KEEGAN WERLIN LLP

ATTORNEYS AT LAW
99 HIGH STREET, SUITE 2900
BOSTON, MASSACHUSETTS 02110

(617) 951-1400

TELECOPIER:
(617) 951-1354

June 30, 2020

Mark D. Marini, Secretary
Department of Public Utilities
One South Station, 5th Floor
Boston, MA 02110

Re: Petition(s) of Massachusetts Electric Company and Nantucket Electric Company, d/b/a National Grid (D.P.U. 15-120), Fitchburg Gas and Electric Light Company d/b/a Unitil (D.P.U. 15-121), and NSTAR Electric Company d/b/a Eversource Energy (D.P.U. 15-122) for Approval by the Department of Public Utilities of its Grid Modernization Plan(s)

Dear Secretary Marini:

On behalf of Massachusetts Electric Company and Nantucket Electric Company, d/b/a National Grid, Fitchburg Gas and Electric Light Company d/b/a Unitil, and NSTAR Electric Company d/b/a Eversource Energy (collectively, the "EDCs"), enclosed please find the Advanced Distribution Automation Performance Metrics Addendum and the Monitoring and Control Automation Performance Metrics Addendum prepared by Guidehouse Inc., the Grid Modernization evaluation consultant, on behalf of the EDCs in the above-referenced proceedings.

Thank you for your attention to this matter. Please contact me with any questions.

Sincerely,

Danielle C. Winter, Esq.

Enclosures

cc: Tina Chin, Hearing Officer
Daniel Licata, Hearing Officer
Greggory Wade, Hearing Officer
D.P.U. 15-120, 15-121, and 15-122 Service Lists

Massachusetts Electric Distribution Companies

Massachusetts Grid Modernization Program Year 2019 Evaluation Report

ADA Performance Metrics Addendum

June 30, 2020

Table of Contents

Disclaimer

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1. Introduction

This Advanced Distribution Automation (ADA) Performance Metrics Addendum provides evaluation of the specific performance metrics pertinent to this Grid Modernization Investment Area. The Addendum is being provided subsequent to the main 2019 evaluation report, the "Massachusetts Grid Modernization Program Year 2019 Evaluation Report" (the PY 19 Evaluation Report) document to accommodate the availability of reliability metrics data that was required to perform the analysis.

The remainder of the Introduction Section provides background on the overall Grid Modernization Evaluation requirements and timing. This background is provided here for convenience, so the reader does not have to refer to other documents, for example the PY 19 Evaluation Report, to understand the context for this Addendum.

1.1 Massachusetts Grid Modernization Background

On May 10, 2018, the Massachusetts Department of Public Utilities (DPU) issued its Order[1] regarding the individual Grid Modernization Plans (GMPs) filed by the three Massachusetts electric distribution companies (EDCs): Eversource, National Grid, and Unitil.[2,3] In the Order, the DPU preauthorized grid-facing investments over 3 years (2018-2020) for each EDC and adopted a 3-year (2018-2020) regulatory review construct for preauthorization of grid modernization investments. These preauthorized GMP investments will advance the achievement of DPU's grid modernization objectives:

1. Optimize system performance by attaining optimal levels of grid visibility command and control, and self-healing;

2. Optimize system demand by facilitating consumer price responsiveness; and

3. Interconnect and integrate distributed energy resources (DER).

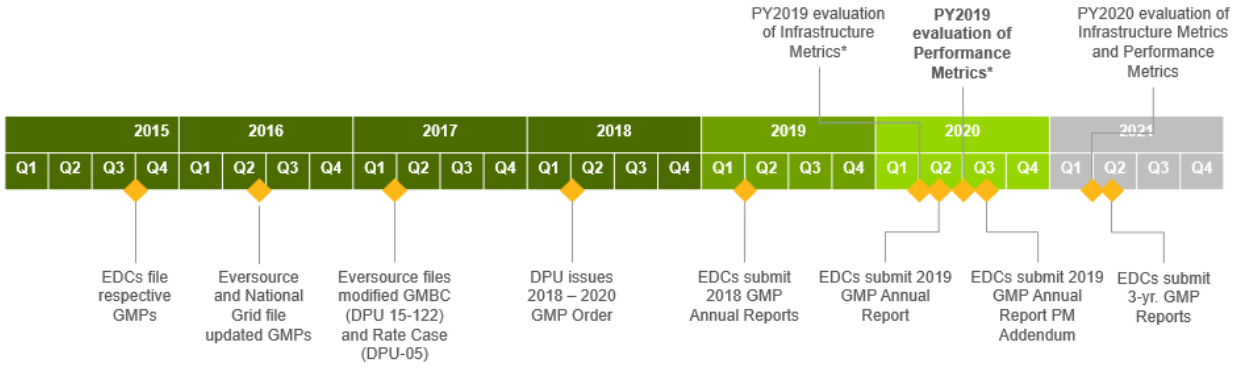
As part of the GMPs, the DPU determined that a formal evaluation process for the preauthorized GMP investments, including an evaluation plan and studies, was necessary to help ensure that the benefits are maximized and achieved with greater certainty. Figure 1 highlights the filing background and timeline of the GMP order and the evaluation process.

[1] Massachusetts D.P.U. 15-120; D.P.U. 15-121; D.P.U. 15-122 (Grid Modernization) Order issued May 10, 2018

[2] On August 19, 2015, National Grid, Unitil, and Eversource each filed a grid modernization plan with the DPU. The Department docketed these plans as D.P.U.15-120, D.P.U.15-121, and D.P.U.15-122, respectively.

[3] On June16, 2016, Eversource and National Grid each filed updates to their respective GMPs

Figure 1. MA Grid Modernization Timeline (by Program Year)



Source: Guidehouse review of the DPU orders and GMP process

The grid modernization investments were organized into six investment areas to facilitate understanding, consistency across EDCs, and analysis.

- Monitoring and Control (M&C)
- Advanced Distribution Automation (ADA)
- Volt/VAR Optimization (VVO)
- Advanced Distribution Management Systems/Advanced Load Flow (ADMS and ALF)
- Communications/IoT (Comms)
- Workforce Management (WFM)

The following subsection discusses these investment areas in greater detail in. This Addendum covers the Program Year 2019 (PY 19) evaluation of relevant performance metrics and focuses on the ADA investment area.

1.2 EDC Approach to ADA Investment

The Eversource ADA investments include new overhead recloser installations, underground oil switch replacements, and the creation of underground auto-reclosing loops. National Grid's ADA investments include new installations of overhead reclosers and upgrades to existing reclosers with SCADA. Table 1 summarizes these GMP ADA devices and technologies. These ADA investments all serve to increase visibility of the distribution grid, add more control and restoration options, reduce the customer zone size for fault isolation, and reduce the impact and extent of outages when they occur.

Table 1. Devices and Technologies Deployed Under ADA Investment

EDC	Device/Investment Type	Description
Eversource	New Overhead Recloser Locations	New SCADA-enabled overhead recloser Installations at new locations to increase auto-sectionalizing capability and reduce customer zone size
	New Recloser Locations with Ties	New SCADA-enabled overhead recloser Installations at new locations with ties to adjacent feeders, to add power supply redundancy and increase switching options
	Underground Oil Switch Replacement	New SCADA-enabled switches that replace century-old oil-filled underground switches in Boston and Cambridge, to reduce manual operation and increase auto-sectionalizing capability
	4kV Auto-Reclosing Loops	Previously called 4kV VFI Retrofit Program, Eversource has expanded this investment to loop several circuits together with multiple tie points. This state-of-the-art program is a new proof of concept for Eversource.
National Grid	New Overhead Recloser Locations	SCADA-enabled overhead recloser installations at new locations to increase auto-sectionalizing capability and reduce customer zone size
	SCADA Upgrades to Existing Overhead Reclosers	Adding automation and control capabilities at existing overhead reclosers which could not previously be remotely controlled, to reduce the duration of outages

Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

1.3 Performance Metrics

Table 2 lists the performance metrics (PMs) for all Investment Areas, with those evaluated in this Addendum highlighted.

Table 2. Performance Metrics Overview

ID	PM Metric	Applicable IA	Applicable EDC
Statewide			
PM-1	VVO Baseline	VVO	All
PM-2	VVO Energy Savings	VVO	All
PM-3	VVO Peak Load Impact	VVO	All
PM-4	VVO Distribution Losses without AMF (Baseline)	VVO	All
PM-5	VVO Power Factor	VVO	All
PM-6	VVO – GHG Emissions	VVO	All
PM-7	Voltage Complaints	VVO	All
PM-8	Increase in Substations with DMS Power Flow and Control Capabilities	ADMS/ ALF	All
PM-9	Control Functions Implemented by Circuit	ADMS/ ALF	All
PM-11	**Numbers of Customers that benefit from GMP funded Distribution Automation Devices**	**ADA**	**All**
PM-12	**Grid Modernization investments' effect on outage durations**	**M&C, ADA**	**All**
PM-13	**Grid Modernization investments' effect on outage frequency**	**M&C, ADA**	**All**
EDC-Specific			
PM-ES1	Advanced Load Flow – Percent Milestone Completion	ADMS/ ALF	ES
PM-ES2	**Protective Zone: Average Zone Size per Circuit**	**ADA, M&C**	**ES**
PM-UTL1	**Customer Minutes of Outage Saved per Circuit**	**M&C**	**UTL**
PM-NG1	**Main Line Customer Minutes of Interruption Saved**	**ADA, M&C**	**NG**

Source: Stamp Approved Performance Metrics, July 25, 2019.

Table 3 provides an overview of metrics relevant to this PM addendum. The metrics that were specifically evaluated are highlighted.

Table 3. Performance Metrics Objectives

Performance Metric	EDC	Overview
PM-12: Grid Modernization investments' **effect on outage durations (CKAIDI)**	**ES, NG, UTL**	This metric will compare the experience of customers on GMP circuits as compared to the prior three-year average for the same circuit. This metric will provide insight into how ADA investments can reduce the duration of outages by looking at the change in the circuit-level System Average Interruption Duration Index (CKAIDI).
PM-12: Grid Modernization investments' **effect on outage frequency (CKAIFI)**	**ES, NG, UTL**	This metric will compare the experience of customers on GMP circuits as compared to the prior three-year average for the same circuit. This metric will provide insight into how ADA investments can reduce the frequency of outages by looking at the change in the circuit-level System Average Interruption Frequency Index (CKAIFI).
PM-11: Numbers of Customers that benefit from GMP funded Distribution Automation Devices	**ES, NG, UTL**	This metric will show the progress in the Distribution Automation investment by tracking the numbers of customers that have benefitted from the installation of Distribution Automation devices. This metric will support the objective of optimizing system performance and more specifically reduce the duration and number of customers impacted by outage events. These investments will also allow for a reduction in manual switching operations, reduce operations cost and potentially defer capital upgrades with enhanced flexibility to shift load.
PM-ES2: Protective Zone: Average Zone Size per Circuit	**ES**	This metric is intended to measure progress in sectionalizing circuits into protective zones designed to limit outages to customers located within the zone. This metric will measure progress in achieving the grid modernization objective of reducing the impact of outages.
PM-UTL1: Customer Minutes of Outage Saved per Circuit	**UTL**	The objective of this metric is to track the customer minutes saved per outage on each feeder. This metric is a study of the overall duration of outages and the number of customer minutes saved based upon grid modernization investments.
PM-NG1: Main Line Customer Minutes of Interruption Saved	**NG**	This metric is designed to measure the impact of ADA Investments on the customer minutes of interruption (CMI) for main line interruptions.

Source: Stamp Approved Performance Metrics, July 25, 2019.

1.4 Case Study Evaluation

A "case study" approach was developed to provide more insight into the actual operation of the GMP devices and to illustrate how these investments provide customer reliability and operational benefits. As discussed below, the impacts of GMP devices on system reliability metrics can be difficult to discern due to the range of factors that affect these metrics. This is likely to be especially true if the device has less than a full year of operation to affect the metric. The case studies help to illustrate the benefits provided by GMP devices during outage events. This approach investigates several outage events on specific circuits where the GMP equipment operated to address an outage. The approach also allows for comparison between what did occur due to the presence of the GMP device and what would have likely happened had the GMP investment not been made.

For the ADA performance metrics evaluation, a total of three case studies were performed. All three case studies are specific to Eversource, as National Grid did not install ADA devices in PY 2019. Further details of the analysis and the results are examined in Section 4.

2. Performance Metrics Data Management

This section discusses the data sources used for the performance metric evaluation and case studies and summarizes the Quality Assessment and Quality Control (QA/QC) steps.

2.1 Data Sources

The following data sources were used to complete the evaluation analysis in this document.

- 2019 Grid Modernization Plan Annual Report Appendix 1[4,5,6]
- Service Quality Index (SQI) Filings[7,8,9]
- Outage Data[10]
- Circuit Topology Diagrams and One-Line Diagrams[11]
- Work Order Information

2019 Grid Modernization Plan Annual Report Appendix 1: On April 1, 2020 each EDC submitted this Appendix along with the Annual Report. The Appendix 1 contains feeder-level data for all feeders within each EDC's territory. All PM-related data presented in this addendum report are from the 2019 GMP Annual Report Appendices. These documents contain baseline and program year data for all circuits for each EDC. They key data from the appendices that were utilized in this analysis include:

- Customer Counts
- Feeder Level SAIDI (CKAIDI) and SAIFI (CKAIFI) for the Plan Year and Baseline
- Number of Customers that Benefit from GMP Investments
- Average Protective Zone Size
- Main Line Customer Minutes of Interruption

SQI Filings: The evaluation team used 2019 and historical SQI filings to cross-check for consistency with the data in the GMP Annual Report Appendices to ensure accuracy across the

[4] Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid, Grid Modernization Plan Annual Report 2019. Submitted to Massachusetts DPU on April 1, 2020 as part of D.P.U. 15-120

[5] NSTAR Electric Company d/b/a Eversource Energy, Grid Modernization Plan Annual Report 2019. Submitted to Massachusetts DPU on April 1, 2020 as part of D.P.U. 15-122. Note: Inconsistencies in calculations and definitions were discovered and Eversource updated the Appendix 1 in May 2020. The updates were provided to Guidehouse.

[6] Fitchburg Gas and Electric Light Company d/b/a Unitil, Grid Modernization Plan Annual Report 2019. Submitted to Massachusetts DPU on April 1, 2020 as part of D.P.U. 15-121

[7] Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid, 2019 Annual Service Quality Report. Submitted to Massachusetts DPU on February 28, 2020 as part of D.P.U. 20-SQ-11 and 20-SQ-12; 2017 Annual Service Quality Report. Submitted to Massachusetts DPU on March 1, 2018 as part of D.P.U. 18-SQ-11 and 18-SQ-12

[8] NSTAR Electric Company and Western Massachusetts Electric Company d/b/a Eversource Energy, 2019 Annual Service Quality Report. Submitted to Massachusetts DPU on February 28, 2020 as part of D.P.U. 20-SQ-13 and 20-SQ-14

[9] Fitchburg Gas and Electric Light Company d/b/a Unitil, 2019 Annual Service Quality Report. Submitted to Massachusetts DPU on February 28, 2020 as part of D.P.U. 20-SQ-10

[10] National Grid and Eversource provided outage reports for all GMP circuits. Guidehouse selected outages to review in more detail and National Grid and Eversource provided SCADA data and detailed one-line diagrams.

[11] GIS diagrams were received and reviewed but were too complex to analyze outages at the device level. To support the analysis, Eversource provided simplified one-line diagrams with GMP devices clearly labeled

sources and contain data for the performance year and the baseline years. Specific QA/QC steps are explained further in Section 2.2.

Work Order Information: Circuit-level work order data was collected during the infrastructure metrics evaluation to understand the current status (e.g., CONSTRUCTION, DESIGN, IN-SERVICE) of GMP investments. This work order data was used to determine when GMP investments were installed at each circuit.[12]

Outage Data and One-Line Diagrams: Outage Data and Circuit Topology and One-Line Diagrams were used to perform the Case Study analyses. The outage data contains details of outage events, such as cause, resolution, and CMI that were integral to understanding the role of the GMP device in resolving the outage. The One-Line Diagrams helped support the analysis by using visualization to better understand the operation of the relevant devices during the outage event. Refer to Section 4 for further explanation about the data sources utilized for case study analyses.

