UES Capital

Reliability Study

2022

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9/15/2022

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1 Executive Summary

The purpose of this document is to report on the overall reliability performance of the UES Capital system from January 1, 2021 through December 31, 2021. 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 outages that occurred during IEEE Major Event Days (MEDs). The UES-Capital 2021 MEDs are listed in the table below.

Date	Type of Event	No. of Interruptions	Customer Interruptions	Cust-Min of Interruption
3/1/2021	IEEE MED	44	9,839	1,179,827
3/29/2021	IEEE MED	27	7195	533,145

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 2022 budget development process.

Circuit / Line / Substation	Proposed Project	Cost ($)
8X3	Install a Fuse Saver on Horse Corner Rd	$2,164
8X3	Reconductor Main Street Chichester	$242,176
8X3	Reconductor Dover Road	$262,711
13W1	Center Road Spacer Cable Installation	$288,718
13W3	N. Water Street and Rabbit Road Spacer Cable Installation	$1,435,872
13W3	Resize Cable on Mutton Rd	$123,338
18W2	Create a Circuit Tie on White Rock Hill Rd	$279,104
18W2	Reconductor Bow Center Rd	$280,976

Note: estimates do not include general construction overheads

The 2021 annual UES Capital system reliability benchmark was 136.91 minutes, after removing Major Event Days. The UES Capital SAIDI performance in 2021 was 64.78 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

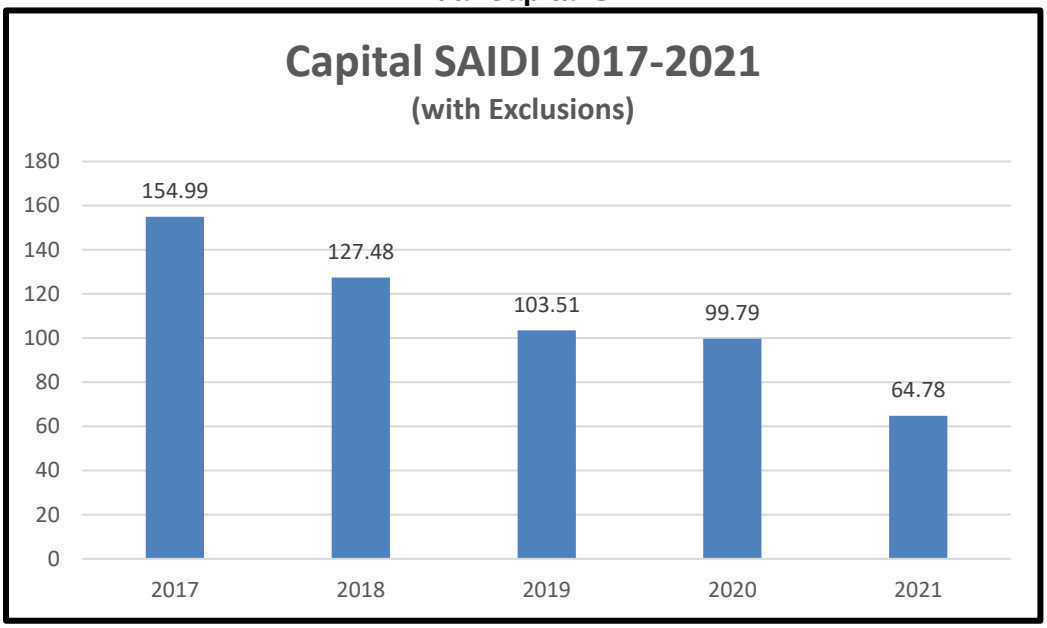


Chart 2
Annual Capital SAIFI

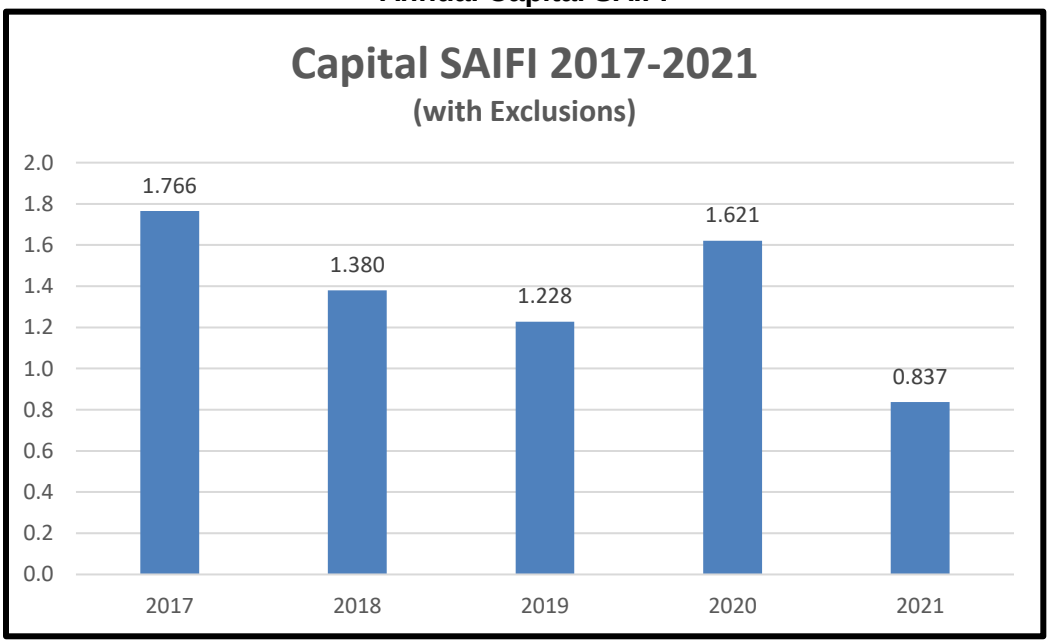
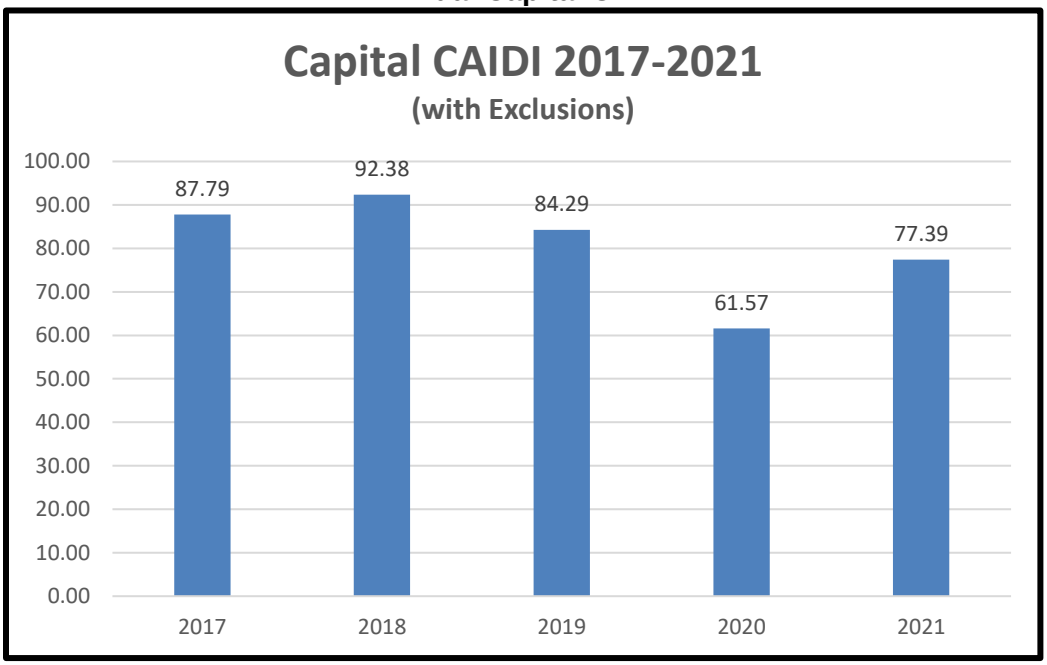


Chart 3
Annual Capital CAIDI



2 Reliability Benchmarks

The new annual UES Capital system reliability benchmark for 2022 is set at 133.12 SAIDI minutes. This was developed by calculating the typical contribution of UES Capital reliability performance to the Unitil system performance using the past five year average. The contribution factor was then set against the 2021 Unitil System goal. The 2021 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 benchmarks.

3 Outages by Cause

This section provides a breakdown of all outages by cause code experienced during 2021. 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

