All streets on the UES CAPITAL system with three or more tree related outages are shown in Table 13 below. The table is sorted by number of interruptions and customer-minutes of interruption.

Table 12

Worst Performing Circuits – Tree Related Outages

Circuit	Customer-Minutes of Interruption	Number of Customers Interrupted	No. of Interruptions
C13W3	714,927	5,624	72
C22W3	327,711	3,945	27
C8X3	321,818	2,399	55
C13W2	269,881	2,177	25
C15W2	63,370	303	5
C18W2	62,570	558	13
C13W1	44,275	392	17
C7W3	42,656	492	10
C7W4	32,542	505	3
C15W1	26,856	391	4

Table 13

Multiple Tree Related Outages by Street

Circuit	Street, Town	# Outages	Customer-Minutes of Interruption	No. of Customer Interruptions
C13W3	Old Turnpike Rd, Salisbury	10	210,337	1,278
C13W3	Daniel Webster Hwy, Boscawen	6	36,500	221
C13W1	Borough Rd, Canterbury	6	20,531	145
C13W3	Battle St, Webster	5	58,423	545
C8X3	New Orchard Rd, Epsom	4	32,119	98
C8X3	Swamp Rd, Epsom	4	19,503	218
C13W3	Mutton Rd, Webster	4	9,865	88
C38	Curtisville Rd, Concord	4	3,011	48
C13W3	High St, Boscawen	3	158,343	1,624
C13W3	White Plains Rd, Webster	3	37,120	324
C13W3	Corn Hill Rd, Boscawen	3	33,806	226
C18W2	Morse Rd, Dunbarton	3	33,728	263
C13W1	Pickard Rd, Canterbury	3	18,139	135
C13W3	Warner Rd, Salisbury	3	15,494	101
C22W3	Page Rd, Bow	3	15,220	118
C13W2	Elm St, Penacook	3	14,904	154
C13W1	Morrill Rd, Canterbury	3	14,497	121
C13W3	Whittemore Rd, Salisbury	3	5,839	67

C13W3	Battle St, Salisbury	3	5,469	84
C15W2	W. Portsmouth St, Concord	3	5,095	45
C13W1	Hackleboro Rd, Canterbury	3	2,986	46
C8X3	Sanborn Hill Rd N., Epsom	3	2,591	21
C13W1	Wilson Rd, Canterbury	3	2,410	22
C22W3	Brown Hill Rd, Bow	3	965	4

During 2018, 13W1, 13W2, and 13W3 was undergoing cycle pruning. These circuits will be re-evaluated in next years' study now that forestry has completed the work in these areas. In the meantime, all of these streets have been given to the forestry team to do hazard tree mitigation. Additionally, a new outage mapping program has been created. This will assist the forestry group to identify problem areas, particularly for hazard tree mitigation. Finally, projects to add reclosing to heavily treed circuits are being proposed for the 2020 budget.

8 Failed Equipment

This section is intended to clearly show all equipment failures throughout the study period from January 1, 2018 through December 31, 2018. Chart 7 shows all equipment failures throughout the study period. Chart 8 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 three categories of failed equipment for the past five years are shown below in Chart 9.

Chart 7

Equipment Failure Analysis by Cause

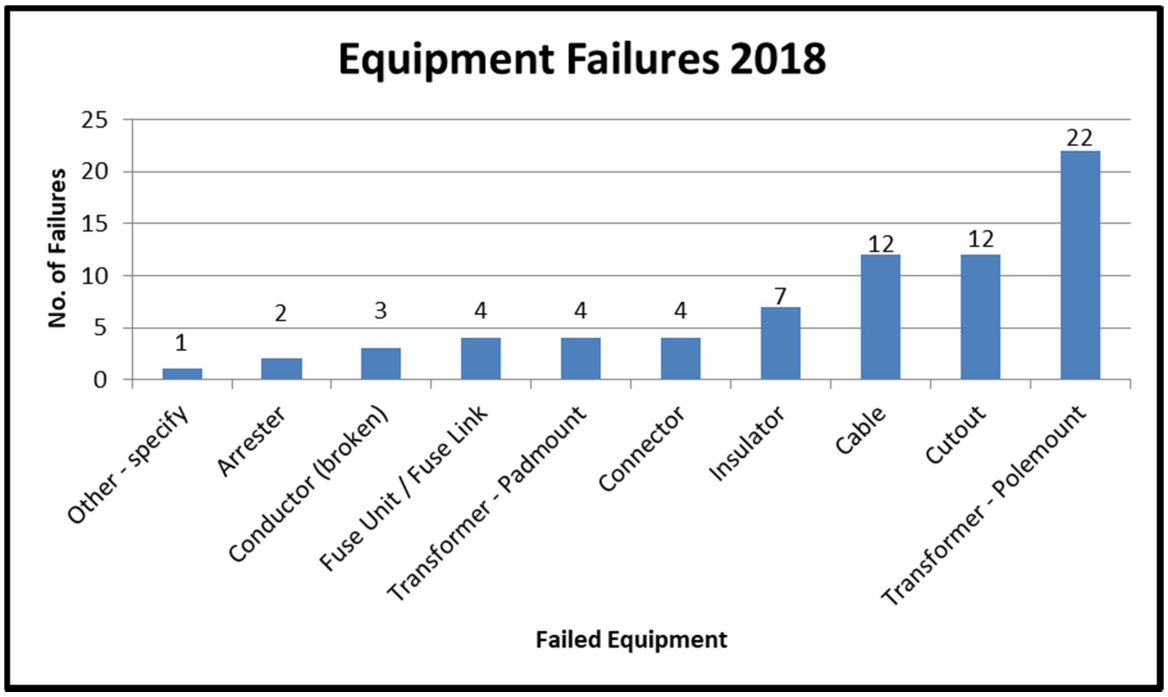


Chart 8

Equipment Failure Analysis by Percentage of Total Failures

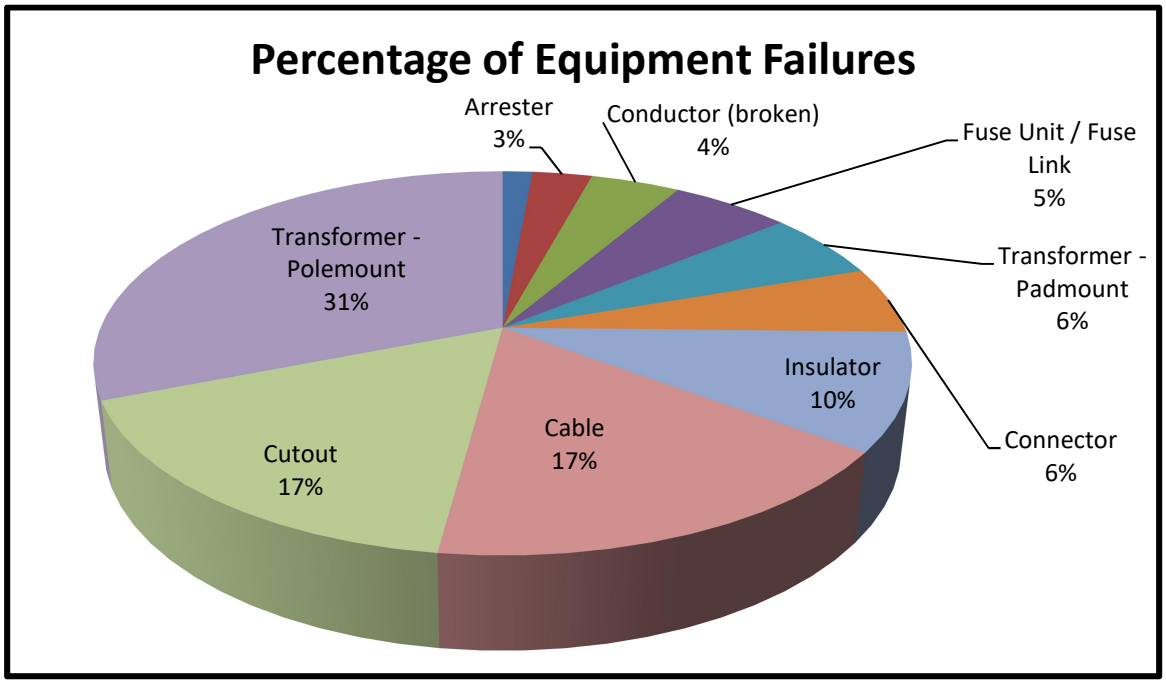
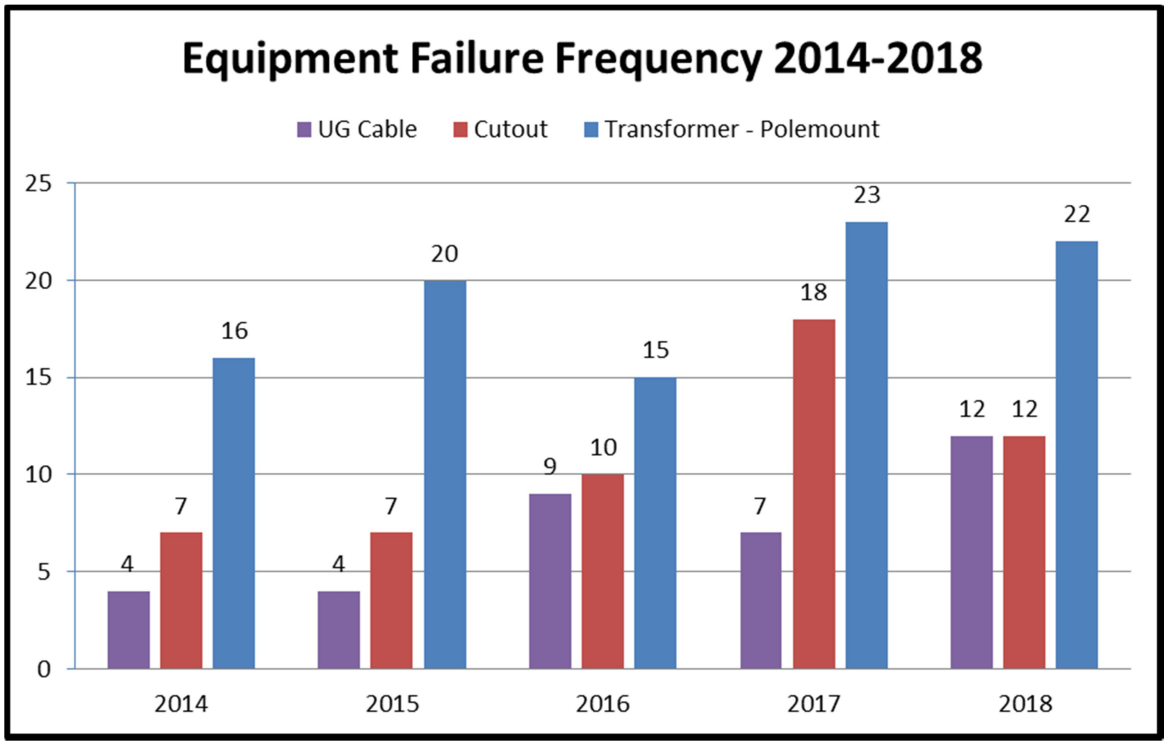