2.2 Data Completeness Checks and QA/QC Review

The evaluation team reviewed the Appendix 1 filings for completeness, accuracy, and alignment with the metrics set forward in the DPU Stamp Approved Metrics. The QA/QC process involved the following:

- Comparison of the 2015-2017 average CKAIDI/CKAIFI values using calculated values from 2015, 2016, and 2017 data in the SQI filing. Note: DPU Stamp Approved Metric Guidance defines this as AVG(2015, 2016, 2017 CKAIDI/CKAIFI)

- Check that the change in CKAIDI/CKAIFI and average zone sizes were properly calculated using the stamp approved metric's definition. Note: DPU Stamp Approved Metric Guidance defines this as "BASELINE – PROGRAM YEAR"

- Comparison of 2019 reliability data with and without major excludable events and circuit information in the SQI filing and the Appendix 1 filing.

- Comparison of circuits with GMP investments in the Appendix 1 filing and the work order data collected during the Infrastructure Metric analysis.

During this QA/QC process, the evaluation team identified issues in both the Eversource and National Grid Appendix 1 filings that required adjustments and updates:

Eversource: Baseline CKAIDI/CKAIFI values and the change in CKAIDI/CKAIFI values had been calculated using an alternative interpretation[13] from the Stamp Approved metrics, requiring adjustment.

[12] Note there are slight differences in the total number of devices reported in the work order data and the official device count reported in the PY 19 Evaluation Report because of minor variations in the work order level data.

[13] This interpretation added the total outage times on each circuit across the three baseline years, added the average annual customer counts across the 3 years, and then divided them to reach the baseline metric. This is different than the strict metric definition, which simply averages the metric for the circuit over the 3 baseline years, and can yield a slightly different result.

National Grid: The change in CKAIDI/CKAIFI calculations were using a different source for the baseline values. National Grid updated and resubmitted its Appendix 1 data and GH then re-completed the QC analysis.

2.3 Selecting Circuits with Sufficient Data for Analysis

Devices and technologies deployed and commissioned in each investment area were made throughout 2019, as well as in 2018. The key reliability metrics involving outage duration (CKAIDI) and frequency (CKAIFI) are annual metrics, and impacts to these metrics from GMP investments would only be seen if the investments were installed for sufficient time on a particular circuit to impact outages that drive these annual metrics.

The approach most likely to detect metric impacts from the investments would be to wait until the investment had been commissioned for a full year on the circuit before attempting to understand its impact on these metrics. However, the evaluation team determined that the use of the technology for at least one-half of the full program year could be enough to make the impacts visible in the annual metrics.[14]

The evaluation team reviewed the installation and commissioning timing for the various investments to understand when during the 2019 Program Year the devices were installed. For the CKAIDI/CKAIFI metrics (PM-12 and PM-13), circuits with *at least* a half year with the technology commissioned and in service were selected for inclusion in the analysis. All circuits receiving ADA investments were included in the remaining performance metrics.

The subsections below detail this analysis and circuit selection for Eversource and National Grid respectively.

2.3.1 Eversource Circuits

Circuits Receiving GMP Investments: Eversource installed and commissioned devices throughout PY 2019 as well as during PY 2018. Table 4 shows the period of deployment of ADA devices through the end of PY 2019

Table 4. Eversource Timeline of Devices Commissioned

Device Type	ADA Devices Installed			
	2018	H1* 2019	H2* 2019	Total
Overhead Automated Switches	25	43	105	173
OH Switches with Circuit Ties	0	12	33	45
4 kV Oil Switches	0	9	80	89
VFI Retrofit for AFR	0	0	17	17
TOTAL	**31**	**60**	**227**	**318**

Source: Eversource 2019 GMP Annual Report Appendix 1, Eversource Work Order Data
**H1: first half of the year or January-June; H2: second half of the year or July-December*

[14] Being mindful that many other factors affect these metrics, including weather, car strikes, and other factors.

The table shows that approximately 30% of the total number of the ADA devices installed and commissioned through PY 19 were installed prior to H2 (second half of the year, or July – December) 2019.

Table 5 shows the number of circuits and associated devices on which any GMP investments were commissioned prior to H2 (July – December) 2019. Several circuits have multiple GMP devices, but in those instances, only the devices that were commissioned prior to H2 2019 are included in the device count.

Table 5. Eversource Circuit Count for ADA Devices

Device Type	Circuits with ADA Investments installed through 2019	Circuits with Devices installed H1-2019 and Prior
OH Recloser Installations	107	42
OH Reclosers installation with creating field ties	12	5
4kV Oil Switch Replacement	39	5
VFI Retrofit for AFR	1	0
Multiple ADA Device Types	14	8
ADA Total	173	60

Note: 24 circuits had both ADA and M&C GMP devices installed through 2019 and 14 circuits have both ADA and M&C devices installed H1-2019 and prior.

Circuits with Sufficient Data for Analysis: The evaluation team also excluded circuits from the analysis that had missing, incomplete, or non-numerical reliability data (CKAIDI/CKAIFI) for baseline or 2019 with or without excludable major events performance metrics. Table 6 summarizes the number of circuits that had sufficient data for analysis after these exclusions.

Table 6. Eversource ADA Circuit Data Completeness

Summary	System-wide[15]	ADA Targeted through 2019	ADA Installed through H1 2019
Circuit Count	2,299	173	60
Circuits for CKAIDI/ CKAIFI Analysis			
Circuits with Complete Data[16]	2,085	171	60
% Circuits Included in Analysis	91%	99%	100%
Circuits for Avg. Zone Size Analysis			
Circuits with Complete Data[17]	1,718	173	60
% Circuits Included in Analysis	75%	100%	100%

Source: Guidehouse review of Eversource data

[15] System-wide refers to all circuits in the 2019 GMP Annual Report Appendix 1.

[16] Of the 214 circuits that did not have complete data, 137 were created during the baseline period, 72 were retired/reconfigured/retired/other, and 5 had insufficient data.

[17] Circuits were excluded if they had an "N/A" for their change in zone size in the Appendix 1 GMP Annual Report. Most circuits with an "N/A" did not provide values for the 2019 avg. zone size field.

2.3.2 National Grid Circuits

National Grid did not deploy any ADA devices in program year 2019. Thus, the evaluation team did not assess performance towards this metric.

3. ADA Performance Metrics Analysis and Results

Evaluation of the various performance metrics for each EDC is provided below. An overview of the approach and results are provided first to facilitate understanding of the detailed results analysis.

Results Summary: Table 7 provides a high-level summary of the results for each performance metric and EDC.

Table 7. Summary of Findings for ADA Investment Area

PM	Eversource	National Grid
PM-12: Grid Modernization investments' effect on outage durations	Outage duration was reduced compared to the system average, but the effect is small compared to overall metric variability.	N/A – no commissioned ADA devices
PM-13: Grid Modernization investments' effect on outage frequency	Outage frequency was reduced compared to the system average, but the effect is small compared to overall metric variability.	N/A – no commissioned ADA devices
PM-11: Numbers of Customers that benefit from GMP funded Distribution Automation Devices	Number of Customers that benefitted increased significantly with the addition of ADA devices.	N/A – no commissioned ADA devices
PM-ES2: Protective Zone: Average Zone Size per Circuit	Average zone size decreased significantly for circuits receiving ADA investments compared to the system-wide average.	N/A – no commissioned ADA devices
PM-NG1: Main Line Customer Minutes of Interruption Saved	N/A – National Grid specific metric	N/A – no commissioned ADA devices

Source: Guidehouse Analysis

Analysis Approach: The following approach was developed to provide additional insight to the EDC PM that have already been published by the EDCs in their Annual Reports for PY 19. Circuit-level data was used for several of the metrics, and the approach used the following three elements:

1. Baseline and Performance Year System-wide and ADA circuit comparisons: The evaluation team compared the baseline and performance year data across the entire system and for qualified circuits receiving ADA investments. Statistical averages for these circuit groupings are used to make simple comparisons, and standard deviations are calculated to provide insight into the variability compared with the average values. For PM-12 (change in CKAIDI) and PM-13 (change in CKAIFI), the system-wide metric baseline was compared against the program year metric using reliability bins. This facilitates a general understanding of where the ADA investments fit into the context of the overall system metric performance and to compare changes in metrics for ADA to those system-wide.

2. Before and after comparison**:** For PM-12, PM-13, and PM-ES2 (change in average zone size) the current year performance was compared to the baseline performance for all circuits

within the system. "Box-and-whisker" plots[18] are used to illustrate the distribution of data across the entire system and for circuits receiving ADA investments.[19]

3. Difference in differences: Calculate the difference in system-wide circuits change from baseline vs. ADA investment circuits change from baseline to understand if there is any discernible reliability improvement on the ADA circuits. This change is defined as "average metric for circuits with ADA investments– average metric for circuits system-wide."

The Metrics sections below leverage these three steps to try and provide additional insights on the impact of ADA investments.

3.1 PM-12: Effect on Outage Duration (CKAIDI)

Metric PM-12, Reliability-Focused Grid Modernization Investments' Effect on Outage Duration (CKAIDI), provides insight on how GMP devices impact outage duration and will track the improvements over time. Per the DPU Stamp Approved GMP Performance Metrics Guidance:

> *This metric will compare the experience of customers on GMP DA-enabled circuits as compared to the prior three-year average for the same circuit. This metric will provide insight into how DA can reduce the duration of outages (by tracking and reporting) the following:*
>
> - *Circuit level SAIDI for the program year*
> - *Three-year average SAIDI for 2015, 2016, and 2017*
> - *Comparison of the current year SAIDI with the three-year historic average: AVERAGE(CKAIDI 2015, CKAIDI 2016, CKAIDI 2017) – PY CKAIDI = if greater than 0, positive impact*

The EDCs have provided the CKAIDI metric in their Appendix 1 filings. As discussed in Section 3.3, only circuits with ADA investments in H1 (January – June) 2019 and prior are included in the analysis. Analysis of this metric for each EDC is presented in the following subsections.

3.1.1 Eversource Analysis

Analysis of the CKAIDI metrics for Eversource is provided in this sub-section:

System-wide and ADA circuit counts: Table 8 is structured with CKAIDI ranges, or "bins", to provide insight about the range of outage durations across the system, and to show where circuits selected for ADA investment fall within these bins. There are a number of circuits with no outages at all within the baseline period. The proportion of these circuits with zero CKAIDI in

[18] The "box-and-whisker" plot divides the sample into quartiles. The boxes show the 2nd and 3rd quartile in the sample. The lower and upper "whiskers" indicate 1.5 times the interquartile range (IQR) (difference between the start of the 2nd and the end of the 3rd quartile) or the maximum/minimum value within the range if it falls within 1.5x the IQR. The "x" indicates the sample average. . Data points that fall outside 1.5x the IQR are not shown on the graph.

[19] Note that the DPU Guidance defines the change as "Baseline – Program Year" which means that positive values of this metric indicate reliability improvement—the opposite of what you would expect for improvement in CKAIDI or CKAIFI metric (which fall with improvement).

the baseline is higher in the system than in the circuits with ADA investments. Additionally, the baseline CKAIDI values for those circuits is much higher than the system average. This provides some indication that these less reliable circuits were targeted more for ADA investment.[20]

An increase in system average CKAIDI from the baseline to PY 19 indicates decreased reliability at the system level, and thus that PY 19 was a "worse" reliability year than baseline. This difference may be due to several factors, including weather, animal faults, tree trimming cycle and other idiosyncratic causes. The CKAIDI standard deviation also increased significantly, indicating increased variability in CKAIDI across the system.

Table 8. Baseline and 2019 Eversource CKAIDI Circuit Counts

Summary	2015-2017 Avg. CKAIDI (Baseline)				2019 CKAIDI (Program Year)			
	System-wide[21]		Targeted for ADA through 2019		System-wide		ADA installed H1 2019 and Prior	
	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs
CKAIDI Statistics								
Total Circuits	2,085	2,085	171	171	2,085	2,085	60	60
% Zero	41%	34%	2%	2%	41%	44%	1%	6%
Average	80.0	63.3	162.9	143.4	169.2	75.5	208.1	117.9
Std. Dev.	135.8	102.5	159.7	141.7	416.0	229.8	270.8	221.8
CKAIDI Range								
0	779	780	3	3	940	1,017	1	4
1-49	491	535	34	36	351	516	12	23
50-149	448	491	68	75	286	291	24	22
150-249	182	166	26	28	151	117	9	3
250-349	84	63	26	21	76	52	3	5
350-449	44	27	7	2	41	27	1	2
450-549	20	10	1	2	44	12	4	0
550-649	13	3	1	0	34	12	3	0
650-749	9	5	1	2	34	6	2	0
750-849	9	3	3	1	25	4	0	0
850-949	3	1	0	0	17	3	0	0
950-1049	1	1	1	1	13	2	0	0
> 1050	2	0	0	0	73	26	1	1

Note: EME = excludable major events. CKAIDI of zero indicates circuit did not experience any outages.

Before and after comparison: A simple graphical summary of the statistical change in CKAIDI is shown in Figure 2 below, which uses the "box-and-whisker" format.[22] This chart compares the

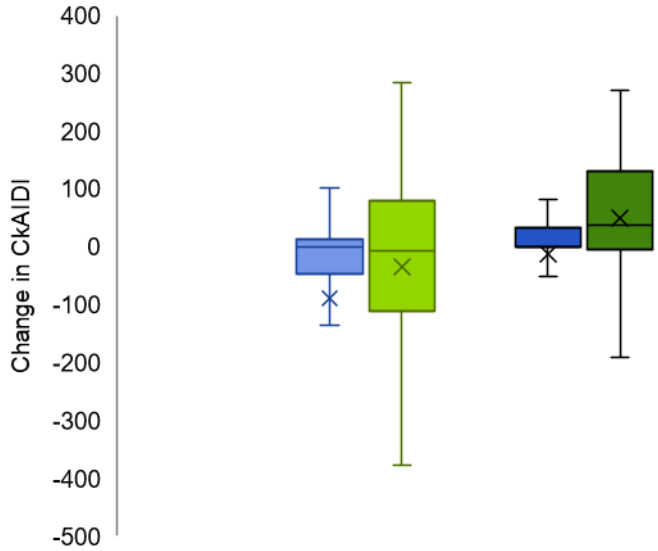
[20] Eversource's 2018 GMP Annual Report contains the following text about methodology of choosing circuits for GMP investments: *Circuit reliability based on historical SAIDI and SAIFI from 2015, 2016 and 2017 was also considered when selecting circuits for investment.*

[21] System-wide refers to all circuits in the 2019 GMP Annual Report Appendix 1 that had complete data.

[22] The "box-and-whisker" plot divides the sample into quartiles. The boxes show the 2nd and 3rd quartile in the sample. The lower and upper "whiskers" indicate 1.5 times the interquartile range (IQR) (difference between the start of the 2nd and the end of the 3rd quartile) or the maximum/minimum value within the range if it falls within 1.5x the IQR. The "x" indicates the sample average. Data points that fall outside 1.5x the IQR are not shown on the graph for visualization purposes.

difference in CKAIDI between baseline and PY 19, for both the system-wide values and the selected ADA circuits.

Figure 2. Impact in Outage Duration Performance Metric Results



System-wide:

	w/ EMEs	w/o EMEs
count	2085	2085
% Zero	32%	33%
Avg.	-89	-12
Std. Dev.	382	226

w/ ADA Investments:

	w/ EMEs	w/o EMEs
count	60	60
% Zero	0%	0%
Avg.	-35	50
Std. Dev.	279	250

Note: EME = excludable major events. Change in CKAIDI is reported as minutes. Change in CKAIDI is calculated as defined by the DPU PM Guidance: 2015-2017 Avg. CKAIDI – 2019 CKAIDI = if greater than zero, positive impact.