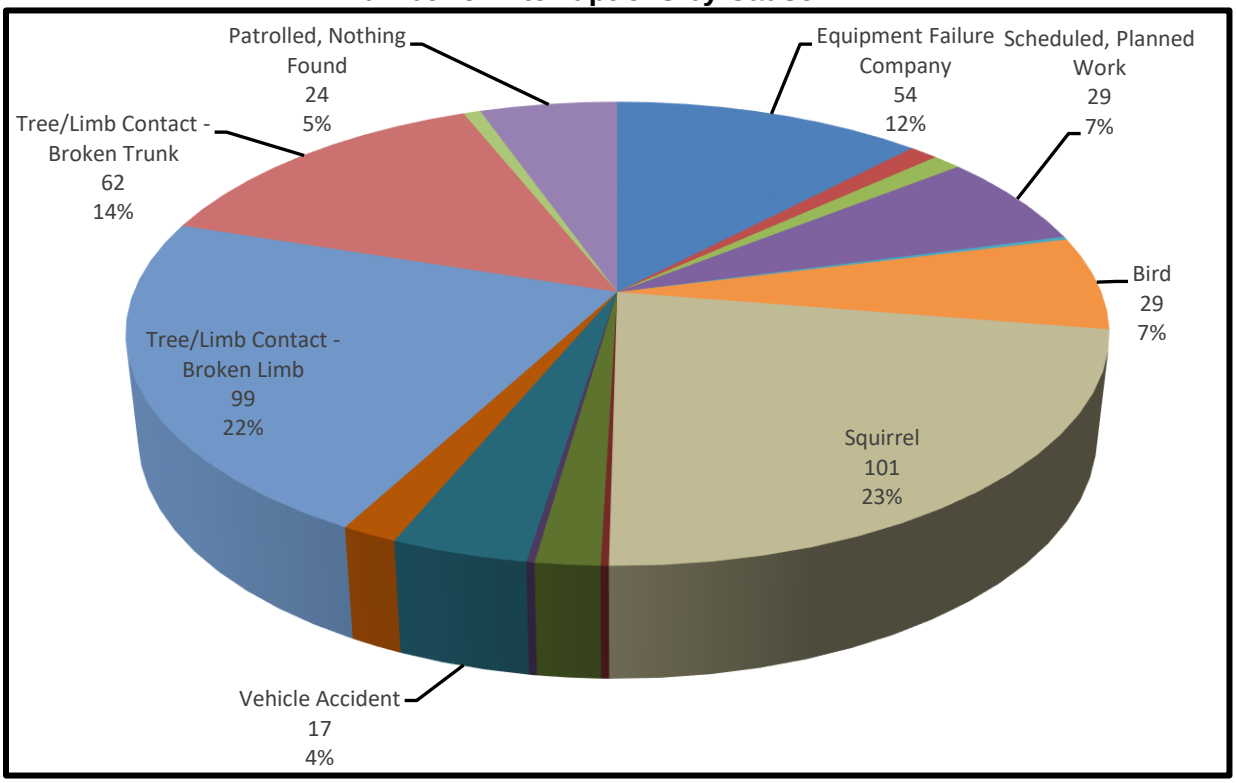


Chart 5
Number of Customers Interrupted by Cause

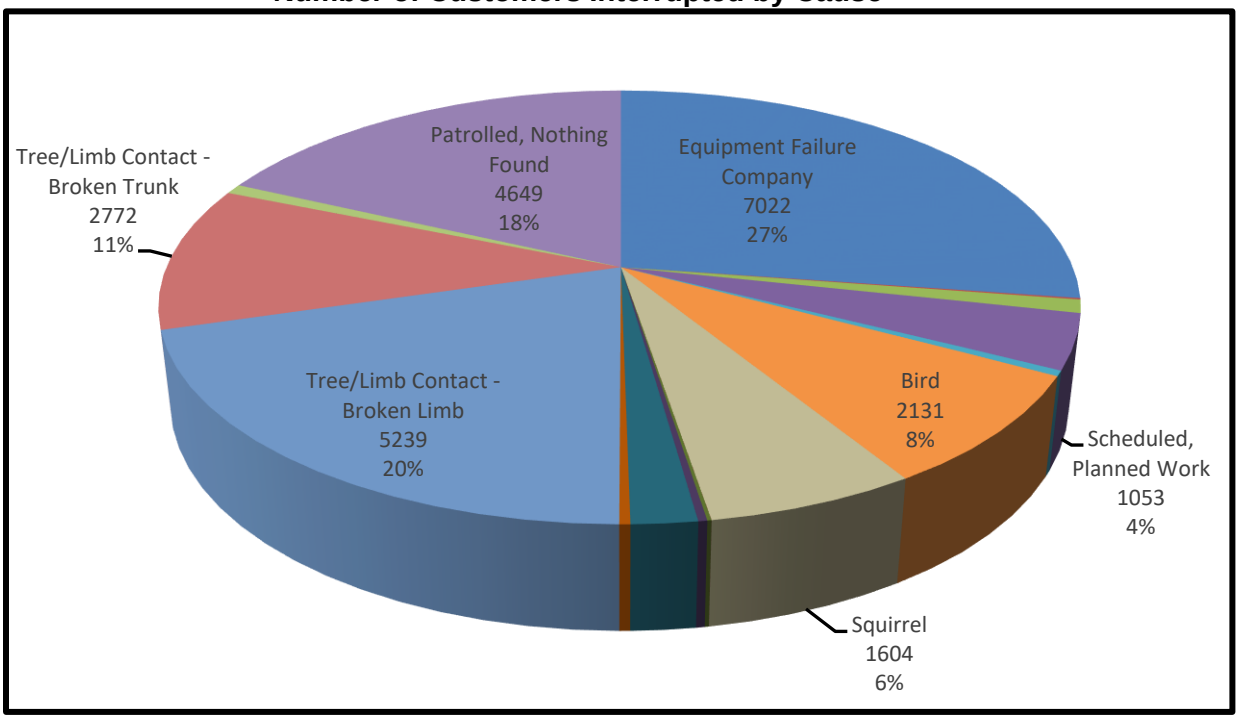


Chart 6
Percent of Customer-Minutes of Interruption by Cause

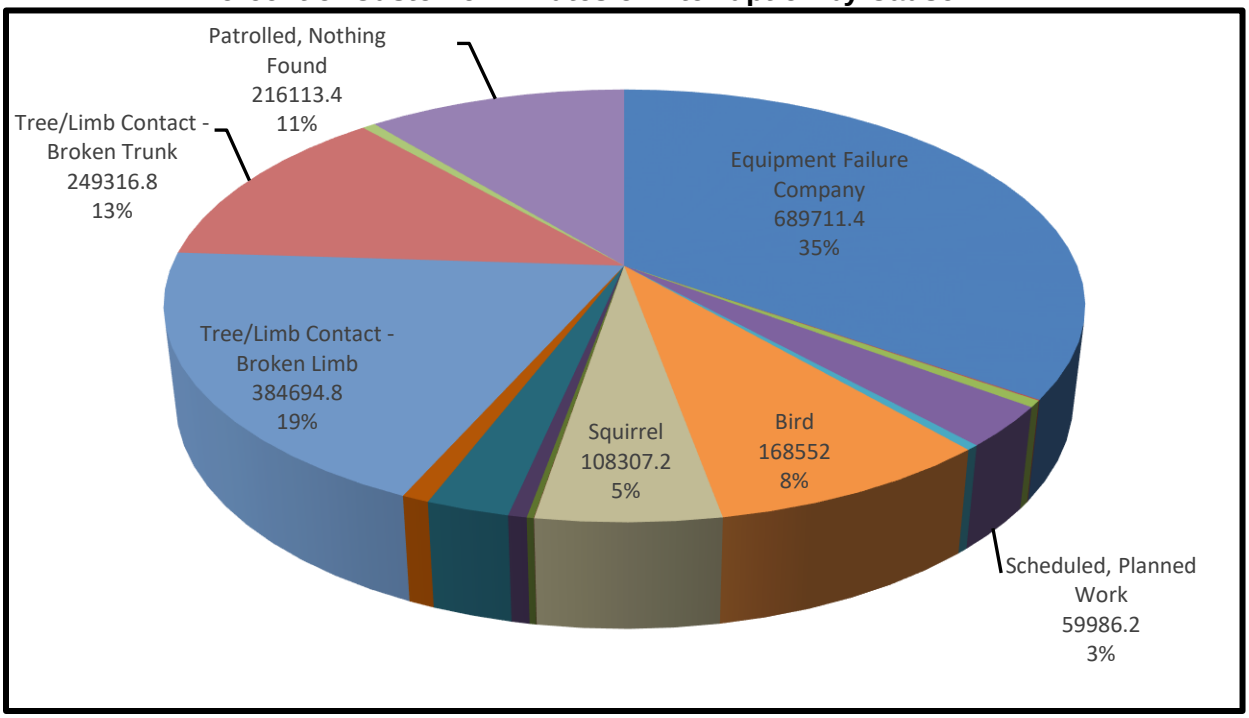


Table 1
Five-Year History of the Number of
Interruptions for the Worst Three Trouble Causes

Year	Tree/Limb Contact - Broken Limb	Tree/Limb Contact - Broken Trunk	Squirrel
2021	62	99	101
2020	133	93	92
2019	74	67	26
2018	134	102	100
2017	86	37	112

4 10 Worst Distribution Outages

The ten worst distribution outages ranked by customer-minutes of interruption during the time period from January 1, 2021 through December 31, 2021 are summarized in Table 2 below.

Table 2
Worst Ten Distribution Outages

Circuit	Description (Date/Cause)	Customer Interruptions	Cust-Min of Interruption	Capital SAIDI	Capital SAIFI
C13W3	8/07/2021 Bird	1,633	141,221	4.58	0.053
C4W3	10/17/2021 Equipment Failure Company	1,400	138,110	4.48	0.045
C18W2	5/20/2021 Equipment Failure Company	848	119,130	3.87	0.028
C18W2	12/12/2021 Tree/Limb Contact - Broken Limb	948	113,901	3.70	0.031
C8X5	6/25/2021 Equipment Failure Company	830	103,552	3.36	0.027
C38	8/5/2021 Equipment Failure Company	239	49,944	1.62	0.008
C1H3	7/18/2021 Patrolled, Nothing Found	615	49,344	1.60	0.020
C4X1	3/8/2021 Scheduled, Planned Work	297	36,234	1.18	0.010
C4X1	2/16/2021 Tree/Limb Contact - Broken Limb	398	26,531	0.86	0.013
C13W3	2/16/2021 Tree/Limb Contact - Broken Limb	584	25,265	0.82	0.019

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 IEEE MEDs.

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, 2021 through December 31, 2021 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 50% of the total customer-minutes of interruption for UES Capital.

Table 3
Subtransmission and Substation Outages

Trouble Location	Description (Date/Cause)	Customer Interruptions	Cust-Min of Interruption	Capital SAIDI	Capital SAIFI	No. Times on List (past 4 yrs)
West Portsmouth St. Substation	12/09/2021 Equipment Failure Company	1,389	125,247	4.06	0.045	0
37 Line	3/15/2021 Patrolled, Nothing Found	3,295	125,210	4.06	0.107	4
Bow Bog Substation	5/20/2021 Equipment Failure Company	848	119,130	3.87	0.028	0

Table 4
Contribution of Subtransmission and Substation Outages

Circuit	Trouble Location	Cust-Min of Interruption	% of Total Circuit Minutes	Circuit SAIDI Contribution	Number of Events
C15W1	West Portsmouth St. Substation	112,991	81%	112.65	1
C15W2	West Portsmouth St. Substation	12,256	55%	40.58	1
C37X1	37 Line	6,992	18%	38.21	1
C13W2	37 Line	37,582	51%	38.08	1

Circuit	Trouble Location	Cust-Min of Interruption	% of Total Circuit Minutes	Circuit SAIDI Contribution	Number of Events
C13W3	37 Line	61,750	17%	37.86	1
C13W1	37 Line	18,848	21%	37.84	1
C13X4	37 Line	38	100%	38	1
C18W2	Bow Bog #18	119,130	44%	140.65	1

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 (1/1/21 – 12/31/21)

A summary of the worst performing circuits during the time period between January 1, 2021 and December 31, 2021 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 2021.

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 (CI)	Worst Event (% of CI)	Cust-Min of Interruption (CMI)	Worst Event (% of CMI)	SAIDI	SAIFI	CAIDI
C13W3	5,314	31%	359,635	39%	220.5	3.258	67.68
C18W2	3,342	28%	273,514	44%	322.92	3.946	81.84
C8X3	3,022	11%	245,353	8%	83.85	1.033	81.19
C4W3	2,073	68%	186,035	74%	130.19	1.451	89.74
C13W1	1,535	32%	89,105	21%	178.93	3.082	58.05
C13W2	1,436	69%	73,402	51%	74.37	1.455	51.12
C22W3	1,177	9%	72,640	15%	45.03	0.73	61.72

C4X1	787	51%	69,970	52%	35.43	0.398	88.91
C38	554	46%	69,283	72%	64.63	0.517	125.06
C37X1	562	33%	38,743	37%	211.71	3.071	68.94

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

Table 6
Circuit Interruption Analysis by Cause

	Customer – Minutes of Interruption / # of Outages					
Circuit	**Equipment Failure Company**	**Tree/Limb Contact - Broken Limb**	**Tree/Limb Contact - Broken Trunk**	**Patrolled, Nothing Found**	**Bird**	**Squirrel**
C13W3	1,614 / 3	55,959 / 13	70,934 / 15	64,187 / 3	141,961 / 4	11,983 / 14
C18W2	134,262 / 4	115,248 / 4	6,910 / 3	11,498 / 3	0 / 0	4,969 / 6
C8X3	31,539 / 15	52,822 / 30	66,481 / 20	10,402 / 7	500 / 4	42,448 / 32
C4W3	138,110 / 1	28,913 / 4	4,800 / 1	0 / 0	617 / 3	7,500 / 4
C13W1	13,319 / 4	35,052 / 10	13,661 / 6	18,973 / 1	156 / 1	1,339 / 5
C13W2	7,716 / 2	8,250 / 3	8,978 / 1	38,000 / 1	3,241 / 2	2,255 / 5
C22W3	6,986 / 8	18,470 / 14	12,519 / 4	6,182 / 2	308 / 2	12,324 / 10
C4X1	647 / 1	26,531 / 1	45 / 1	144 / 1	0 / 0	253 / 1
C38	49,944 / 1	1,618 / 1	16,922 / 2	0 / 0	0 / 0	266 / 1
C37X1	0 / 0	8,929 / 4	20,741 / 3	6,992 / 1	0 / 0	0 / 0

6.2 Worst Performing Circuits of the Past Five Years (2017 – 2021)

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 IEEE major event days.

