

The Narragansett Electric Company
d/b/a/ National Grid

**Electric Infrastructure, Safety,
and Reliability Plan
FY 2019 Proposal**

**Inspection & Maintenance
Program Cost/Benefit Study**

**Working Document for August
31, 2017 meeting**

August 11, 2017

Submitted to:
Rhode Island Division of Public Utilities &
Carriers

Submitted by:

nationalgrid

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Background

In the June 29, 2012 compliance filing in Docket No.4307, National Grid¹ agreed to the tracking and reporting of the costs and benefits for its Inspection and Maintenance (I&M) Program to be submitted to the Rhode Island Division of Public Utilities and Carriers (Division) each year in preparation for the negotiation for the Company's annual Electric Infrastructure, Safety and Reliability (Electric ISR) Plan proposal. The I&M Program is primarily a safety and asset conditioning program that provides secondary reliability benefits. The Company agreed to track and report these safety and reliability benefits beginning a year after completion of construction of the FY 2013 I&M Program.

The FY 2013 – FY 2016 Inspection & Maintenance Cost and Benefit Study

In preparation for negotiations with the Division for the FY 2019 Electric ISR Plan, the Company conducted the following cost and benefit study of the Company's Distribution I&M Program. This analysis included 99 feeders in the Rhode Island electric distribution system that had all repair work completed. This included fifteen (15) feeders completed by the end of FY 2013 (March 2013), thirty-two (32) feeders completed by the end of FY 2014 (March 2014), thirty-seven (37) feeders completed by the end of FY 2015 (March 2015), and fifteen (15) feeders completed by the end of FY2016 (March 2016). To calculate the reliability benefits for the I&M Program, the Company used the average number of events and customer interruptions (CI) due to deteriorated equipment, animals, and lightning over a three year period prior to the repair work year as the baseline². Since repairs often take the majority of the year to complete, the year the repair work was performed was excluded from any analysis. The number of events and CI's were then calculated for the subsequent years post repair work. For feeders with repairs completed in FY 2013 and FY 2014, three years of data was used. For feeders with repairs completed in FY 2015 two years of data was used. Finally for feeders with repairs completed in FY 2016, one year of data was used.

The Company then compared the difference between the pre-repair and post-repair average number of events and CI's by feeder. Finally, to provide a full comparison of the results, data for all 375 Rhode Island feeders is presented in the same manner as the repairs completed on feeders though the I&M Program.

CI's in this study were derived from the three incident-causing categories: (1) animals, (2) lightning and (3) overhead equipment deterioration. Animal caused interruptions are the result of small animals climbing on equipment, causing fuses or circuit breakers to operate which limit the extent of the interruption and protect the system as a whole. These interruptions are typically the result of contacts from small animals like squirrels and raccoons, and all sizes of birds, including geese and seagulls. Lightning caused interruptions are the result of lightning strikes to the Company's electrical equipment. Overhead equipment deterioration interruptions are caused when equipment, such as poles, transformers, fused cutouts, cross arms, lightning arrestors, conductor and services, fail during regular operation.

The analysis done in this report includes 72 feeders from the Capital Region and 27 feeders from the Coastal Region. It should be noted that this represents slightly more than a quarter of the 375 total feeders in the overall electric system in Rhode Island. As such, very limited information as to the secondary reliability benefits of the I&M Program are available at this time. However, as the I&M Program progresses under future Electric ISR Plans, additional feeders and years of data will be added to the analysis, providing a better picture of the costs and reliability benefits associated with the I&M Program.

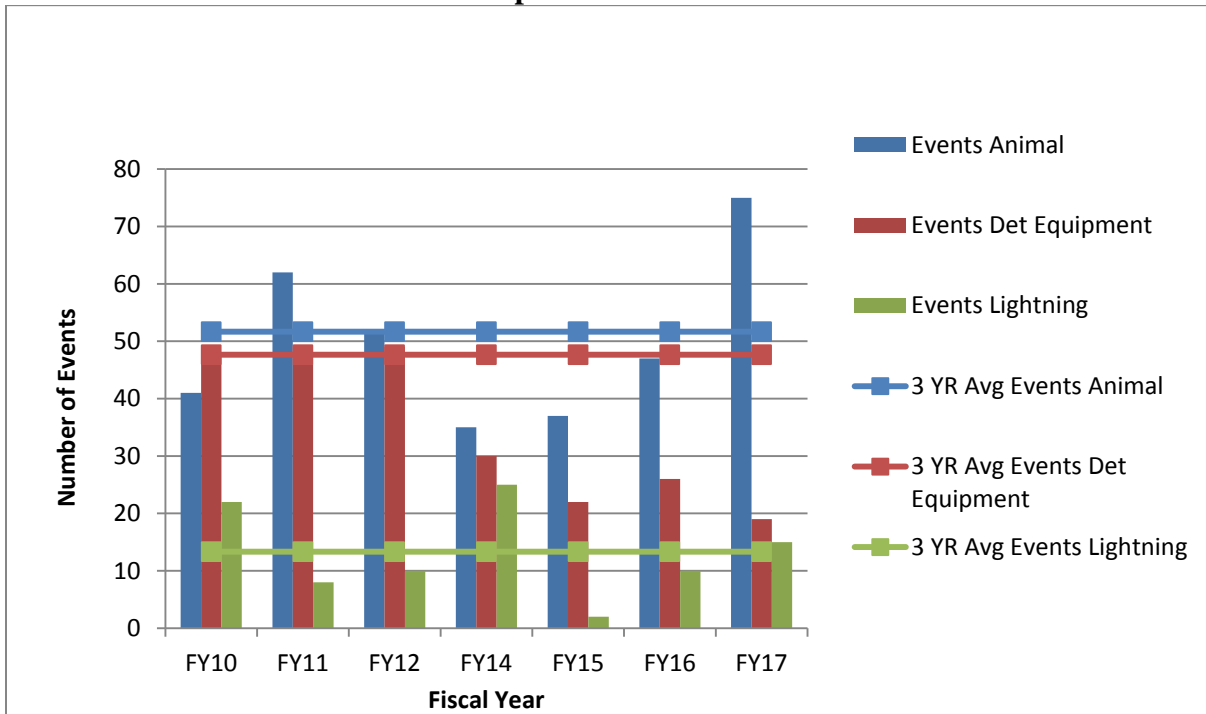
¹ The Narragansett Electric Company d/b/a National Grid (National Grid or the Company).

² Reliability analysis in this report excludes Major Event Days.

Customer Interruption Events for FY 2013 through FY 2017 on I&M Feeders

For the fifteen feeders that had repairs completed in FY 2013, the fourth year of results show mixed results in all three of the incident causing categories. Chart 1 below shows the total number of events per category by FY, with the three year average before the I&M repairs were performed.

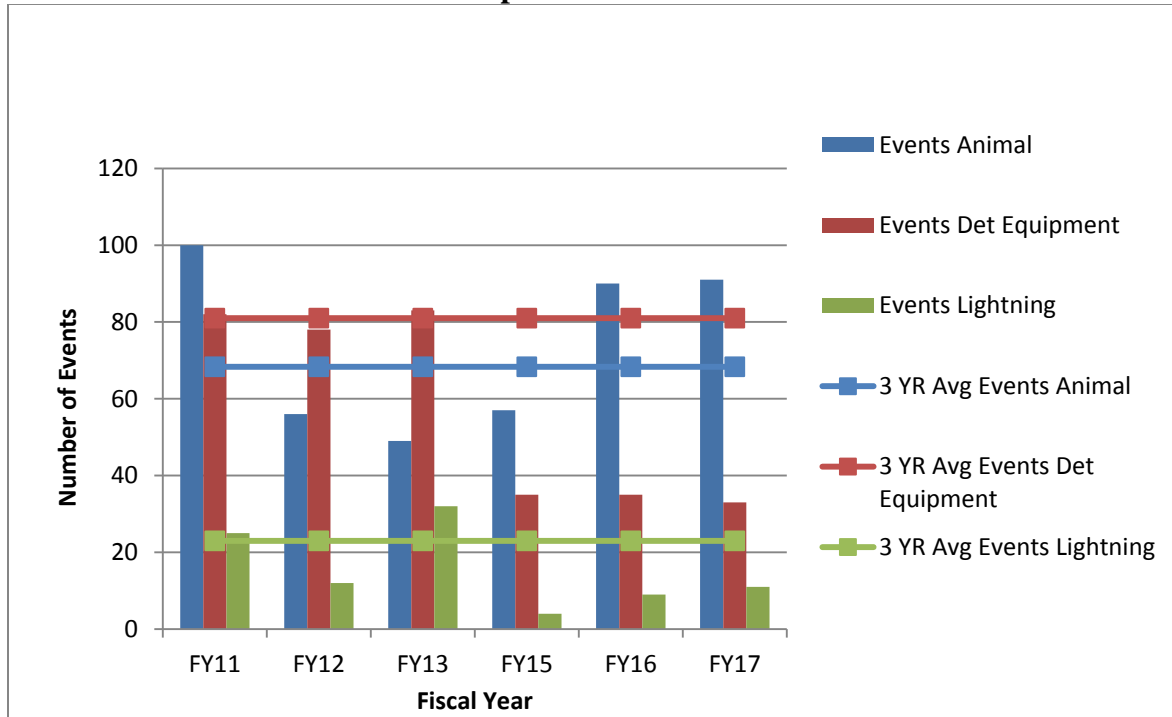
Chart 1 – Customer Interruption Events for FY 2013 on I&M Feeders



As reported previously, for FY 2014, FY 2015 and FY 2016 the number of events for both animal and deteriorated equipment post-repairs were lower than the three year average. Events caused by animals increased in FY 2017, while deteriorated equipment was well below the three year average and events caused by lightning were slightly higher than the three year average. Numbers for FY 2016 and FY 2017 show an upward trend in both animal and lightning events with animal events surpassing the three year average and lightning just slightly above average. Still, events for deteriorated equipment continue be lower than half of the average and consistent over the four years after construction complete. In summary, these results were positive because they show a significant decrease in the average number of events after construction was completed compared to the three year average before repairs were performed. Overall, for all fifteen feeders, when comparing the pre-construction to post-construction year averages, all fifteen feeders saw fewer events after construction was complete, and comparing the overall total number of events, they showed a combined drop of over 30% in the last three fiscal years.