On average, the system-wide CKAIDI increased slightly (negative change) in PY 19 over the baseline indicating worsened performance. For the selected ADA circuits, CKAIDI decreased indicating improved performance.[23] As described above, the 2019 performance for circuits with and without ADA investment was very similar; however, the baseline performance for circuits with ADA investments was worse. As a result, the change in CKAIDI for circuits receiving ADA investments was positive and indicates improved reliability.

However, the standard deviation of CKAIDI for each group is significantly larger—several times larger-- than the average change in CKAIDI itself, indicating that the change in the average is of limited statistical significance, and not indicative of any clearly discernible trend in CKAIDI. There are also many potential reasons for these changes and many factors impacting this metric. The impact of the ADA investment in operation is one of the factors but is not discernable using the metric itself.

Difference in differences: The difference in the change in CKAIDI between the system-wide average (-89 with EMEs, -12 without EMEs) and the average for circuits with ADA investments (-35 with EMEs, 50 without EMEs) is 54 with EMEs and 62 without EMEs. The change in CKAIDI for circuits with ADA investments was greater than the circuits without ADA investments, indicating improved performance. However, the standard deviation for these samples is much larger than the average CKAIDI changes, suggesting that the difference is likely not statistically significant and is more probably a factor of randomness in the metric data

[23] Note that the "whiskers" extend further for the circuits with ADA investments because there are fewer ADA circuits that experienced zero change in CKAIDI. As a result, the IQR for these circuits is larger than the IQR range of the whole system.

than any clear trend. Thus, the metric data is “too noisy” to tell us much if anything about the impact of ADA investments.

3.1.2 National Grid Analysis

National Grid did not deploy any ADA devices in program year 2019. Thus the evaluation team did not assess performance towards this metric.

3.2 PM-13: Effect on Outage Frequency (CKAIFI)

Metric PM-12, Reliability-Focused Grid Modernization Investments’ Effect on Outage Frequency (CKAIFI), provides insight on how GMP devices impact outage duration and will track the improvements over time. Per the DPU Stamp Approved GMP Performance Metrics Guidance:

> *This metric will compare the experience of customers on GMP DA-enabled circuits as compared to the prior three-year average for the same circuit. This metric will provide insight into how DA can reduce the frequency of outages (by tracking and reporting) the following:*
>
> - *Circuit level SAIFI (CKAIFI) for the program year*
> - *Three-year average SAIFI (CKAIFI) for 2015, 2016, and 2017*
> - *Comparison of the current year SAIFI (CKAIFI) with the three-year historic average: AVERAGE(CKAIFI 2015, CKAIFI 2016, CKAIFI 2017) – PY CKAIFI = if greater than 0, positive impact*

The EDCs have provided the CKAIFI metric in their Appendix 1 filings. As discussed in Section 3.3, only circuits with ADA investments in H1 2019 and prior are included in the analysis. Analysis of this metric for each EDC is presented in the following subsections and align closely with the previous metric (PM-12: Impact on Outage Duration).

3.2.1 Eversource Analysis

Analysis of the CKAIDI metrics for Eversource is provided in this sub-section.

System-wide and ADA circuit counts: Table 9 is structured with CKAIFI ranges, or “bins,” to provide insight about the range of outage durations across the system, and to show where circuits selected for ADA investment fall within these bins. There are several circuits with no outages at all within the baseline period. The proportion of these circuits with zero CKAIFI in the baseline is higher in the system than in the circuits with ADA investments and the baseline CKAIFI values for those circuits is much higher than the system average. This provides some indication that these less reliable circuits were targeted more for ADA investment.[24]

[24] Eversource’s 2018 GMP Annual Report contains the following text about methodology of choosing circuits for GMP investments: *Circuit reliability based on historical SAIDI and SAIFI from 2015, 2016 and 2017 was also considered when selecting circuits for investment.*

The average system-wide reliability did not change from the baseline to 2019; however, the standard deviation increased and both the number of circuits with zero CKAIFI and the number of circuits with CKAIFI greater than 5 increased. This suggests increased variability in reliability throughout 2019.

Table 9. Baseline and 2019 Eversource CKAIFI Circuit Counts

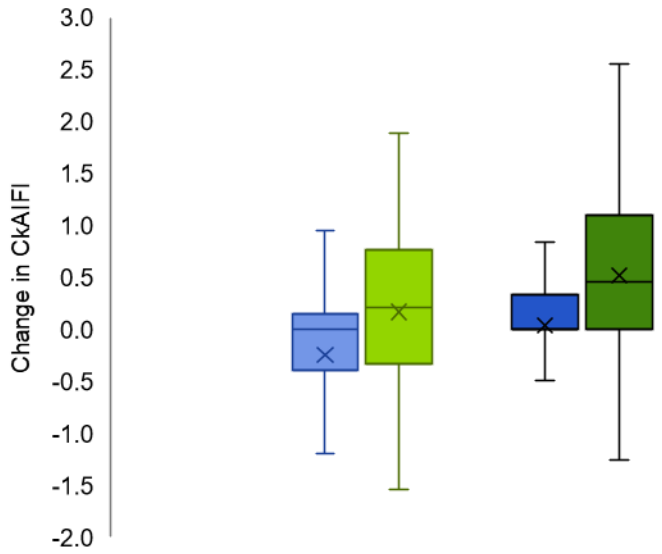
Summary	2015-2017 Avg. CKAIFI (Baseline)				2019 CKAIFI (Program Year)			
	System-wide		Targeted for ADA through 2019		System-wide		ADA installed H1 2019 and Prior	
	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs
CKAIFI Statistics								
Total Circuits	2,085	2,085	171	171	2,085	2,085	60	60
% Zero	34%	34%	2%	2%	41%	45%	1%	6%
Average	0.5	0.5	1.2	1.2	0.8	0.5	1.1	0.7
Std. Dev.	0.7	0.7	0.8	0.8	1.3	0.8	1.1	0.8
CKAIFI Range								
0	779	780	3	3	940	1,017	1	4
0.01-0.24	491	535	34	36	351	516	12	23
0.25-0.74	448	491	68	75	286	291	24	22
0.75-1.24	182	166	26	28	151	117	9	3
1.25-1.74	84	63	26	21	76	52	3	5
1.75-2.24	44	27	7	2	41	27	1	2
2.25-2.74	20	10	1	2	44	12	4	0
2.75-3.24	13	3	1	0	34	12	3	0
3.25-3.74	9	5	1	2	34	6	2	0
3.75-4.24	9	3	3	1	25	4	0	0
4.25-4.74	3	1	0	0	17	3	0	0
4.75-5.24	1	1	1	1	13	2	0	0
> 5.25	2	0	0	0	73	26	1	1

Note: EME = excludable major events. CKAIFI of zero indicates circuit did not experience any outages

Before and after comparison: A simple graphical summary of the statistical change in CKAIFI is shown in Figure 3 below, which uses the "box-and-whisker" format.[25] This chart compares the difference in CKAIFI between baseline and PY 19, for both the system-wide values and the selected ADA circuits.

[25] The "box-and-whisker" plot divides the sample into quartiles. The boxes show the 2nd and 3rd quartile in the sample. The lower and upper "whiskers" indicate 1.5 times the interquartile range (IQR) (difference between the start of the 2nd and the end of the 3rd quartile) or the maximum/minimum value within the range if it falls within 1.5x the IQR. The "x" indicates the sample average. Data points that fall outside 1.5x the IQR are not shown on the graph for visualization purposes.

Figure 3. Impact in Outage Frequency Performance Metric Results



System-wide:

	w/ EMEs	w/o EMEs
count	2085	2085
% Zero	32%	33%
Avg.	-0.2	0.0
Std. Dev.	1.1	0.8

w/ ADA Investments:

	w/ EMEs	w/o EMEs
count	60	60
% Zero	0%	0%
Avg.	0.2	0.5
Std. Dev.	1.0	0.9

Note: EME = excludable major events. Change in CKAIFI is calculated as defined by the DPU PM Guidance: 2015-2017 Avg. CKAIFI – 2019 CKAIFI = if greater than zero, positive impact.

On average, the system-wide CKAIFI changed minimally from the baseline.[26] For the selected ADA circuits, CKAIFI decreased (positive change) indicating improved performance. As described above, the 2019 performance for circuits with and without ADA investment was similar; however, the baseline performance for circuits with ADA investments was worse. As a result, the change in CKAIFI for circuits receiving ADA investments was positive and indicative of improved reliability.

However, the standard deviation of CKAIFI for each group is larger than the average change in CKAIFI itself, in some cases many times larger, indicating that the change in the average is of limited significance, and not indicative of any clearly discernable trend in CKAIFI. There are also many potential reasons for these changes and many factors impacting this metric. The impact of the ADA investment in operation is one of the factors but is not discernable using the metric itself.

Difference in differences: The difference in the change in CKAIFI between the system-wide average (-0.2 with EMEs, 0.04 without EMEs) and the average for circuits with ADA investments (0.2 with EMEs, 0.5 without EMEs) is 0.41 with EMEs and 0.48 without EMEs. The change in CKAIFI for circuits with ADA investments was greater than the circuits without ADA investments, indicating improved performance. However, the standard deviation for these samples is much larger that the CKAIFI changes, suggesting that the difference is likely not statistically significant and is more probably a factor of randomness in the metric data than any type of trend. Thus, the metric data is “too noisy” to tell us much if anything about the impact of ADA investments.

[26] Note that the “whiskers” extend further for the circuits with ADA investments because there are fewer ADA circuits that experienced zero change in CKAIFI. As a result, the IQR range for these circuits is larger than the IQR range of the whole system.

3.2.2 National Grid Analysis

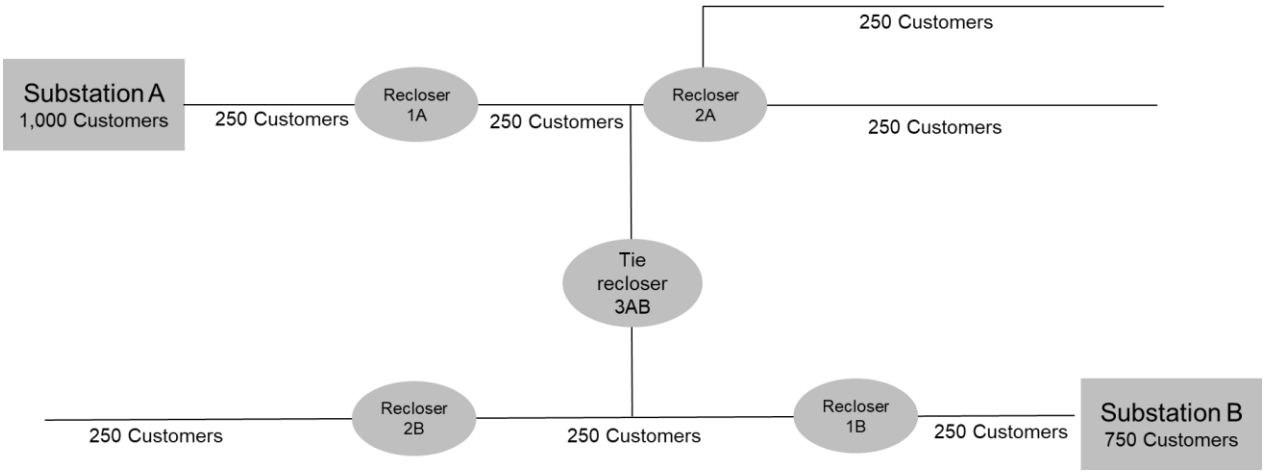
National Grid did not deploy any ADA devices in PY 19, thus the evaluation team did not assess performance towards this metric.

3.3 PM-11: Numbers of Customers that Benefit from GMP Funded Distribution Automation Devices

The goal of this metric is to track the number of customers that have benefitted from the installation of ADA devices. In discussions with the EDCs about the detailed definition of this metric, it was determined that a more detailed definition would provide more consistency in this metric across EDCs, helping meet the Department's goals for common metrics approach. The evaluation team worked with the EDCs to align on a common, more detailed, definition and method of calculation.

At a high-level, a customer is counted as benefitting from an ADA device when their zone size has been reduced. A specific example and explanation is provided below:

Figure 4. Example One-Line Diagram of Grid Modernization Devices



Source: Guidehouse and National Grid

Broadly speaking, all of the customers within the zone in which a recloser is placed benefit from the device. In Figure 4, if Recloser 1A was installed in 2019 as part of the GMP and all other devices previously existed, then 500 customers benefitted from the installation of this device. All customers between the new device and the next connective device benefit. In this case, that is 250 customers on each side of the device for a total of 500 customers.

The customers that benefit from tie reclosers are counted in the same way. In Figure 4, if Tie Recloser 3AB was installed in 2019 as part of the GMP and all other devices previously existed, then 500 customers benefitted from the installation of this device. The 500 customers include the 250 customers between Recloser 1A and 2A and the 250 customers between Recloser 2B and 1B. This is a very conservative method of estimating the number of customers that benefit

from a tie recloser, as in many cases the majority of customers on affected circuit may benefit from this addition.

3.3.1 Eversource Analysis

The metric calculation was performed by the EDC, as detailed data is required to calculate this metric for each circuit that had ADA devices.

The number of customers that benefit from ADA devices is reported in Appendix 1 of the Company's Annual GMP Report. The number of customers that benefit is non-zero only for circuits that had sectionalizing devices installed. Through PY 19, these devices (OH Reclosers and Ties) were installed on 128 Eversource circuits. Table 10 shows the average number of customers that benefitted as well as the total across all 128 circuits. As of the end of PY 19, over 151,000 Eversource customers (11% of total customers) benefitted from GMP ADA devices.

Table 10. Number of Eversource Customers that Benefitted from GMP ADA Devices

Summary Statistic	Applicable* ADA Circuits
Number of Circuits	129
Average Number of Customers that Benefitted from ADA Devices (Customers per Circuit)	1,181
Total Customers that Benefitted from GMP ADA Devices	152,310
Percent of Total Customers that Benefitted from ADA Devices	11%

*Circuits that had OH Reclosers and/or Reclosers with Ties installed

3.3.2 National Grid Analysis

National Grid did not deploy any ADA devices in program year 2019. Thus the evaluation team did not assess performance towards this metric.

3.4 PM-ES2: Eversource Customer Outage Metric: Average Zone Size

The goal of this metric is to track the progress in sectionalizing circuits into protective zones via the deployment of ADA devices. A zone size is defined as the number of customers located between sectionalizing devices. The average zone size for the whole circuit is the average number of customers in each protective zone on that circuit. Over time with increased deployment of ADA devices, the average zone size should decrease, which increases the overall reliability of the circuit and the system.

3.4.1 Eversource Analysis

Table 11 shows the Average zone size of the circuits that had ADA devices installed as part of the GMP program in PY 19. The baseline average zone size was higher than the system-wide average, which illustrates that this metric was a factor in the decision of on which circuits to deploy ADA devices.

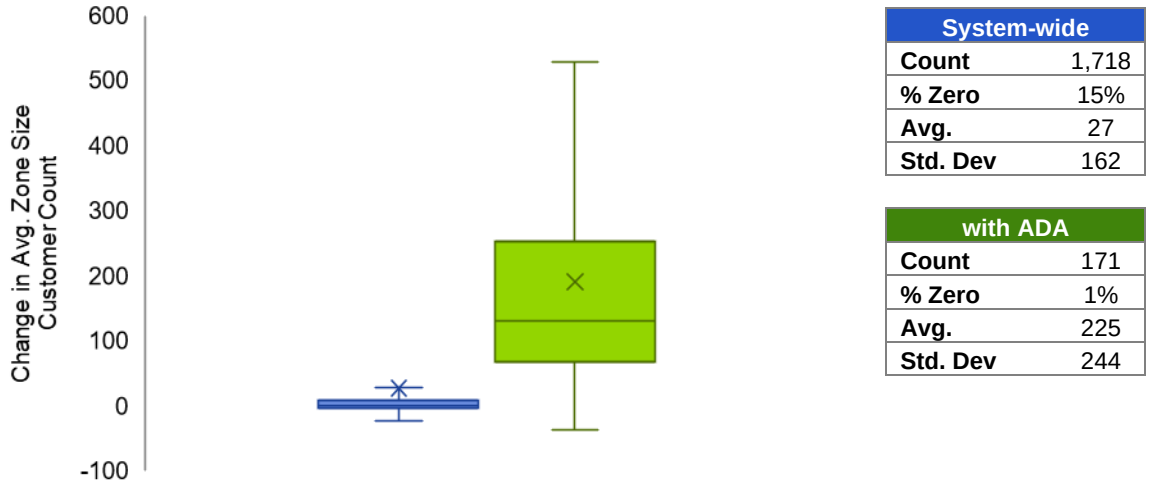
Table 11. Baseline and 2019 Average Zone Size Customer Count

Summary Statistics	2017 Avg. Zone Size Customer Count (Baseline)		2019 Avg. Zone Size Customer Count	
	System-wide	Circuits that received ADA through PY 19	System-wide	Circuits with Installed ADA through PY 19
Total # Circuits	1,718	173	1,718	173
Average Zone Size (# customers)	353	617	326	392
Std. Dev. In Zone Size	364	360	326	213

Source: Guidehouse Analysis

A simple graphical summary of the statistical change in average zone size customer count is shown in Figure 5 below, which uses a "box-and-whisker" format.[27] This chart compares the difference in the average zone size customer count between baseline and PY 19 for each circuit, for both the system-wide values and the selected ADA circuits.