Chart 9
Annual Equipment Failures by Category (top three)

The top three equipment failures continue to be underground cable, cutouts, and polemount transformers. Underground cable failures have generally increased over the last five years. Two life-extending cable injections were executed in 2019. Additional cable injections and direct-buried cable replacement projects are planned for 2020-2021. Cutout failures experienced a slight reprieve in 2018; however they have trended upward over the course of five years. A porcelain cutout replacement program is planned for 2019-2021. Polemount transformer failures continue to be the highest rate of failure with a general, five-year upward trend. There is no planned program to address the transformer failure.



9 Multiple Device Operations and Streets with Highest Number of Outages

A summary of the devices that have operated four or more times from January 1, 2018 to December 31, 2018 are included in table 14 below. Refer to section 11 for project recommendations that address some of the areas identified.

A summary of the streets on the UES Capital system that had customers with 7 or more non-exclusionary outages in 2018 is included in Table 15 below. The table is sorted by circuit and then the maximum number of outages seen by a single customer on that street.

Table 14

Multiple Device Operations

Circuit	Device	Number of Operations	Customer Minutes	Customer Interruptions	# of Times on List in Previous 4 Years
C38	Fuse, Pole 25, Line 38 - East, Concord	5	121,042	716	0
C13W2	Fuse, Pole 50, Borough Rd, Canterbury	5	18,209	98	0
C13W3	Fuse, Pole 145, Old Turnpike Rd, Salisbury	5	10,234	105	0
C15W2	Fuse, Pole 8, W. Portsmouth St, Concord	5	6,564	75	1
C13W3	Recloser, Pole 84, High St, Boscawen	4	133,773	1130	1
C13W3	Fuse, Pole 75, Old Turnpike Rd, Salisbury	4	112,580	812	0
C15W2	Recloser, Pole S/S, Foundry St, Concord	4	71,664	834	0
C13W1	Recloser, Pole 1, Morrill Rd, Canterbury	4	21,599	240	0
C8X3	Fuse, Pole 2, Swamp Rd, Epsom	4	16,858	164	0
C13W2	Fuse, Pole 1, Randall Rd, Canterbury	4	15,579	80	0
C13W3	Fuse, Pole 30, Long St, Webster	4	9,865	88	0
C8X3	Fuse, Pole 1, Sanborn Hill Rd North, Epsom	4	5,347	40	1
C38	Fuse, Pole 7, Curtisville Rd, Concord	4	3,011	48	0

Table 15

Streets with the Highest Number of Outages

Circuit	Street	Max Number of Outages Seen by a Single Customer	Number of Times on List in Previous 4 Years
C13W3	OLD TURNPIKE RD	13	1
C13W3	WHITE PLAINS RD	12	2
C13W1	BOROUGH RD	11	2
C13W3	LITTLE HILL RD	9	2
C13W3	BATTLE ST	8	2
C13W3	MUTTON RD	8	2
C15W2	W PORTSMOUTH ST	8	1
C13W2	ELM ST	7	1
C13W1	TIOGA RD	7	1
C13W1	RANDALL RD	7	1
C13W1	MORRILL RD	7	1
C13W1	OLD TILTON RD	7	1
C8X3	SANBORN HILL RD	7	0
C22W3	BEAVER BROOK DR	7	0
C22W3	TONGA DR	7	1

10 Other Concerns

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

10.1 13.8kV Underground Electric System Improvements

There are condition concerns in the 13.8kV Concord Downtown Underground. Portions of the cable have been replaced due to faults. There is historical evidence of connector failure as well. Transformers with primary switches are still in the process of being installed in place of the existing transformers. By the end of 2019, 18 of 21 transformers will have switches in them. A 2020 proposed budget project will address three more of these transformers. The same project will also create a loop out of manhole 25, allowing for additional restoration switching. A 2020 proposed budget project will allow switching all times of the year. This is expected to reduce outage duration and allow time for condition-based replacement as opposed to a quick fix to restore customers quickly.

10.2 URD Cable Failure

URD cables are failing at an average rate of 10 failures per year, from 2016 through 2018. There is a trend of increasing cable failures each year from 2015 to 2018. When a direct buried cable fails, Unitil splices in a small section of new cable into the existing cable. Generally, cable failures in conduit result in cable replacement. The remaining aged cable in the area is still susceptible to failure. Options to decrease the number of failures include: direct replacement, rejuvenation, and replacement with conduit (for existing direct buried options). Projects for rejuvenation and replacement with conduit are underway in 2019 and further proposed for the 2020 budget.

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 2020 capital budget. All project costs are shown without general construction overheads.

11.1. Circuit 13W3: Create a Loop between Water St and High St

11.1.1. Identified Concerns

Circuit 13W3 had three of the worst distribution outages in 2018, including the number one worst outage. It has been on the list of worst performing circuits four out of the last five years, ranked by SAIDI and SAIFI.

11.1.2. Recommendations

Build N. Water St, Boscawen from single phase to three phase spacer cable. Extend the phases through to P.50 Old Turnpike Rd, Salisbury. Install two Reclosers and one three-phase, remote and motor operated switch. Implement an auto transfer scheme.

Estimated Project Cost (without construction overheads): $1,200,000

Estimated Annual Savings:

Customer Minutes: 144,600

Customer Interruptions: 673

11.1.3. Alternate Option

Install a recloser at P.49 Old Turnpike Rd, Salisbury.

Estimate Project Cost (without construction overheads): $50,000

Estimated Annual Savings:

Customer Minutes: 1,746

Customer Interruptions: 21

11.2. Circuit 15W1: Install Recloser on Mountain Rd

11.2.1. Identified Concerns

15W1 has experienced several operations on the fuses at P.5 Mountain Rd. Replacing the fuses with a recloser allows reclosing to eliminate some of the outages; particularly the patrolled, nothing found outages, squirrel and animal-related outages, and some broken limb outages.

11.2.2. Recommendations

Replace cutouts and fuses at P.5 Mountain Rd, Concord with a Recloser.

Estimated Project Cost (without construction overheads): $32,401

Estimated Annual Savings:

Customer Minutes: 27,838

Customer Interruptions: 335

11.3. Circuit 8X3: Replace Hydraulic Recloser with Digital Relay/Recloser

11.3.1. Identified Concern

The hydraulic recloser at P.167 Main St, Chichester does not coordinate well with downline devices. As such, there is low-side fusing for the step down transformers at P.164 and 166. These low-side fuses have operated multiple times in the last three years. The hydraulic recloser does allow for fuse savings downline. Replacing the hydraulic recloser and low-side fuses with a microprocessor-based recloser will allow reclosing for the 451 exposed customers.

11.3.2. Recommendation

Install a Recloser at P.168 Main St, Chichester.

Estimated Project Cost (without construction overheads): $35,967

Estimated Annual Savings:

Customer Minutes of Interruption: 33,655

Customer Interruptions: 405

11.4. Circuit 13W2: Reconductor N. Main St, Boscawen with Spacer

11.4.1. Identified Concern

The master plan is to create a backup for the 37 Line, as it radially feeds the Boscawen S/S. The 13W2 circuit will be converted to 34.5kV and tie with 4X1 from Penacook. This project is expected to provide increased reliability for 13W2 right now, but also establish the back bone for even greater reliability at the sub-transmission and distribution levels.

11.4.2. Recommendation

Reconductor 13W2 mainline from the S/S, down N. Main St, Boscawen, and end at the Village St bridge in Penacook. The reconductoring and reinsulating will be done to system planning capacity and 34.5kV construction. This construction is approximately 2.5 miles of spacer cable construction.