For the thirty-two feeders with construction complete in FY 2014 the results overall look positive for the first and second years post-construction compared to the three year average between FY 2011 and FY 2013, with the exception of the events caused by animals which increased above the three year average in FY 2016 and FY 2017. Chart 2 below shows the number of events per category by FY, with the three year average before the I&M repairs were performed.

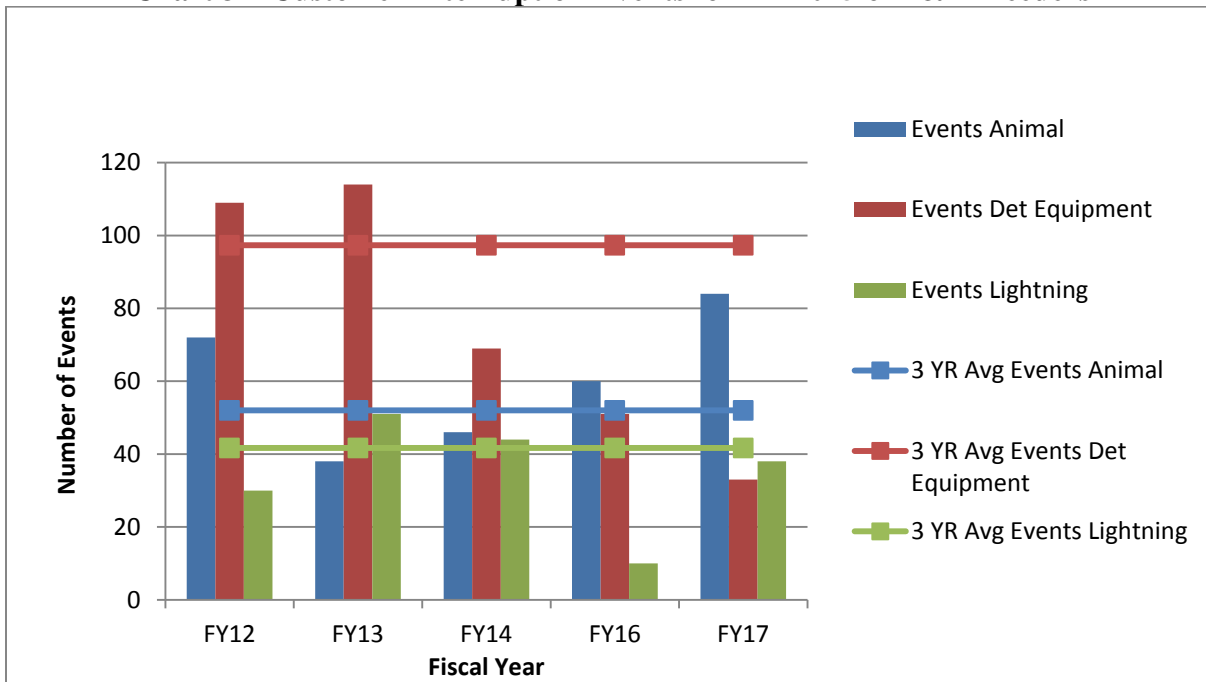
Chart 2 – Customer Interruption Events for FY 2014 on I&M Feeders



The FY 2017 results for events caused by deteriorated equipment and lightning events showed similar results to FY15 and FY16. Similar to FY16, Animal events were again above the 3yr average, but a positive is only 1 main line interruption while 36 events were on fused branches and 54 events were on transformers. The FY 2016 results for events caused by deteriorated equipment and lighting events showed similar results to those in FY 2015 and FY 2016 with results well below the three year average. Three feeders in the Coastal area had 38 of these events, with the majority of them coming from small events caused by transformer fuse failures from squirrel contact with the transformer leads. Still, these results are positive, continuing the trend seen above for feeders with construction complete in FY 2013. Overall, for the 32 feeders with construction complete in FY 2014, comparing the three year average of events before and after construction complete, only four feeders had an increase in events, and five feeders reduced their events to zero. Looking at the three year average for all 32 feeders, we saw a reduction of 33% in total events. As a side note, the 53-17W42 is no longer in service.

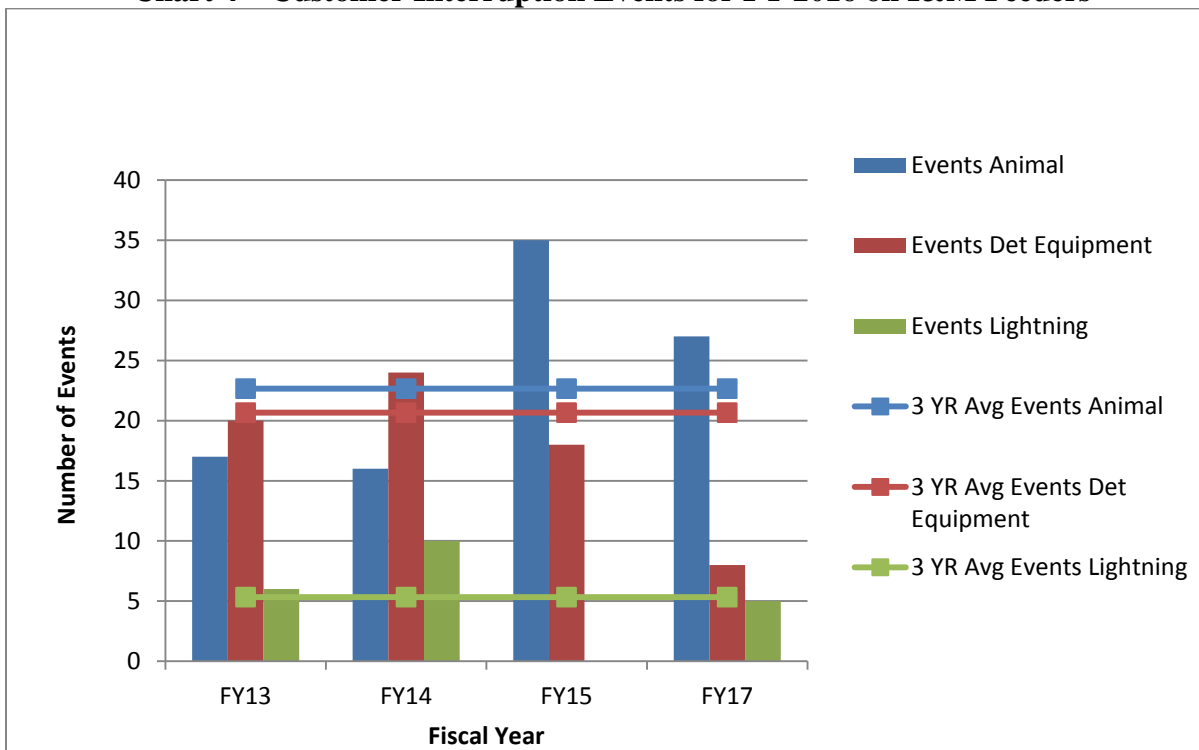
For the thirty-seven feeders with construction complete in FY 2015, the results were mixed for the first year post-construction compared to the three year average between FY 2011 to FY 2013. Chart 3 below shows the number of events per category by FY, with the three year average before the I&M repairs were performed.

Chart 3 – Customer Interruption Events for FY 2015 on I&M Feeders



For deteriorated events caused by equipment and lightning, the FY17 results continued to be significantly lower than the three year average, while animal events continued to be higher than the three year average. Three of four main line outages were on the same feeder, the 7F4, while there where 32 fused branch events and 48 transformer events. For deteriorated events caused by equipment and lightning, the results for FY 2016 were significantly lower than the three year average, but animal caused events were slightly above the three year average, showing similar results with feeders from FY 2014 construction. A quarter of these animal events came from one feeder, which were all small transformer fuse failure events caused animal contact with the transformer leads. Overall, these results are positive, continuing the trend seen above for feeders with construction complete in FY 2013 and FY 2014.

Chart 4 – Customer Interruption Events for FY 2016 on I&M Feeders



Deteriorated equipment events and lightning events were significantly lower than the three year average, animal events, as in past years were above the three year average, but improved from FY15. Two animal events were mainline on the 126W54 due to squirrels. There were 13 fused branch outages, and 17 transformer outages.

Customer Interruption Events for FY 2013 through FY 2017 on all RI Feeders

Chart 5 below shows the same information as Chart 1 above, but for all 375 RI feeders, not just for the fifteen feeders that had repairs completed in FY 2013.

**Chart 5 – Customer Interruption Events for all RI Feeders
FY 2010 – FY 2012 and FY 2014 – FY 2017**

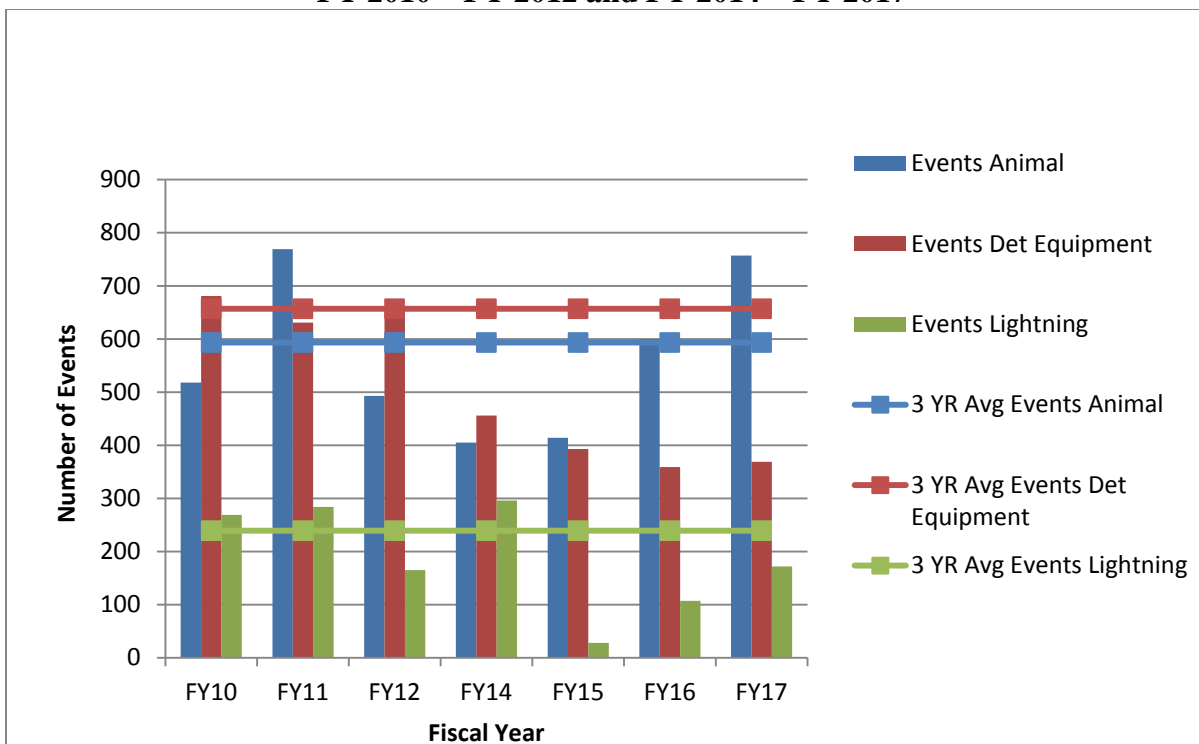


Chart 6 below shows the same information as Chart 2 above, but for all 375 RI feeders, not just for the thirty-two feeders that had repairs completed in FY 2014.