Figure 5. Change in Average Zone Size Customer Count



Note: Per DPU Guidance, the change in average zone size is defined as "baseline – program year"

The average zone size per circuit for the entire system decreased by 27 customers; however, the average zone size for customers receiving ADA investments decreased by 225. Circuits with ADA investments decreased their average zone size nearly 10 times the system average, indicating that ADA investments had a major impact in decreasing the zone size customer counts.

[27] The "box-and-whisker" plot shows divides the sample into quartiles. The lower and upper "whiskers" indicate the lowest and highest values in the range, and the boxes show the 2nd and 3rd quartile in the sample. The "x" indicates the sample average.

3.5 PM-NG1: National Grid Reliability-Related Metric: Main Line Customer Minutes of Interruption Saved

National Grid did not deploy any ADA devices in program year 2019. Thus the evaluation team did not assess performance towards this metric.

4. Case Studies

Three case studies were performed for the ADA investment area; each of the case studies was conducted on Eversource investments, as the other EDCs had no ADA investments commissioned during or prior to PY 19.

The case study analyses below illustrate the operation and impacts of the GMP devices installed through PY 2019. The analyses were based on information from EDCs including OMS data, one-line diagrams, SCADA data, switching orders and discussions with EDCs. However, Guidehouse made certain reasonable assumptions in cases where not all information was available to reconstruct the precise details of an outage event.

Case Study #1: Eversource ADA and M&C Devices Operate During an Emergency for Rapid Restoration

Time of Event: January 7, 2020 at 1:40AM

Eversource Outage ID 4074586 on Circuit 17K5

Background

As part of the GMP, Eversource installed two overhead ADA reclosers on circuit 17K5 in Amherst, Massachusetts for auto-sectionalizing capability. Eversource also performed an M&C upgrade on the same circuit, adding SCADA capability to a tie recloser device which connects the circuit with an alternate (back-up) circuit during emergency situations or routine maintenance. The circuit serves a fire department, considered a critical facility, among other customers. The devices were commissioned in 2019.

Event Description

The outage occurred on January 7, 2020 when a vehicle crashed into pole 39/69 on Amity Street in Amherst, Massachusetts. The circuit was operating normally before the incident. After the vehicle crashed into the pole, it caused a 13,000-volt overhead line to break and fall to ground.

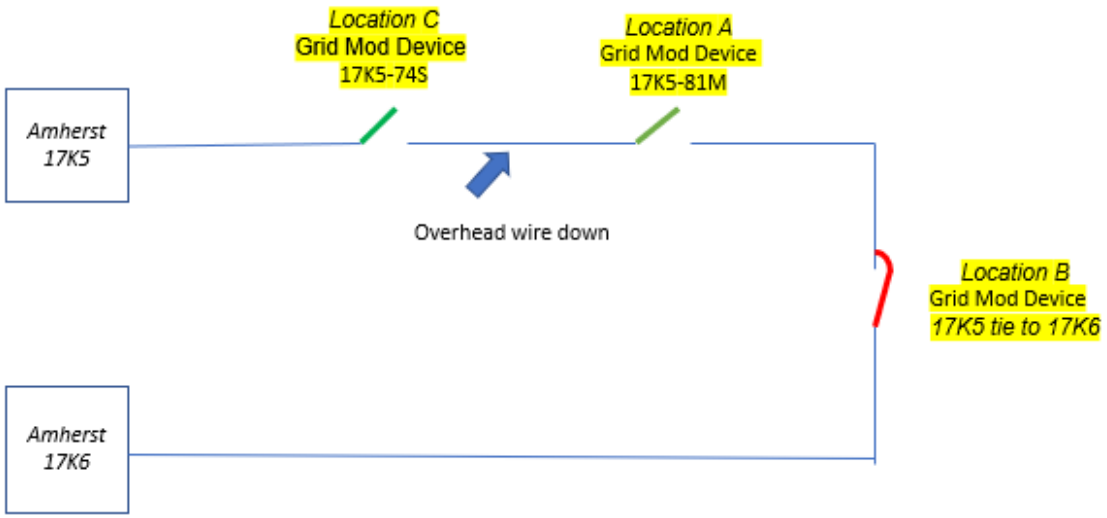
Eversource's Control Center received SCADA alarms via several SCADA controlled devices including the newly installed GMP devices reporting the incident. After the responding crew analyzed the situation, the Control Room Operators de-energized the sparking wires to make the area safe for vehicle occupant and first responders. They then used GMP devices to isolate the damage location and restore customers outside the damage zone within one minute.

The following switching sequence took place:

- Operators opened switch #17K5-74S (Location C in Figure 6), de-energizing the faulted zone. This is also a newly installed GMP device.
- Operators opened switch # 17K5-81M (Location A in Figure 6) isolating the faulted zone. This is a newly installed GMP device.
- This caused tie recloser #17K5-90T (Location B in Figure 6) to automatically close, restoring most customers. This is also a newly upgraded GMP device.

- The combination of the aforementioned steps isolated the faulted area to the minimum impact possible.

Figure 6. 17K5 One-Line Diagram



Source: Guidehouse analysis of Eversource One-Line Diagrams

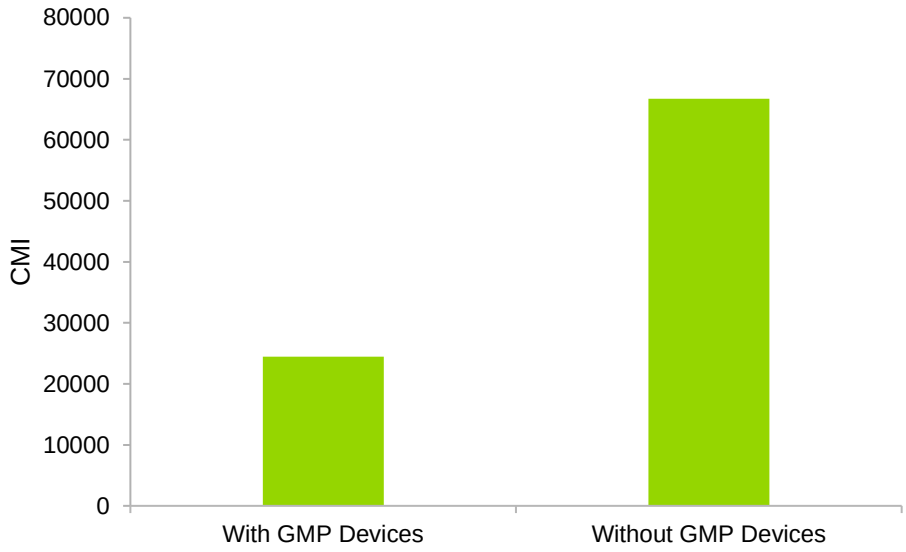
The three steps of emergency switching, using SCADA controlled GMP ADA and M&C devices, restored 716 customers in one minute. Manual repair work was then performed to fix the damage caused by the vehicle, and the 198 customers in the fault zone were restored in 120 minutes.

Benefit of Grid Modernization Investment

This case study illustrates GMP devices reducing customer outage time for a relatively common occurrence of an automobile strike on a utility pole. In addition to reducing outage time, the GMP devices also reduced the safety risks in the area of the accident.

Without the newly installed SCADA controlled GMP devices, the 716 customers that were restored in one minute would have experienced an outage estimated at an hour while manual switching was performed. The resulting customer minutes of interruption (CMI) impact is shown in Figure 7. GMP devices allowed Eversource to operate devices remotely and efficiently without the use of its field crews.

Figure 7. CMI Impacts of Grid Mod Devices



Source: Guidehouse analysis of outage data

Case Study #2: Tie Recloser Operates Automatically for Faster Power Restoration During Inclement Weather

Time of Event: April 18, 2020 at 2:46AM

Eversource Outage ID 4132704 on Circuit 18G7

Background

As part of the GMP, Eversource installed an ADA device called a tie recloser on circuit 18G7 to create an alternate (back-up) supply to customers to be used during emergency situations and for routine maintenance. The circuit serves customers in Leverett, Massachusetts, among them critical customers including a fire station, a safety complex and an elementary school. The ADA device was commissioned in Q1 2019.

Event Description

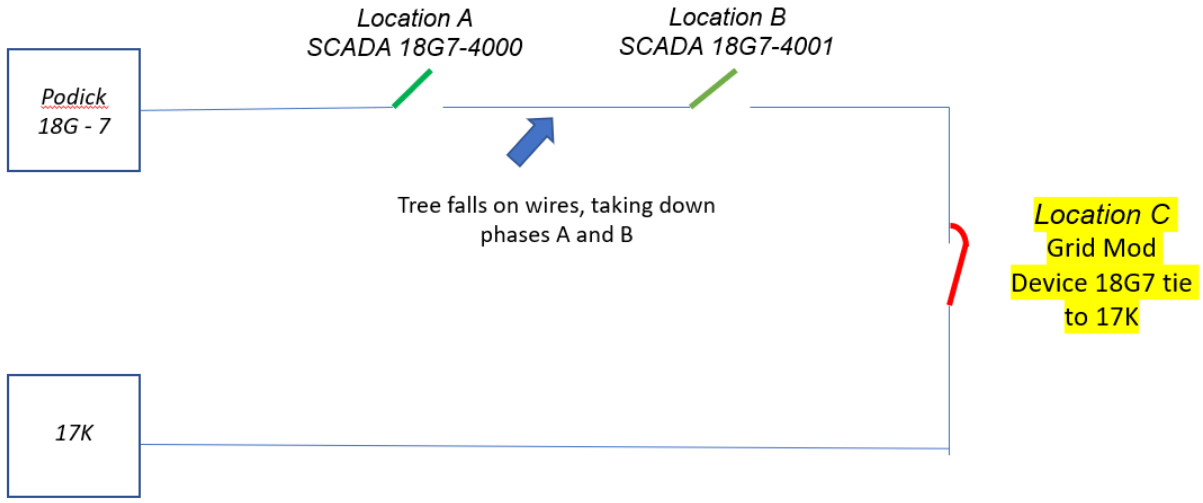
The outage occurred on April 18, 2020 when a snow-storm caused a tree to fall on overhead wires. The circuit was operating in its normal configuration prior to the incident. When the tree made impact with the wires, Phases A and B 13,800-volt wires came down and were burning on the ground. Eversource's Control Center received SCADA information indicating a loss of voltage at the line-side of 18G7-4001 and a loss of load on two phases at 18G7-4000, allowing them to identify the damaged area.

The following switching sequence took place:

1. Operators opened recloser #18G7-4000 (Location A in Figure 8) to isolate the customers load-side of the incident.

2. Operators opened switch #18G7-4001 (Location B in Figure 8) to fully isolate the fault zone where the incident occurred.
3. Opening recloser #18G7-4001 caused the tie recloser #18G7-90T (Location C in Figure 8) to automatically close, restoring all customers beyond Switch #18G7-4001. The tie recloser is a newly installed GMP ADA device.

Figure 8. 18G7 One-Line Diagram



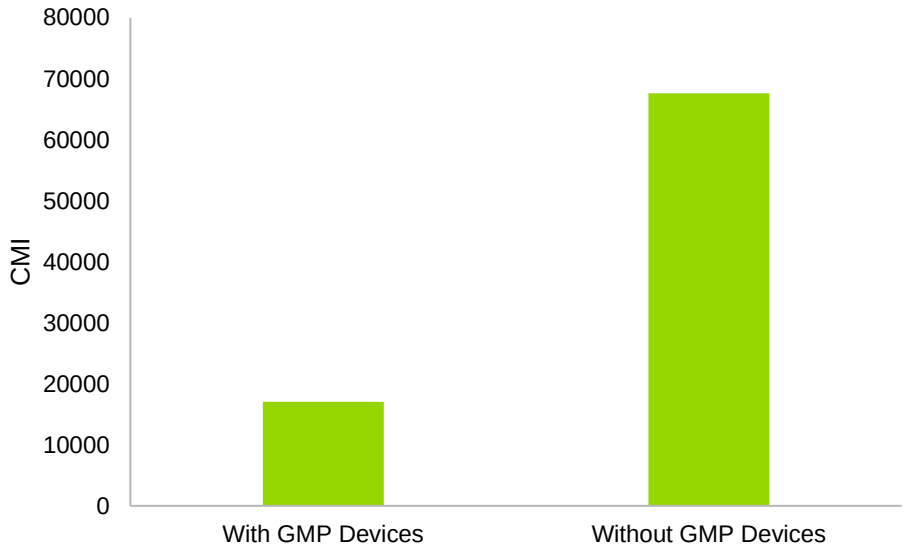
Source: Guidehouse analysis of Eversource One-Line Diagrams

The three steps of switching restored 857 customers in one minute. Without the automated tie recloser, a crew would have been required to manually close the switch, which in snowy conditions could have taken an hour.

Benefit of Grid Modernization Investment

This case study illustrates a GMP ADA device reducing customer outage time during a snow-storm. With GMP devices, Eversource was able to restore electric service quickly and make a hazardous location safe prior to the arrival of fields crews. The GMP investment led to cost-efficiencies as well as customer reliability benefits. The impact of GMP devices on customer minutes of interruption (CMI) in this instance is shown in Figure 9.

Figure 9. CMI Impacts of Grid Mod Devices



Source: Guidehouse analysis of outage data

Case Study #3: ADA Recloser Operates to Avoid Larger Outage

Time of event: December 8, 2019 at 4:54AM

Eversource Outage ID 4058379 on Circuit 22B7

Background

As part of the GMP, an ADA device known as an overhead recloser was installed to enable switching and isolation of outages and provide backup supply to customers to be used during emergency situations and for routine maintenance. The circuit 22B7 serves customers in Greenfield, Massachusetts including a customer on life support, considered critical by Eversource. The device was commissioned in Q4 of 2018.

Event Description

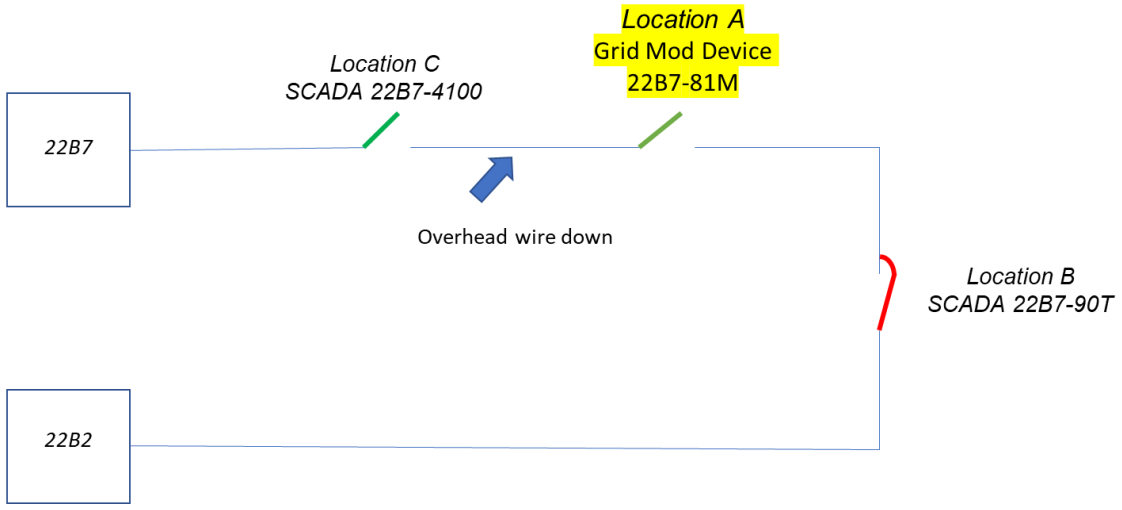
The outage occurred on December 8, 2019. Prior to the incident the weather conditions and circuit operation were normal. The outage was caused by the unexpected failure of an overhead conductor and overhead wiring coming down.