Estimated Project Cost (without construction overheads): $674,174

Estimated Annual Savings:

Customer Minutes of Interruption: 107,510

Customer Interruptions: 1,294

11.5 Circuit 13W1: Reconductor Morrill Rd, Canterbury

11.5.1 Identified Concern

A number of tree related outages on this single phase lateral occurred in 2018. There are limited trimming abilities in the area. Reconductoring with insulated wire will reduce the number of outages.

11.5.2 Recommendation

Reconductor approximately 14,000 ft of #6 Cu with insulated 1/0 ACSR on Morrill Rd, Canterbury.

Estimated Project Cost (without construction overheads): $445,000

Estimated Annual Savings:

Customer Minutes of Interruption: 7,630

Customer Interruptions: 84

11.6 Circuit 8X5: Install a Recloser on Regional Dr.

11.6.1 Identified Concern

A number of motor vehicle accidents and large tree related outages occurred in 2018 that caused the substation recloser to trip to lockout. A mid-line recloser will be another sectionalizing point with reclosing that will help lessen the effect of a mainline fault beyond the recloser.

11.6.2 Recommendation

Install a Recloser at P.5 Regional Dr., Concord.

Estimated Project Cost (without construction overheads): $34,531

Estimated Annual Savings:

Customer Minutes of Interruption: 27,429

Customer Interruptions: 330

11.7 Circuit 6X3: Install a Recloser on Pleasant St

11.7.1 Identified Concern

6X3 exits the Pleasant St S/S and branches to the left and right. In order to limit the scale of the outage, a sectionalizing device in each direction will prevent a full circuit outage. This project is for a recloser in the east direction of Pleasant St. It will replace a set of fuses on P.78.

11.7.2 Recommendation

Install a Recloser at P.78 Pleasant St, Concord.

Estimated Project Cost (without construction overheads): $31,492

Estimated Annual Savings:

Customer Minutes of Interruption: 27,774

Customer Interruptions: 334

11.8 Circuit 13W3: Reconductor Long St, Webster with Spacer Cable

11.8.1 Identified Concern

The sectionalizers on P.138 Long St, Boscawen operated several times in 2018, most as patrolled, nothing found outages. Reconductoring approximately 1.6 miles of three phase mainline will reduce the number of outages normally associated with trees and animals.

11.8.2 Recommendation

Reconductor approximately 1.6 miles of three-phase mainline on Long St, Boscawen and Webster with 13.8kV, 336AAC spacer.

Estimated Project Cost (without construction overheads): $533,936

Estimated Annual Savings:

Customer Minutes of Interruption: 23,315

Customer Interruptions: 281

11.9 Circuit 13W1: Reconductor West Rd, Canterbury and Install Recloser

11.9.1 Identified Concern

13W1 does not have a circuit tie that can back feed the circuit for restoration. This project aims to harden the stand alone system, lessen overall outage impact with an additional reclosing point, and prepare for a potential future tie, according to the master plan.

11.9.2 Recommendation

Reconductor approximately 4 miles of three phase mainline on West Rd, Canterbury with 13.8kV, 336AAC spacer.

Install a Recloser at P.31 North West Rd, Canterbury.

Estimated Project Cost (without construction overheads): $750,000

Estimated Annual Savings:

Customer Minutes of Interruption: 73,583

Customer Interruptions: 886

11.10 Circuit 8X3: Install a Recloser on Dover Rd, Epsom

11.10.1 Identified Concern

8X3 does not currently have a circuit backup to restore load for an outage outside of the substation. Adding sectionalizing points will limit the impact of outages beyond the new recloser.

11.10.2 Recommendations

Install a Recloser at P.5 Dover Rd, Epsom.

Estimated Project Cost (without construction overheads): $50,000

Estimate Annual Savings:

Customer Minutes of Interruption: 50,025

Customer Interruptions: 602

11.11 Fusesaver Installation Locations

11.11.1 Identified Concern

In an effort to continually improve upon reliability, fusesavers have been identified as capable to eliminate most momentary outages by allowing for a single trip clearing time. The following is a list of locations in which fusesavers have been identified as beneficial additions.

11.11.2 Recommendations

1) Install a fusesaver at P.22 N. Main St, Boscawen.

Estimated Project Cost (without construction overheads): Minimal

Estimated Annual Savings:

Customer Minutes of Interruption: 13,095

Customer Interruptions: 195

2) Install a fusesaver at P.1 New Orchard Rd, Epsom.

Estimated Project Cost (without construction overheads): Minimal

Estimated Annual Savings:

Customer Minutes of Interruption: 10,111

Customer Interruptions: 31

3) Install a fusesaver at P.16 Stickney Hill Rd, Hopkinton

Estimated Project Cost (without construction overheads): Minimal

Estimated Annual Savings:

Customer Minutes of Interruption: 7,565

Customer Interruptions: 120

4) Install a fusesaver at P.56 Knox Rd, Bow.

Estimated Project Cost (without construction overheads): Minimal

Estimated Annual Savings:

Customer Minutes of Interruption: 5,720

Customer Interruptions: 30

5) Install three fusesavers at P.4 King Rd, Chichester.

Estimated Project Cost (without construction overheads): Minimal

Estimated Annual Savings:

Customer Minutes of Interruption: 5,565

Customer Interruptions: 67

6) Install three fusesavers at P.1 Rocky Point Dr., Bow.

Estimated Project Cost (without construction overheads): Minimal

Estimated Annual Savings:

Customer Minutes of Interruption: 5,073

Customer Interruptions: 61

7) Install a fusesaver at P.62 Elm St, Boscawen.

Estimated Project Cost (without construction overheads): Minimal

Estimated Annual Savings:

Customer Minutes of Interruption: 4,733

Customer Interruptions: 57

8) Install a fusesaver at P.145 Old Turnpike Rd, Salisbury.

Estimated Project Cost (without construction overheads): Minimal

Estimated Annual Savings:

Customer Minutes of Interruption: 4,271

Customer Interruptions: 35

9) Install a fusesaver at P.50 Borough Rd, Canterbury.

Estimated Project Cost (without construction overheads): Minimal

Estimated Annual Savings:

Customer Minutes of Interruption: 4,200

Customer Interruptions: 20

10) Install a fusesaver at P.8 W. Portsmouth St, Concord.

Estimated Project Cost (without construction overheads): Minimal

Estimated Annual Savings:

Customer Minutes of Interruption: 2,166

Customer Interruptions: 25

11.12 Circuit 37X1: Install a Recloser at the 37X1 Tap

11.12.1 Identified Concern

37X1 is a lateral on the radial 37 line that is unprotected. This recloser will prevent 37 line outages when the fault occurs somewhere on 6,615 feet of unprotected lateral. Outages that occur here would no longer affect the Boscawen S/S and its 2,253 customers.

11.12.2 Recommendation

Install a Recloser on transmission Pole 42 of the 37 line, i.e. the 37X1 tap.

Estimated Project Cost (without construction overheads): $71,000

Estimated Annual Savings:

Customer Minutes of Interruption: 187,095

Customer Interruptions: 2,253

11.13. Miscellaneous Circuit Improvements to Reduce Recurring Outages

11.13.1. 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 2018. It is recommended that a forestry review of these areas be performed in 2019 in order to identify and address any mid-cycle growth or hazard tree problems.

- C13W1
  - Borough Rd, Canterbury
  - Pickard Rd, Canterbury
  - Morrill Rd, Canterbury
  - Hackleboro Rd, Canterbury
  - Wilson Rd, Canterbury
- C13W2
  - Elm St, Penacook
- C13W3
  - Battle St, Salisbury
  - Old Turnpike Rd, Salisbury
  - Warner Rd, Salisbury
  - White Plains Rd, Salisbury
  - Whittemore Rd, Salisbury
  - Battle St, Webster
  - Mutton Rd, Webster
  - White Plains Rd, Webster
  - Corn Hill Rd, Boscawen
  - Daniel Webster Hwy, Boscawen
  - High St, Boscawen
- C15W2
  - W. Portsmouth St, Concord
- C18W2
  - Morse Rd, Dunbarton
- C22W3
  - Brown Hill Rd, Bow
  - Page Rd, Bow
- C38
  - Curtisville Rd, Concord
- C8X3
  - New Orchard Rd, Epsom

- Sanborn Hill Rd N., Epsom
- Swamp Rd, Epsom

Animal Guard Installation Recommendations

The areas identified below experienced three or more patrolled nothing found / animal outages in 2018.

- Woodhill Rd, Bow
- Stickney Hill Rd, Hopkinton
- Allen Rd, Bow
- Mountain Rd, Concord
- Morrill Rd, Canterbury

12 Conclusion

During 2018, tree related outages still present one of the largest problems in the UES-Capital System, 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.

Squirrel related outages saw a sharp decrease in outages in 2018, which is expected to continue into 2019. Animal guards were installed during 2018. A further project to target specific areas is in progress in 2019. Animal guards are continually being placed on equipment whenever an animal causes an outage. In addition, when there is an animal-related outage, any equipment in the vicinity will be checked. If nearby equipment does not have animal guards, the animal guards will be installed at that location. Also, all streets and circuits identified as having high numbers of animal related outages will be checked and proper animal protection will be installed where applicable.

Recommendations developed from this study are mainly focused on reducing the impact of multiple permanent outages and improving reliability of the sub transmission system. 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 measures to be taken. 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 Study 2019

Unitil Energy Systems – Seacoast

Reliability Study

2019

Prepared By:

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Unitil Service Corp.