**Chart 6 – Customer Interruption Events for all RI Feeders
FY 2011 – FY 2013 and FY 2015 – FY 2017**

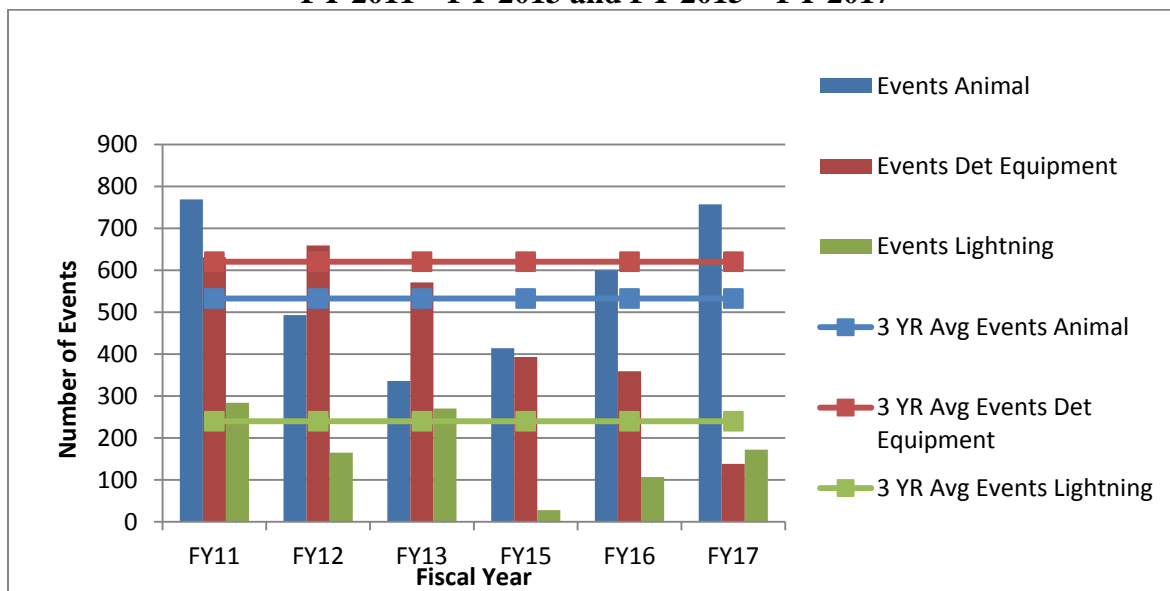


Chart 7 below shows the same information as Chart 3 above, but for all 375 RI feeders, not just for the thirty-seven feeders that had repairs completed in FY 2015.

**Chart 7 – Customer Interruption Events for all RI Feeders
FY 2012 – FY 2014 - FY 2017**

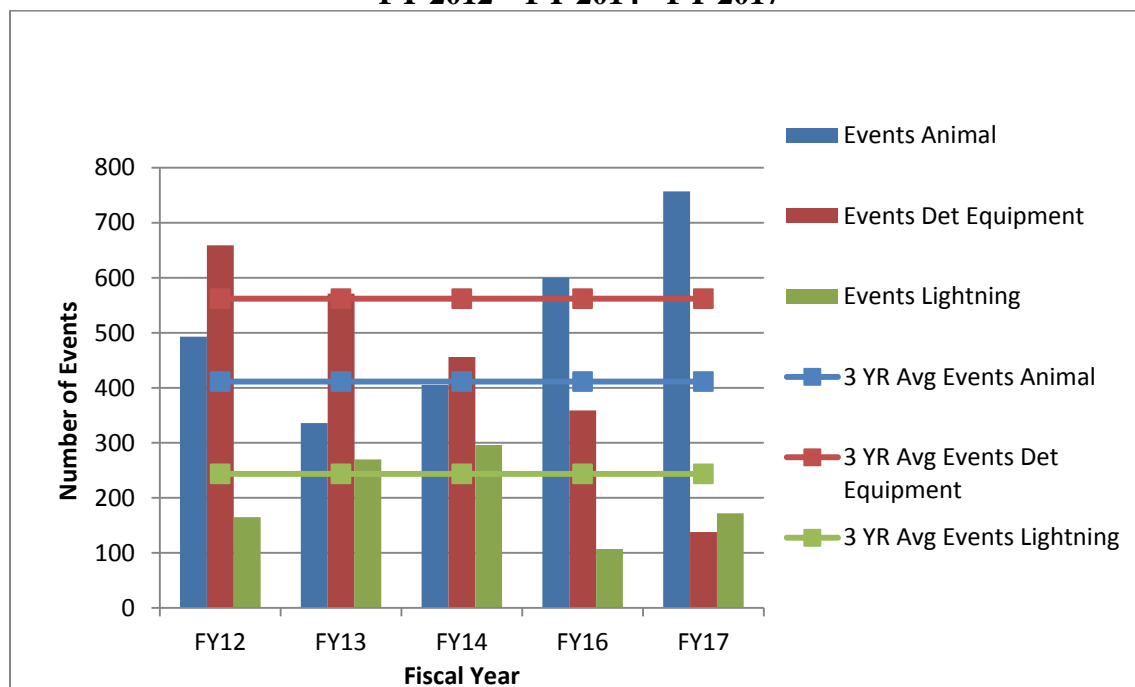
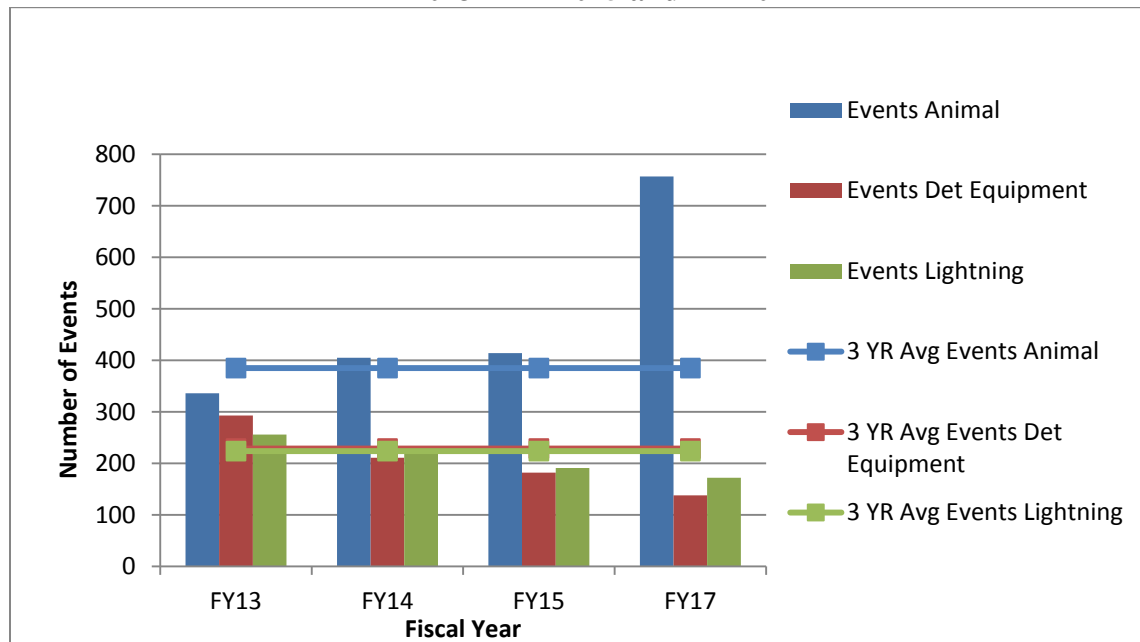


Chart 8 below shows the same information as Chart 4 above, but for all 375 RI feeders, not just for the fifteen feeders that had repairs completed in FY 2016.

**Chart 8 – Customer Interruption Events for all RI Feeders
FY 2013 – FY 2015 and FY 2017**



In summary, almost the same pattern is observed for all three incident-causing categories. Events caused by deteriorated equipment and lightning dropping significantly below the three year average after construction complete. Events caused by animals dropped for feeders where construction was completed in FY 2014 and FY 2015 for the first year after construction was complete. However, for events caused by animals for feeders where construction was completed in FY 2017, events increased, showing the same pattern as the charts showing the results for only the I&M feeders.

Lightning Strike Data

Updated lightning strike data was collected for the same periods as the reliability data. Table 1 below shows the total number of lightning strikes for the state of Rhode Island between FY 2010 and FY 2017. The total number of lightning strikes has little correlation to the number events experienced year to year. In FY 2015, there was a large drop in the number of lightning strikes, and subsequently a large drop in lightning related events in all RI feeders. However in FY 2016 and FY 2017, the number of lightning strikes returned to the levels seen in previous FY's, yet the number of lightning related events in all RI feeders only slightly increased.