The following switching sequence took place:

1. Operators closed 21C1-90T tie switch.
2. Operators then opened 22B7-71S to transfer a portion of the load.
3. Operators closed the 22B7-90T tie switch (location B in Figure 10).
4. Operators then opened recloser 22B7-81M (Location A in Figure 10) to transfer more load to the circuit 22B2. 22B7-81M is a newly installed GMP ADA device.
5. Operators opened switch 22B7-4100 (Location C in Figure 10) to isolate the incident.

6. Crew repaired broken wire on pole 118/7 Homestead Ave.
7. Operators returned circuit to normal, restoring all customers.

Figure 10. 22B7 One-Line Diagram

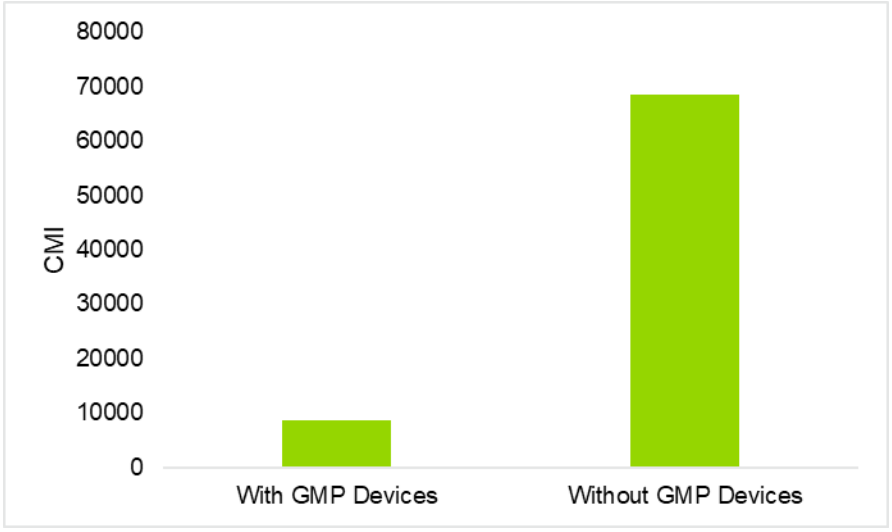


Source: Guidehouse analysis of Eversource One-Line Diagrams

Benefit of Grid Modernization Investment

This case study illustrates a GMP device reducing customer outage minutes resulting from overhead equipment failure. The 231 customers located in the damage zone experienced an outage of 38 minutes while a crew made the necessary repairs. Without the GMP device installed on this circuit, approximately 1,800 customers would have experienced the 38-minute outage. Figure 11 shows the impact of the GMP devices on the CMI.

Figure 11. CMI Impacts on Grid Mod Devices



Massachusetts Electric Distribution Companies

Massachusetts Grid Modernization Program Year 2019 Evaluation Report

M&C Performance Metrics Addendum

June 30, 2020

Table of Contents

Disclaimer

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1. Introduction

This Monitoring & Control (M&C) Performance Metrics Addendum provides evaluation of the specific performance metrics pertinent to this Grid Modernization Investment Area. The Addendum is being provided subsequent to the main 2019 evaluation report – the "Massachusetts Grid Modernization Program Year 2019 Evaluation Report" (the PY 19 Evaluation Report) document – to accommodate the availability of reliability metrics data that was required to perform the analysis.

The remainder of the Introduction Section provides background on the overall Grid Modernization Evaluation requirements and timing. This background is provided here for convenience, so the reader does not have to refer to other documents, for example the PY 19 Evaluation Report, to understand the context for this Addendum.

1.1 Massachusetts Grid Modernization Background

On May 10, 2018, the Massachusetts Department of Public Utilities (DPU) issued its Order[1] regarding the individual Grid Modernization Plans (GMPs) filed by the three Massachusetts Electric Distribution Companies (EDCs): Eversource, National Grid, and Unitil.[2,3] In the Order, the DPU preauthorized grid-facing investments over 3 years (2018-2020) for each EDC and adopted a 3-year (2018-2020) regulatory review construct for preauthorization of grid modernization investments. These preauthorized GMP investments will advance the achievement of DPU's grid modernization objectives:

1. Optimize system performance by attaining optimal levels of grid visibility command and control, and self-healing;

2. Optimize system demand by facilitating consumer price responsiveness; and

3. Interconnect and integrate distributed energy resources (DER).

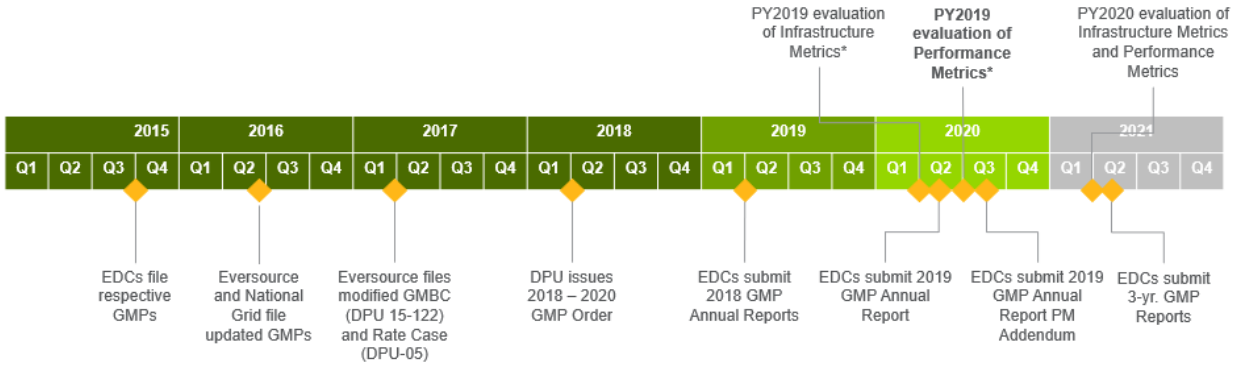
As part of the GMPs, the DPU determined that a formal evaluation process for the preauthorized GMP investments, including an evaluation plan and studies, was necessary to help ensure that the benefits are maximized and achieved with greater certainty. Figure 1 highlights the filing background and timeline of the GMP order and the evaluation process.

[1] Massachusetts D.P.U. 15-120; D.P.U. 15-121; D.P.U. 15-122 (Grid Modernization) Order issued May 10, 2018

[2] On August 19, 2015, National Grid, Unitil, and Eversource each filed a grid modernization plan with the DPU. The Department docketed these plans as D.P.U.15-120, D.P.U.15-121, and D.P.U.15-122, respectively.

[3] On June16, 2016, Eversource and National Grid each filed updates to their respective GMPs

Figure 1. MA Grid Modernization Timeline (by Program Year)



Source: Guidehouse review of the DPU orders and GMP process

The grid modernization investments were organized into six investment areas to facilitate understanding, consistency across EDCs, and analysis.

- Monitoring and Control (M&C)
- Advanced Distribution Automation (ADA)
- Volt/VAR Optimization (VVO)
- Advanced Distribution Management Systems/Advanced Load Flow (ADMS and ALF)
- Communications/IoT (Comms)
- Workforce Management (WFM)

The following subsection discusses these investment areas in greater detail in. This Addendum covers the Program Year 2019 (PY 19) evaluation of relevant performance metrics and focuses on the M&C investment area.

1.2 EDC Approach to M&C Investment

Each EDC has a unique approach to their M&C investment area. Eversource and Unitil are focused on expanding SCADA on their substations and distribution systems, while National Grid is focused on deploying feeder monitors on its distribution system. Unitil has an additional investment focused on integrating its advance metering infrastructure (AMI) data with its outage management system (OMS). Table 1 defines the devices and technologies deployed as part of M&C.

Table 1. Devices and Technologies Deployed Under M&C Investment

EDC	Device/Investment Type	Description
Eversource	Microprocessor relays	Include advance overcurrent protection, pushbutton controls for the breakers, safety Hot Line Tagging, reclosing, breaker failure, and under-frequency load-shedding schemes.
	Recloser SCADA	Addition of communications capability so the device can be centrally monitored and controlled from the dispatch center.
	4 kV Circuit Breaker SCADA	Provides real-time visibility of loading conditions on the underground circuits that are among the most heavily loaded on Eversource's distribution system.
	Padmount Switch SCADA	Addition of a radio package to enable communications and central monitoring.
	Network Protector SCADA	Provide real-time system load data.
National Grid	Feeder Monitors	Installation of interval power monitoring devices on feeders where National Grid currently does not have distribution information.
Unitil	Substation SCADA	The installation and interconnection of a SCADA terminal unit at the site, the establishment of communications between the terminal unit and the remotely located SCADA Master system, and the associated programming to implement desired functions.
	AMI-OMS Integration	The deployment of software that analyzes AMI status changes and relevant data points, detects suspect outages, and reports them as such to the OMS.

Source: Guidehouse analysis of 2018 Grid Modernization Plan (GMP) Annual Reports and EDC Data

1.3 Performance Metrics

Table 2 lists the performance metrics (PMs) for all Investment Areas, with those evaluated in this Addendum highlighted.

Table 2. Performance Metrics Overview

ID	PM Metric	Applicable IA	Applicable EDC
Statewide			
PM-1	VVO Baseline	VVO	All
PM-2	VVO Energy Savings	VVO	All
PM-3	VVO Peak Load Impact	VVO	All
PM-4	VVO Distribution Losses without AMF (Baseline)	VVO	All
PM-5	VVO Power Factor	VVO	All
PM-6	VVO – GHG Emissions	VVO	All
PM-7	Voltage Complaints	VVO	All
PM-8	Increase in Substations with DMS Power Flow and Control Capabilities	ADMS/ ALF	All
PM-9	Control Functions Implemented by Circuit	ADMS/ ALF	All
PM-11	**Numbers of Customers that benefit from GMP funded Distribution Automation Devices**	**ADA**	**All**
PM-12	**Grid Modernization investments' effect on outage durations**	**M&C, ADA**	**All**
PM-13	**Grid Modernization investments' effect on outage frequency**	**M&C, ADA**	**All**
EDC-Specific			
PM-ES1	Advanced Load Flow – Percent Milestone Completion	ADMS/ ALF	ES
PM-ES2	**Protective Zone: Average Zone Size per Circuit**	**ADA, M&C**	**ES**
PM-UTL1	**Customer Minutes of Outage Saved per Circuit**	**M&C**	**UTL**
PM-NG1	**Main Line Customer Minutes of Interruption Saved**	**ADA, M&C**	**NG**

Source: Stamp Approved Performance Metrics, July 25, 2019.

Table 3 provides an overview of relevant metrics evaluated in this PM addendum. The metrics that are specific to M&C are highlighted.

Table 3. Performance Metrics Objectives

Performance Metric	EDC	Overview
PM-12: Grid Modernization investments' **effect on outage durations (CKAIDI)**	**ES, NG, UTL**	This metric will compare the experience of customers on GMP circuits as compared to the prior three-year average for the same circuit. This metric will provide insight into how M&C investments can reduce the duration of outages by looking at the change in the circuit-level System Average Interruption Duration Index (CKAIDI).
PM-12: Grid Modernization investments' **effect on outage frequency (CKAIFI)**	**ES, NG, UTL**	This metric will compare the experience of customers on GMP circuits as compared to the prior three-year average for the same circuit. This metric will provide insight into how M&C investments can reduce the frequency of outages by looking at the change in the circuit-level System Average Interruption Frequency Index (CKAIFI).
PM-11: Numbers of Customers that benefit from GMP funded Distribution Automation Devices	**ES, NG, UTL**	This metric will show the progress in the Distribution Automation investment by tracking the numbers of customers that have benefitted from the installation of Distribution Automation devices. This metric will support the objective of optimizing system performance and more specifically reduce the duration and number of customers impacted by outage events. These investments will also allow for a reduction in manual switching operations, reduce operations cost and potentially defer capital upgrades with enhanced flexibility to shift load.
PM-ES2: Protective Zone: Average Zone Size per Circuit	**ES**	This metric is intended to measure progress in sectionalizing circuits into protective zones designed to limit outages to customers located within the zone. This metric will measure progress in achieving the grid modernization objective of reducing the impact of outages.
PM-UTL1: Customer Minutes of Outage Saved per Circuit	**UTL**	The objective of this metric is to track the customer minutes saved per outage on each feeder. This metric is a study of the overall duration of outages and the number of customer minutes saved based upon grid modernization investments.
PM-NG1: Main Line Customer Minutes of Interruption Saved	**NG**	This metric is designed to measure the impact of M&C Investments on the customer minutes of interruption (CMI) for main line interruptions.

Source: Stamp Approved Performance Metrics, July 25, 2019.

1.4 Case Study Evaluation

A "case study" approach was developed to provide more insight into the actual operation of the GMP devices and to illustrate how these investments provide customer reliability and operational benefits. As discussed below, the impacts of GMP devices on system reliability metrics can be difficult to discern due to the range of factors that affect these metrics. This is likely to be especially true if the device has less than a full year of operation to affect the metric. The case studies help to illustrate the benefits provided by GMP devices during outage events. This approach investigates several outage events on specific circuits where the GMP equipment operated to address an outage. The approach also allows for comparison between what did

occur due to the presence of the GMP device and what would have likely happened had the GMP investment not been made.

For the M&C performance metrics evaluation, a total of three case studies were performed: two for Eversource and one for National Grid. The details of the analysis and the results are examined in Section 4.

2. Performance Metrics Data Management

This section discusses the data sources used for the performance metric evaluation and case studies and summarizes the Quality Assessment and Quality Control (QA/QC) steps.

2.1 Data Sources

The following data sources were used to complete the evaluation analysis in this document.

- 2019 Grid Modernization Plan Annual Report Appendix 1[4,5,6]
- Service Quality Index (SQI) Filings[7,8,9]
- Outage Data[10]
- Circuit Topology Diagrams and One-Line Diagrams[11]
- Work Order Information

2019 Grid Modernization Plan Annual Report Appendix 1: On April 1, 2020 each EDC submitted this Appendix along with the Annual Report. The Appendix 1 contains feeder-level data for all feeders within each EDC's territory. All PM-related data presented in this addendum report are from the 2019 GMP Annual Report Appendices. These documents contain baseline and program year data for all circuits for each EDC. They key data from the appendices that were utilized in this analysis include:

- Customer Counts
- Feeder Level SAIDI (CKAIDI) and SAIFI (CKAIFI) for the Plan Year and Baseline
- Number of Customers that Benefit from GMP Investments
- Average Protective Zone Size
- Main Line Customer Minutes of Interruption

SQI Filings: The evaluation team used 2019 and historical SQI filings to cross-check for consistency with the data in the GMP Annual Report Appendices to ensure accuracy across the

[4] Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid, Grid Modernization Plan Annual Report 2019. Submitted to Massachusetts DPU on April 1, 2020 as part of D.P.U. 15-120

[5] NSTAR Electric Company d/b/a Eversource Energy, Grid Modernization Plan Annual Report 2019. Submitted to Massachusetts DPU on April 1, 2020 as part of D.P.U. 15-122. Note: Inconsistencies in calculations and definitions were discovered and Eversource updated the Appendix 1 in May 2020. The updates were provided to Guidehouse.