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)	2021		2020		2019		2018		2017	
	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI
1	C14X3	613.00	C4W3	243.64	C2H2	467.50	C13W3	532.47	C13W2	577.74
2	C18W2	322.92	C13W1	198.35	C8X5	256.74	C13W2	327.56	C18W2	560.64
3	C13W3	220.50	C7W3	197.61	C13W3	214.08	C15W2	268.14	C13W1	555.75
4	C37X1	211.71	C4X1	154.72	C6X3	166.25	C22W3	242.20	C13W3	496.50
5	C13W1	178.93	C15W1	135.00	C8X3	141.38	C21W1A	166.74	C396X2	454.70
6	C15W1	139.86	C22W1	133.56	C13W2	134.14	C8X3	164.27	C17X1	410.37
7	C4W3	130.19	C13W2	129.10	C18W2	121.03	C13W1	155.29	C16H3	403.03
8	C8X5	125.24	C13W3	115.33	C15W1	118.34	C7W3	142.86	C8X3	326.03
9	C8X3	83.85	C34X2	111.11	C37X1	117.78	C38	128.52	C33X4	246.98
10	C1H3	79.97	C37X1	102.09	C13W1	108.30	C2H4	87.85	C8H2	246.67

Table 8
Circuit SAIFI

Circuit Ranking (1 = worst)	2021		2020		2019		2018		2017	
	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI
1	C18W2	3.946	C4W3	3.933	C2H2	3.664	C13W2	6.694	C21W1A	3.993
2	C13W3	3.258	C7W3	2.685	C8X5	3.388	C13W1	5.818	C37X1	2.418
3	C13W1	3.082	C22W1	2.612	C18W2	1.778	C13W3	5.267	C18W2	1.995
4	C37X1	3.071	C13W2	2.483	C13W3	1.641	C16H3	4.693	C15W1	1.938
5	C14X3	2.000	C4X1	2.458	C37X1	1.506	C18W2	4.131	C13W1	1.785
6	C15W1	1.515	C16X4	2.359	C3H3	1.383	C8H2	3.122	C1X7P	1.778
7	C15W2	1.500	C13W1	2.219	C8X3	1.365	C8X3	3.108	C4X1	1.738
8	C13W2	1.455	C1H1	2.199	C15W2	1.350	C17X1	3.000	C22W3	1.509
9	C4W3	1.451	C37X1	1.568	C13W2	1.335	C396X2	3.000	C7W3	1.396
10	C21W1P	1.199	C15W2	1.228	C6X3	1.294	C37X1	2.770	C13W3	1.348

Table 9
Worst Performing Circuit past Five Years

SAIDI			SAIFI		
Circuit Ranking	**Circuit**	**# Appearances**	**Circuit Ranking**	**Circuit**	**# Appearances**
1	C13W3	5	**1**	C37X1	5
2	C13W1	5	**2**	C13W3	4
3	C8X3	4	**3**	C13W1	4
4	C13W2	4	**4**	C13W2	4
5	C18W2	3	**5**	C18W2	4
6	C37X1	3	**6**	C15W2	3
7	C15W1	3	**7**	C8X3	2
8	C4W3	2	**8**	C15W1	2
9	C8X5	2	**9**	C4W3	2
10	C7W3	2	**10**	C7W3	2

6.3 System Reliability Improvements (2021 and 2022)

Vegetation management projects completed in 2021 or planned for 2022 that are expected to improve the reliability of the 2021 worst performing circuits are included in table 10 below. Table 11 below details electric system upgrades that are scheduled to be completed in 2022, or were completed in 2021, that were performed to improve system reliability.

Table 10
Vegetation Management Projects on Worst Performing Circuits

Circuit(s)	Year of Completion	Project Description
C18W2	2021/2022	Cycle Pruning/Hazard Tree Mitigation
C21W1P	2021	Cycle Pruning
C37X1	2021	Cycle Pruning/Hazard Tree Mitigation
C4W3	2021	Cycle Pruning/Hazard Tree Mitigation
C13W2	2021	Hazard Tree Mitigation/Mid-Cycle Review
C13W3	2021/2022	Hazard Tree Mitigation/Reliability Analysis

Circuit(s)	Year of Completion	Project Description
C13W1	2021/2022	Hazard Tree Mitigation/Reliability Analysis/Mid-Cycle Review
C8X3	2021/2022	Cycle Pruning/ Hazard Tree Mitigation/Reliability Analysis
C8X5	2021/2022	Reliability Analysis/Mid-Cycle Review
C4X1	2022	Hazard Tree Mitigation/Mid-Cycle Review
C38	2022	Mid-Cycle Review

Table 11
Electric System Improvements Performed to Improve Reliability

Circuit(s)	Year of Completion	Project Description
Various	2021/2022	Install Animal Guards
18W2	2021	Direct Buried Cable Replacement
18W2	2021	Fusesaver Installation
16H3	2021	Cable Injection
4W4	2021	Cable Injection
4W4	2021	Recloser Installation
37X1	2021	Cable Injection
6X3	2021	Recloser Installation
8X3	2021	Recloser Installation
13W1	2021	Fusesaver Installation
13W2	2021	Fusesaver Installation
13W3	2021	Fusesaver Installation
15W2	2021	Fusesaver Installation
13W2	2022	Reconductor 13W2 Mainline with 336 Spacer
13W1	2022	Recloser Installation

Circuit(s)	Year of Completion	Project Description
15W2	2022	Replace Direct Buried Cable
38 Line	2022	Spacer Cable Replacement

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, 2021 and December 31, 2021.

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 Interruptions	Cust-Min of Interruption	No. of Interruptions
C8X3	138,200	1,679	54
C13W3	127,603	1,766	30
C18W2	122,157	1,066	7
C13W1	48,713	840	16
C22W3	38,249	641	20
C4W3	33,713	361	5
C37X1	29,670	367	7
C4X1	26,623	400	3
C3H2	20,384	143	2
C38	18,540	261	3

Table 13
Multiple Tree Related Outages by Street

Circuit	Street, Town	No. Of Outages	Customer Interruptions	Cust-Min of Interruption
C8X3	Horse Corner Rd, Chichester	338	27,183	5
C8X3	Mountain Rd, Epsom	150	20,358	3
C22W3	Hooksett Tpke, Bow	158	13,904	3
C13W1	Old Tilton Rd, Canterbury	130	7,724	3
C13W3	Branson Line, Webster	23	3,481	3
C8X3	Center Hill Rd, Epsom	20	1,348	3
C8X3	Cass Rd, Epsom	12	628	3

8 Failed Equipment

This section is intended to clearly show all equipment failures throughout the study period from January 1, 2021 through December 31, 2021. 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

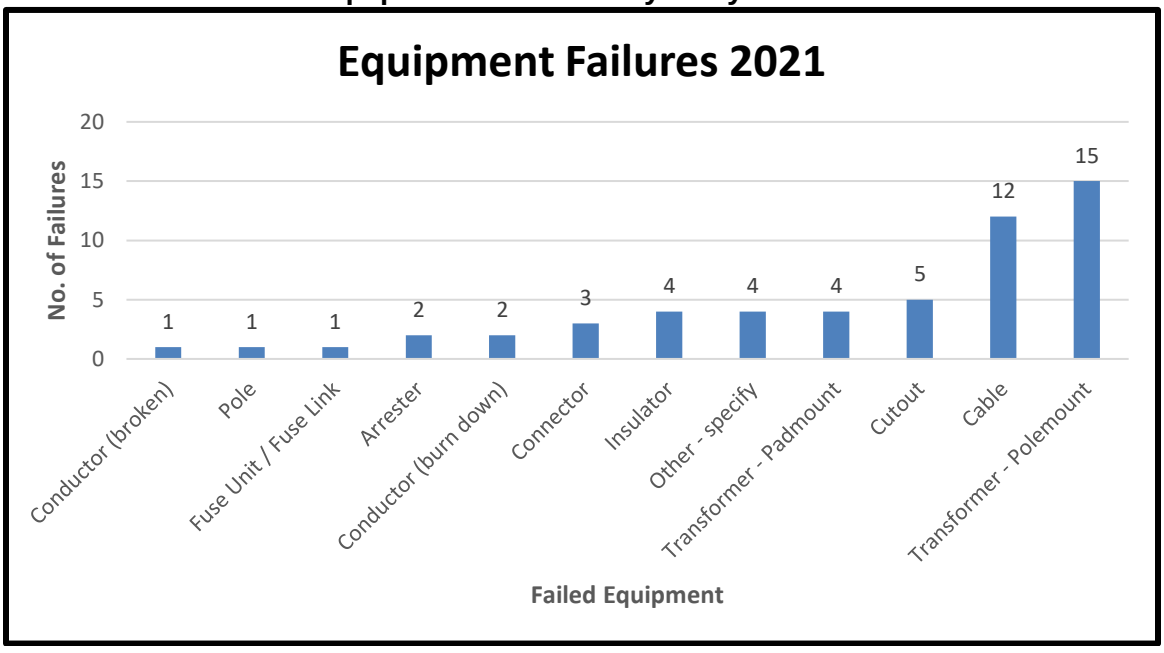


Chart 8
2021 Equipment Failure Analysis by Percentage of Total Failures

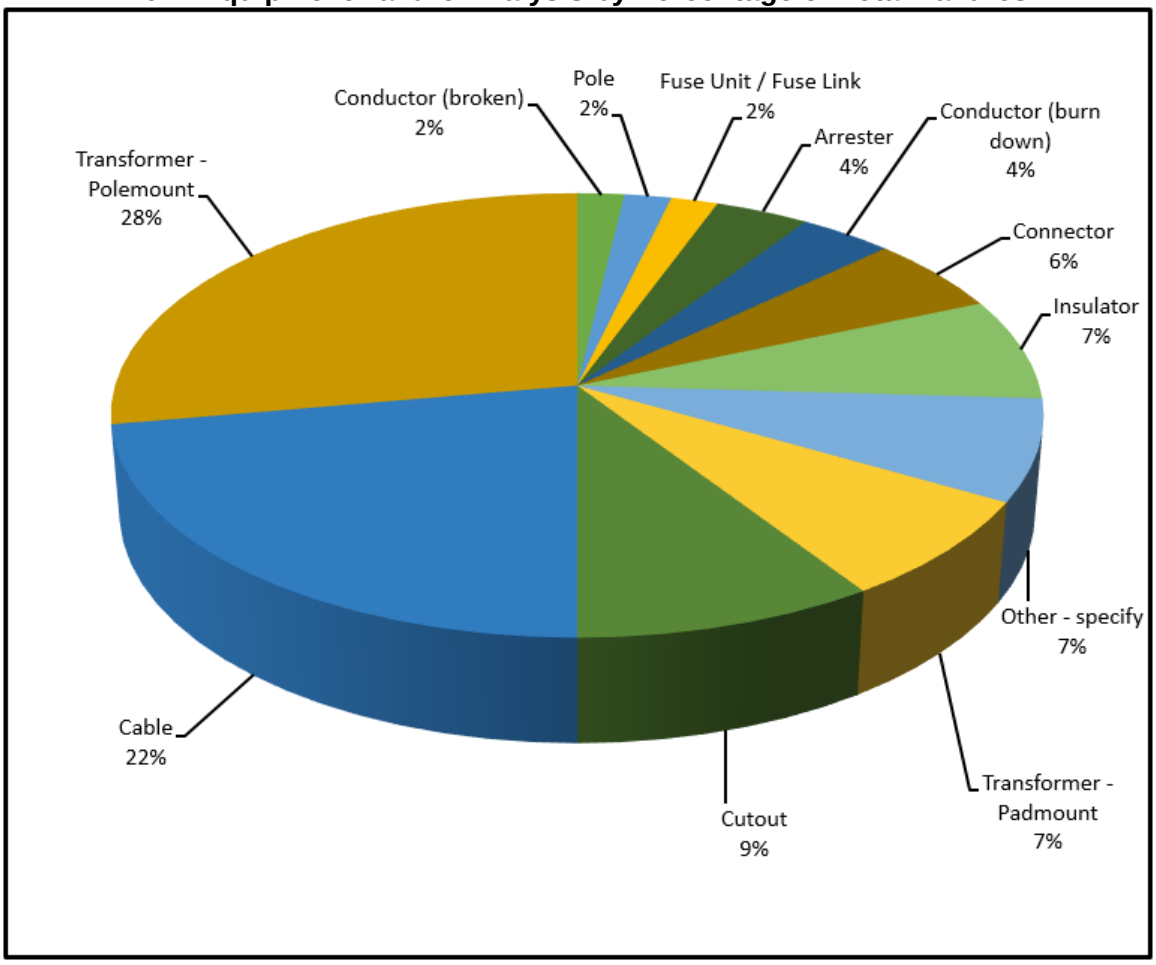
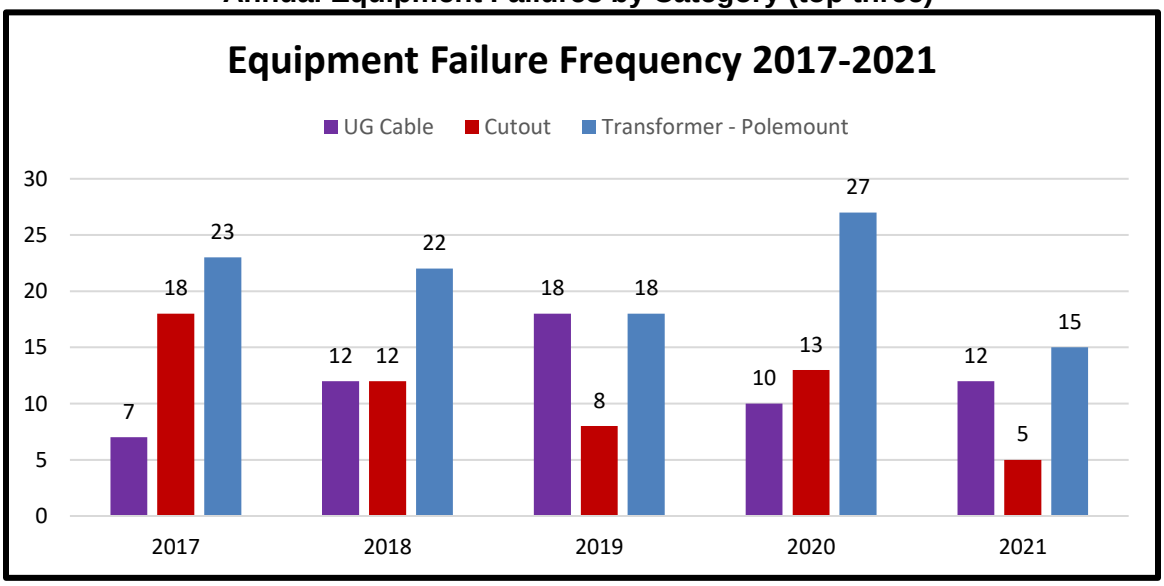