October 25, 2019

Table of Contents

1 Executive Summary

The purpose of this document is to report on the overall reliability performance of the Unitil Energy Systems – Seacoast (UES-Seacoast) system from January 1, 2018 through December 31, 2018. The scope of this report will also evaluate individual circuit reliability performance over the same time period. The outage data used in this report excludes the data in Section 5 (sub-transmission and substation outages), as well as the outage data from IEEE Major Event Days (MEDs). UES-Seacoast MEDs are listed in the table below:

# MEDs in Event	Dates of MEDs	Interruptions	Customer Interruptions	Cust-Min of Interruption
3	3/7/18 – 3/9/18	186	40,438	24,792,654

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 2020 budget development process.

Circuit / Line / Substation	Proposed Project	Cost ($)
6W1	Re-conductor portion of South Road with Spacer Cable	$250,000
43X1	Install Reclosers and Implement Distribution Automation	$350,000
3343 and 3354	Install Reclosers	$150,000
58X1	Install Reclosing Devices	$120,000

Note: estimates do not include general construction overheads

The 2018 annual UES-Seacoast system reliability goal was set at 105.61 SAIDI minutes, after removing exclusionary outages. UES-Seacoast's SAIDI performance in 2018 was 108.28 minutes. Charts 1, 2, and 3 below show UES-Seacoast's SAIDI, SAIFI, and CAIDI performance over the past five years.

Chart 1

Annual UES-Seacoast SAIDI

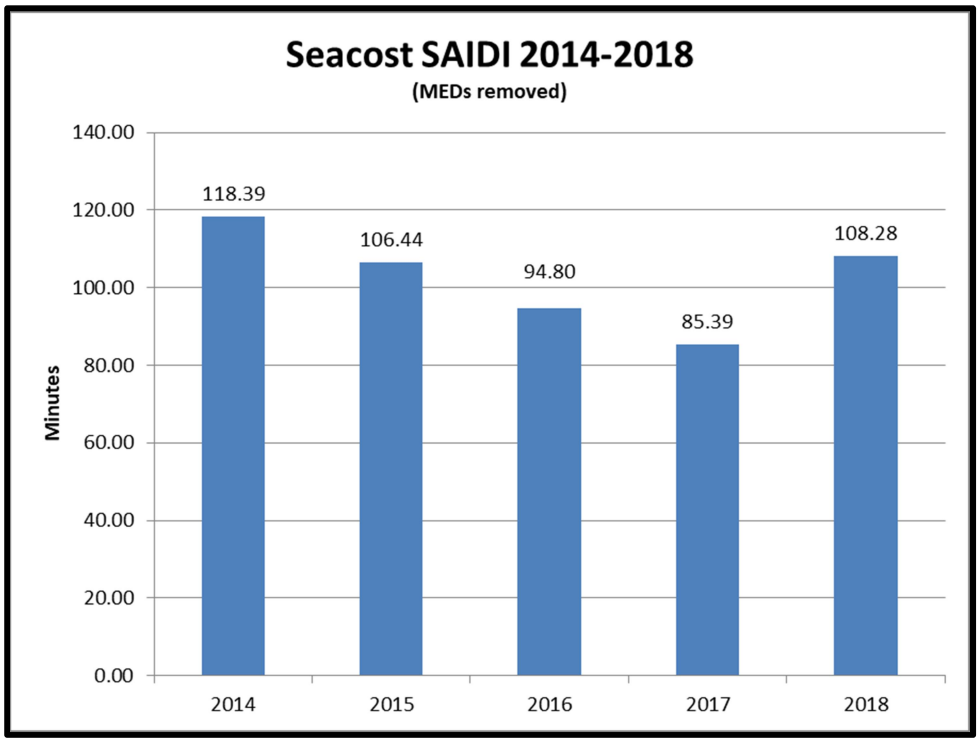


Chart 2

Annual UES-Seacoast SAIFI

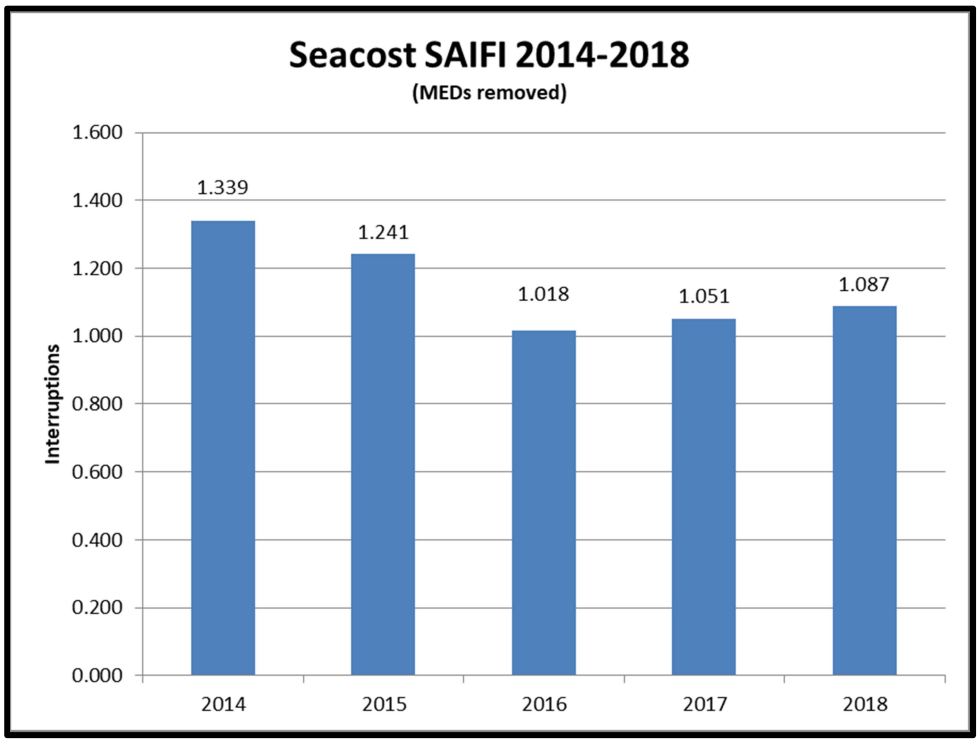
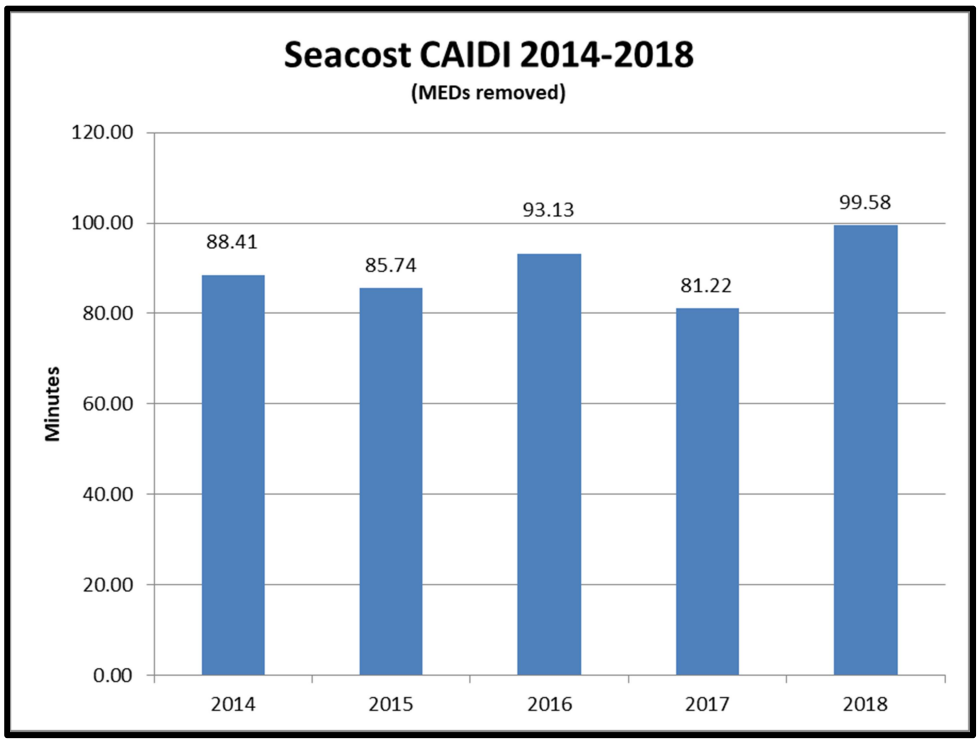


Chart 3
Annual UES-Seacoast CAIDI



2 Reliability Goals

The new annual UES-Seacoast system reliability goal for 2019 has been set at 113.25 SAIDI minutes. This was developed by calculating the contribution of UES-Seacoast to the Unitil system performance using the past five year average. The contribution factor was then set against the 2019 Unitil system goal. The 2019 Unitil system goal was developed through benchmarking the Unitil system performance with nationwide utilities.

Individual circuits will be analyzed based upon circuit SAIDI, SAIFI, and CAIDI. Analysis of individual circuits along with analysis of the entire UES-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 2018. Charts 4, 5, and 6 list the number of interruptions, the number of customer interruptions, and total customer-minutes of interruption due to each cause respectively. Only the causes contributing 3% or greater of the total are labeled. Table 1 shows the number of interruptions for the top three trouble causes for the previous five years.