[6] Fitchburg Gas and Electric Light Company d/b/a Unitil, Grid Modernization Plan Annual Report 2019. Submitted to Massachusetts DPU on April 1, 2020 as part of D.P.U. 15-121

[7] Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid, 2019 Annual Service Quality Report. Submitted to Massachusetts DPU on February 28, 2020 as part of D.P.U. 20-SQ-11 and 20-SQ-12; 2017 Annual Service Quality Report. Submitted to Massachusetts DPU on March 1, 2018 as part of D.P.U. 18-SQ-11 and 18-SQ-12

[8] NSTAR Electric Company and Western Massachusetts Electric Company d/b/a Eversource Energy, 2019 Annual Service Quality Report. Submitted to Massachusetts DPU on February 28, 2020 as part of D.P.U. 20-SQ-13 and 20-SQ-14

[9] Fitchburg Gas and Electric Light Company d/b/a Unitil, 2019 Annual Service Quality Report. Submitted to Massachusetts DPU on February 28, 2020 as part of D.P.U. 20-SQ-10

[10] National Grid and Eversource provided outage reports for all GMP circuits. Guidehouse selected outages to review in more detail and National Grid and Eversource provided SCADA data and detailed one-line diagrams.

[11] GIS diagrams were received and reviewed but were too complex to analyze outages at the device level. To support the analysis, Eversource provided simplified one-line diagrams with GMP devices clearly labeled

sources and contain data for the performance year and the baseline years. Specific QA/QC steps are explained further in Section 2.2.

Work Order Information: Circuit-level work order data was collected during the infrastructure metrics evaluation to understand the current status (e.g., CONSTRUCTION, DESIGN, IN-SERVICE) of GMP investments. This work order data was used to determine when GMP investments were installed at each circuit.[12]

Outage Data and One-Line Diagrams: Outage Data and Circuit Topology and One-Line Diagrams were used to perform the Case Study analyses. The outage data contains details of outage events, such as cause, resolution, and CMI that were integral to understanding the role of the GMP device in resolving the outage. The One-Line Diagrams helped support the analysis by using visualization to better understand the operation of the relevant devices during the outage event. Refer to Section 4 for further explanation about the data sources utilized for case study analyses.

2.2 Data Completeness Checks and QA/QC Review

The evaluation team reviewed the Appendix 1 filings for completeness, accuracy, and alignment with the metrics set forward in the DPU Stamp Approved Metrics. The QA/QC process involved the following:

- Comparison of the 2015-2017 average CKAIDI/CKAIFI values using calculated values from 2015, 2016, and 2017 data in the SQI filing. Note: DPU Stamp Approved Metric Guidance defines this as AVG(2015, 2016, 2017 CKAIDI/CKAIFI)

- Check that the change in CKAIDI/CKAIFI and average zone sizes were properly calculated using the stamp approved metric's definition. Note: DPU Stamp Approved Metric Guidance defines this as "BASELINE – PROGRAM YEAR"

- Comparison of 2019 reliability data with and without excludable major events and circuit information in the SQI filing and the Appendix 1 filing.

- Comparison of circuits with GMP investments in the Appendix 1 filing and the work order data collected during the Infrastructure Metric analysis.

During this QA/QC process, the evaluation team identified issues in both the Eversource and National Grid Appendix 1 filings that required adjustments and updates:

Eversource: Baseline CKAIDI/CKAIFI values and the change in CKAIDI/CKAIFI values had been calculated using an alternative interpretation[13] from the Stamp Approved metrics, requiring adjustment.

[12] Note there are slight differences in the total number of devices reported in the work order data and the official device count reported in the PY 19 Evaluation Report because of minor variations in the work order level data.

[13] This interpretation added the total outage times on each circuit across the three baseline years, added the average annual customer counts across the 3 years, and then divided them to reach the baseline metric. This is different than the strict metric definition, which simply averages the metric for the circuit over the 3 baseline years, and can yield a slightly different result.

National Grid: the change in CKAIDI/CKAIFI calculations were using a different source for the baseline values. National Grid updated and resubmitted its Appendix 1 data and GH then re-completed the QC analysis

2.3 Selecting Circuits with Sufficient Data for Analysis

Devices and technologies deployed and commissioned in each investment area were made throughout 2019, as well as in 2018. The key reliability metrics involving outage duration (CKAIDI) and frequency (CKAIFI) are annual metrics, and impacts to these metrics from GMP investments would only be seen if the investments were installed for sufficient time on a particular circuit to impact outages that drive these annual metrics.

The approach most likely to detect metric impacts from the investments would be to wait until the investment had been commissioned for a full year on the circuit before attempting to understand its impact on these metrics. However, the evaluation team determined that the use of the technology for at least one-half of the full program year could be enough to make the impacts visible in the annual metrics.[14]

The evaluation team reviewed the installation and commissioning timing for the various investments to understand when during the 2019 Program Year the devices were installed. For the CKAIDI/CKAIFI metrics (PM-12 and PM-13), circuits with *at least* a half year with the technology commissioned and in service were selected for inclusion in the analysis. All circuits receiving M&C investments were included in the remaining performance metrics.

The subsections below detail this analysis and circuit selection for Eversource and National Grid respectively.

2.3.1 Eversource Circuits

Circuits Receiving GMP Investments: Eversource installed and commissioned devices throughout PY 2019 as well as during PY 2018. Table 4 shows the period of deployment of M&C devices through the end of PY 2019.

Table 4. Eversource Timeline of Devices Commissioned

Device Type	M&C Devices Installed			
	2018	H1* 2019	H2* 2019	Total
13.8/23 kV SS relays	10	10	77	97
4 kV SS SCADA	0	0	16	16
OH recloser SCADA	15	16	3	34
Network protector SCADA	0	0	0	0
Padmount switch SCADA	3	24	18	45
TOTAL	**28**	**50**	**114**	**192**

Source: Eversource 2019 GMP Annual Report Appendix 1, Eversource Work Order Data
**H1: January-June; H2: July-December*

[14] Being mindful that many other factors affect these metrics, including weather, car strikes, and other factors.

The table shows that approximately 40% of the total number of the M&C devices installed and commissioned through PY 19 were installed prior to H2 2019.

Table 5 shows the number of circuits and associated devices on which any GMP investments were commissioned prior to H2 2019. Several circuits have multiple GMP devices, but in those instances, only the devices that were commissioned prior to H2 2019 are included in the device count.

Table 5. Circuit Count for M&C Devices

Device Type	Circuits with M&C Investments installed through 2019	Circuits with M&C investments installed H1-2019 and Prior
Microprocessor relays	71	26
4 kV SS SCADA	15	0
Recloser SCADA	16	16
Network protector SCADA	0	0
Padmount Switch SCADA	29	22
Multiple M&C Device Types	8	7
Total	139	71

Source: Eversource 2019 GMP Annual Report Appendix 1, Eversource Work Order Data
Note: 11 circuits had both ADA and M&C GMP devices installed

Circuits with Sufficient Data for Analysis: The evaluation team also excluded circuits from the analysis that had missing, incomplete, or non-numerical reliability data (CKAIDI/ CKAIFI) for baseline or 2019 with or without excludable major events performance metrics. Table 6 summarizes how many circuits had sufficient data for analysis after these exclusions.

Table 6. Eversource M&C Circuit Data Completeness

Summary	System-wide[15]	M&C Targeted through 2019	M&C Installed through H1 2019
Circuit Count	2,299	139	71
Circuits with Complete Data[16]	2,085	133	68
% Circuits Included in Analysis	91%	96%	96%

Source: Guidehouse analysis of Eversource data

2.3.2 National Grid Circuits

Circuits Receiving GMP Investments: Table 7 below shows the deployment and commissioning timing for National Grid's M&C investments.

[15] System-wide refers to all circuits in the 2019 GMP Annual Report Appendix 1.

[16] Of the 214 circuits that did not have complete data, 137 were created during the baseline period, 72 were retired/reconfigured/retired/other, and 5 had insufficient data.

Table 7. National Grid Timeline of Devices Commissioned

Device Type	M&C Devices Installed			
	2018	H1 2019	H2 2019	Total
Feeder Monitor	0	0	5	5

Source: Guidehouse Analysis of National Grid Data

National Grid Installed 5 GMP devices in 2019: 4 commissioned in Q4 PY 19, and one in Q3. Thus, none of the GMP circuits "qualify" for reliability analysis for PY 2019.

Under the chosen selection criteria, National Grid had no investments that were installed long enough in PY 19 to show impacts in the duration and frequency reliability metrics. Thus, no further analysis was performed on the M&C circuits. However, baseline and system-wide data is provided below for reference.

Additionally, there is a case study described in Section 4 that details how the M&C investment is being used to improve reliability.

Circuits with Sufficient Data for Analysis: The National Grid data was nearly 100% complete. Data was received for the 5 circuits targeted for M&C through 2019.

Table 8. National Grid M&C Circuit Data Completeness

Summary	System-wide[17]	M&C Targeted thru. 2019	M&C Installed thru. H1 2019
Circuit Count	1,123	5	0
Circuits with Complete Data	1,111	5	N/A
% Circuits Included in Analysis	99%	100%	N/A

Source: Guidehouse Analysis of National Grid Data

[17] System-wide refers to all circuits in National Grid's 2019 GMP Annual Report Appendix 1.

3. M&C Performance Metrics Analysis Approach and Results

Evaluation of the various performance metrics for each EDC is provided below. An overview of the approach and results are provided first to facilitate understanding of the detailed results analysis.

Results Summary: Table 9 provides a high-level summary of the results for each performance metric and EDC.

Table 9. Summary of Findings for M&C Investment Area

PM	Eversource	National Grid	Unitil
PM-12: Grid Modernization investments' effect on outage durations	Outage duration was not reduced compared to the system average, but the average effect is small compared to overall metric variability.	M&C devices have not been operating long enough to measure impacts	N/A – no commissioned M&C devices
PM-13: Grid Modernization investments' effect on outage frequency	Outage frequency slightly increased compared to the system average, but the average effect is small compared to overall metric variability.	M&C devices have not been operating long enough to measure impacts	N/A – no commissioned M&C devices
PM-UTL1: Customer Minutes of Outage Saved per Circuit	N/A – Unitil specific metric	N/A – Unitil specific metric	N/A – no commissioned M&C devices
PM-NG1: Main Line Customer Minutes of Interruption Saved	N/A – NG specific metric	M&C devices have not been operating long enough to measure impacts	N/A – no commissioned M&C devices

Source: Guidehouse Analysis

Analysis Approach: The following approach was developed to provide additional insight to the EDC PM that have already been published by the EDCs in their Annual Reports for PY 19. Circuit-level data was used for a number of the metrics, and this allowed a similar approach to be followed for these metrics. The approach has three elements:

1. Baseline and Performance Year System-wide and M&C circuit comparisons: The evaluation team compared the baseline and performance year data across the entire system and for qualified circuits receiving M&C investments. Statistical averages for these circuit groupings are used to make simple comparisons, and standard deviations are calculated to provide insight into the variability compared with the average values. For PM-12 (change in CKAIDI) and PM-13 (change in CKAIFI), the system-wide metric baseline was compared against the program year metric using reliability bins. This facilitates a general understanding of where the M&C investments fit into the context of the overall system metric performance and to compare changes in metrics for M&C to those system-wide.

2. Before and after comparison**:** For PM-12 and PM-13, the current year performance was compared to the baseline performance for all circuits within the system. "Box-and-whisker"

plots[18] are used to illustrate the distribution of data across the entire system and for circuits receiving M&C investments.[19]

3. Difference in differences: Calculate the difference in system-wide circuits change from baseline vs. M&C investment circuits change from baseline to understand if there is any discernable reliability improvement on the M&C circuits. This change is defined as "average metric for circuits with M&C investments – average metric for circuits system-wide."

The Metrics sections below leverage these three steps to try and provide additional insights on the impact of M&C investments.

3.1 PM-12: Effect on Outage Duration (CKAIDI)

Metric PM-12, Reliability-Focused Grid Modernization Investments' Effect on Outage Duration (CKAIDI), provides insight on how GMP devices impact outage duration and will track the improvements over time. Per the DPU Stamp Approved GMP Performance Metrics Guidance:

> *This metric will compare the experience of customers on GMP DA-enabled circuits as compared to the prior three-year average for the same circuit. This metric will provide insight into how DA can reduce the duration of outages (by tracking and reporting) the following:*
>
> - *Circuit level SAIDI for the program year*
> - *Three-year average SAIDI for 2015, 2016, and 2017*
> - *Comparison of the current year SAIDI with the three-year historic average: AVERAGE(CKAIDI 2015, CKAIDI 2016, CKAIDI 2017) – PY CKAIDI = if greater than 0, positive impact*

The EDCs have provided the CKAIDI metric in their Appendix 1 filings. As discussed above, only circuits with M&C investments in H1 (January – June) 2019 and prior are included in the analysis. Analysis of this metric for each EDC is presented in the following subsections.

3.1.1 Eversource Analysis

Analysis of the CKAIDI metrics for Eversource is provided in this sub-section:

System-wide and M&C circuit counts: Table 10 is structured with CKAIDI ranges, or "bins", to provide insight about the range of outage durations across the system, and to show where circuits selected for M&C investment fall within these bins. There are a number of circuits with no outages at all within the baseline period. The proportion of these circuits is higher in the

[18] The "box-and-whisker" plot divides the sample into quartiles. The boxes show the 2nd and 3rd quartile in the sample. The lower and upper "whiskers" indicate 1.5 times the interquartile range (IQR) (difference between the start of the 2nd and the end of the 3rd quartile) or the maximum/minimum value within the range if it falls within 1.5x the IQR. The "x" indicates the sample average. . Data points that fall outside 1.5x the IQR are not shown on the graph..

[19] Note that the DPU Guidance defines the change as "Baseline – Program Year" which means that positive values of this metric indicate reliability improvement—the opposite of what you would expect for improvement in CKAIDI or CKAIFI metric (which fall with improvement).

system than in the circuits with M&C investments for both 2015-2017 and 2019, providing some indication that circuits with lower than average reliability were targeted for M&C investment.[20]

An increase in system average CKAIDI from the baseline to PY 19 indicates decreased reliability at the system level, and thus that PY 19 was a "worse" reliability year than baseline. This difference may be due to a number of factors, including weather, animal faults, tree trimming cycle and other idiosyncratic causes. The CKAIDI standard deviation also increased significantly, indicating increased variability in CKAIDI across the system.

Table 10. Baseline and 2019 CKAIDI Eversource Circuit Count Bins

Summary	2015-2017 Avg. CKAIDI (Baseline)				2019 CKAIDI (Program Year)			
	System-wide[21]		Targeted for M&C through 2019		System-wide		M&C installed H1 2019 and Prior	
	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs
CKAIDI Statistics								
Total Circuits	2,085	2,085	133	133	2,085	2,085	68	68
% Zero	41%	34%	25%	25%	41%	44%	12%	13%
Average	80.0	63.3	72.4	68.5	169.2	75.5	185.0	107.8
Std. Dev.	135.8	102.5	111.2	93.1	416.0	229.8	273.7	134.8
CKAIDI Range								
0	779	780	33	33	940	1,017	8	9
1-49	491	535	44	44	351	516	19	28
50-149	448	491	41	41	286	291	18	15
150-249	182	166	6	7	151	117	7	6
250-349	84	63	5	5	76	52	7	6
350-449	44	27	2	2	41	27	1	1
450-549	20	10	1	1	44	12	3	2
550-649	13	3	0	0	34	12	0	1
650-749	9	5	0	0	34	6	2	0
750-849	9	3	1	0	25	4	1	0
850-949	3	1	0	0	17	3	0	0
950-1049	1	1	0	0	13	2	1	0
> 1050	2	0	0	0	73	26	1	0

Note: EME = excludable major events. CKAIDI of zero indicates circuit did not experience any outages.