Chart 9
Annual Equipment Failures by Category (top three)



The top three equipment failures continue to be underground cables, cutouts, and polemount transformers. The polemount transformer failures, although high, do not show signs of increasing over the last 5 years and are consistent with historical failure rates. Cutout failures are trending downward as a result of the cutout replacement program that occurred in 2018 and 2019. Operations and engineering will continue to review locations in which cable injection and replacement of direct buried cable could reduce the frequency of underground cable failures.

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, 2021 to December 31, 2021 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 2021 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
C8X3	Fuse, Pole 59, Horse Corner Rd, Chichester	5	26,977	354	1
C22W3	Transformer/Customer, Pole 12-3, Clough Rd, Bow	4	324	4	0
C8X3	Fuse, Pole 11, Durgin Rd, Chichester	4	691	8	0
C3W3	Fuse, Pole 3, South Spring St, Concord	4	3,293	60	0
C8X3	Fuse, Pole 1, Mountain Rd, Epsom	4	22,430	200	0
C8X3	Fuse, Pole 28, Center Hill Rd, Epsom	4	1,001	16	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	Pond Hill Rd	9	2
C13W3	Lake Rd	9	1
C8X3	Durgin Rd	9	1
C13W3	Westwind Village Rd	8	2

C13W3	Rolfe Rd	8	1
C13W3	Warner Rd	8	1
C18W2	Kelsea Rd	8	0
C8X3	Garvin Hill Rd	8	0
C13W1	Old Tilton Rd	7	2
C13W1	Randall Rd	7	2
C13W3	Walker Pond Rd	7	0
C13W3	Longver Ln	7	0
C13W3	Battle St	7	1
C13W3	White Plains Rd	7	4
C13W3	Knights Meadow Rd	7	2
C13W3	Mutton Rd	7	1
C13W3	Pleasant St	7	0
C18W2	Montalona Rd	7	0
C18W2	Jay Dr	7	1
C18W2	Morse Rd	7	0
C18W2	County Rd	7	0
C8X3	Horse Corner Rd	7	0
C8X3	Mountain Rd	7	2

10 Other Concerns

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

10.1 URD Cable Failure

URD cables are failing at an average rate of 11.8 failures per year over the last five years, for a total of 59 cable failures in the past five years. When a direct buried cable fails, Unitil typically excavates the area of the failure and splices in a small section of new cable into the existing cable. In these cases the remaining aged cable in the area remains. Generally, cable failures in conduit result in the cable run being replaced. In recent years, projects to address direct buried cable failures have included cable injection and replacement with cable in conduit where cable injection has been deemed unfeasible. It is anticipated that additional projects for cable injection and or direct buried cable replacement will be proposed in future years.

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

2023 capital budget. All project costs are shown without general construction overheads.

11.1. Circuit 8X3: Dover Road and Main Street Spacer Cable Installations

11.1.1. Identified Concerns

Circuit 8X3 was on the SAIDI worst performing circuit list 4 times in the past 5 years. The outages in 2021 were caused by a variety of reasons, with tree-related and squirrel-related outages surpassed all other causes.

Horse Corner Road in Chichester has a fuse on pole 59 that was tripped 5 times in 2021 and has appeared before on the multiple device operations list in the previous 4 years.

An outage on Main Street that resulted from a broken trunk resulted in 208 customer interruptions and caused 18,727 customer minutes of interruption. This incident accounted for approximately 28% of the broken trunk customer minutes of interruptions in 2021. Additionally, this portion of Main Street from Horse Corner Road to Center Road has a section of large trees adjacent to the primary pole line.

Three outages caused by broken trunks occurred in the Ridgewood Road area of Dover Road in 2021. These outages totaled 22,085 customer minutes of interruption, or 33% of the total customer minutes of interruption caused by broken trunks on circuit 8X3 in 2021. Additionally, the line on this portion of Dover Road runs parallel to areas with large trees.

11.1.2. Recommendations

11.1.2.1 Install a Fuse Saver on Horse Corner Rd

Install a 100 A fuse saver on pole 59 on Horse Corner Rd.

Estimated Project Cost (without construction overheads): $2,164 (Doesn’t include cost of the fuse saver)

Estimated Annual Savings:

Customer Minutes: 11,084

Customer Interruptions: 210

11.1.2.2. Reconductor Main Street Chichester

Reconductor Main Street from Horse Corner Road to Center Road with 336Al spacer cable, 052AWA messenger and 4/0ACSR neutral.

Estimated Project Cost (without construction overheads): $242,176

Estimated Annual Savings:

Customer Minutes: 10,263

Customer Interruptions: 102

11.1.2.3. Reconductor Dover Road

Reconductor Dover Road in Epsom from pole 63 to pole 91 with 336Al spacer cable, 052AWA messenger and 4/0ACSR neutral.

Estimated Project Cost (without construction overheads): $262,711

Estimated Annual Savings:

Customer Minutes: 11,981

Customer Interruptions: 120

11.2. Circuit 13W1: Center Road Spacer Cable Installation

11.2.1. Identified Concerns

Circuit 13W1 was on the SAIDI worst performing circuit list 5 times in the past 5 years and was on the SAIFI worst performing circuit list 4 times in the past 5 years.

On Old Tilton Rd, broken trunks were responsible for 8511.07 customer minutes of interruption in 2021/2022 and broken tree limbs were responsible for 2374.93 customer minutes in 2021.

A broken limb on Center Road resulted in an outage to 496 customers and totaled 17,856 customer minutes of interruption. Additionally, there are large trees on both sides of Center Road that could cause damage to the three-phase line in the event of broken trunks or limbs.

11.2.2. Recommendations

11.2.2.1 Center Road Spacer Cable Installation

Reconductor Center Road from South West Road to Kimball Pond Road with 336Al spacer cable, 052AWA messenger and 4/0ACSR neutral.

Estimated Project Cost (without construction overheads): $288,718

Estimated Annual Savings:

Customer Minutes: 11,885

Customer Interruptions: 146

11.3. Circuit 13W3: Create Internal Circuit Tie

11.3.1. Identified Concerns

Circuit 13W3 was on the SAIDI worst performing circuit list 5 times in the past 5 years and was on the SAIFI worst performing circuit list 4 times in the past 5 years. 13W3 is a radial circuit with no back up to adjacent circuits.

11.3.2. Recommendation

11.3.2.1. N. Water Street and Rabbit Road Spacer Cable Installation

Rebuild N. Water Street and Rabbit Road from Long Street to Old Coach Road with 336AL spacer cable, 052AWA messenger and 4/0ACSR neutral. Install three microprocessor controlled reclosers and implement an auto transfer scheme. One recloser is to be installed at P.49 Old Turnpike Rd, one at P.1 Rabbit Rd and the third in the area of the intersection of N. Water St and Long St. Ultimately, this project is to create a loop between High St and Water St in Boscawen. It will allow for the entirety of the Webster territory or Salisbury territory to be restored after a fault on either Water St or High St, respectively.

Estimated Project Cost (without construction overheads): $1,435,872

Estimated Annual Savings:

Customer Minutes: 30,069
Customer Interruptions: 668

11.3.2.2. Reconductor Cable Mutton Rd

Rebuild the conductor on Mutton Road in Webster with 1/0 ACSR tree wire and add a fuse to Hemlock Hollow road. This will allow Mutton Road to be less susceptible to tree damage. The conductor presently there is #4 ACSR which breaks easily under a tree limb. Rebuilding it will help reduce the high frequency of tree-related outages on Mutton Rd.

Estimated Project Cost (without construction overheads): $123,338

Estimated Annual Savings:

Customer Minutes: 4,387

Customer Interruptions: 33

11.4. Circuit 18W2: Create New Tie with 22W3

11.4.1. Identified Concerns

Circuit 18W2 was on the SAIFI worst performing circuit list 4 times in the past 5 years.

There was a 2021 outage on Bow Center Rd which caused 113,901 customer minutes of interruption for 948 customers. Additionally, the southwest portion of 18W2 does not currently have a tie to an adjacent circuit and the existing 18W2 tie to 22W3 is in close proximity to Bow Bog substation.

11.4.2. Recommendations

11.4.2.1. Create a Circuit Tie on White Rock Hill Rd

Rebuild the single-phase portion of White Rock Hill Road on circuits 18W2 and 22W3 to three-phase (spacer cable should be considered if heavily treed). A new normally open tie switch will be installed along White Rock Hill Road creating a new circuit tie between 18W2 and 22W3. Replace the fuses on pole 18/104 on Bow Center Rd and the fuses on pole 122/53 on White Rock Hill Rd with solid blades.

Estimated Project Cost (without construction overheads): $279,104

Estimated Annual Savings:

Customer Minutes: 11,168

Customer Interruptions: 8

11.4.2.2. Reconductor Bow Center Rd

Reconductor Bow Center Road from Bow Bog Rd to Branch Londonderry Turnpike with 336AL spacer cable, 052AWA messenger and 4/0ACSR neutral.

Estimated Project Cost (without construction overheads): $280,976

Estimated Annual Savings:

Customer Minutes: 28,270

Customer Interruptions: 289

11.5. Miscellaneous Circuit Improvements to Reduce Recurring Outages

11.5.1. Identified Concerns & Recommendations

The following concerns were identified based on a review of Tables 12 & 13 of this report; Multiple Tree Related Outages by Street and Multiple Device Operations respectively and reviewing the fault locations on the worst performing circuits.

Forestry Reviews

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

- C8X3
  - Horse Corner Rd. area, Chichester
  - Bear Hill Rd, East Ricker Rd area, Loudon
  - Mountain Rd, Epsom
  - Center Hill Rd, Epsom
  - Cass Rd, Epsom
  - Mountain View Rd. area, Epsom
  - Main St, Chichester
  - Ridgewood Cir. Area, Epsom
- C22W3
  - Hooksett Tpke. area, Bow
- C13W1
  - Old Tilton Rd. area, Canterbury
  - Cogswell Rd., Northwest Rd. and West Rd. area, Canterbury
- C13W3
  - Branson Line area, Webster
  - Mutton Rd area, Webster
  - Woodbury Ln. area, Bow
- C18W2
  - Bow Center Rd, Bow

Animal Guard Installation Recommendations

It is recommended that the on-going animal guard installation program be continued in 2023. The areas identified below should be reviewed and have animal guards installed where needed.