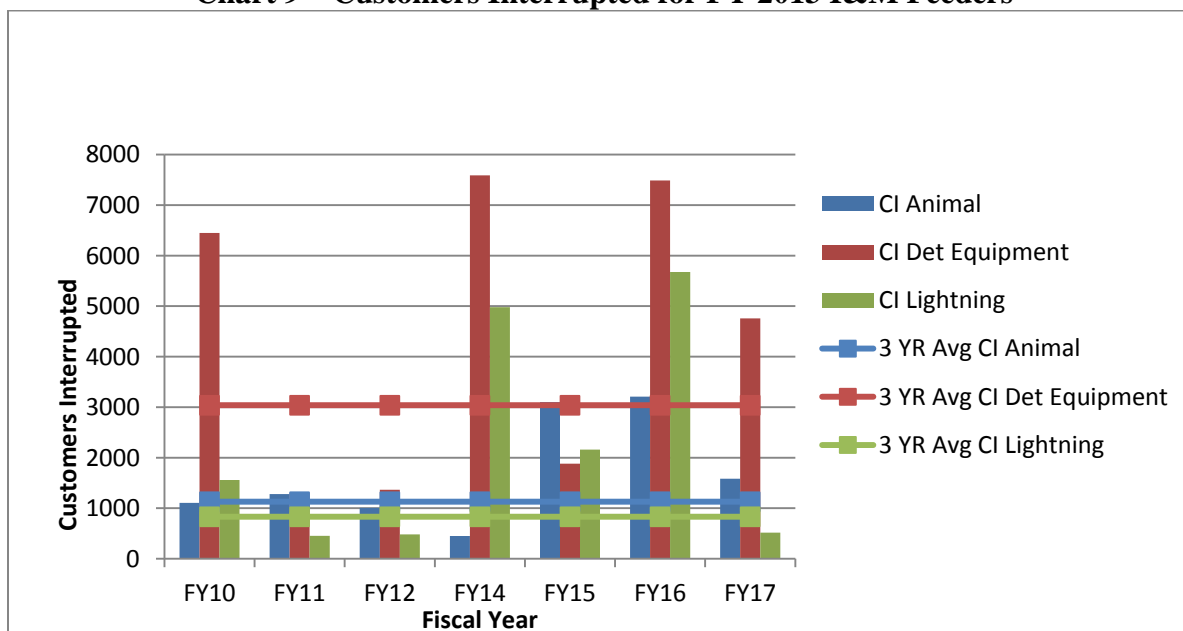
Table 1 – Number of Lightning Strikes Rhode Island³

FY	Number of Lightning Strikes
2010	5,075
2011	9,451
2012	2,900
2013	6,206
2014	7,304
2015	647
2016	7,135
2017	8,888

Customers Interrupted for FY 2013 through FY 2017 on I&M Feeders

In addition to looking at the total number of events caused by the three incident-causing categories (animals, lightning, and deteriorated equipment), the Company also looked at the total number of CI's for those categories. Chart 9 below shows the total number of CI's for the fifteen I&M feeders with construction completed in FY 2013.

Chart 9 – Customers Interrupted for FY 2013 I&M Feeders

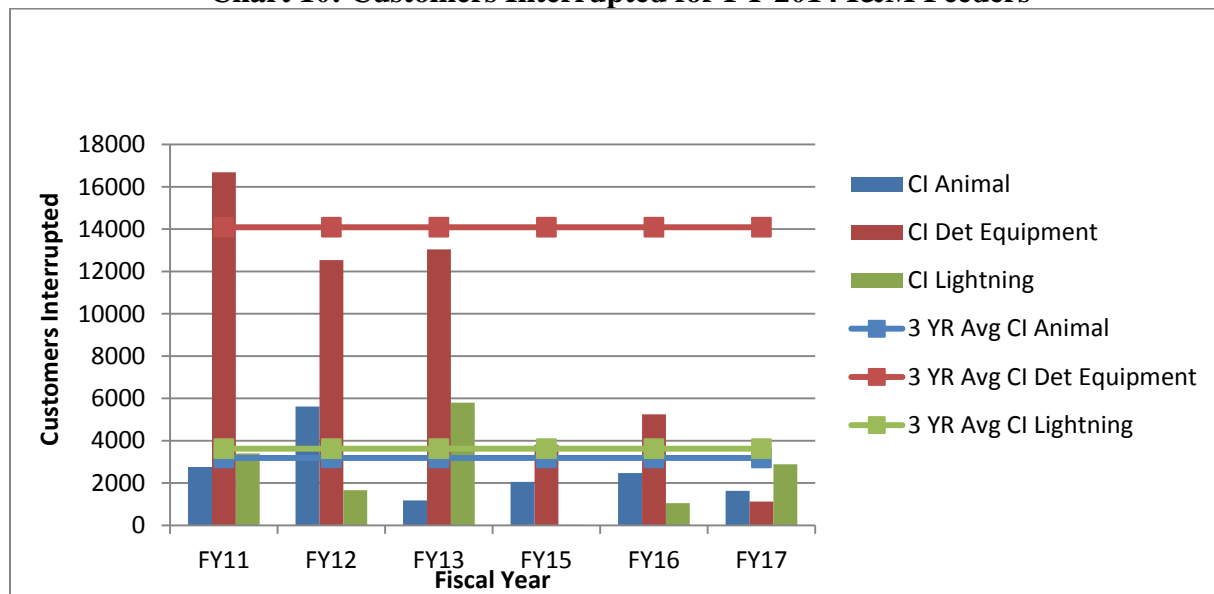


³ The historical data in Table 1 has been updated to reflect the improved processing of sensor data technology used by the Company's outside vendor to measure lightning strikes.

In FY 2015 (two years post construction), there was a significant reduction in the number of CI's related to lightning and deteriorated equipment. However CI's related to lightning were above the three year average. In FY 2016, the number of customer interruptions returned to the levels seen in FY 2014, with all three categories above their respective three year average. FY 2017 saw a significant decrease in CI's related to Animal contacts and Deteriorated Equipment, but are still above their three year average. CI's due to Lightning returned to levels we saw in FY 11 and FY12 below the three year average.

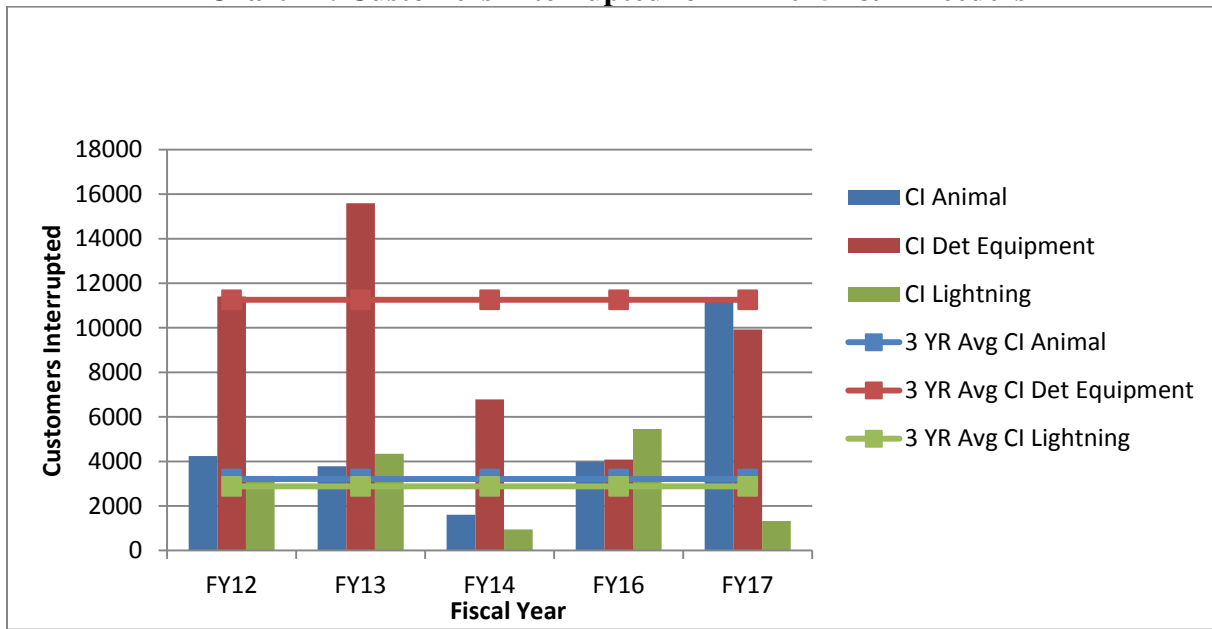
Chart 10 below shows the total number of CI's for the thirty-two I&M feeders with construction completed in FY 2014. Looking at the third year post construction (FY 2016), the I&M feeders with construction completed in FY 2013, had a total number of CI's that exceed their respective three year pre-construction average in all three incident-causing categories. This matched the results seen during the first year after construction complete (FY 2014). Through the six years of study there were a total of 572 events recorded for the three incident-causing categories.

Chart 10: Customers Interrupted for FY 2014 I&M Feeders



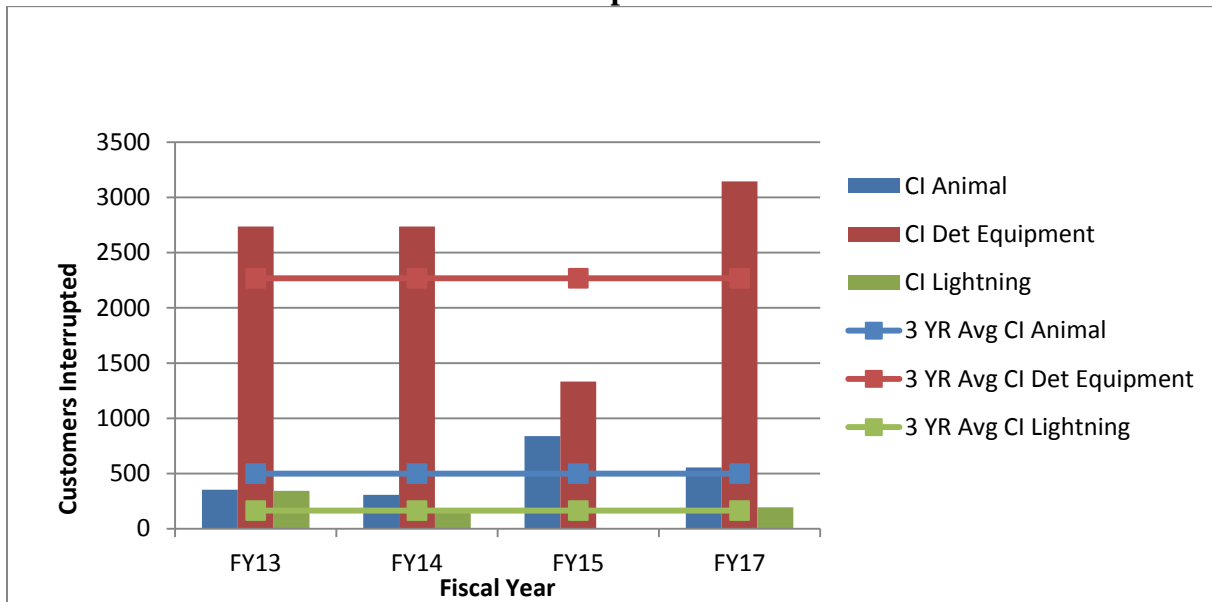
In FY 2015, FY 2016 and FY2017 (three subsequent years post construction), there was a significant reduction in the number of CI's related to all three incident-causing categories. During that time period, all three categories were below their respective three year averages. Chart 11 below shows the total number of CI's for the thirty-seven I&M feeders with construction completed in FY 2015.