Chart 4

Number of Interruptions by Cause

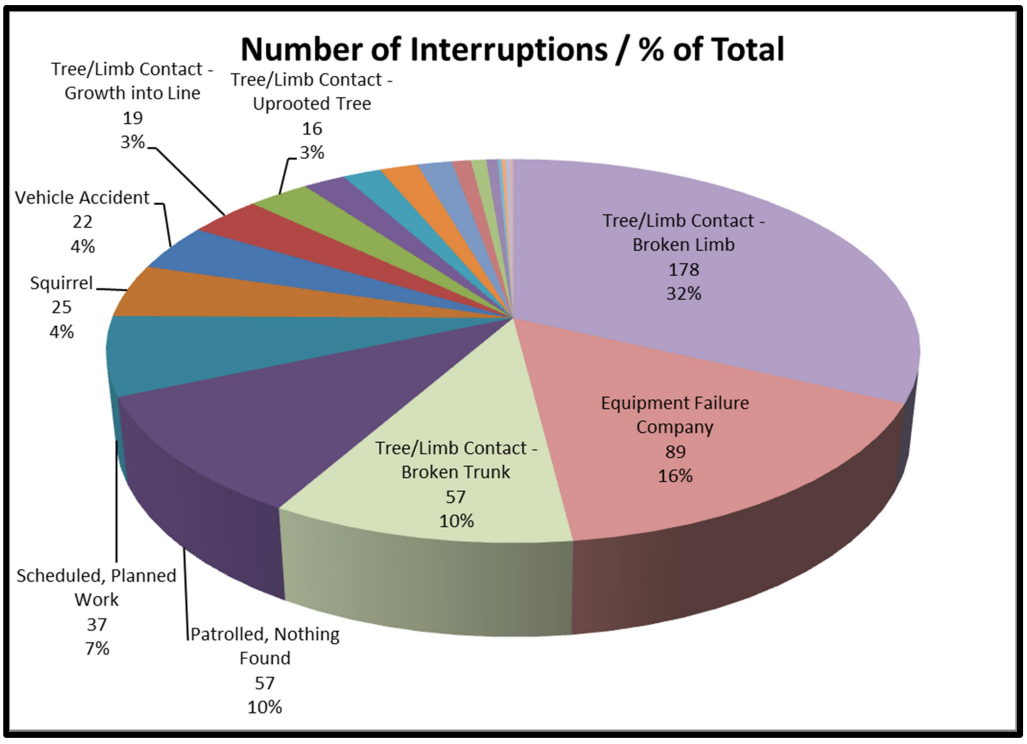


Chart 5

Number of Customer Interruptions by Cause

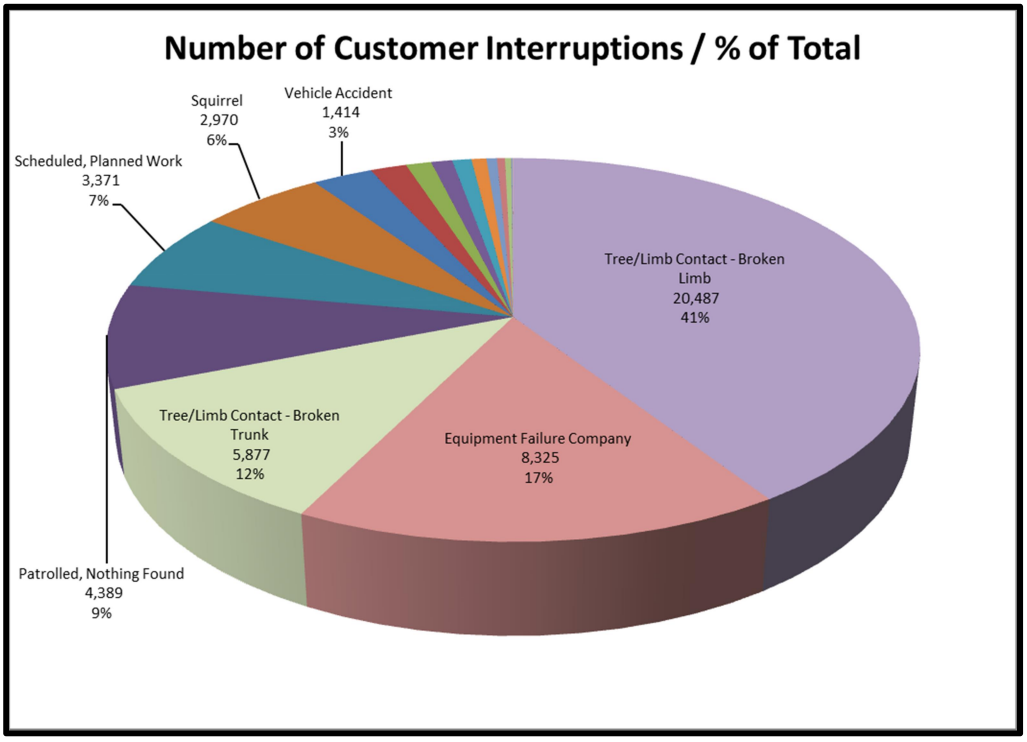


Chart 6

Percent of Customer-Minutes of Interruption by Cause

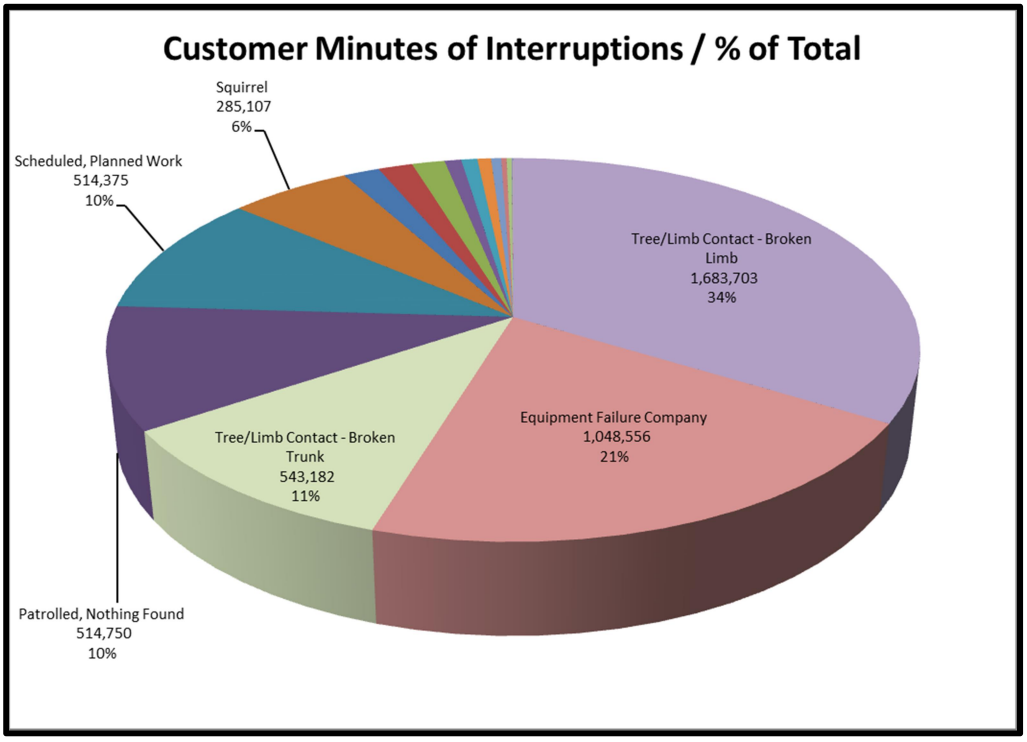


Table 1

Five-Year History of the Number of

Interruptions for the Worst Three Trouble Causes

Year	Tree/Limb Contact - Broken Limb	Equipment Failure Company	Patrolled, Nothing Found
2018	178	89	57
2017	121	78	43
2016	147	79	46
2015	87	88	62
2014	131	70	63

4 10 Worst Distribution Outages

The ten worst distribution outages ranked by customer-minutes of interruption during the time period from January 1, 2018 through December 31, 2018 are summarized in Table 2 below.

Table 2

Worst Ten Distribution Outages

Circuit	Date/Cause	Customer Interruptions	Cust-Min of Interruption	SAIDI	SAIFI
E7W1	5/14/2018 Equipment Failure Company	1,226	231,891	4.90	0.026
E13W2	10/27/2018 Equipment Failure Company	1,629	199,227	4.21	0.034
E22X1	1/4/2018 Tree/Limb Contact - Broken Limb	1,159	196,898	4.16	0.024
E54X1	6/1/2018 Vehicle Accident	1,019	192,079	4.06	0.022
E58X1	3/13/2018 Equipment Failure Company	1,143	186,990	3.95	0.024
E54X2	1/23/20 Tree/Limb Contact - Broken Limb	1,020	186,660	3.94	0.022
E21W1	3/22/2018 Equipment Failure Company	1,366	178,445	3.77	0.029
E59X1	10/27/2018 Tree/Limb Contact - Broken Trunk	262	125,448	2.65	0.006
E58X1	7/31/2018 Tree/Limb Contact - Uprooted Tree	737	109,149	2.31	0.016
E7W1	12/20/2018 Vehicle Accident	1,250	107,965	2.28	0.026

5 Sub-transmission and Substation Outages

This section describes the contribution of sub-transmission line and substation outages on the UES-Seacoast system.

All substation and sub-transmission outages ranked by customer-minutes of interruption during the time period from January 1, 2018 through December 31, 2018 are summarized in Table 3 below.