- C8X3
  - Bear Hill Rd. area, Chichester
  - Center Hill Rd. area, Epsom
  - Connemara Dr. area, Chichester
  - Durgin Rd. area, Chichester
  - Horse Corner Rd. area, Chichester
  - Bailey Rd. area, Chichester
  - King Rd. and Canterbury Rd. area, Chichester and Loudon
  - Durgin Rd. area, Chichester

  - Highland Dr. area, Chichester
  - Colonial Dr. area, Epsom
  - Albert Nye Dr. area, Epsom (around McClary Hill)
  - Baybutt Rd., Epsom
- C13W1
  - Goodwin Rd. area, Canterbury
- C13W2
  - Academy St. area, Boscawen
  - Best Ave. area, Boscawen
  - Chandler St. area, including Hollins Ave, Boscawen
- C13W3
  - Water St. area, Boscawen
  - Keneval Ave. area, Boscawen
  - White Plains Rd. area, Webster
  - Area surrounding Walker Pond and Corser Hill, Webster
  - Warner Rd. area, Salisbury
- C18W2
  - Bow Center Rd. area, Bow
  - Risingwood Dr. area, Bow

12 Conclusion

During 2021, 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 along the mainlines for most of the worst performing circuits identified in this study.

Due to the number of animal related outages that occur on the UES-Capital system an animal guard installation program began in 2019. This program is expected to continue in 2023. Furthermore, 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, animal guards will be installed at that location. Also, 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. 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.

Unitil Energy Systems – Seacoast

Reliability Study
2022

Prepared By:

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Unitil Service Corp.
October 18, 2022

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, 2021 through December 31, 2021. 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 sub-transmission and substation outages (listed in Section 5), as well as outages during 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
1	3/2/2021	51	9,555	1,322,695

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 2023 budget development process.

Circuit / Line / Substation	Proposed Project	Cost ($)
21W1	Install Sectionalizer on Devonshire Rd	$5,000
23X1	Install FuseSavers on Amesbury Rd	$18,000
23X1	Install FuseSavers on Highland St	$29,000
23X1	Implement Distribution Automation with 27X1	$509,000
6W1	Install FuseSaver on Main Ave	$10,000
6W1	Implement Distribution Automation with 6W2	$1,609,000
51X1	Install Sectionalizer on Dumbarton Oaks Rd	$5,000

Note: estimates do not include general construction overheads

The 2021 annual UES-Seacoast system reliability goal was set at 117.33 SAIDI minutes, after removing exclusionary outages. UES-Seacoast's SAIDI performance in 2021 was 127.06 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

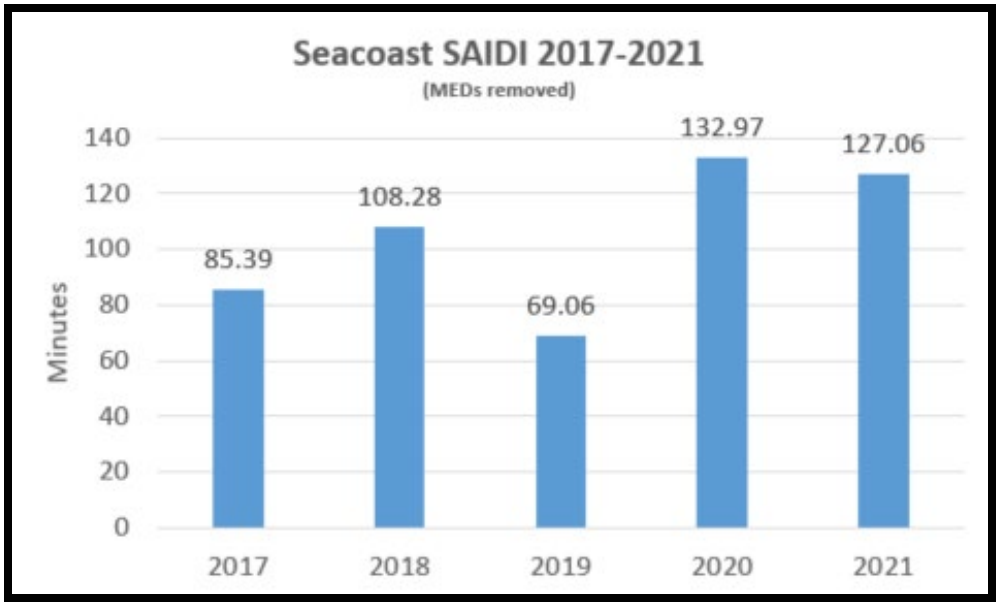


Chart 2
Annual UES-Seacoast SAIFI

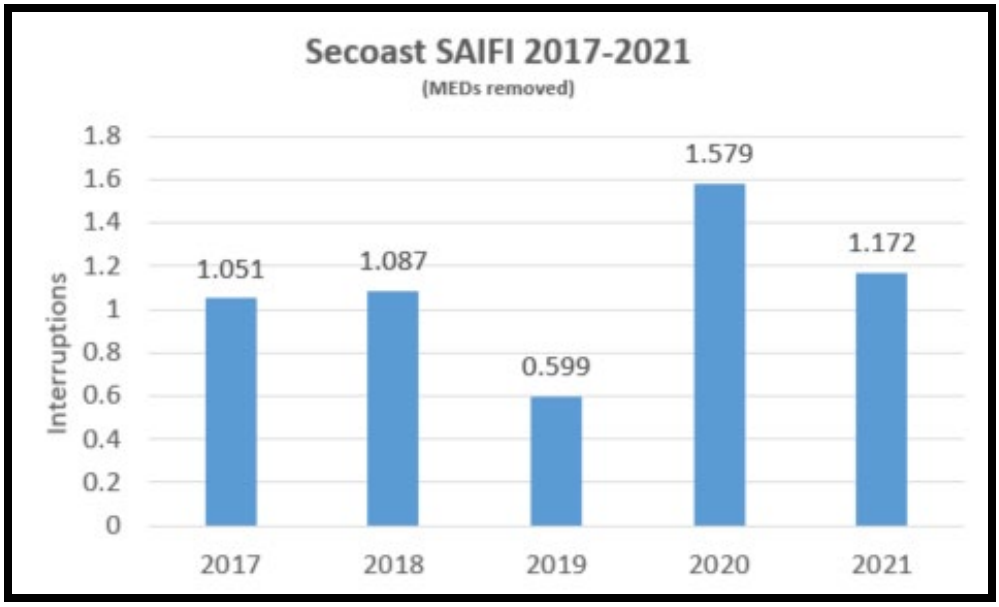
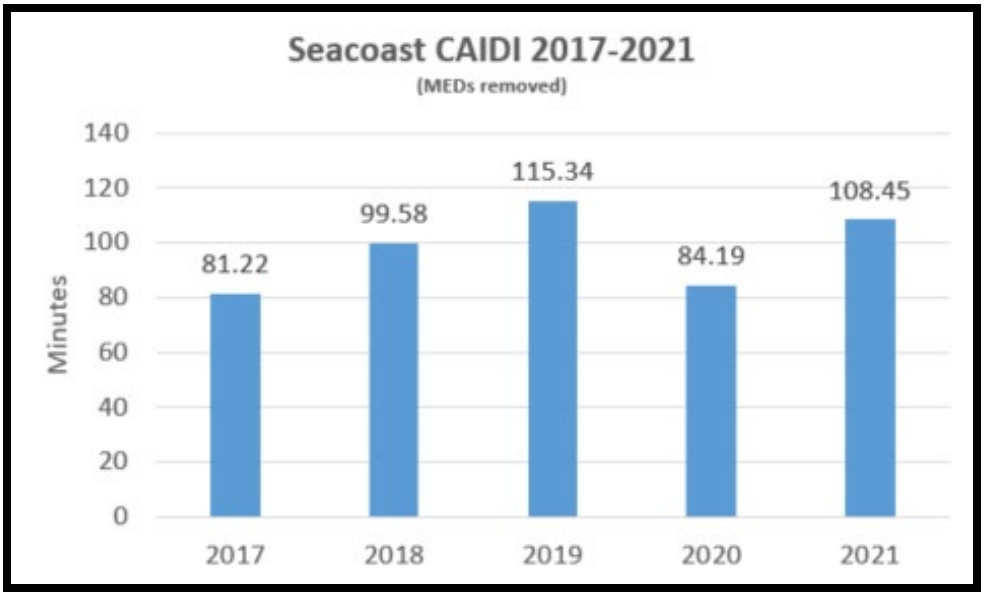


Chart 3
Annual UES-Seacoast CAIDI



2 Reliability Benchmarks

The new annual UES-Seacoast system reliability benchmark for 2022 is 121.68 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 2022 Unitil system goal. The 2022 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 2021. 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