Chart 11: Customers Interrupted for FY 2015 I&M Feeders



FY2017 saw a significant increase in animal CI due to 3 feeder lockouts of the 7F4 feeder. The increase in CI due to OH events was caused by 7 mainline on 7 different circuits triggered by high winds, failed switches, and failed insulators. Lightning CI did fall below the three year average. In FY 2016 (one year post completion), the results are mixed, with only CI's related to deteriorated equipment falling to below the three year average.

Chart 12 – Customers Interrupted for FY 2016 I&M Feeders



In FY2017, CI's due to lightning and animals hovered close to their three year average, while OH events CI jumped to well over the three year average.

The trends shown earlier in Chart 1, which show the total number of events, differ from the trends shown earlier in Chart 9, which show the total number of CI's. Chart 9 takes into account the number of CI's recorded in

each event. For example, an event such as a blown fuse would only interrupt a small number of customers on a particular street. If a feeder breaker were to operate at the substation, it would interrupt the entire feeder, causing several thousand customers to lose power. Table 2 below shows the total CI's for each individual feeder for the three incident-causing categories (animal, lightning, and deteriorated equipment) for feeders with construction completed in FY 2013. When comparing the averages before and after construction, eight feeders showed improvement in the number of CI's after the I&M work was completed, and seven feeders did not show any improvement.

Table 2: Customers Interrupted by Feeder for Feeders Construction Complete FY 2013

Feeder	Average Customers Served	CI FY 2010	CI FY 2011	CI FY 2012	Average CI FY 10-12	Standard Deviation		CI FY 2014	CI FY 2015	CI FY 2016	CI FY 2017	Average CI FY 14-17	Change CI	% Improvement
53-108W62	2078	15	124	12	50	64		17	106	0	81	51	-1	-1%
53-112W44	2319	46	479	787	437	372		238	107	97	2442	721	-284	-65%
53-18F6	2071	160	514	178	284	199		49	2107	2276	2368	1700	-1416	-499%
53-21F4	1841	88	169	89	115	46		1414	80	65	57	404	-289	-250%
53-23F1	1510	209	28	59	99	97		88	127	18	123	89	10	10%
53-38F2	508	36	0	9	15	19		24	0	0	42	17	-2	-10%
53-38F4	1722	408	216	141	255	138		118	84	13	179	99	157	61%
53-4F2	3021	3249	355	372	1325	1666		169	172	5305	523	1542	-217	-16%
53-5F2	2507	3048	119	222	1130	1662		246	62	5117	22	1362	-232	-21%
53-69F1	3497	87	328	160	192	124		2493	67	33	45	660	-468	-244%
53-7F1	2970	110	147	45	101	52		2979	1518	2768	54	1830	-1729	-1718%
56-3F1	2241	1083	70	119	424	571		54	54	320	61	122	302	71%
56-46F4	1643	220	108	129	152	60		59	12	44	354	117	35	23%
56-63F2	1379	185	73	191	150	66		8	4	5	93	28	122	82%
56-63F5	3616	167	304	339	270	91		5063	2642	311	216	2058	-1788	-662%
Total	32,923	9,111	3,034	2,852	4,999			13,019	7,142	16,372	10,798			

An operation of the feeder breaker at a substation, which interrupts the entire feeder, is referred to as a feeder lockout. For FY 2016, there were four feeder lockouts causing a large number of CI's. These four feeder lockouts account for 90% of all CI's for the fiscal year. Feeder 53-18F6 had a feeder lockout for a second year in a row, but in FY 2016 it was caused by a failed insulator on a 2227 line feeder constructed above the 53-18F6 feeder. This caused a phase of the 23kV line to make contact with the distribution feeder behind the station. Although the failed device is not on the I&M feeder, it's still considered for the purposes of this report. A second feeder lockout caused by deteriorated equipment was recorded on the 53-4F2. This was caused by a failed connector. In this outage, as with the previous event, the actual deteriorated equipment occurred on a second feeder that is not in the I&M feeder list. The 53-5F1 feeder was carrying the entire 53-4F2 load, due to an earlier problem on the station feed. In summary, this event caused both feeders to lockout, magnifying the effect of the outage and the total number of CI's for this event. Both deteriorated equipment events occurred on feeders not on the I&M construction complete list, but are included in this report because the customers still experienced the event. The third feeder lockout occurred on the 53-7F1 feeder. This was caused by an animal contact on a distribution transformer on the feeder. The last feeder lockout was on the 53-5F2 feeder caused by a lightning strike, causing a phase to fall on a second underbuilt feeder. The 53-5F2 feeder locked out after the initial contact, and the second feeder had to be de-energized to conduct repairs, which increased the total number of CI's for this event.

Table 3 below shows the total CI's for each individual feeder for the three incident-causing categories (animal, lightning, and deteriorated equipment) for feeders with construction completed in FY 2014. Comparing the three year averages before construction to the FY 2015 through FY 2016 results, resulted in twenty-seven

feeders showing improvement in the number of CI's after the I&M work was completed. Four feeders did not show an improvement, and one feeder had no data.

Table 3: Customers Interrupted by Feeder for Feeders Construction Complete FY 2014

Feeder	Average Customers Served	CI FY 2011	CI FY 2012	CI FY 2013	Average CI FY 11-13	Standard Deviation		CI FY 2015	CI FY 2016	CI FY 2017	Average CI FY 15-17	Change CI	% Improvement
53-104J5	748	0	0	749	250	432		0	0	0	0	250	100%
53-104J7	1136	0	1495	1182	892	788		50	0	0	17	876	98%
53-108W61	2627	58	3282	361	1234	1780		155	41	11	69	1165	94%
53-112W42	2838	92	364	45	167	172		3308	3049	239	2199	-2032	-1217%
53-112W43	949	1091	979	98	723	544		685	1796	133	871	-149	-21%
53-126W50	1479	282	18	768	356	380		38	1529	954	840	-484	-136%
53-13F5	3169	434	268	463	388	105		0	84	159	81	307	79%
53-17W42	596	0	0	0	0	0		0	0	0	0	0	0%
53-18F7	2735	338	2935	3210	2161	1585		83	68	48	66	2095	97%
53-20F2	1970	8	196	272	159	136		131	0	10	47	112	70%
53-23F4	205	0	26	76	34	39		16	10	0	9	25	75%
53-27F4	542	0	9	0	3	5		0	0	0	0	3	100%
53-27F6	3486	0	1032	0	344	596		0	0	56	19	325	95%
53-36J2	661	0	47	669	239	373		0	0	0	0	239	100%
53-38F5	2488	216	43	2659	973	1463		23	148	116	96	877	90%
53-38F6	2680	72	49	181	101	71		67	179	89	112	-11	-11%
53-48F1	3381	2180	171	50	800	1196		122	72	884	359	441	55%
53-48F3	3394	3449	0	2731	2060	1820		75	122	81	93	1967	96%
53-5F4	3236	4688	185	263	1712	2578		43	248	64	118	1594	93%
53-76F1	1965	78	33	83	65	28		67	26	10	34	30	47%
53-76F4	4524	190	239	138	189	51		95	203	75	124	65	34%
53-78F3	1282	2149	70	28	749	1213		0	0	54	18	731	98%
53-79F2	2276	112	192	81	128	57		43	130	36	70	59	46%
53-9J1	920	0	0	37	12	21		0	0	194	65	-52	-424%
56-17F1	2785	344	156	5100	1867	2802		226	335	243	268	1599	86%
56-22F4	2343	261	424	161	282	133		142	280	196	206	76	27%
56-29F1	2967	3323	311	56	1230	1817		237	76	184	166	1064	87%
56-43F1	2253	235	811	79	375	386		22	181	121	108	267	71%
56-52F2	1702	19	2628	49	899	1498		94	33	33	53	845	94%
56-59F3	2753	1187	1413	172	924	661		124	114	491	243	681	74%
56-72F4	2590	230	2175	81	829	1168		8	21	526	185	644	78%
56-72F6	1757	1811	271	177	753	917		41	17	633	230	523	69%
Grand Total	68,437	22,847	19,822	20,019	20,896			5,895	8,762		6,766		

For the feeders shown in Table 3, from FY 2011 to FY 2013, and FY 2015 to FY 2017 there were a total of 877 events recorded for the three incident-causing categories. I&M Cost and Benefit Analysis Report for 2016 documented every major outage event recorded on these feeders before construction was completed in FY 2014, which included ten feeder lockouts, and nine pole top recloser operations for all three incident-causing categories. For FY 2015 (first year after construction completion), there was only one feeder lockout for deteriorated equipment. For FY 2016 (two years after construction completion), there were three feeder lockouts recorded, one for an animal contact and two for deteriorated equipment. The feeder lockout on the 53-112W43 was caused by an animal contact on the line side of a distribution pole top recloser on the feeder, cascading to the station breaker. Feeder lockouts on the 53-126W50 and 53-112W42 were caused by a failed lightning arrester and a failed insulator respectively. These three feeders that experienced feeder lockouts are the feeders with the least improvement after construction complete because of these large outage events. However, even with the three feeder lockouts, CI number for all three incident-causing categories in FY 2016 were well below the pre-construction three year averages due to the poor reliability numbers all 32 feeders experienced before the inspection and repairs were completed through the I&M Program. Most notable, fifteen feeders saw an over 90% improvement in their CI numbers. For FY2017 (three years post construction

complete), there were no feeder lockouts and only one recloser lockout due to an OH event. Twenty-six (26) of the 32 feeders showed improved reliability, while 5 feeders took a step backwards. One feeder did not change.