Table 4 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 11% of the total customer-minutes of interruption for UES-Seacoast.

Table 3

Sub-transmission and Substation Outages

Line / Substation	Date/Cause	Customer Interruptions	Cust-Min of Interruption	SAIDI	SAIFI	Number of Outages in Prior Four Years
3348/3350 Line	9/10/2018 Equipment Failure Company	1,112	120,096	2.54	0.023	0

Table 4
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
7W1	3348/50	53,460	8%	43.68	1
7X2	3348/50	66,636	27%	37.27	1

6 Worst Performing Circuits

This section compares the reliability of the worst performing circuits using various performance measures.

6.1 Worst Performing Circuits in Past Year (1/1/18 – 12/31/18)

A summary of the worst performing circuits during the time period between January 1, 2018 and December 31, 2018 is included in the tables below.

Table 5 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 6 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 during 2018.

Circuits having one outage contributing more than 80% of the Customer-Minutes of interruption were excluded from this analysis.

Table 5: 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
E7W1	7,545	17%	584,159	40%	477.25	6.164	77.42
E21W1	3,411	40%	390,105	4%	285.58	2.519	113.37
E58X1	2,597	44%	375,007	50%	167.86	1.162	144.40
E54X2	1,991	51%	322,312	58%	315.37	1.948	161.88
E13W2	2,896	56%	319,857	62%	196.23	1.777	110.45
E54X1	5,003	77%	309,716	62%	304.24	4.915	61.91
E22X1	1,974	59%	284,263	69%	209.94	1.458	144.00
E19X3	2,155	22%	236,890	23%	68.88	0.627	109.93
E21W2	3,118	34%	197,626	34%	130.10	2.053	63.38
E51X1	1,522	26%	169,504	32%	88.51	0.795	111.37

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

Table 6

Circuit Interruption Analysis by Cause

Circuit	Customer-Minutes of Interruption / # of Outages					
	Tree/Limb Contact - Broken Limb	Tree/Limb Contact - Broken Trunk	Equipment Failure Company	Squirrel	Patrolled, Nothing Found	Loose/Failed Connection
E7W1	0 / 0	233,688 / 3	0 / 0	185,495 / 4	107,965 / 1	0 / 0
E21W1	100,535 / 7	180,654 / 2	20,651 / 4	3,593 / 2	8,019 / 3	0 / 0
E58X1	32,709 / 9	191,126 / 7	27,806 / 2	7102 / 3	1,300 / 2	110,518 / 3
E54X2	221,962 / 8	1,247 / 2	67,816 / 2	23,431 / 3	0 / 0	2,720 / 1
E13W2	73,169 / 9	20,133 / 5	4,340 / 2	30,374 / 5	5,247 / 1	0 / 0
E54X1	113,046 / 3	1,774 / 3	78 / 1	764 / 1	192,079 / 1	0 / 0
E22X1	223,665 / 11	8,014 / 3	15,035 / 2	9,399 / 2	3,444 / 1	0 / 0
E19X3	13,940 / 7	8,700 / 9	9,443 / 2	61,514 / 3	38,417 / 2	67,817 / 2
E21W2	153,214 / 15	0 / 0	29,825 / 1	4,612 / 4	0 / 0	0 / 0
E7X2	697 / 1	7,216 / 2	7,101 / 2	228 / 1	99,161 / 1	0 / 0
E51X1	99,216 / 16	9,235 / 6	3,073 / 3	17,417 / 3	9,539 / 1	0 / 0

6.2 Worst Performing Circuits of the Past Five Years (2014 – 2018)

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 7 lists the ten worst performing circuits ranked by SAIDI and Table 7 lists the ten worst performing circuits ranked by SAIFI. Table 8 lists the ten worst overall performing circuits ranked by average SAIDI and SAIFI over the past five years. Table 9 lists the ten worst circuits in terms of SAIFI and SAIDI for the past five years.

The data used in this analysis includes all system outages except those outages that occurred during Snowstorm Cato in 2014 and IEEE MEDs in 2015 through 2018.

Table 7

Circuit SAIDI

Circuit Ranking (1=worst)	2018		2017		2016		2015		2014	
	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI
1	E7W1	520.93	E54X2	275.94	E3H2	463.53	E6W1	429.2	E6W1	392.13
2	E54X2	338.4	E6W1	269.71	E7W1	375.29	E58X1	371.96	E19X3	358.77
3	E21W1	285.58	E19H1	254.56	E3H3	255.03	E47X1	362.03	E54X1	304.14
4	E54X1	221.9	E22X1	238.1	E54X2	249.35	E6W2	306.7	E20H1	271.23
5	E22X1	209.94	E5H1	200.6	E6W1	241.11	E51X1	201.87	E18X1	258.98
6	E6W1	205.87	E15X1	192.52	E43X1	226.55	E22X1	168.43	E43X1	183.86
7	E13W2	196.23	E51X1	158.75	E21W2	214.57	E56X2	138.86	E51X1	180.9
8	E2H1	192.59	E58X1	134.36	E17W2	210.69	E17W2	136.96	E21W1	170.41
9	E23X1	176.73	E59X1	125.01	E58X1	203.82	E27X1	126.5	E1H3	158.85
10	E58X1	167.86	E22X2	117.33	E54X1	196.61	E3W4	97.95	E1H4	158.03

Table 8

Circuit SAIFI

Circuit Ranking (1=worst)	2018		2017		2016		2015		2014	
	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI
1	E7W1	6.569	E6W1	4.096	E43X1	2.945	E47X1	3.824	E20H1	4.287
2	E6W1	3.257	E22X1	2.606	E3H2	2.867	E6W1	2.871	E51X1	3.558
3	E54X2	2.949	E15X1	2.536	E21W2	2.641	E51X1	2.511	E6W2	3.288
4	E21W1	2.519	E54X2	2.271	E17W2	2.309	E58X1	2.354	E19X3	3.09
5	E6W2	2.334	E19H1	2.012	E21W1	2.198	E2X3	2.176	E6W1	2.73
6	E54X1	2.115	E23X1	1.527	E58X1	2.107	E22X1	1.922	E11X1	2.451
7	E21W2	2.053	E59X1	1.496	E22X1	1.922	E17W2	1.86	E21W1	2.315
8	E13W2	1.777	E43X1	1.481	E27X1	1.917	E13X3	1.466	E43X1	2.133
9	E43X1	1.465	E18X1	1.414	E54X1	1.892	E13W1	1.444	E22X1	2.12
10	E22X1	1.458	E19X2	1.387	E6W1	1.772	E21W2	1.425	E18X1	1.84

Table 9

Worst Performing Circuits in Past Five Years

SAIDI			SAIFI		
Circuit Ranking (1=worst)	**Circuit**	**# of Times in Worst 10**	**Circuit Ranking (1=worst)**	**Circuit**	**# of Times in Worst 10**
1	E6W1	5	**1**	E6W1	5
2	E7W1	2	**2**	E22X1	5
3	E58X1	4	**3**	E21W1	3
4	E54X2	3	**4**	E7W1	1
5	E22X1	3	**5**	E6W2	2
6	E21W1	2	**6**	E43X1	3
7	E54X1	3	**7**	E51X1	2
8	E6W2	1	**8**	E21W2	3
9	E51X1	3	**9**	E54X2	2
10	E43X1	2	**10**	E47X1	1

6.3 System Reliability Improvements (2018 and 2019)

Vegetation management projects completed in 2018 or planned for 2019 that are expected to improve the reliability of the 2018 worst performing circuits are included in Table 10 below. Table 11 below details electric system upgrades that are scheduled to be completed in 2019 or were completed in 2018 that were performed to improve system reliability.

Table 10: Vegetation Management Projects Worst Performing Circuits

Circuit(s)	Year of Completion	Project Description
E6W1	2018	Hazard Tree Mitigation Storm Resiliency Pruning
E58X1	2018	Cycle Pruning Hazard Tree Mitigation
E22X1	2018	Mid-Cycle Pruning
E21W1	2019	Cycle Pruning Hazard Tree Mitigation
E21W2	2019	Cycle Pruning Hazard Tree Mitigation
E54X1	2019	Hazard Tree Mitigation
E6W2	2018	Storm Resiliency Pruning
E51X1	2019	Hazard Tree Mitigation Mid-Cycle Pruning
E43X1	2019	Hazard Tree Mitigation Mid-Cycle Pruning
E47X1	2019	Cycle Pruning
E13W2	2018	Cycle Pruning Hazard Tree Mitigation
E19X3	2019	Hazard Tree Mitigation Mid-Cycle Pruning

Table 11

Electric System Improvements Performed to Improve Reliability

Circuit(s)	Year of Completion	Project Description
E43X1	2018	Replace Willow Road tap recloser and install distribution recloser on Exeter Road
E43X1	2018	Install Electronically Controlled Recloser – Exeter Road
Guinea Sw/S	2018	Installation of additional animal protection, replacement aging insulators and arresters that have been prone to failure.
Various	2018/2019	Various protection changes identified through the distribution planning process and the review of outage reports.
	2019	Porcelain Cutout Replacements
E5X3/E58X1	2019	Establish Distribution Circuit Tie
3346 Line	2019	Install Reclosers and Implement an Automatic Transfer Scheme
E17W1	2019	Install Hydraulic Reclosers – North Shore Road
E17W2	2019	Install Electronically Controlled Recloser – Little River Road
E3W1, E3W4, E17W1	2019	Conversion of Hampton Beach area included the creation of distribution circuit ties between circuits 3W1/3W4 and 3W1/17W1 and the installation of two electronically controlled reclosers.