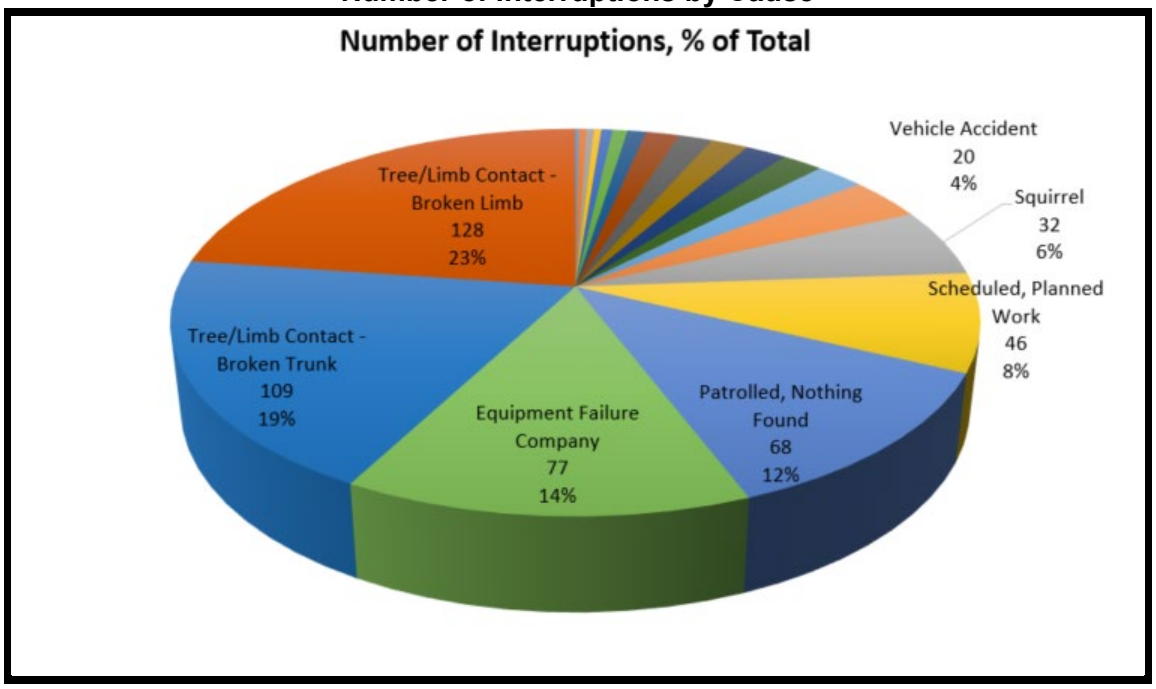


Chart 5
Number of Customer Interruptions by Cause

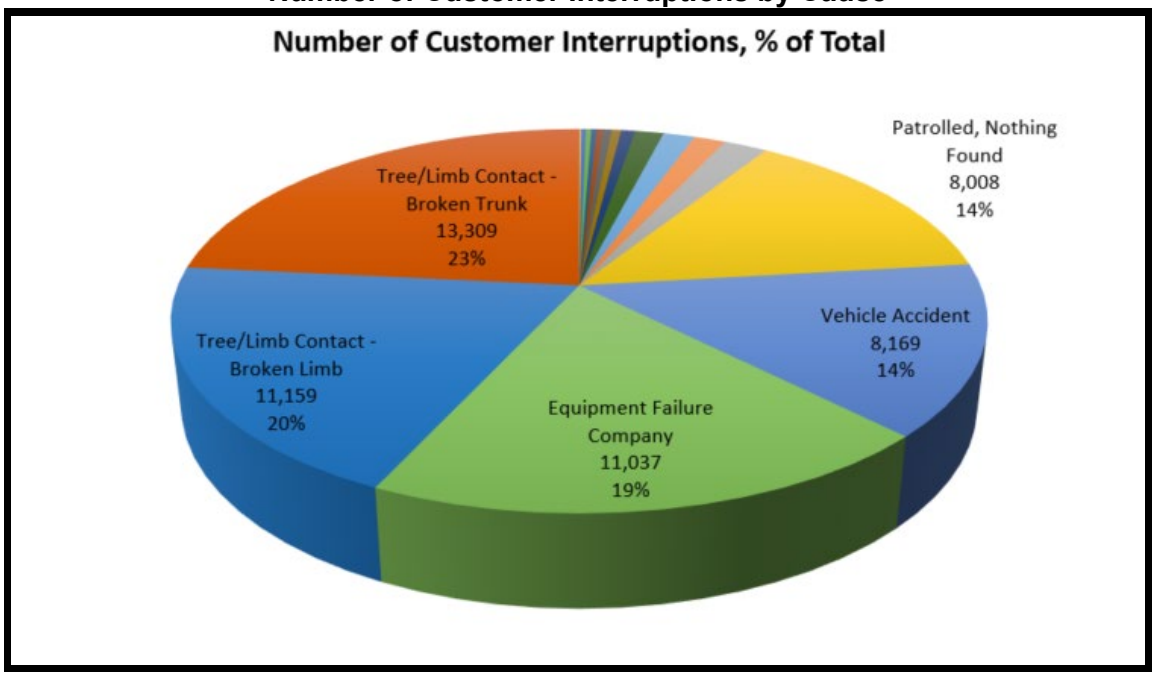


Chart 6
Percent of Customer-Minutes of Interruption by Cause

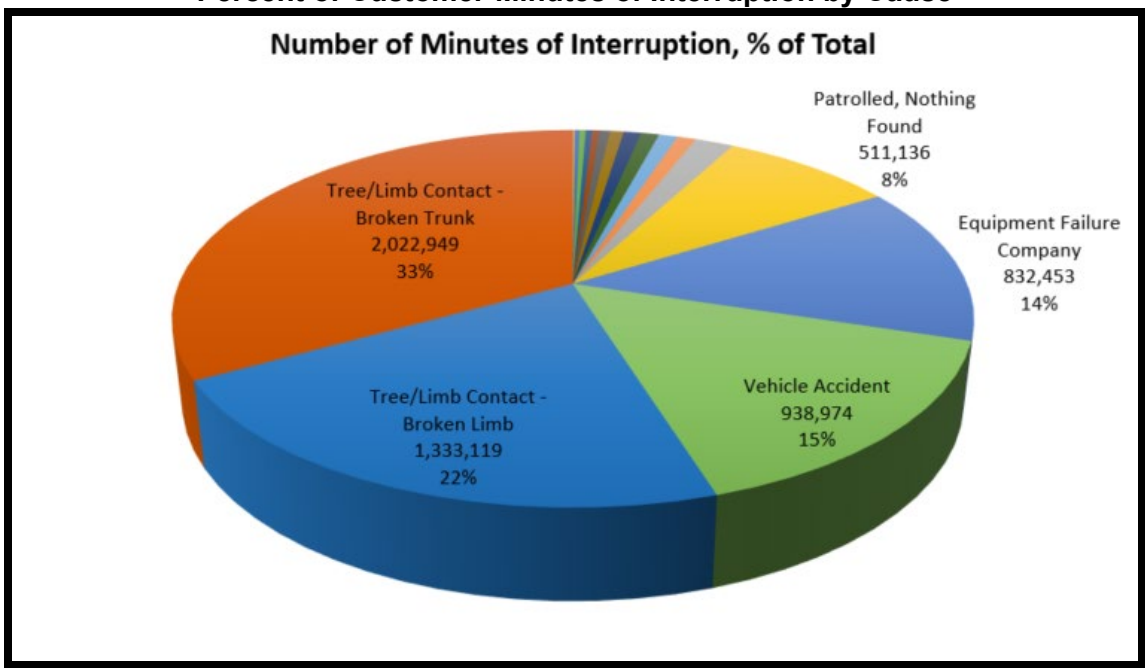


Table 1
Five-Year History of the Number of Interruptions for the Worst Three Trouble Causes

Year	# of Interruptions Per Trouble Cause		
	Tree/Limb Contact - Broken Limb	Equipment Failure Company	Tree/Limb Contact - Broken Trunk
2021	128	77	109
2020	132	84	61
2019	88	69	68
2018	179	93	57
2017	121	79	46

4 10 Worst Distribution Outages

The ten worst distribution outages ranked by customer-minutes of interruption during the time period from January 1, 2021 through December 31, 2021 are summarized in Table 2 below.

Table 2
Worst Ten Distribution Outages

Circuit	Date/Cause	Customer Interruptions	Cust-Min of Interruption	SAIDI	SAIFI
E22X1	06/14/2021 Vehicle Accident	1,413	402,912	8.37	0.029
E21W1	06/30/2021 Tree/Limb Contact - Broken Trunk	914	346,627	7.2	0.019
E19X3	03/29/2021 Tree/Limb Contact - Broken Limb	892	334,660	6.95	0.019
E47X1	03/01/2021 Tree/Limb Contact - Broken Limb	1,659	239,532	4.98	0.034
E15X1	04/30/2021 Tree/Limb Contact - Broken Trunk	996	204,095	4.24	0.021
E15X1	03/12/2021 Tree/Limb Contact - Broken Trunk	3,001	184,057	3.82	0.062
E15X1	09/27/2021 Patrolled, Nothing Found	2,991	183,507	3.81	0.062
E18X1	05/04/2021 Vehicle Accident	2,298	171,842	3.57	0.048
E51X1	04/30/2021 Tree/Limb Contact - Broken Trunk	850	154,203	3.2	0.018
E54X1	12/14/2021 Vehicle Accident	2,076	152,658	3.17	0.043

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, 2021 through December 31, 2021 are summarized in Table 3 below.

Table 4 shows the substations 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 13% 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
3359 Line	03/12/2021 Tree/Limb Contact - Broken Trunk	3,001	184,057	3.82	0.062	2
3350 Line	08/30/2021 Equipment Failure Company	3,043	130,941	2.72	0.063	2
Seabrook S/S	02/17/2021 Equipment Failure Company	3,036	255,530	5.31	0.063	0
3343 Line	07/18/2021 Tree/Limb Contact - Broken Trunk	1,835	239,009	4.97	0.038	0

Table 4
Affected Substations

Substation/Tap	Substation / Transmission Line Outage	Customer Interruptions	Cust-Min of Interruption	Number of Events
Cemetary Lane	3359 Line	996	61,752	1
Mill Lane	3359 Line	960	58,560	1
Stard Rd Tap	3359 Line	1,045	63,745	1
Seabrook	3350 Line, Seabrook S/S	6,079	386,471	2
Willow Rd Tap	3343 Line	1,835	239,009	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 (1/1/21 – 12/31/21)

A summary of the worst performing circuits during the time period between January 1, 2021 and December 31, 2021 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 2021.

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
E21W1	6,131	51%	524,141	77%	517.49	4.395	117.75
E22X1	2,761	53%	448,003	75%	371.47	1.957	189.84
E19X3	1,693	28%	385,087	53%	124.51	0.471	264.62
E15X1	3,569	78%	303,618	79%	387.02	3.587	107.9
E47X1	2,115	32%	291,003	20%	182.46	1.271	143.55
E23X1	3,016	40%	269,547	24%	303.66	3.148	96.46
E18X1	3,134	46%	205,852	75%	116.76	1.718	67.95
E51X1	1,862	14%	205,250	18%	105.35	0.953	110.55
E58X1	1,410	42%	197,333	16%	90.62	0.623	145.57
E54X1	2,216	68%	169,668	44%	172.53	2.154	80.12

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	Vehicle Accident	Equipment Failure Company	Patrolled, Nothing Found	Action by Others
E21W1	371,679 / 8	93,539 / 9	4,667 / 1	186,004 / 5	53,652 / 3	0 / 0
E22X1	45,090 / 6	20,352 / 3	458,267 / 2	0 / 0	0 / 0	0 / 0
E19X3	12,092 / 3	366,009 / 7	27,821 / 1	6,798 / 7	10,282 / 2	17,073 / 2
E15X1	265,847 / 2	6,120 / 2	0 / 0	10,488 / 3	52,735 / 1	0 / 0
E47X1	2,013 / 4	256,064 / 5	25,113 / 1	17,967 / 4	176 / 2	0 / 0
E23X1	205,770 / 9	10,480 / 5	13,708 / 1	1,519 / 2	57,517 / 1	0 / 0
E18X1	9,212 / 1	4,106 / 4	171,842 / 1	1,514 / 2	0 / 0	396 / 1
E51X1	154,203 / 1	941 / 2	0 / 0	46,026 / 4	1,554 / 2	0 / 0
E58X1	95,685 / 8	24,067 / 7	0 / 0	54,323 / 3	6,071 / 3	790 / 1
E54X1	16,202 / 2	620 / 3	154,968 / 2	88 / 2	5,882 / 5	0 / 0

6.2 Worst Performing Circuits of the Past Five Years (2017 – 2021)

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 SAIFI and Table 8 lists the ten worst performing circuits ranked by SAIDI. 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 the IEEE MEDs in 2017 through 2021.

Table 7
Circuit SAIFI

Circuit Ranking (1=worst)	2021		2020		2019		2018		2017	
	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI
1	E21W1	4.395	E15X1	3.597	E3W1	2.062	E7W1	6.569	E6W1	4.096
2	E15X1	3.587	E21W1	2.924	E6W1	1.991	E6W1	3.257	E22X1	2.606
3	E23X1	3.148	E51X1	2.486	E22X1	1.758	E54X2	2.949	E15X1	2.536
4	E59X1	2.473	E6W2	2.103	E51X1	1.693	E21W1	2.519	E54X2	2.271
5	E27X1	2.384	E13X3	2.000	E23X1	1.677	E6W2	2.334	E19H1	2.012
6	E6W1	2.256	E19H1	2.000	E11X1	1.356	E54X1	2.115	E23X1	1.527
7	E54X1	2.154	E17W2	1.518	E21W1	1.290	E21W2	2.053	E59X1	1.496
8	E22X1	1.957	E6W1	1.505	E18X1	1.261	E13W2	1.777	E43X1	1.481
9	E18X1	1.718	E56X1	1.484	E17W2	0.998	E43X1	1.465	E18X1	1.414
10	E7X2	1.467	E2H1	1.223	E6W2	0.901	E22X1	1.458	E19X2	1.387

Table 8
Circuit SAIDI

Circuit Ranking (1=worst)	2021		2020		2019		2017		2016	
	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI
1	E21W1	517.49	E51X1	370.76	E6W1	459.13	E7W1	520.93	E54X2	275.94
2	E15X1	387.02	E13X3	335.64	E51X1	354.92	E54X2	338.4	E6W1	269.71
3	E22X1	371.47	E15X1	283.77	E21W1	176.68	E21W1	285.58	E19H1	254.56
4	E23X1	303.66	E21W1	240.24	E22X1	170.09	E54X1	221.90	E22X1	238.1
5	E27X1	283.93	E6W2	225.28	E11X1	167.39	E22X1	209.94	E5H1	200.6
6	E59X1	258.19	E21W2	219.48	E15X1	116.15	E6W1	205.87	E15X1	192.52
7	E27X2	218.64	E6W1	166.78	E17W2	115.43	E13W2	196.23	E51X1	158.75
8	E47X1	182.46	E22X2	154.73	E13W1	113.6	E2H1	192.59	E58X1	134.36
9	E54X1	172.53	E22X1	153.4	E23X1	112.91	E23X1	176.73	E59X1	125.01
10	E6W1	148.9	E19H1	147.89	E6W2	93.03	E58X1	167.86	E22X2	117.33

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	E21W1	4	**1**	E6W1	5
2	E6W1	5	**2**	E21W1	4
3	E22X1	5	**3**	E15X1	3
4	E51X1	3	**4**	E7W1	1
5	E15X1	4	**5**	E22X1	4
6	E23X1	3	**6**	E23X1	3
7	E54X2	2	**7**	E51X1	2
8	E7W1	1	**8**	E6W2	3
9	E59X1	2	**9**	E18X1	3
10	E6W2	2	**10**	E59X1	2

6.3 System Reliability Improvements (2021 and 2022)

Vegetation management projects completed in 2021 or planned for 2022 that are expected to improve the reliability of the 2021 worst performing circuits are included in Table 10 below. Table 11 below details electric system upgrades scheduled to be completed in 2022 or completed in 2021 to improve system reliability of the 2021 worst performing circuits.