Table 4 below shows the total CI's for each individual feeder for the three incident-causing categories (animal, lightning, and deteriorated equipment) for feeders with construction completed in FY 2015. Comparing the three year averages before construction to the FY 2016 results, shows that twenty-eight feeders experienced an improvement in the number of CI's after the I&M work was completed. In addition, five feeders did not show any improvement, and four feeders had no data.

Table 4: Customers Interrupted by Feeder for Feeders Construction Complete FY 2015

Feeder	Average Customers Served	CI FY 2012	CI FY 2013	CI FY 2014	Average CI FY 11-14	Standard Deviation		CI FY 2016	CI FY 2017	Average CI FY 16-17	Change CI	% Improvement
53-102W54	2285	556	296	850	567	277		138	2407	1273	-705	-124%
53-107W60	353	3335	130	0	1155	1889		0	0	0	1155	100%
53-107W61	997	39	240	34	104	118		0	138	69	35	34%
53-112W41	2348	2674	1964	104	1581	1327		40	2073	1057	524	33%
53-12J1	357	37	0	0	12	21		0	1606	803	-791	-6411%
53-12J4	1091	0	21	0	7	12		0	0	0	7	100%
53-13F3	1549	31	160	55	82	69		0	3	2	81	98%
53-18F9	2956	208	28	50	95	98		227	0	114	-18	-19%
53-28J2	1110	0	53	0	18	31		0	0	0	18	100%
53-34F2	2494	975	1822	424	1074	704		0	514	257	817	76%
53-37J3	837	11	80	22	38	37		0	44	22	16	42%
53-38F1	2999	1515	330	206	684	723		296	1142	719	-35	-5%
53-47J3	755	1637	39	0	559	934		0	0	0	559	100%
53-51F3	2128	0	295	25	107	164		17	2463	1240	-1133	-1063%
53-5F3	2410	128	144	228	167	54		5105	120	2613	-2446	-1468%
53-71J4	569	0	42	563	202	314		0	90	45	157	78%
53-71J5	1282	0	40	1354	465	770		0	0	0	465	100%
53-73J3	294	24	0	0	8	14		0	0	0	8	100%
53-76F2	3192	209	319	120	216	100		192	2	97	119	55%
53-76F6	2325	133	1162	37	444	624		101	95	98	346	78%
53-76F7	3068	48	3472	150	1223	1948		0	36	18	1205	99%
53-7F2	3197	153	2449	2759	1787	1424		20	0	10	1777	99%
53-7F4	2656	2810	2977	225	2004	1543		2709	8136	5423	-3419	-171%
56-16F3	2096	115	2637	43	932	1477		21	80	51	881	95%
56-17F2	2841	559	523	141	408	232		439	121	280	128	31%
56-22F3	2335	102	97	230	143	75		131	969	550	-407	-285%
56-33F1	2634	390	91	106	196	168		2800	185	1493	-1297	-663%
56-49J1	624	0	0	14	5	8		13	0	7	-2	-39%
56-54F1	3044	1217	570	435	741	418		141	168	155	586	79%
56-59F2	2503	184	83	157	141	52		40	208	124	17	12%
56-59F4	1074	34	266	72	124	124		11	0	6	119	96%
56-68F1	2508	1779	2727	97	1534	1332		67	1904	986	549	36%
56-85T1	784	94	653	829	525	384		785	25	405	120	23%
Grand Total	61,695	18,997	23,710	9,330	17,346			13,293	22529	17911	-565	

For the feeders shown in Table 4, from FY 2012 to FY 2014, and FY 2016 – FY2017, there were a total of 840 events recorded for the three incident-causing categories. For the three years prior to construction, there were twenty-one major events causing a feeder lockout or a main device to operate. Analyzing the results by fiscal year, FY 2012 saw the majority of the events with large customer outages, with four feeder lockouts and five pole top recloser operations. Feeder lockouts occurred on feeder's 53-47J3, 53-112W41 and 53-107W60 for deteriorated equipment, a broken crossarm, a failed insulator, and a broken tap respectively. On feeder 53-7F4

there was an event caused by a squirrel that resulted in a feeder lockout. Feeder 56-68F1 had two pole top recloser events in FY 2012, one for lightning and one for deteriorated equipment for a failed phase tap. Feeder 53-34F2 had a pole top recloser event related to deteriorated equipment for a broken crossarm. The last two pole top recloser operations were lightning events on the 56-54F1 and 53-38F1 feeders. Looking into FY 2013, there were four feeder lockouts and four pole top recloser operations for all three incident-causing categories. Feeder lockouts occurred on the 53-112W41, 56-16F3 and 56-68F1 for deteriorated equipment, catastrophic failure of a pole top recloser due to flashed over arresters, a failed insulator and pole top fire respectively. The last feeder lockout was on the 53-7F4 from an animal caused event where a squirrel made contact with a pole top recloser. Pole top recloser events were recorded on the 53-34F2 and 53-7F2 caused by lightning events, and on the 53-34F2 and 53-76F7 caused by deteriorated equipment for a pole top fire and failed tap respectively. For FY 2014, all four events (three feeder lockouts and a pole top recloser) were caused by deteriorated equipment. Feeder lockouts on the 53-71J4, 56-85T1, and 53-71J5 occurred from a failed cutout, phase off insulator, and guy wire failure respectively. Feeder 53-7F2 experienced the pole top recloser event for a failed insulator. In summary, for the years prior to I&M construction complete, there were twenty-one major outage events on fourteen feeders on the list, where a majority were caused by deteriorated equipment. Twelve of the fourteen feeders that had major outages saw major improvements in their performance following I&M Program construction, averaging over a 73% reduction in the number of CI's, and overall five feeders had no events in its first year after repairs were completed. For FY 2016, the first year after repairs were completed there were 4 feeder lockouts. Two of the events came from feeders that also had feeder lockouts before construction complete, and account for the two feeders that saw no improvement, the 56-85T1 which had a deteriorated equipment event from a failed dead-end insulator, and the 53-7F4 which had an animal caused event from a squirrel contact on the line side of a pole top recloser. Feeder 56-33F1 had the second deteriorated equipment event from a failed primary tap, and the 53-5F3 had the last event from a lightning event. For FY 2017, the second year post construction complete, 23 feeders saw improved reliability, and 10 feeders saw a reduction. Circuits 7F4, 51F3, 102W54, and 112W431 locked out. Reclosers on the 28J2 and the 22F3 locked out. Animal events exceeded the three year average, while deteriorated equipment and lightning outage were below the 3 year average. In summary, evaluation of data for the FY 2016 and FY 2017 events shows mixed results. Some circuits showed a big jump in improved reliability while others performance dropped significantly.

Table 5: Customers Interrupted by Feeder for Feeders Construction Complete FY 2016

Feeder	Average Customers Served	CI FY 2013	CI FY 2014	CI FY 2015	Average CI FY 13-15	Standard Deviation		CI FY 2017	Change CI	% Improvement
53-107W62	1198	71	0	1167	413	654		24	389	94%
53-107W80	2013	1974	1974	242	1397	1000		2820	-1423	-102%
53-107W81	786	2	2	0	1	1		0	1	100%
53-107W83	1430	76	76	7	53	40		13	40	75%
53-126W54	739	6	6	11	8	3		42	-34	-448%
53-148J7	74	3	3	0	2	2		0	2	100%
53-15F1	2583	32	28	45	35	9		71	-36	-103%
53-48F2	596	550	561	0	370	321		0	370	100%
53-48F6	1787	128	14	77	73	57		131	-58	-79%
53-5F1	309	179	284	148	204	71		49	155	76%
56-14F3	1634	26	39	3	23	18		132	-109	-482%
56-17F3	2086	99	25	95	73	42		44	29	40%
56-33F2	343	13	114	310	146	151		119	27	18%
56-36W43	298	274	65	65	135	121		29	106	78%
Grand Totals	15876	3433	3191	2170	2931.333			3474	-542.67	

For the feeders shown previously in Table 5, from FY 2013 to FY 2015, and FY2017, there were a total of 186 events recorded for the three incident-causing categories. In FY2017 there were 40 events. The 126W54 and 107W80 locked out. There were 30 animal events, 13 fused branch and 17 transformer events. Eight events occurred on OH equipment deterioration, 2 main line, 2 fused branch, and 4 transformer events. Five events were attributed to lightning: 3 fused branches and 2 transformers.

Customers Interrupted for FY 2013 through FY 2017 on all RI Feeders

Chart 13 below shows the same information as Chart 9, but for all 375 RI feeders, not just for the 15 feeders that had repairs completed in FY 2013. In FY 2015 and FY 2016, CI's caused by animals were above the three year pre-construction average. CI's caused by lightning and deteriorated equipment were below the three year pre-construction average for all feeders in all years after construction was completed. However, this is in contrast to the performance of the I&M feeders which had lightning caused interruptions above the three year average in all three years, and deteriorated equipment events above the pre-construction average in FY 2014 and FY 2016.