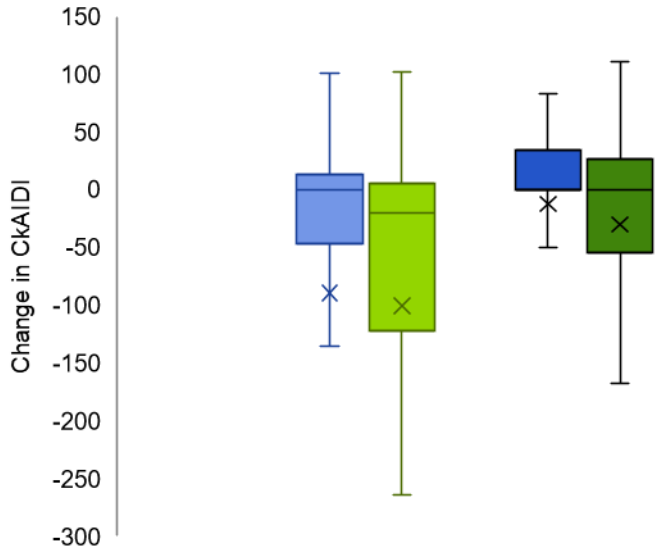
Before and after comparison: A simple graphical summary of the statistical change in CKAIDI is shown in Figure 2 below, which uses the "box-and-whisker" format.[22] This chart compares the difference in CKAIDI between baseline and PY 19, for both the system-wide values and the selected M&C circuits.

[20] Eversource's 2018 GMP Annual Report contains the following text about methodology of choosing circuits for GMP investments: *Circuit reliability based on historical SAIDI and SAIFI from 2015, 2016 and 2017 was also considered when selecting circuits for investment.*

[21] System-wide references to all circuits in the 2019 GMP Annual Report Appendix 1 that had complete data.

[22] The "box-and-whisker" plot divides the sample into quartiles. The boxes show the 2nd and 3rd quartile in the sample. The lower and upper "whiskers" indicate 1.5 times the interquartile range (IQR) (difference between the start of the 2nd and the end of the 3rd quartile) or the maximum/minimum value within the range if it falls within 1.5x the IQR. The "x" indicates the sample average. Data points that fall outside 1.5x the IQR are not shown on the graph.

Figure 2. Impact in Outage Duration Performance Metric Results



System-wide:

	w/ EMEs	w/o EMEs
count	2085	2085
% Zero	32%	33%
Avg.	-89	-12
Std. Dev.	382	226

w/ M&C Investments:

	w/ EMEs	w/o EMEs
count	68	68
% Zero	12%	12%
Avg.	-101	-30
Std. Dev.	251	117

Note: EME = excludable major events. Change in CKAIDI is reported as minutes and is calculated as defined by the DPU PM Guidance: 2015-2017 Avg. CKAIDI – 2019 CKAIDI = if greater than zero, positive impact.

The system-wide CKAIDI increased, on average, in PY 19 over the baseline. For the selected M&C circuits, CKAIDI increased slightly more than on a system-wide basis, indicating a worsening performance on the M&C circuits on average.[23]

However, the standard deviation of CKAIDI for each group is significantly larger—several times larger-- than the average change in CKAIDI itself, providing an indication that the change in the average is of limited statistical significance, and not indicative of any clearly discernible trend in CKAIDI. As indicated above, there are many potential reasons for these changes and many factors impacting this metric. The impact of the M&C investment in operation is one of the factors but is not discernable using the metric itself.

Difference in differences: The difference in the change in CKAIDI between the system-wide average (-89 with EMEs, -12 without EMEs) and the average for circuits with M&C investments (-100 with EMEs, -30 without EMEs) is -11 with EMEs and -18 without EMEs. The change in CKAIDI for circuits with M&C investments was approximately 30% worse than the circuits without M&C investments. However, the standard deviation for these samples is much larger than the CKAIDI changes indicating that the difference is likely not statistically significant and is more probably a factor of randomness in the metric data than any type of trend. Thus, the metric data is “too noisy” to tell us much if anything about the impact of M&C investments during PY 19.

[23] Note that the “whiskers” extend further for the circuits with M&C investments because there are fewer M&C circuits that experienced zero change in CKAIDI. As a result, the IQR range for these circuits is larger than the IQR range of the system-wide group.

3.1.2 National Grid Analysis

National Grid did not have any M&C investments installed prior to H1 2019; however, the evaluation team reviewed the baseline and PY 19 system-wide performance to see if there were any noticeable trends.

System-wide and M&C circuit counts: Table 11 is structured with CKAIDI ranges, or "bins," to provide insight about the range of outage durations across the system, and to show where circuits selected for M&C investment fall within these bins. There are a number of circuits with no outages at all within the baseline period; however, none of these circuits were targeted for M&C investments through 2019. The circuits receiving M&C investments had higher than average CKAIDI values, providing some indication that these less reliable and higher customer count circuits were targeted more for M&C investment.[24]

An increase in system average CKAIDI from the baseline to PY 19 indicates decreased reliability at the system level, and thus that PY 19 was a "worse" year due to a number of factors, potentially including weather, animal faults, tree trimming cycle and other idiosyncratic causes. The CKAIDI standard deviation also increased significantly, indicating increased variability in CKAIDI across the system.

Table 11. Baseline and 2019 National Grid CKAIDI Circuit Count Bins

Summary	2015-2017 Avg. CKAIDI (Baseline)				2019 CKAIDI (Program Year)			
	System-wide		Targeted for M&C through 2019		System-wide		M&C installed H1 2019 and Prior	
	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs
Reliability Statistics								
Count	1,111	1,111	5	5	1,111	1,111	0	0
% Zero	5%	6%	0%	0%	18%	20%	N/A	N/A
Avg.	177.5	111.3	340.0	160.0	182.0	134.0	N/A	N/A
Std. Dev.	200.4	118.9	135.6	49.0	211.3	161.9	N/A	N/A
CKAIDI Range								
0	56	62	0	0	197	223	N/A	N/A
1-49	259	334	0	0	259	311	N/A	N/A
50-149	358	441	0	2	251	284	N/A	N/A
150-249	184	176	2	3	140	134	N/A	N/A
250-349	81	57	1	0	83	77	N/A	N/A
350-449	42	17	0	0	46	26	N/A	N/A
450-549	27	11	2	0	28	17	N/A	N/A
550-649	26	6	0	0	18	10	N/A	N/A
650-749	18	1	0	0	18	9	N/A	N/A
750-849	10	1	0	0	7	4	N/A	N/A

[24] National Grid's 2019 GMP Annual Report contains the following text about methodology of choosing circuits for GMP investments: *Preliminary Engineering was completed in order to assess and choose the highest areas of impact for feeder monitoring to be installed. These areas were typically categorized as feeders with large customer counts but low historical data.*

Summary	2015-2017 Avg. CKAIDI (Baseline)				2019 CKAIDI (Program Year)			
	System-wide		Targeted for M&C through 2019		System-wide		M&C installed H1 2019 and Prior	
	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs
850-949	15	3	0	0	11	2	N/A	N/A
950-1049	5	0	0	0	9	3	N/A	N/A
> 1050	30	2	0	0	44	11	N/A	N/A

Note: EME = excludable major events. CKAIDI of zero indicates circuit did not experience any outages.

Before and after comparison: The impact on outage duration was not assessed because there were no circuits with completed M&C investments in operation for more than half of PY 19.

3.1.3 Unitil Analysis

Unitil did not have qualifying M&C investments installed in 2019.[25] As such, progress towards this metric has not be evaluated.

3.2 PM-13: Effect on Outage Frequency (CKAIFI)

Metric PM-12, Reliability-Focused Grid Modernization Investments' Effect on Outage Frequency (CKAIFI), provides insight on how GMP devices impact outage duration and will track the improvements over time. Per the DPU Stamp Approved GMP Performance Metrics Guidance:

> *This metric will compare the experience of customers on GMP DA-enabled circuits as compared to the prior three-year average for the same circuit. This metric will provide insight into how DA can reduce the frequency of outages (by tracking and reporting) the following:*
>
> - *Circuit level SAIFI (CKAIFI) for the program year*
> - *Three-year average SAIFI (CKAIFI) for 2015, 2016, and 2017*
> - *Comparison of the current year SAIFI (CKAIFI) with the three-year historic average: AVERAGE(CKAIFI 2015, CKAIFI 2016, CKAIFI 2017) – PY CKAIFI = if greater than 0, positive impact*

The EDCs have provided the CKAIFI metric in their Appendix 1 filings. As discussed in Section 3.3, only circuits with M&C investments in H1 2019 and prior are included in the analysis. Analysis of this metric for each EDC is presented in the following subsections and align closely with the previous metric (PM-12: Impact on Outage Duration).

3.2.1 Eversource Analysis

Analysis of the CKAIFI metric for Eversource is provided in this sub-section below:

[25] There was one circuit receiving substation-level SCADA in 2019; however, this circuit is not in operation.

System-wide and M&C circuit counts: Table 12 is structured with CKAIFI ranges, or "bins", to provide insight about the range of outage durations across the system, and to show where circuits selected for M&C investment fall within these bins. There are several circuits with no outages at all within the baseline period. The proportion of these circuits is higher in the system than in the circuits with M&C investments for both 2015-2019 and 2019, providing some indication that these less reliable circuits were targeted for M&C investment.[26]

An increase in system average CKAIFI from the baseline to PY 19 and 25 outliers with CKAIFI greater than 5 indicates decreased reliability at the system level, and thus that PY 19 was a "worse" due to a number of factors, potentially including weather, animal faults, tree trimming cycle and other idiosyncratic causes. The CKAIFI standard deviation also increased significantly, indicating increased variability in CKAIFI across the system.

Table 12. Baseline and 2019 Eversource CKAIFI Circuit Counts

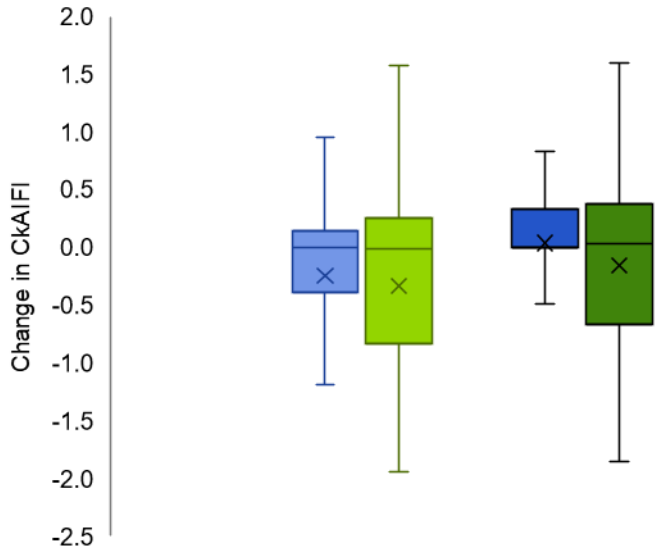
Summary	2015-2017 Avg. CKAIFI (Baseline)				2019 CKAIFI (Program Year)			
	System-wide		Targeted for M&C through 2019		System-wide		M&C installed H1 2019 and Prior	
	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs
CKAIFI Statistics								
Total Circuits	2,085	2,085	133	133	2,085	2,085	68	68
% Zero	34%	34%	25%	25%	41%	45%	12%	13%
Average	0.5	0.5	0.6	0.6	0.8	0.5	1.1	0.9
Std. Dev.	0.7	0.7	0.6	0.6	1.3	0.8	1.1	1.0
CKAIFI Range								
0	779	780	33	33	940	1,017	8	9
0.01-0.24	491	535	44	44	351	516	19	28
0.25-0.74	448	491	41	41	286	291	18	15
0.75-1.24	182	166	6	7	151	117	7	6
1.25-1.74	84	63	5	5	76	52	7	6
1.75-2.24	44	27	2	2	41	27	1	1
2.25-2.74	20	10	1	1	44	12	3	2
2.75-3.24	13	3	0	0	34	12	0	1
3.25-3.74	9	5	0	0	34	6	2	0
3.75-4.24	9	3	1	0	25	4	1	0
4.25-4.74	3	1	0	0	17	3	0	0
4.75-5.24	1	1	0	0	13	2	1	0
> 5.25	2	0	0	0	73	26	1	0

Note: EME = excludable major events. CKAIFI of zero indicates circuit did not experience any outages.

[26] Eversource's 2018 GMP Annual Report contains the following text about methodology of choosing circuits for GMP investments: *Circuit reliability based on historical SAIDI and SAIFI from 2015, 2016 and 2017 was also considered when selecting circuits for investment.*

Before and after comparison: A simple graphical summary of the statistical change in CKAIFI is shown in Figure 3 below, which uses a "box-and-whisker" format.[27] This chart compares the difference in CKAIFI between baseline and PY 19 for each circuit, for both the system-wide values and the selected M&C circuits.

Figure 3. Impact in Outage Frequency Performance Metric Results



System-wide:

	w/ EMEs	w/o EMEs
count	2085	2085
% Zero	32%	33%
Avg.	-0.2	0.0
Std. Dev.	1.1	0.8

w/ M&C Investments:

	w/ EMEs	w/o EMEs
count	68	68
% Zero	12%	12%
Avg.	-0.3	-0.2
Std. Dev.	1.1	1.0

Note: EME = excludable major events. Change in CKAIFI is calculated as defined by the DPU PM Guidance: 2015-2017 Avg. CKAIFI – 2019 CKAIFI = if greater than zero, positive impact.

The system-wide CKAIFI did not change in PY 19 over the baseline. However, for the selected M&C circuits, CKAIFI increased slightly (-0.3 with EMEs, -0.2 without EMEs), indicating a worsening performance on the M&C circuits on average.[28]

The standard deviation of CKAIFI for each group is significantly larger—several times larger--than the average change in CKAIFI itself, providing an indication that the change in the average is of limited statistical significance, and not indicative of any clearly discernible trend in CKAIFI. As indicated above, there are many potential reasons for these changes and many factors impacting this metric. The impact of the M&C investment in operation is one of the factors but is not discernable using the metric itself.

Difference in differences: The difference in the change in CKAIFI between the system-wide average (-0.25 with EMEs, 0.04 without EMEs) and the average for circuits with M&C investments (-0.34 with EMEs, -0.16 without EMEs) is -0.09 with EMEs and -0.20 without EMEs.

[27] The "box-and-whisker" plot divides the sample into quartiles. The boxes show the 2nd and 3rd quartile in the sample. The lower and upper "whiskers" indicate 1.5 times the interquartile range (IQR) (difference between the start of the 2nd and the end of the 3rd quartile) or the maximum/minimum value within the range if it falls within 1.5x the IQR. The "x" indicates the sample average. Data points that fall outside 1.5x the IQR are not shown on the graph for visualization purposes.

[28] Note that the "whiskers" extend further for the circuits with M&C investments because there are fewer M&C circuits that experienced zero change in CKAIFI. As a result, the IQR range for these circuits is larger than the IQR range of the system-wide group..

The change in CKAIFI for circuits with M&C investments was slightly worse than the circuits without M&C investments. However, the standard deviation for these samples is much larger that the CKAFDI changes indicating that the difference is likely not statistically significant and is more probably a factor of randomness in the metric data than any type of trend. Thus, the metric data is "too noisy" to tell us much if anything about the impact of M&C investments during PY 19.

3.2.2 National Grid Analysis

National Grid did not have any M&C investments installed prior to H1 2019; however, the evaluation team reviewed the baseline and 2019 wide performance to see if there were any noticeable trends.

System-wide and M&C circuit counts: Table 13 is structured with CKAIFI ranges, or "bins", to provide insight about the range of outage durations across the system, and to show where circuits selected for M&C investment fall within these bins. There are a number of circuits with no outages at all within the baseline period; however, none of these circuits were targeted for M&C investments through 2019. The circuits receiving M&C investments had higher than average CKAIFI values, providing some indication that these less reliable circuits were targeted for M&C investment.[29]

An increase in system average CKAIFI from the baseline to PY 19 and 26 outliers with CKAIFI greater than 5 indicates decreased reliability at the system level, and thus that PY 19 was a "worse" due to a number of factors, potentially including weather, animal faults, tree trimming cycle and other idiosyncratic causes. The CKAIFI standard deviation also increased significantly, indicating increased variability in CKAIFI across the system.