Table 10
Vegetation Management Projects Worst Performing Circuits

Circuit(s)	Year of Completion	Project Description
E21W1	2021	Storm Resiliency Pruning
	2022	Hazard Tree Mitigation Mid-Cycle Pruning
E15X1	2021	Mid-Cycle Pruning
	2022	Storm Resiliency Pruning
E27X1	2021	Hazard Tree Mitigation
E47X1	2022	Reliability Trimming Mid-Cycle Pruning
E59X1	2021	Cycle Pruning
E54X1	2022	Cycle Pruning
E19X3	2021	Cycle Pruning Hazard Tree Mitigation

Circuit(s)	Year of Completion	Project Description
E51X1	2021	Cycle Pruning Hazard Tree Mitigation
E18X1	2022	Hazard Tree Mitigation Mid-Cycle Pruning
E58X1	2021	Hazard Tree Mitigation Mid-Cycle Pruning
	2022	Reliability Trimming
E21W2	2022	Reliability Trimming Mid-Cycle Pruning
E7X2	2022	Hazard Tree Mitigation Mid-Cycle Pruning
3358 Line[1]	2022	Sub-Transmission Clearing
3341/3352 Line[2]	2021	Sub-Transmission Clearing
3343/3354 Line[3]	2022	Sub-Transmission Clearing
3345/3356 Line[4]	2022	Sub-Transmission Clearing
3351/3362 Line[5]	2021	Sub-Transmission Clearing

Table 11
Electric System Improvements Performed to Improve Reliability

Circuit(s)	Year of Completion	Project Description
E21W1	2021	Install set of sectionalizers
	2022	Install two FuseSavers Fuse changes to address/improve device coordination
E15X1	2022	Install recloser at tie and implement auto-restoration scheme with 59X1
E22X1	2021	Install two reclosers and implement auto-restoration scheme with 54X2
	2022	Install two FuseSavers Fuse changes to address/improve device coordination

[1] The 3358 line is the normal feed for the Westville (#21) Substation and the Westville Rd (#58) Tap
[2] The 3341 and 3352 lines are the normal and alternate feeds for the Gilman Lane (#19) Substation
[3] The 3343 and 3354 lines are the normal and alternate feeds for the Shaw's Hill (#27) Tap, the New Boston Rd (#54) Tap, and the East Kingston (#6) Substation.
[4] The 3345 and 3356 lines are the normal and alternate feeds for the 3358 line which feeds the Westville (#21) Substation and the Westville Rd (#58) Tap
[5] The 3351 and 3362 lines are the normal and alternate feeds for the Winnicutt Road (#51) Substation. They also feed the 3347 line which feeds the Guinea Road (#47) Substation. They also feed the 3341 and 3352 lines which feed the Gilman Lane (#19) Substation

Circuit(s)	Year of Completion	Project Description
E27X1	2021	Fuse changes to address/improve device coordination
E47X1	2022	Fuse changes to address/improve device coordination
E59X1	2022	Install two reclosers and implement auto-restoration scheme with 15X1
E54X1	2022	Fuse changes to address/improve device coordination
E19X3	2021	Fuse changes to address/improve device coordination
E51X1	2021	Fuse changes to address/improve device coordination
	2022	Install three sectionalizers Fuse changes to address/improve device coordination
E6W1	2021	Install two reclosers
E58X1	2021	Fuse changes to address/improve device coordination
	2022	Install two FuseSavers
E21W2	2022	Fuse changes to address/improve device coordination
E7X2	2021	Fuse changes to address/improve device coordination

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, 2021 and December 31, 2021.

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
E21W1	465,218	1,864	17
E19X3	378,800	1,206	14
E15X1	310,380	2,217	6
E47X1	259,914	1,846	10
E23X1	216,890	1,939	15
E27X1	188,333	1,565	16
E51X1	155,314	861	4
E58X1	127,459	872	17
E59X1	112,951	1,218	6
E21W2	109,336	950	5

Table 13
Multiple Tree Related Outages by Street

Circuit(s)	Street, Town	# Outages	Customer-Minutes of Interruption	Number of Customer Interruptions
E13W1	North Main St, Plaistow	5	33,881	354
E28X1	Exeter Rd, Hampton Falls	5	734	7
E6W1	Hilldale Ave, South Hampton	4	36,754	281
E27X1	Osgood Rd, Kensington	4	13,671	94
E13W2	Main St, Newton	4	9,745	56
E19X3	Linden St, Exeter	3	220,009	587
E23X1	Amesbury Rd, Kensington	3	98,607	528
E15X1	Perkins Ave, Seabrook	3	44,456	224
E43X1	Kingston Rd, Exeter	3	33,020	869
E17W2	Woodland Rd, Hampton	3	32,362	294
E43X1	Exeter Rd, Kingston	3	23,571	71
E58X1	Main St, Atkinson	3	17,951	227
E58X1	Forest St, Plaistow	3	15,326	83
E27X1	Drinkwater Rd, Hampton Falls	3	14,201	86
E11X2	Hampton Falls Rd, Exeter	3	11,844	125
E58X1	Harriman Rd, Plaistow	3	6,810	49
E2X2	Winnacunnet Rd, Hampton	3	6,265	69
E23X1	Highland Ave, Kensington	3	894	10
E19X3	Epping Rd, Exeter	3	331	3

8 Failed Equipment

This section is intended to clearly show all equipment failures throughout the study period from January 1, 2021 through December 31, 2021. 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

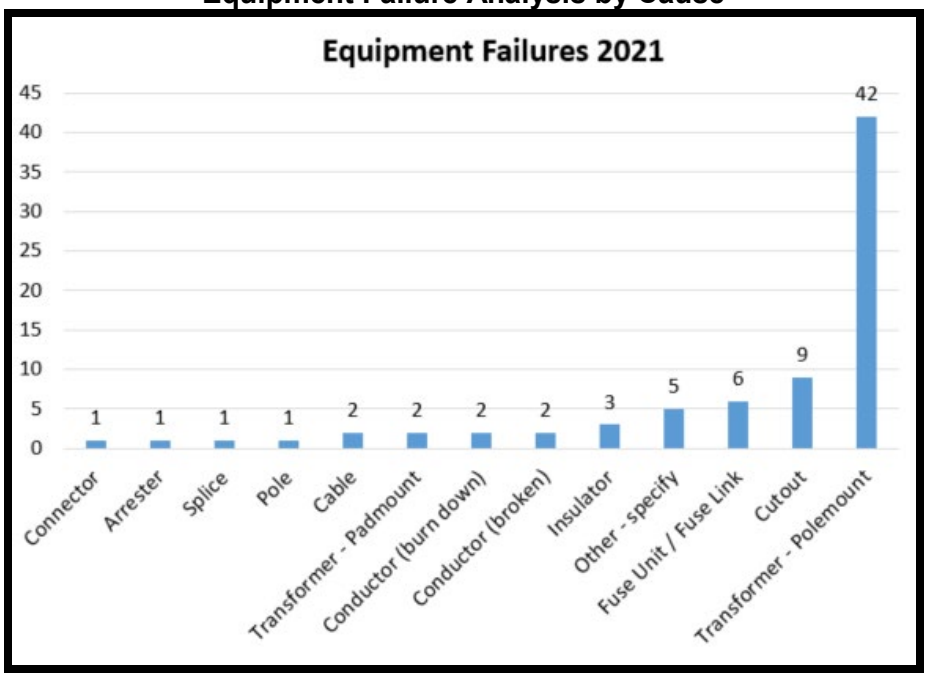


Chart 8
Equipment Failure Analysis by Percentage of Total Failures

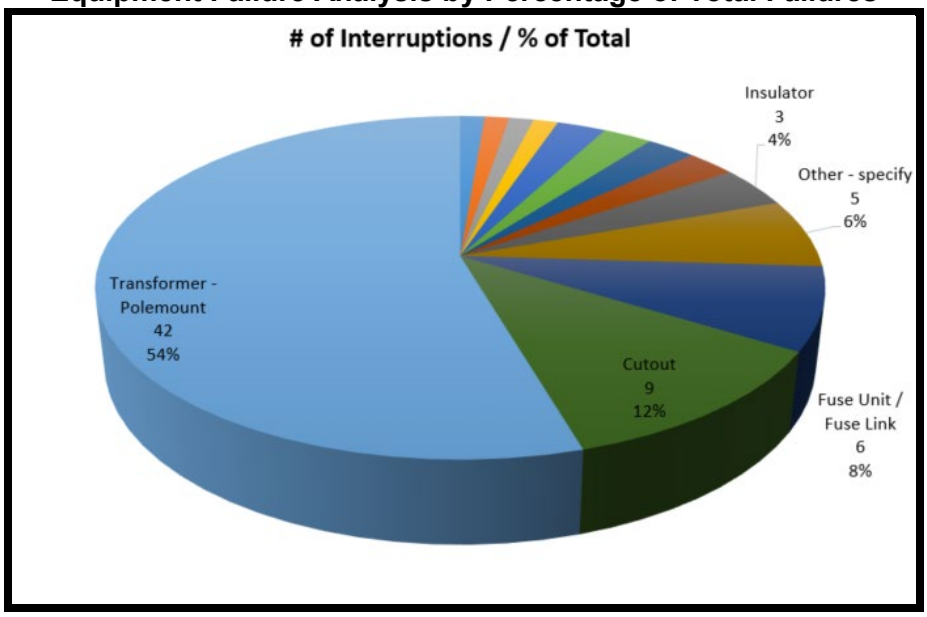
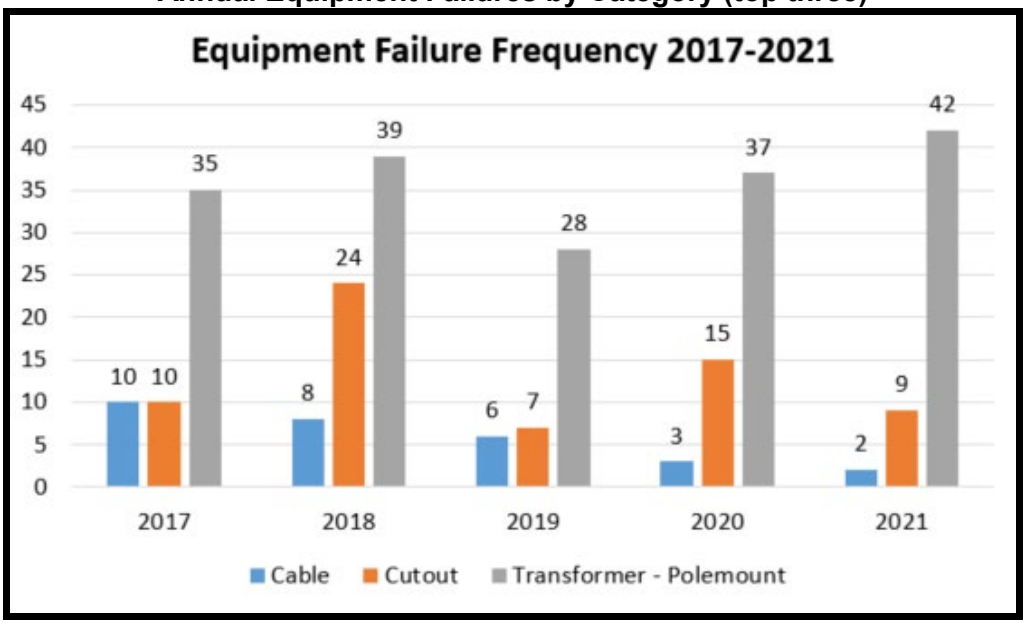


Chart 9
Annual Equipment Failures by Category (top three)



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, 2021 to December 31, 2021 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 2021.