**Chart 13 – Customers Interrupted for all RI Feeders
FY 2010 – FY 2012 and FY 2014 – FY 2016**

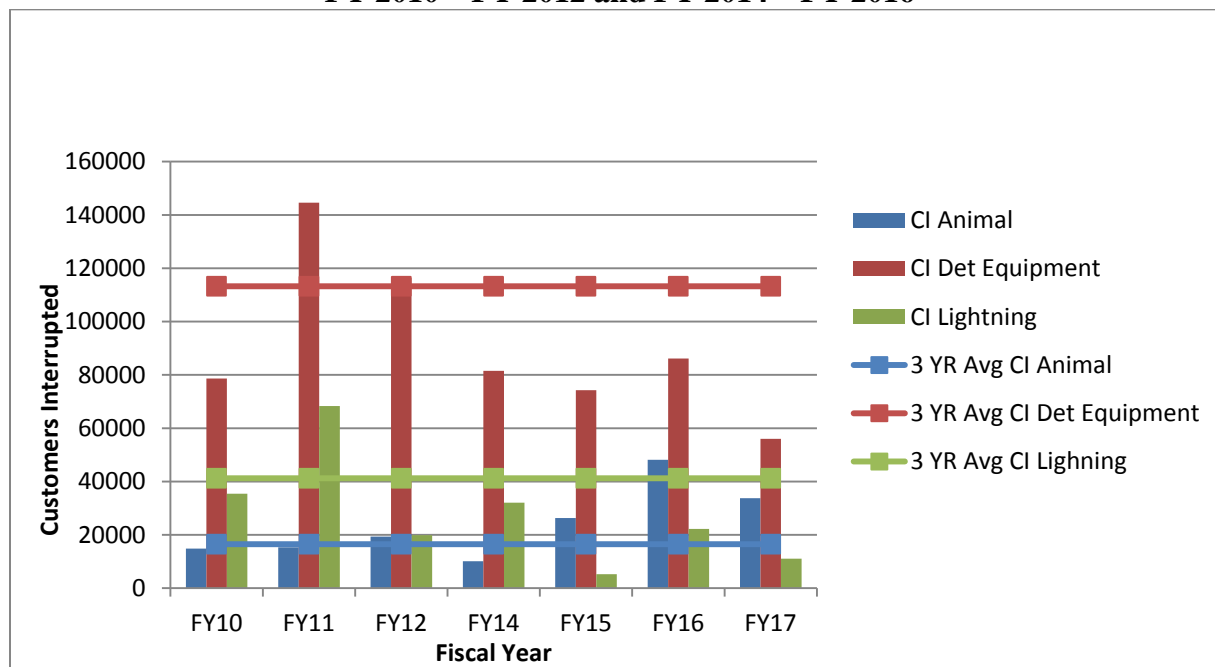


Chart 14 below shows the same information as Chart 10, but for all 375 RI feeders, not just for the thirty-two feeders that had repairs completed in FY 2014. CI's caused by lightning and deteriorated equipment were below the three year pre-construction average in FY 2015 and FY 2016. CI's caused by animals were above the three year pre-construction average for both years. However, this is in contrast to the performance of the I&M feeders which had animal caused interruptions below the three year pre-construction average. In summary, for all RI feeders, CI's were below the average for deteriorated equipment and lightning caused events.

**Chart 14 – Customers Interrupted for all RI Feeders
FY 2011 – 2013 and FY 2015 – FY 2017**

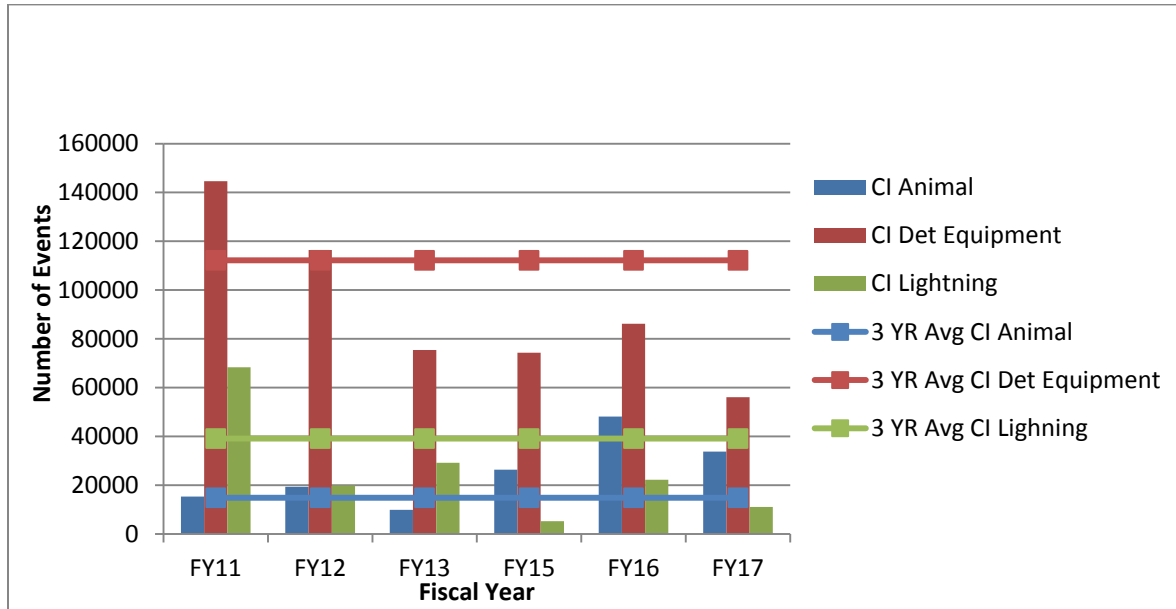


Chart 15 below shows the same information as Chart 11, but for all 375 RI feeders, not just for the thirty-seven (37) feeders that had repairs completed in FY 2015. For the first year after repairs complete, lightning and deteriorated equipment were below the three year pre-construction average, which was in contrast to the I&M feeders where only deteriorated equipment fell below the three year pre-construction average. CI's caused by animals were above the three year pre-construction average, which was the same as the performance of the I&M feeders. The biggest difference, when comparing I&M feeders to all RI feeders, was that deteriorated equipment events for the I&M feeders for FY 2016 were greatly reduced. In FY 2017 lightning and deteriorated equipment CI was over or closer to the three year average as compared to all RI feeders.

**Chart 15 – Customers Interrupted for all RI Feeders
FY 2012 – 2014 and FY 2016 -2017**

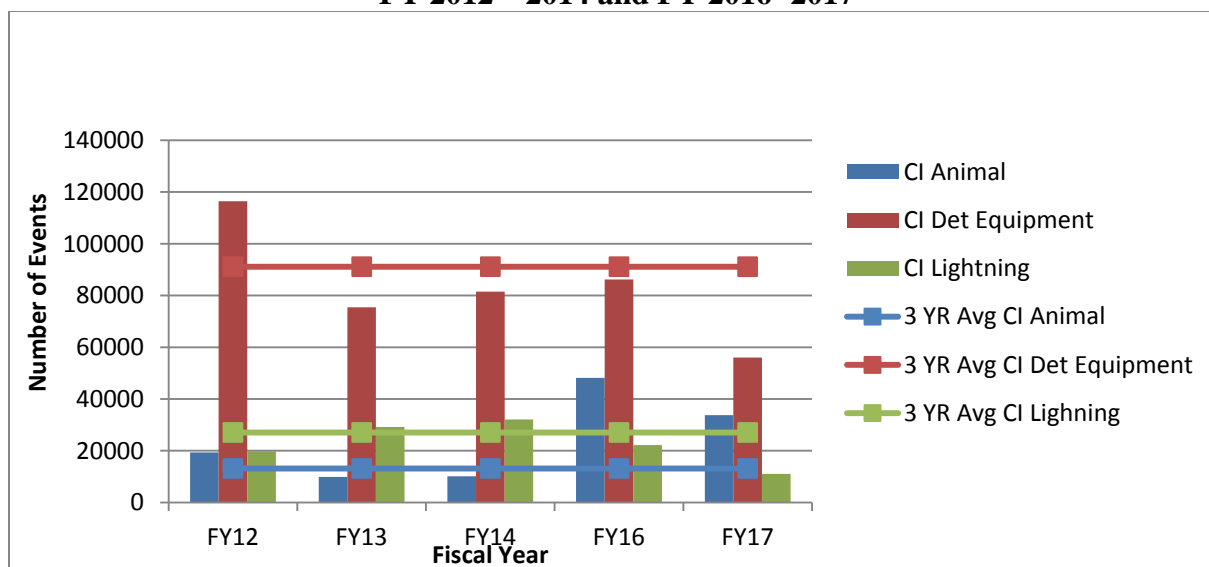
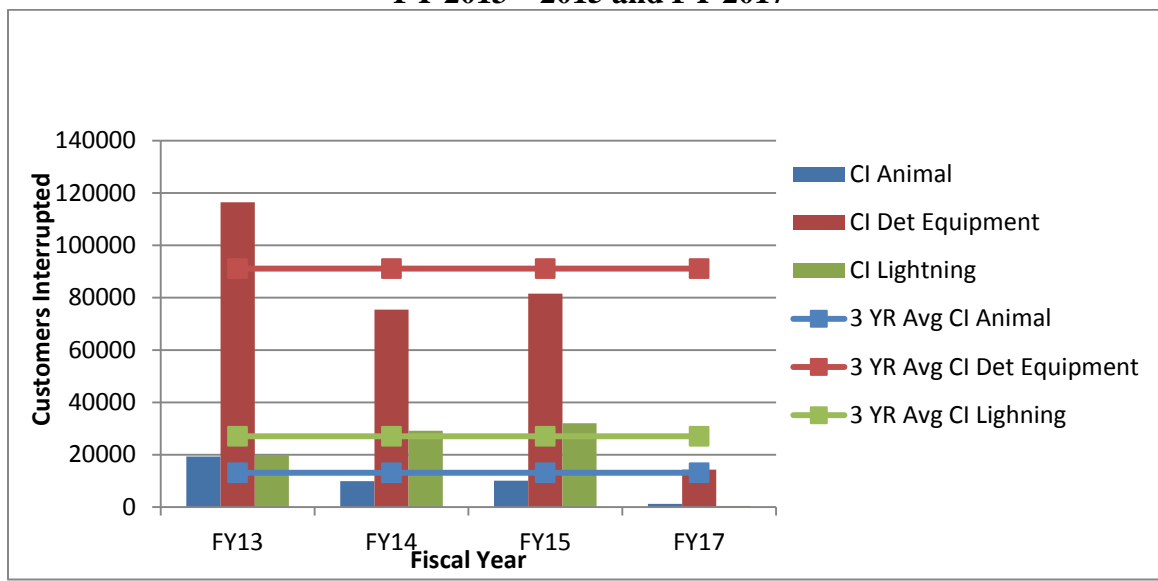


Chart 16 below shows the same information as Chart 12, but for all 375 RI feeders, not just for the fifteen feeders that had repairs completed in FY 2016.

**Chart 16 – Customers Interrupted for all RI Feeders
FY 2013 – 2015 and FY 2017**



I&M Feeder vs. All RI Feeders Performance

Table 3 below shows the performance of feeders in the I&M Program compared to all RI feeders. For I&M feeders where construction was completed in FY 2013, there was actually an average increase in the number of CI's post-project completion, compared to a decrease in the number of CI's post project for all RI Feeders. However, there was a significant reduction in CI's for I&M feeders where construction was completed in FY 2014 and FY 2015. This percent improvement was greater than all the RI feeders for the same FY period.