Table 13. Baseline and 2019 National Grid CKAIFI Circuit Counts

Summary	2015-2017 Avg. CKAIFI (Baseline)				2019 CKAIFI (Program Year)			
	System-wide		Targeted for M&C through 2019		System-wide		M&C installed H1 2019 and Prior	
	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs
Reliability Statistics								
Count	1,111	1,111	5	5	1,111	1,111	0	0
% Zero	8%	10%	0%	0%	26%	29%	N/A	N/A
Avg.	0.9	0.9	1.3	1.2	1.2	1.1	N/A	N/A
Std. Dev.	0.6	0.6	0.4	0.5	1.0	0.9	N/A	N/A
CKAIFI Range								
0	93	109	0	0	287	324	N/A	N/A
0.01-0.24	93	103	0	0	165	171	N/A	N/A
0.25-0.74	370	403	0	1	136	145	N/A	N/A
0.75-1.24	301	277	3	2	224	216	N/A	N/A

[29] National Grid's 2019 GMP Annual Report contains the following text about methodology of choosing circuits for GMP investments: *Preliminary Engineering was completed in order to assess and choose the highest areas of impact for feeder monitoring to be installed. These areas were typically categorized as feeders with large customer counts but low historical data.*

Summary	2015-2017 Avg. CKAIFI (Baseline)				2019 CKAIFI (Program Year)			
	System-wide		Targeted for M&C through 2019		System-wide		M&C installed H1 2019 and Prior	
	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs
1.25-1.74	155	138	1	1	96	87	N/A	N/A
1.75-2.24	65	55	1	1	95	87	N/A	N/A
2.25-2.74	20	16	0	0	36	31	N/A	N/A
2.75-3.24	8	6	0	0	30	24	N/A	N/A
3.25-3.74	3	1	0	0	17	7	N/A	N/A
3.75-4.24	2	2	0	0	12	9	N/A	N/A
4.25-4.74	0	0	0	0	3	2	N/A	N/A
4.75-5.24	0	0	0	0	5	4	N/A	N/A
> 5.25	1	1	0	0	5	4	N/A	N/A

Note: EME = excludable major events. CKAIFI of zero indicates no outages occurred.

Before and after comparison: The impact on outage frequency was not assessed because there were no circuits with completed M&C investments with more than half a year of operation during PY 19.

3.2.3 Unitil Analysis

Unitil did not have any qualifying M&C investments installed in 2019.[30] As such, progress towards this metric has not be evaluated.

3.3 PM-11: Numbers of Customers that Benefit from GMP Funded Distribution Automation Devices

This metric is intended for ADA; however, the evaluation team had proposed to review it for M&C as well. It was originally thought that understanding the number of customers that benefit from DA devices even on circuits with M&C investment would help facilitate understanding of this metric, as an increase in customers benefiting from DA devices could affect the measurement of the M&C reliability metric.

Through detailed discussions with EDCs about how this metric is calculated, it was determined that it has limited value in understanding reliability on M&C circuits. After further discussion with the EDCs about the method of calculation, it was decided to not report the metric for M&C, and that the case study approach would be better used to understand the relative operation and benefit of M&C investments vs. ADA investments.

3.4 PM-ES2: Eversource Customer Outage Metric: Average Zone Size

This metric is intended for ADA; however, the evaluation team had proposed to review it for M&C as well. Similar to PM-11, the zone size is only changed by the installation of ADA devices. Any changes on M&C circuits is a result of ADA devices also being installed on those

[30] There was one circuit receiving substation-level SCADA in 2019; however, this circuit is not in operation.

circuits and would have limited or no value in providing insight for M&C device function. After further discussion with the EDCs, it was decided to not report the metric for M&C, and that the case study approach would be better used to understand the relative operation and benefit of M&C investments vs. ADA investments.

3.5 PM-UTL1: Unitil Reliability-Related Metric: Customer Minutes Saved per Outage

Unitil had no M&C devices installed during PY 19 and has not provided any baseline data related to this metric. As such, the performance was not assessed at this time.

3.6 PM-NG1: National Grid Reliability-Related Metric: Main Line Customer Minutes of Interruption Saved

This metric was designed to measure the impact of Advanced Distribution Automation (ADA) Investments on the customer minutes of interruption (CMI) for main line interruptions. This metric will also be considered for M&C circuits to better understand whether M&C impacts on CMI can be observed.

3.6.1 National Grid Analysis

National Grid did not install any M&C devices prior to H2 2019, so this report only presents the baseline data for this metric. Table 14 shows the baseline (2015-2017) CMI data for the entire system and for the five circuits on which M&C Devices were installed. The average CMI, number of customers, and CKAIDI of the circuits that were targeted for M&C Investments are higher than the system-wide averages, which indicates that circuits with more significant outage impacts were prioritized. In future evaluations when the GMP devices have been operating for at least one-year, statistical analyses similar to that done for the reliability metrics can be performed to draw conclusions about the impact of GMP devices on main line CMI.

Table 14. National Grid Baseline (2015-2017) CMI Data

Parameter	System-Wide	Targeted for M&C through 2019
Circuit Count	1111	5
Average CMI	69,653	165,935
Average # customers	1,184	2,257
CKAIDI	115	156

Source: National Grid 2019 GMP Annual Report Appendix 1

From this baseline analysis, it appears that the circuits targeted for M&C investment in PY 19 performed worse on average during the baseline period, providing some indication that the investments are being targeted on circuits that have worse than average performance, which seems appropriate.

4. Case Studies

Three case studies were performed for the M&C investment area, two for Eversource investments and one for National Grid. The case study analyses below illustrate the operation and impacts of the GMP devices installed through PY 2019. The analyses were based on information from EDCs including OMS data, one-line diagrams, SCADA data, switching orders and discussions with EDCs. However, Guidehouse made certain reasonable assumptions to reconstruct the precise details of an outage event in cases where not all information was available.

4.1 Eversource

M&C Case Study #1: Recovery from Automobile Pole Strike

ES Outage ID 4058545 on circuit 19J1

December 9, 2019

Background

As part of the GMP M&C investment, Eversource modernized an existing pole-mounted device called a tie recloser. The device has been enabled with remote SCADA control, along with near-real-time remote indication of field conditions including three phase voltage, three phase current, and fault conditions. The circuit serves, among other customers, a fire department in Montgomery, Massachusetts, considered critical by Eversource.

Event Description

The outage occurred on December 9, 2019 when a vehicle crashed into a pole on Searle Road in Huntington, Massachusetts. The circuit was operating normally prior to the incident. After the vehicle crashed into the pole, the 23,000-volt line began to spark and burn on the pole, with a person stuck in the vehicle under the sparking wires.

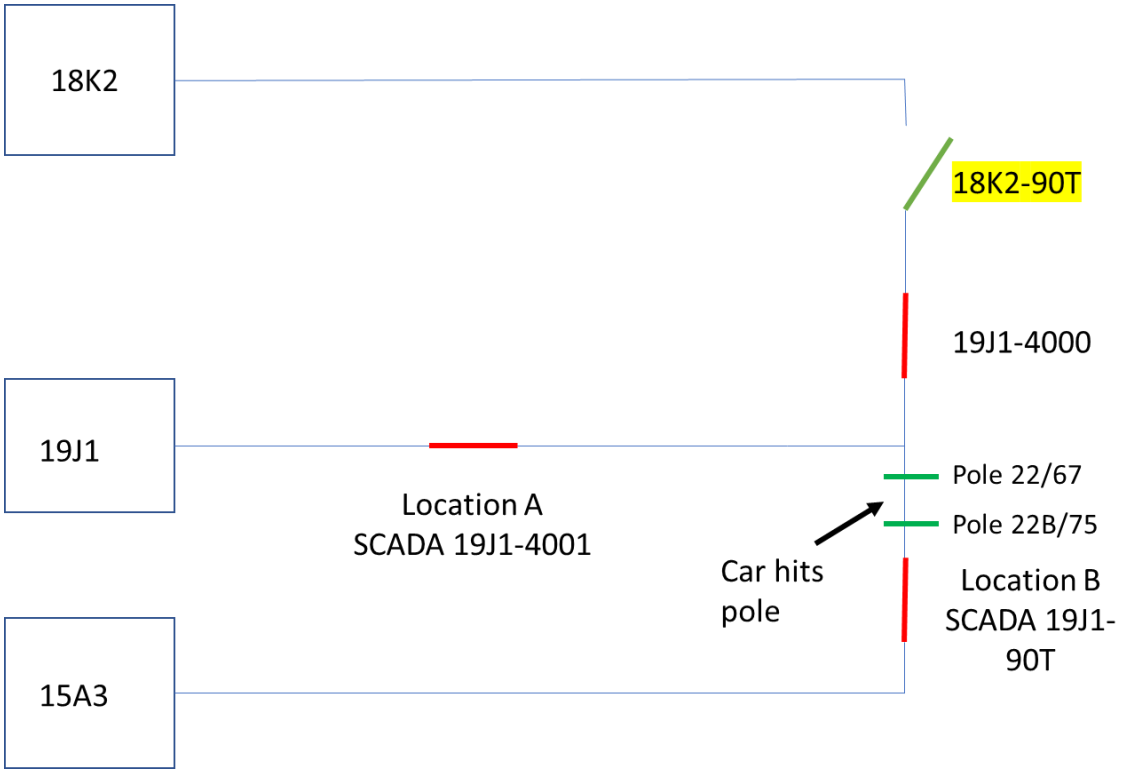
Eversource operators received SCADA alarms about the incident. They de-energized the sparking wires using a SCADA-controlled device and made the area electrically safe for the person stuck in the vehicle and first responders. They then used the GMP device to isolate the faulted location and restore customers.

Based on Guidehouse review, the automated loop scheme should have operated but did not. The operators proceeded to use SCADA-controlled device to make the area safe and restore service. As illustrated in Figure 4 below, the following switching sequence was performed:

- Operators used SCADA to block the tie switch #19J1-90T (Location B) and open switch # 19J1-4001 (Location A in Figure 4) on Worthington Rd, de-energizing the hazardous condition.
- Field crew lifted and tagged 3-phase taps at P22/67 on Pond Brook Road to isolate source side of fault.

- Operators used SCADA to close switch #19J1-4001 (Location A) to energize customers up to the lifted taps at P22/67
- Field crew lifted and tagged 3-phase taps at P22B/75 on Pond Brook Road to isolate load side of fault.
- Operators closed tie recloser #19J1-90T (Location B in Figure 4) restoring customers on the load side the taps that were lifted at P22B/75.
- Manual repair work was performed to fix the damage caused by the vehicle, and the remaining customers were restored in 57 minutes.

Figure 4. 19J1 One-line Diagram



Source: Guidehouse analysis of Eversource One-Line Diagrams

Although no GMP devices were used during this outage event, the newly upgraded 18K2-90T SCADA-enabled recloser (GMP M&C device, highlighted in the figure) was a viable alternative for the System Operators, in the event it was needed. In reviewing the switching order and the field work performed to isolate the fault, it was determined that a non-GMP SCADA device was utilized. If the 18K2-90T had been needed, significant time would have been saved by the System Operators having monitoring and control over the device, as opposed to deploying a crew to perform the switching.

Findings

In this case, the GMP device improved situational awareness during a relatively common occurrence of an automobile strike on a utility pole. SCADA capability allowed operators to

verify the loss of power in the area. It was also determined that the auto-reclosing loop scheme did not operate. The operators utilized SCADA information to make the area safe and restore service.

M&C Case Study #2: Microprocessor Relay Functionality During Outage Event

Event Time: April 13, 2020 at 11:47AM

Eversource Outage ID 4121322 on Circuit 22H16

Background

One of Eversource's GMP M&C Investments is the installation of microprocessor relays. This M&C investment replaces electromechanical relays with state-of-the-art microprocessor relays. The microprocessor relays are designed to provide near real-time data that is not available with electromechanical relays. The microprocessor relays provide substation breaker control and protection of distribution feeders. A total of 97 microprocessor relays were installed during 2018 and 2019. The microprocessor relay examined in this outage was installed in Q2 2019 on circuit 22H16 serving Longmeadow and Springfield, Massachusetts.

This case study examines the functionality of the microprocessor relay during an outage event. The review focused on (a) the ability of the microprocessor relay to provide data to operating personnel, and (b) the operation of the microprocessor relay during an actual outage event.

Event Description

On April 13, 2020, high wind caused a tree to pull down several pole sections of wire along Eversource's right-of-way (ROW), just outside the 22H substation. This resulted in a permanent fault condition.

The microprocessor relays are designed to coordinate with other devices, i.e., remain closed to maintain electric service if the fault is temporary or if another protective device operated, or open/lockout if the fault is permanent between the substation breaker and first recloser. During this event, a tree pulled down the wires just outside the substation before the first recloser, resulting in a permanent fault.

Analysis:

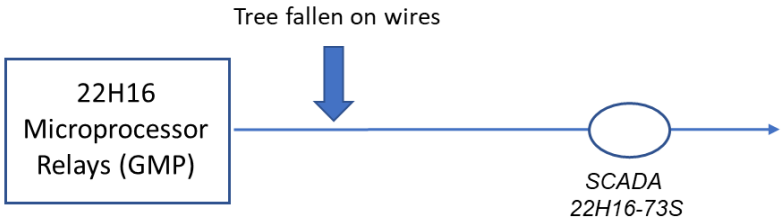
To determine if the microprocessor relay functioned properly and reported data to Eversource's operating personnel, Guidehouse requested and received outage information and historical "PI" data from the microprocessor relay.

Based on the outage location (fault just outside the substation) and the following information as stored in the PI database, we determined the microprocessor device operated open/locked-out correctly:

- Fault between substation breaker and first reclosure
- Fault current (Amps) recorded at 6,267 Amps
- Breaker lock-out status received

- Three-phase current verified as zero

Figure 5. 22H16 One-Line Diagram



Source: Guidehouse analysis of Eversource One-Line Diagrams

GMP Benefit

Guidehouse also performed a review of historical PI data to verify that advanced data is being provided by the microprocessor relay. This data is expected to provide valuation information to improve customer reliability and performance. The review verified that the following near-time data was available to operating personnel:

- Current and voltage Profiles in near-real time
- Breaker status (open or close)
- Fault current levels during an event
- Breaker lock-out alarm
- Breaker "failure" alarms
- Breaker slow to operate (maintenance required)
- Trip coil defective (maintenance required)
- Communications status

This case study determined that the microprocessor relays installed at the substation operated as expected during an event that occurred during a storm with high wind conditions. Additional case studies will be useful to continue to verify the operation of the microprocessor relays and assess the benefits they are providing.

4.2 National Grid

M&C Case Study #3: Line Sensor Functionality During Outage Event

Event Time: December 17, 2019 at 2:29AM

National Grid Outage ID 8757514 on Circuit 07-99W32

Background

As part of the GMP M&C Investment, National Grid implemented M&C line sensor devices during 2019. The first 5 locations were installed and commissioned during Q3 and Q4 2019. The sensor installation analyzed was installed on October 1, 2019 on circuit 07-99W32 serving North Abington, Massachusetts.

Event Description

The outage occurred on December 17, 2019 when an animal breached the substation enclosure in North Abington, Massachusetts. This caused the substation breaker to fail, causing loss of supply to all four circuits feeding from the substation. Approximately 2,705 customers lost power immediately. This was a major outage requiring rapid response.

National Grid control room operators received SCADA alarms from several SCADA devices, including the newly installed GMP M&C device. The SCADA logs from the GMP M&C sensors indicate they operated correctly. The three phase voltage readings went from a normal voltage of 8 kV to 0 kV at the time of the incident. The current readings from the sensors went from a typical three phase current reading to zero when the loss of supply occurred. Operators dispatched emergency crews to restore all customers.

GMP Benefit

This case study determined that the installation, including the sensors, control unit and communications, provided the expected information during an actual major outage event. It is expected that the M&C sensors will provide real-time load information to improve customer reliability, while providing critical information to planners and engineers.

The sensors, control cabinet and communications equipment properly reported the correct information to the SCADA System. As the new equipment is rolled out, additional case studies will be useful to continue to verify the operation of the GMP devices and assess the benefits they are providing.