7 Tree Related Outages in Past Year

This section summarizes the worst performing circuits by tree related outage during the time period between January 1, 2018 and December 31, 2018.

Table 12 shows the ten worst 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.

All streets on the UES-Seacoast system with three or more tree related outages are shown in Table 13 below. The table is sorted by number of interruptions and customer-minutes of interruption.

Table 12

Worst Performing Circuits – Tree Related Outages

Circuit	Customer Minutes of Interruption	Number of Customers Interrupted	No. of Interruptions
E54X2	292,498	1,778	11
E22X1	263,032	1,779	14
E21W2	183,712	2,944	17
E58X1	172,018	1,265	16
E59X1	146,825	506	6
E6W1	139,972	1,805	14
E21W1	122,266	1,760	13
E43X1	119,412	2,530	16
E19X3	115,900	836	14
E54X1	114,399	3,947	5

Table 13

Multiple Tree Related Outages by Street

Circuit(s)	Street, Town	# Outages	Customer-Minutes of Interruption	Number of Customer Interruptions
E21W2	Maple Ave, Atkinson	4	772	5
E22X1	Sandown Rd, Danville	4	5,420	79
E51X1	Squamscott Rd, Stratham	4	14,058	195
E6W1	Haverhill Rd, East Kingston	4	18,794	245
E13W1	North Main St, Plaistow	3	1,260	10
E13W1	Old County Rd, Plaistow	3	10,043	138
E13W2	Main St, Newton	3	5,506	76
E13W2	Thornell Rd, Newton	3	67,902	492
E21W1	Meditation Ln, Atkinson	3	48,341	256
E27X2	North Rd, East Kingston	3	12,717	155
E51X1	High St, Stratham	3	4,111	66
E51X1	Jack Rabbit Lane, Stratham	3	2,978	30
E54X2	Ball Rd, Kingston	3	211,072	1407
E6W1	South Rd, East Kingston	3	91,209	1100
E6W2	Main St, Kingston	3	52,207	1001

8 Failed Equipment

This section is intended to clearly show all equipment failures throughout the study period from January 1, 2018 through December 31, 2018. Chart 7 shows all equipment failures throughout the study period. Chart 8 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 three categories of failed equipment for the past five years are shown below in Chart 9.

Chart 7

Equipment Failure Analysis by Cause

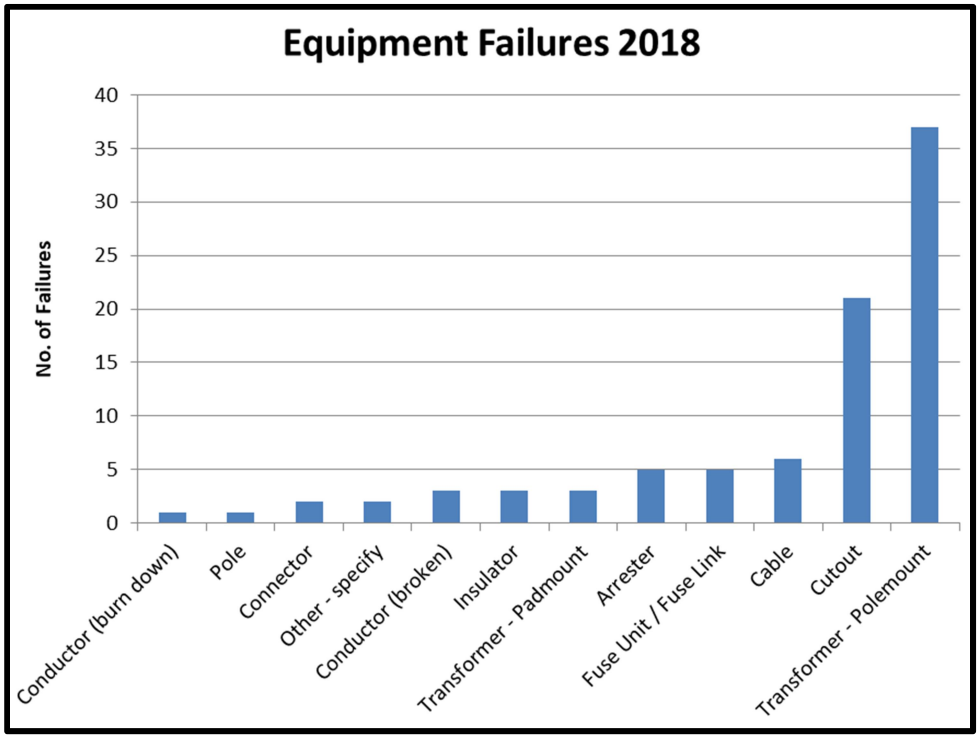


Chart 8

Equipment Failure Analysis by Percentage of Total Failures

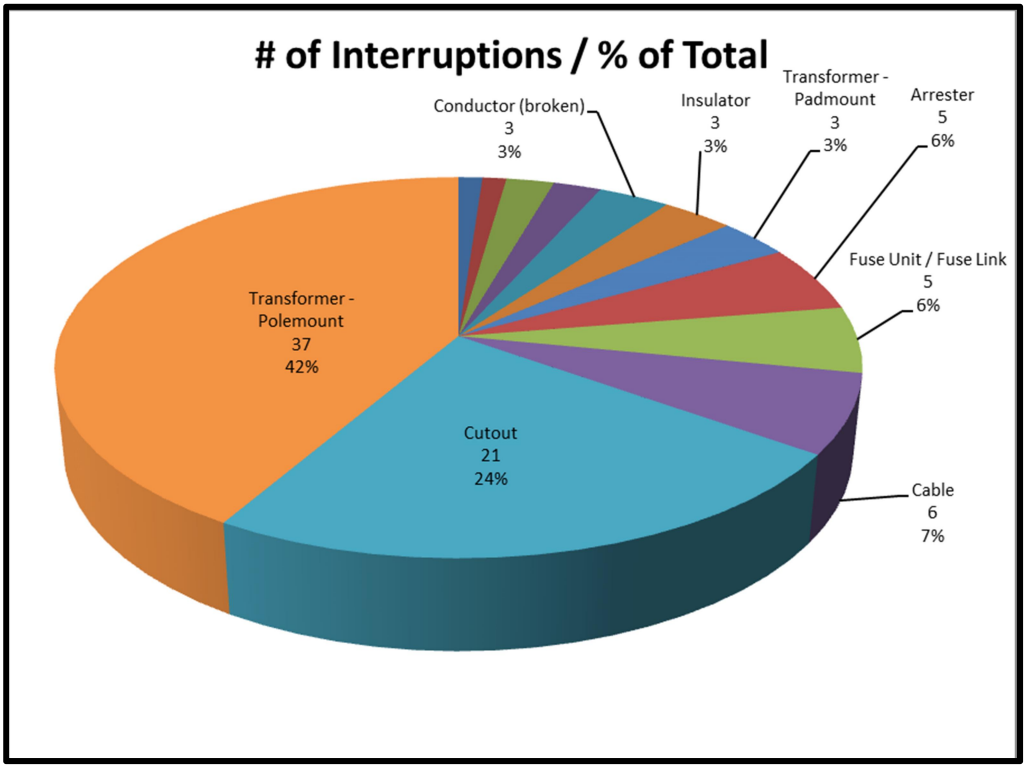
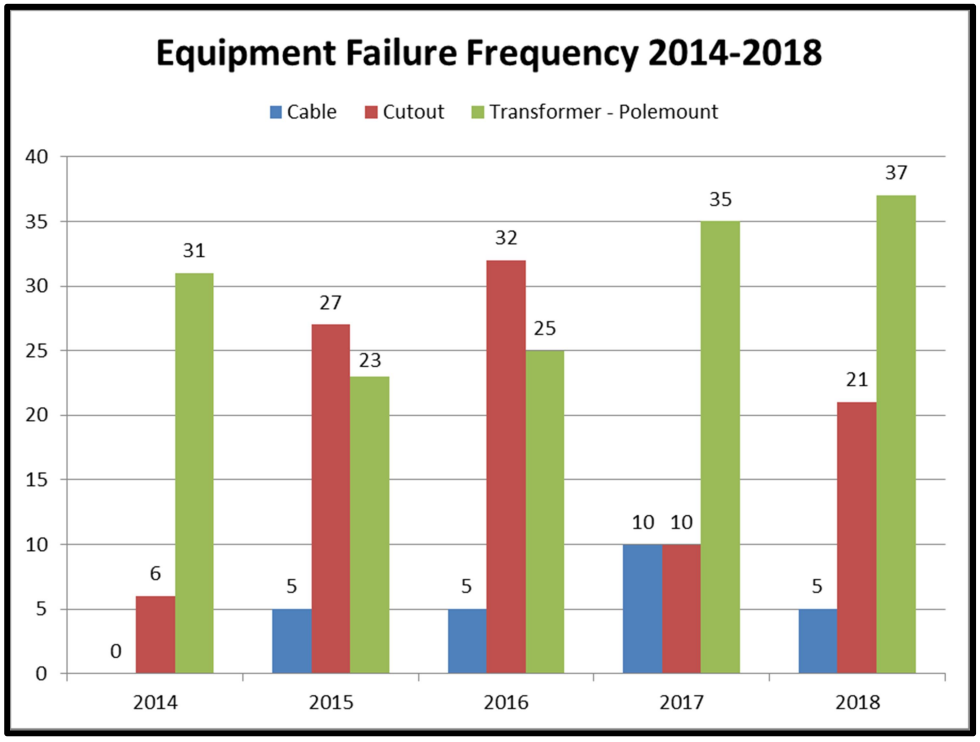


Chart 9

Annual Equipment Failures by Category (top three)



9 Multiple Device Operations and Streets with Highest Number of Outages

A summary of the devices that have operated three or more times from January 1, 2018 to December 31, 2018 is included in Table 14 below. Refer to section 11.6 for recommendations to address some of the areas identified that have experienced recurring outages in 2018.