A summary of the streets on the UES-Seacoast system that had customers with 7 or more non-exclusionary outages in 2021 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
E58X1	4	Fuse, P28 Main St, Atkinson	22,343	171	0
E21W1	3	Fuse, P1 Devonshire Rd, Atkinson	8,670	63	0
E58X1	3	Fuse, P1 Sawyer Ave, Atkinson	8,685	56	1
E43X1	3	Transformer, Pole 31, Willow Rd, East Kingston	793	9	0
E19X3	3	Fuse, P4 Dogtown Rd, Exeter	5,787	42	0
E17W2	3	Fuse, P20 Woodland Rd, Hampton	24,838	162	0
E7W1	3	Fuse, P3 Portsmouth Ave, Hampton	18,809	97	0
E23X1	3	Fuse, P142 Amesbury Rd, Kensington	86,258	454	0
E43X1	3	Fuse, P1-A Exeter Rd, Kingston	21,413	90	0
E54X2	3	Fuse, P100 Rt 125, Kingston	35,335	376	0
E54X1	3	Recloser, P4-A New Boston Rd, Kingston	71,107	1,077	0
E54X1	3	Fuse, P10 Pond St, Newton	13,250	85	0
E13W2	3	Fuse, P19 Merrimac Rd, Newton	2,200	24	0
E7X2	3	Customer, 29 MARSHVIEW CIR, SEABROOK	196	3	0
E23X1	3	Fuse, P11 Exeter Rd (South), South Hampton	23,836	91	0
E6W1	3	Fuse, P82 Main Ave, South Hampton	13,874	132	0
E51X1	3	Fuse, P1 Dumbarton Oaks Rd, Stratham	17,142	198	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
E6W1	Hilldale Ave, South Hampton	8	1
E15X1	Perkins Ave, Seabrook	8	0
E21W1	Providence Hill, Atkinson	7	0
E23X1	Wild Pasture, Kensington	7	0

10 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 2023 capital budget. All project costs are shown without general construction overheads.

10.1 Miscellaneous Circuit Improvements to Reduce Recurring Outages

10.1.1 Forestry Review

Table 13 of this report; Multiple Tree Related Outages by Street indicates that there were fourteen streets that experienced three or more tree related outages in 2021.

It is recommended that a forestry review of the areas identified in Table 13 be performed in 2022 in order to identify and address any growth or hazard tree problems.

10.2 Circuit 21W1 – Install Sectionalizer on Devonshire Rd

10.2.1 Identified Concerns

Circuit 21W1 was the worst performing circuit in terms of SAIDI and SAIFI in 2021. It has also been one of the 10 worst performing circuits in terms of both SAIFI and SAIDI for the Seacoast system in four of the past five years. The fuses at Devonshire Rd, Atkinson Pole 1 operated three times in 2021. One of these operations was due to squirrel contact, the other two operations were due to patrolled nothing found.

10.2.2 Recommendation

This project will consist of removing the existing fuse and installing a cutout-mounted sectionalizer at Devonshire Rd, Atkinson Pole 1.

Customer Exposure = 21 customers

The projected average annual savings for this project is 357 customer minutes of interruptions and 3 customer interruptions.

Estimated Project Cost: $5,000

10.3 Circuit 23X1 – Install FuseSavers on Amesbury Rd

10.3.1 Identified Concerns

Circuit 23X1 was the third worst performing circuit in terms of SAIFI and the fourth worst performing circuit in terms of SAIDI in 2021. It has also been one of the 10 worst performing circuits in terms of both SAIFI and SAIDI for the Seacoast system in three of the past five years. The fuses at Amesbury Rd, Kensington Pole 142 operated three times in 2021.

10.3.2 Recommendation

This project will consist of installing three Siemens FuseSavers at Amesbury Rd, Kensington Pole 142.

Customer Exposure = 192 customers

The projected average annual savings for this project is 3,540 customer minutes of interruptions and 33 customer interruptions.

Estimated Project Cost: $18,000

10.4 Circuit 23X1 – Install FuseSavers on Highland St

10.4.1 Identified Concerns

Circuit 23X1 was the third worst performing circuit in terms of SAIFI and the fourth worst performing circuit in terms of SAIDI in 2021. It has also been one of the 10 worst performing circuits in terms of both SAIFI and SAIDI for the Seacoast system in three of the past five years. The fuses at Highland St, South Hampton Pole 11 operated three times in 2021.

10.4.2 Recommendation

This project will consist of installing three Siemens FuseSavers at Highland St, South Hampton Pole 11.

Customer Exposure = 45 customers

The projected average annual savings for this project is 673 customer minutes of interruptions and 6 customer interruptions.

Estimated Project Cost: $29,000

10.5 Circuits 23X1 and 27X1 – Convert Circuit Portion, Create Circuit Tie, Install Reclosers, and Implement Distribution Automation

10.5.1 Identified Concerns

Circuit 23X1 was the third worst performing circuit in terms of SAIFI and the fourth worst performing circuit in terms of SAIDI in 2021. It has also been one of the 10 worst performing circuits in terms of both SAIFI and SAIDI for the Seacoast system in three of the past five years.

10.5.2 Recommendation

This project will consist of converting a portion of circuit 23X1 from 4.16/2.4kV to 34.5/19.92kV, creating a circuit tie between cirtuits 23X1 and 27X1, and installing three G&W Viper reclosers along circuits 23X1 and 27X1.

The conversion will be on circuit 23X1 from Amesbury Rd Pole 79 to Pole 141.

One of the reclosers will replace the fuses on circuit 27X1 at Amesbury Rd, Kensington Pole 44. A new recloser will be installed at the new tie point between 23X1 and 27X1 at Amesbury Rd, Kensington Pole 79. The third recloser will replace the existing high-side stepdown fuses on circuit 23X1 at Amesbury Rd, Kensington Pole 141.

Once installed, a distribution automation scheme will be implemented among the new reclosers. The intent of the scheme is to have 23X1 and 27X1 automatically reconfigure for permanent faults on the mainline of either circuit.

- Fault between 23X1 and new 23X1 recloser at Amesbury Rd Pole 141 – 23X1 and new 23X1 recloser lockout and 23X1/27X1 tie recloser closes.
- Fault between 27X1 and new 27X1 recloser at Amesbury Rd Pole 44 – 27X1 and new 27X1 recloser lockout and 23X1/27X1 tie recloser closes.

Customer Exposure = 415 customers

The projected average annual savings for this project is 46,577 customer minutes of interruptions and 417 customer interruptions.

Estimated Project Cost: $509,000

10.6 Circuit 6W1 – Install FuseSaver on Main Ave

10.6.1 Identified Concerns

Circuit 6W1 was the sixth worst performing circuit in terms of SAIFI and the tenth worst performing circuit in terms of SAIDI in 2021. It has also been one of the 10 worst performing circuits in terms of both SAIFI and SAIDI for the Seacoast system in each of the past five years. The fuses at Main Ave, South Hampton Pole 82 operated three times in 2021.

10.6.2 Recommendation

This project will consist of installing one Siemens FuseSaver at Main Ave, South Hampton Pole 82.

Customer Exposure = 44 customers

The projected average annual savings for this project is 2,051 customer minutes of interruptions and 21 customer interruptions.

Estimated Project Cost: $10,000

10.7 Circuits 6W1 and 6W2 – Reconductor and Convert Circuit Sections, Create Circuit Tie, Install Reclosers, and Implement Distribution Automation

10.7.1 Identified Concerns

Circuit 6W1 has been one of the ten worst performing circuits in the Seacoast system in terms of SAIDI for nine out of the previous ten years, and it has been one of the ten worst in terms of SAIFI for each of the past ten years. In the past five years, 6W1 has been the worst performing circuit in terms of SAIFI and the second worst performing circuit in terms of SAIDI. Customers on the end of circuit 6W1 also saw the most outages of any customers on the Seacoast system in 2021. The owner of a section of property along South Road on 6W1 has repeatedly refused to allow effective pruning and hazard tree mitigation, and this section has been the cause of several tree outages over the years. A project to re-conductor the section of South Road with spacer has been proposed in the past, but even if the project could have been justified for reliability spending, it was impossible to construct because the level of trimming needed for the spacer cable construction wasn't even possible.

10.7.2 Recommendation

This project will consist of reconductoring and converting portions of circuit 6W1 and 6W2 from 4.16/2.4kV to 13.8/7.97kV, extending sections of each circuit, creating a circuit tie between circuits 6W1 and 6W2, and installing three G&W Viper reclosers.

The following portions of circuits 6W1 and 6W2 will be converted from 4.16/2.4kV to 13.8/7.97kV:
- 6W2: Powwow River Rd Pole 33 to Pole 3
- 6W1: Burnt Swamp Rd Pole 1 to Pole 28

The following portions of circuits 6W1 and 6W2 will be extended and/or reconductored with 3-phase 336AAC:
- 6W2: Depot Rd Pole 27 to Pole 44
- 6W2: Depot Rd Pole 27 to Powwow River Rd Pole 1 (along Powwow River Rd)
- 6W1: Powwow River Rd Pole 1 to Main Ave Pole 20 in South Hampton (along Burnt Swamp Rd)

New open points will be created at Haverhill Rd Pole 37 and Main Ave Pole 19. The portion of 6W1 along Haverhill Rd (south of the intersection with Powwow River Rd and Burnt Swamp Rd), Burnt Swamp Rd, and Main Ave, South Hampton will be transferred to circuit 6W2.

One of the reclosers will be installed on circuit 6W2 at Powwow River Rd, Kingston Pole 1. A second recloser will be installed at the new tie point between 6W1 and 6W2 at Main Ave, South Hampton Pole 19. The third recloser will be installed at South Rd, East Kingston Pole 51.

Once installed, a distribution automation scheme will be implemented among the new reclosers and the recently installed reclosers on the mainline of 6W1. The intent of the scheme is to have 6W1 and 6W2 automatically reconfigure for permanent faults on the mainline of either circuit.

- Fault between 6W2 and new 6W2 recloser at Powwow River Rd Pole 1 – 6W2 and new 6W2 recloser lockout and 6W1/6W2 tie recloser closes.
- Fault between 6W1 and 6W1 recloser at Main St Pole 34 – 6W1 and Main St P34 recloser lockout and 6W1/6W2 tie recloser closes.
- Fault between 6W1 recloser at Main St Pole 34 and 6W1 recloser at South Rd Pole 2 – Both reclosers lockout and 6W1/6W2 tie recloser closes.
- Fault between 6W1 recloser at South Rd Pole 2 and new 6W1 recloser at South Rd Pole 50 – Both reclosers lockout and 6W1/6W2 tie recloser closes.

Customer Exposure = 766 customers

The projected average annual savings for this project is 101,693 customer minutes of interruptions and 1,083 customer interruptions.

Estimated Project Cost: $1,609,000

10.8 Circuit 51X1 – Install Sectionalizer on Dumbarton Oaks Rd

10.8.1 Identified Concerns

Circuit 51X1 was the fourth worst performing circuit in terms of SAIDI and the seventh worst in terms of SAIFI in the last five years. The fuses at Dumbarton Oaks Rd, Stratham Pole 1 operated three times in 2021.

10.8.2 Recommendation

This project will consist of removing the existing fuse and installing a cutout-mounted sectionalizer at Dumbarton Oaks Rd, Stratham Pole 1.

Customer Exposure = 66 customers

The projected average annual savings for this project is 2,513 customer minutes of interruptions and 16 customer interruptions.

Estimated Project Cost: $5,000

11 Conclusion

The annual electric service reliability of the UES-Seacoast system has seen improvement in the last ten years over prior years after discounting MEDs. Much of the overall improvement in reliability can be attributed to an aggressive vegetation management program; however, 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 faulted sections 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.