Table 6 – I&M Feeders vs. All RI Feeders Performance

	Average Annual CI Pre-Project	Average Annual CI Post-Project	% Improvement
	FY 2010-2012	FY 2014-2016	
I&M Feeders FY 2013	4,999	12,178	-144%
All RI Feeders	170,947	128,693	25%
	FY 2011-2013	FY 2015-2017	
I&M Feeders FY 2014	20,896	7,329	65%
All RI Feeders	166,142	122,229	26%
	FY 2012-2014	FY 2016-FY2017	
I&M Feeders FY 2015	17,346	13,522	22%
All RI Feeders	131,286	130,424	1%
	FY 2013-2015	FY2017	
I&M Feeders FY 2016	2,931	3474	-19%
All RI Feeders	103,088	100,831	2%

I&M Program Cost Analysis

Work resulting from the I&M Program is packaged and constructed by feeder. Tables 6, 7, and 8 below show repair costs by feeder, the change in average CI, and the resulting cost per CI, for FY 2013, FY 2014, and FY 2015. These costs include the total capital, removal, and expense related costs for repairs performed on each feeder. These costs do not include any emergency repairs (Level 1) which may have been made immediately after the inspection, as these are captured under the Damage/Failure category, not in the I&M Program. Also, these costs do not include the costs for the inspections themselves.

Table 7 – FY 2013 I&M Feeder Construction Cost per Feeder

Feeder	I&M Repair Cost	Change Average CI	\$/Change CI
53-108W62	\$252,579.85	9	\$27,062.13
53-112W44	\$180,949.31	290	\$623.96
53-18F6	\$160,633.53	-1193	(\$134.61)
53-21F4	\$117,493.11	-404	(\$290.58)
53-23F1	\$31,334.04	21	\$1,492.10
53-38F2	\$38,379.69	7	\$5,482.81
53-38F4	\$115,734.34	183	\$631.28
53-4F2	\$188,151.37	-557	(\$338.00)
53-5F2	\$37,665.47	-679	(\$55.50)
53-69F1	\$436,186.41	-673	(\$648.44)
53-7F1	\$252,878.96	-2321	(\$108.95)
56-3F1	\$1,270,320.24	281	\$4,515.36
56-46F4	\$47,205.72	114	\$414.09
56-63F2	\$138,965.80	144	\$965.04
56-63F5	\$142,915.98	-2402	(\$59.50)
Total	\$3,411,393.82		

Table 8 – FY 2014 I&M Feeder Construction Cost per Feeder

Feeder	I&M Repair Cost	Change Average CI	\$/Change CI
53-104J5	\$644,854.24	250	\$2,582.86
53-104J7	\$35,874.25	867	\$41.36
53-108W61	\$177,140.44	1136	\$155.98
53-112W42	\$259,504.14	-3012	(\$86.17)
53-112W43	\$140,960.98	-518	(\$272.21)
53-126W50	\$271,483.09	-428	(\$635.05)
53-13F5	\$205,431.50	346	\$593.16
53-17W42	\$144,674.95	0	NA
53-18F7	\$295,530.81	2086	\$141.71
53-20F2	\$262,811.29	93	\$2,820.87
53-23F4	\$15,660.24	21	\$745.73
53-27F4	\$157,830.38	3	\$52,610.13
53-27F6	\$307,354.52	344	\$893.47
53-36J2	\$100,967.38	239	\$423.05
53-38F5	\$304,215.06	887	\$342.91
53-38F6	\$195,851.56	-22	(\$8,769.47)
53-48F1	\$371,309.15	703	\$527.93
53-48F3	\$439,482.84	1962	\$224.05
53-5F4	\$439,672.03	1567	\$280.67
53-76F1	\$231,219.72	18	\$12,727.69
53-76F4	\$571,436.16	40	\$14,285.90
53-78F3	\$146,768.85	749	\$195.95
53-79F2	\$134,841.83	42	\$3,223.31
53-9J1	\$141,079.38	12	\$11,438.87
56-17F1	\$328,721.57	1586	\$207.24
56-22F4	\$228,176.67	71	\$3,213.76
56-29F1	\$52,846.99	1074	\$49.23
56-43F1	\$179,601.20	274	\$656.68
56-52F2	\$456,348.73	835	\$546.42
56-59F3	\$291,126.89	805	\$361.65
56-72F4	\$626,908.66	814	\$770.00
56-72F6	\$224,692.95	724	\$310.35
Total	\$8,384,378.45		

Table 9 – FY 2015 I&M Feeder Construction Cost per Feeder

Feeder	I&M Repair Cost	Change Average CI	\$/Change CI
53-102W40	\$0.00	0	NA
53-102W54	\$287,097.00	429	\$668.70
53-107W60	\$68,430.00	1155	\$59.25
53-107W61	\$181,116.00	104	\$1,735.94
53-112W41	\$162,044.00	1541	\$105.18
53-12J1	\$31,342.00	12	\$2,541.24
53-12J4	\$95,838.00	7	\$13,691.14
53-13F3	\$254,436.00	82	\$3,102.88
53-18F9	\$141,092.00	-132	(\$1,071.58)
53-27F3	\$50,424.00	0	NA
53-28J2	\$62,116.00	18	\$3,516.00
53-34F2	\$265,858.00	845	\$314.75
53-37J2	\$91,699.00	0	NA
53-37J3	\$197,803.00	38	\$5,251.41
53-38F1	\$276,442.00	388	\$713.09
53-47J3	\$65,046.00	559	\$116.43
53-51F3	\$346,632.00	90	\$3,865.78
53-5F3	\$265,033.00	-4938	(\$53.67)
53-71J3	\$0.00	0	NA
53-71J4	\$84,071.00	202	\$416.88
53-71J5	\$116,208.00	465	\$250.09
53-73J3	\$109,212.00	8	\$13,651.50
53-76F2	\$435,324.00	24	\$18,138.50
53-76F6	\$508,933.00	343	\$1,483.77
53-76F7	\$385,408.00	1223	\$315.05
53-7F2	\$0.00	1767	\$0.00
53-7F4	\$483,104.00	-705	(\$685.25)
56-16F3	\$236,853.00	911	\$260.09
56-17F2	\$193,733.00	-31	(\$6,182.97)
56-22F3	\$266,567.00	12	\$22,213.92
56-33F1	\$309.00	-2604	(\$0.12)
56-49J1	\$141,624.00	-8	(\$16,994.88)
56-54F1	\$460,637.00	600	\$768.16
56-59F2	\$328,892.00	101	\$3,245.64
56-59F4	\$108,390.00	113	\$959.20
56-68F1	\$457,169.00	1467	\$311.56
56-85T1	\$423,755.00	-260	(\$1,631.92)
Total	\$7,582,637.00		

Table 10 FY2016 I&M Feeder Construction Cost per feeder

Feeder	I&M Repair Cost	Change Average CI	\$/Change CI
53-107W62	\$326,763.91	389	\$840.01
53-107W80	\$204,868.63	-1423	(\$143.97)
53-107W81	\$163,606.89	1	\$163,606.89
53-107W83	\$347,854.91	40	\$8,696.37
53-126W54	\$72,863.90	-34	(\$2,143.06)
53-148J7	\$193,914.04	2	\$96,957.02
53-15F1	\$722,827.88	-36	-\$20,078.55
53-48F2	\$123,722.37	370	\$334.38
53-48F6	\$148,662.71	-58	(\$2,563.15)
53-5F1	\$404,514.86	155	\$2,609.77
56-14F3	\$173,662.47	-109	(\$1,593.23)
56-17F3	\$308,956.74	29	\$10,653.68
56-33F2	\$552,417.87	27	\$20,459.92
56-36W43	\$325,268.87	106	\$3,068.57
Total	\$4,069,906.05		

Conclusion

The main objective of the I&M Program is to provide a systematic inspection of the overhead system for safety and environmental reasons. The replacement of assets prior to failure provides incremental employee and public safety benefits and avoidance of potential environmental problems related to some assets. This program satisfies section 214 of the National Electric Safety Code (NESC), which outlines the inspection of equipment guidelines for electric utilities. The fourth annual review of the Cost Benefits of the I&M Program showed mixed customer reliability results for the three fiscal year feeder groups with at least one year of post-project data.

For the feeders completed in FY 2013, and as stated in a previous report, the majority of the feeders had good performance during the FY 2010 to FY 2012 time frame, with relatively low customers interrupted, and therefore any subsequent feeder lockouts can, and have shown, to have a significant impact on the final reliability results. When looking at outage events, the first year post construction showed a majority of the incident-causing categories to be below the three year pre-construction average, but with an increasing trend over time. When looking at the total number of CI's, all three incident-causing categories were above their three year pre-construction average, which were caused primarily by four feeder lockouts. While there have been less outage events each FY, the number of customers being affected by those outages has increased.

For the feeders completed in FY 2014, with the exception of events caused by animals, deteriorated equipment and lightning events decreased to below their three year pre-construction average. Also, the average CI's for all three incident-causing categories decreased below their three year pre-project averages. Unlike the feeders completed in FY 2013, the results for feeders where construction was completed in FY 2014 are more in line with what the Company expects for the costs and resources needed for this program. The biggest difference between these two FY's are the effect of major outage events in the years after construction is complete. For

example, the thirty-two (32) feeders that were completed in FY 2014 had only four major interruptions, compared to the fifteen feeders that were completed in FY 2015 that had eleven major interruptions.

For the feeders completed in FY 2015, the first and second years post-project completion show mixed results, with events caused by animals above the three year pre-project average, but deteriorated equipment and lightning events are below their three year pre-project averages, but did increase in FY2017. Likewise, CI's for deteriorated equipment decreased below the three year pre-project averages.

For the feeders completed in FY2016, the first year post construction has mixed results with increases in CI for animal and deteriorated equipment. Animal events were over the three year average in FY2017.

Although all data contained in this report shows a positive trend for reliability in FY 2015 and FY 2016. In FY 2017, OH and lightning events are similar to FY 2016. FY 2017 showed an increase in animal events on both I&M and all RI feeders. Furthermore, additional years of data will need to be collected prior to coming to any conclusions on the ultimate reliability benefits of the I&M Program. Although we have four years of data for the first set of I&M feeders, it is still a small sample size compared to the 375 feeders we have in the entire state of RI. Therefore, more time and feeders are needed to show any conclusive results.