A summary of the streets on the UES-Seacoast system that had customers with 7 or more non-exclusionary outages in 2018 is included in Table 15 below. The table is sorted by circuit and then the maximum number of outages seen by a single customer on that street.

Table 14

Multiple Device Operations

Circuit	Number of Operations	Device	Customer Minutes	Customer Interruptions	# of Times on List in Previous 4 Years
E7W1	6[6]	7W1 Recloser, Seabrook S/S	566,353	7,354	0
E13W2	4	Fuse, Pole 29/33 Thornell Rd, Newton	78,984	596	0
E51X1	4	Fuse, Pole 47/1, Jack Rabbit Lane, Stratham	3,483	40	0

Table 15

Streets with the Highest Number of Outages

Circuit	Street	Max Number of Outages Seen by a Single Customer	Number of Times on List in Previous 4 Years
7W1	Various, Seabrook	9	0
21W1	Sawyer Ave, Atkinson	8	0
13W2	Wentworth Drive, Newton	7	0

[6] Four of these outages were a result of patrolled nothing found and occurred within a period in which the 7W1 reclosing functionality was not functioning and has since been repaired.

10 Other Concerns

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

10.1 Subtransmission Lines across Salt Marsh

The 3348 and 3350 lines are constructed through salt marsh, making them very difficult to access and repair. There are significant condition related concerns associated with their aging infrastructure

Over the last five years these lines have experienced damage on multiple occasions resulting in outage to circuits 7W1 and 7X2. In addition, damage to these lines results in the lines being out of service months at time while repairs are permitted, scheduled and executed.

In 2019 a detailed assessment of the present condition of these lines was completed. Following the completion of the assessment options for repairs, replacement, or relocation of these lines will be evaluated to mitigate the identified concerns.

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 2019 capital budget. All project costs are shown without general construction overheads.

11.1 Miscellaneous Circuit Improvements to Reduce Recurring Outages

11.1.1 Forestry Review

Table 13 of this report; Multiple Tree Related Outages by Street indicates that there were fifteen streets that experienced three or more tree related outages in 2018.

It is recommended that a forestry review of the areas identified in Table 13 be performed in 2019 in order to identify and address any growth or hazard tree problems.

11.2 Circuit 6W1 – Re-conductor Portion of South Road with Spacer Cable

11.2.1 Identified Concerns

6W1 has been on the worst performing SAIDI and SAIFI list for the last five consecutive years. The owner of a section of property along South has repeatedly refused to allow effective pruning and hazard tree mitigation. This section of South Road has experienced five interruptions due to tree contacts, totaling 1,557 customer interruptions and 696,479 customer minutes of interruption since January 1st, 2017.

11.2.2 Recommendation

Re-conductor South Road from pole 28 to pole 49 with spacer cable.

Customer Exposure = 367 customers

The projected average annual savings for this project is 230,000 customer minutes of interruptions and 500 customer interruptions.

Estimated Project Cost: $250,000

Forestry and operations are currently reviewing this project to determine if the appropriate pruning can be performed to increase pole height to accommodate spacer cable construction.

11.3 Circuit 43X1 – Install Reclosers and Implement Distribution Automation

11.3.1 Identified Concerns

Circuit 43X1 is typically one of the worst performing circuits on the UES-Seacoast system. It is on both the Worst Performing Circuits in the Past Five Years SAIDI and SAIFI lists.

11.3.2 Recommendation

This project will consist of installing four electronically controlled reclosers along circuit 43X1 and 19X3.

Two of the reclosers will be installed along the mainline of circuit 43X1 between 43X1R1 and 19X3J43X1 tie. The 43X1J19X3 tie switch will be replaced with a recloser.

In order to increase the load carrying capability of the 19X3J43X1 tie the cutout mounted sectionalizers along Pine Street will be replaced with a recloser and the solid blades on Court Street will be replaced with a switch. Additionally, circuits 43X1 and 19X3 will be balanced to reduce loading on phase B.

Once installed a distribution automation scheme will be implemented between the new reclosers and the existing 43X1R1 recloser. The intent of the scheme is to have 43X1 and 19X3 automatically reconfigure for permanent faults on the mainline of circuit 43X1.

- Fault between 43X1 and 43X1R1 – 43X1 and 43X1R1 lockout and 19X3J43X1 closes.
- Fault between 43X1R1 and 43X1R2 – 43X1R1 and 43X1R2 lockout and 19X3J43X1 closes.
- Fault between 43X1R2 and 43X1R3 – 43X1R2 and 43X1R3 lockout and 19X3J43X1 closes.
- Fault between 43X1R3 and 19X3J43X1 – 43X1R3 lockout and 19X3J43X1 remains open.

Customer Exposure = 1,200 customers

The projected average annual savings for this project is 125,000 customer minutes of interruptions and 1,650 customer interruptions.

Estimated Project Cost: $350,000 (4 reclosers @ $75,000 per location plus switch replacement)

11.4 3343 and 3354 Lines – Install Reclosers

11.4.1 Identified Concerns

The 3343 and 3354 lines have historically experienced one interruption per year and are routinely damaged during major storms.

11.4.2 Recommendation

This project will consist of installing electronically controlled reclosers, one on the 3354 line and one on the 3343 line between East Kingston substation and Willow Road tap.

These reclosers will be programmed to coordinate with Kingston and operate for downline faults. Additionally, these reclosers will be remotely opened in the event of a lockout of the 03343 or 03354 at Kingston allowing load on the Guinea side of the reclosers to be restored remotely without patrolling.

In order to obtain the desired benefit East Kingston substation will be transferred to the 3343 line and Willow Road Tap will be transferred to the 3354 line.

Customer Exposure = 7,150 customers

The projected average annual savings for this project is 290,000 customer minutes of interruptions and 1,250 customer interruptions.

Estimated Project Cost: $150,000 (2 reclosers @ $75,000 per location plus)

11.5 58X1 – Install Reclosing Devices Wentworth Ave

11.5.1 Identified Concerns

The Wentworth Avenue Plaistow and Atkinson area has experienced eleven patrolled nothing found outages since January 1, 2017. Additionally, circuit 58X1 is typically one of the worst performing circuits on the UES-Seacoast system. It is currently on the Worst Performing Circuits in the Past Five Years SAIDI list.

11.5.2 Recommendation

This project will consist of installing an electronically controlled recloser between pole 6 and 7 on Wentworth Ave.

In addition to the recloser installation the 200QA's at pole 20 Atkinson Depot Road will be replaced with solid blades. The 125QAs at poles 28 and 29 and the 75QAs at pole 75/1 Sawyer Avenue will be replaced with S&C TripSavers.

Customer Exposure = 315 customers

The projected average annual savings for this project is 17,800 customer minutes of interruptions and 140 customer interruptions.

Estimated Project Cost: $120,000

12 Conclusion

The annual electric service reliability of the UES-Seacoast system over the last few years has been some of the best years on record after discounting MEDs. The improvement in reliability can be largely attributed to an aggressive vegetation management program. Still, the most significant risk to reliability of the electric system continues to be vegetation.

The recommendations in this report focus on addressing equipment concerns as well as increasing the flexibility of the system to facilitate quicker restoration of customers that can be isolated from a faulted section of the system. This includes upgrading equipment and adding additional circuit sectionalizing points and protection where it will be most effective. 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

Reliability Project Listing

2019 Budget Versus Actual Expenditures

Reliability Project Listing
2019 Budget Versus Actual Expenditures

DOC	Bud #	Description	Auth #	Budgeted	Authorized	Actual 2019 Exp.	Comment
UES Capital	DPBC01	Distribution Pole Replacement	190112	$566,446	$874,500	$936,170	Complete
UES Seacoast	DPBE01	Distribution Pole Replacement	191010	$986,235	$986,235	$1,129,997	Complete
UES Capital		Reliability Enhancement Projects		$229,462	$274,008	$191,199	
	DRBC13	396X1 Tap - Install Recloser	190119		$94,208	$56,700	Active into 2020
	DRBC04	Install Recloser & Fuse Saver - Bow Bog Rd., Bow	190140		$139,800	$109,474	Complete
	DRBC07	Install Animal Protection on Distribution Transformers	190136		$40,000	$25,025	Complete
UES Seacoast		Reliability Enhancement Projects		$799,818	$596,291	$277,497	
	DRBE14	Circuit 19X2 - Distribution Automation Scheme with Portsmouth Ave.	191040		$205,291	$56,164	Active into 2020
	DRBE07	Install Hydraulic Reclosers, North Shore Rd., Hampton	191032		$40,000	$29,182	Complete
	DRBE08	Install Electronic Recloser, Little River Road, Hampton	191033		$101,000	$100,761	Complete
	DRBE09	Circuit 13W2, Install Reclosers, Various Locations, Newton	191058		$250,000	$91,390	Active into 2020
Total				$2,581,961	$2,731,034	$2,534,863	