Guidehouse

Massachusetts Grid Modernization Program Year 2023 Evaluation Report: Monitoring & Control (M&C)

Prepared for:

EVERSOURCE nationalgrid Unitil

Massachusetts Electric Distribution Companies

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Introduction

As a part of the Grid Modernization Plan (GMP), the Massachusetts Electric Distribution Companies (EDCs) are investing to enable Monitoring and Control (M&C) on selected circuits across their distribution networks. These investments should enhance grid visibility and control capabilities to increase reliability, facilitate integration of DERs, and provide other grid and customer benefits.

This evaluation focuses on the progress and effectiveness of each EDC's preauthorized M&C investments toward meeting the Department of Public Utilities (Department) grid modernization objectives for Program Year (PY) 2023.

Evaluation Process

The Department requires a formal evaluation process, including an evaluation plan and evaluation studies, for the EDCs' preauthorized grid modernization plan investments. Guidehouse is completing the evaluation to establish a uniform statewide approach and to facilitate coordination and comparability. The evaluation is to measure and assess progress toward achieving the Department's grid modernization objectives. The evaluation uses the Department-established Performance Metrics along with a set of Case Studies to understand if the GMP investments are meeting the Department's objectives.

The original Evaluation Plan developed by Guidehouse[1] was submitted to the Department by the EDCs in a petition for approval on May 1, 2019. Modifications to this original Evaluation Plan were required to enable evaluation of PY 2022 through PY 2025. These modifications included an 1) extension of the evaluation window from the four year term spanning 2018 – 2021[2] (hereon referred to as Term 1) to incorporate the new four year term spanning 2022 – 2025 (hereon referred to as Term 2), 2) revisions required to reflect the new Term 2 investment activity, and 3) revisions required to remove Infrastructure Metrics and increase the number of ADA and M&C case studies included in evaluation. Modifications to the original Evaluation Plan were filed on February 7, 2024.[3] The modified Evaluation Plan has been used to develop the analysis and evaluation provided below in this document.

In PY 2023, Guidehouse did not evaluate Infrastructure Metrics for any of the three EDCs per instruction by the Department[4] In addition, since Unitil's Outage Management System (OMS) – Advanced Metering Infrastructure (AMI) integration is not yet complete, Guidehouse did not evaluate the Customer Minutes of Outage Saved per Circuit, a Unitil-only Performance Metric.

[1] Guidehouse had previously filed as "Navigant Consulting" and did so during the initial evaluation plan filing.

[2] On May 10, 2018, the Department issued its Order regarding the individual GMPs filed by the three Massachusetts EDCs. In the Order, the Department 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. On May 12, 2020, the Department issued an Order extending the 3-year grid modernization plan investment term to a 4-year term, which introduced a 2021 program year. In addition, on July 1, 2020, Eversource filed a request for an extension of the budget authorization associated with grid modernization investments. The 2018-2021 GMP term results provided for Eversource reflect these changes.

[3] On February 7, 2024, Eversource, National Grid, and Unitil filed evaluation plans with the Department for the period spanning 2022-2025. The Department docketed these plans as D.P.U. 21-80, 21-81, and 21-82, respectively.

[4] D.P.U. 21-80/21-81/21-82, Hearing Officer Memorandum at 4 (November 9, 2023).

As such, the PY 2023 evaluation focuses on 15 case studies conducted for Eversource, National Grid, and Unitil. Table 1, Table 2, and

Table 3 illustrate for each EDC the Department evaluation objectives,[5] applicable evaluation questions, and the Case Studies that were conducted to answer these evaluation questions.

Table 1. Eversource Case Studies and Corresponding Department Evaluation Objective*

Department Evaluation Objective*	Evaluation Questions	Case Studies that Accomplish Department Evaluation Objective
Grid visibility, command and control during blue sky days	• Did SCADA provide Dispatch/ Operations timely visibility of grid events/emergencies?	• CS1: SCADA Provides Real-Time Information about Outage in Downtown Boston • CS2: SCADA Alerts Eversource to an Emergency Outage in Lexington
Grid visibility, command and control during major events	• Did M&C provide real-time actionable information to Dispatch/Operations during major events or peak load days? Was corrective action taken? • Was M&C used for peak load monitoring or management on heavily loaded circuits?	• CS3: SCADA Gives Early Indication of Faulted Cable at Hyde Park • CS4: On the hottest day of the year, Eversource used M&C to maintain voltage at acceptable level • CS5: SCADA Helps Determine Peak Load in Waltham and Natick
Effectiveness of investments in detecting power surges	• Was M&C used to monitor voltage and troubleshoot customer power quality or power surge complaints?	• CS6: Power Quality Monitor Gives Detailed View of Voltage Flickers • CS4: On the hottest day of the year, Eversource used M&C to maintain voltage at acceptable level
Impacts of investments on DG integration	• Was M&C used to facilitate DG integration or DG operation, including managing risk of voltage fluctuations or backflow? • Was M&C used to determine circuit hosting capacity or conduct DG interconnection studies?	• CS7: DG Integration on 4kV Circuits

* Department Evaluation Objectives are detailed in D.P.U. 21-80/21-81/21-82, Hearing Officer Memorandum at 5 (November 9, 2023).

Source: Guidehouse

[5] D.P.U. 21-80/21-81/21-82, Hearing Officer Memorandum at 5 (November 9, 2023).

Table 2. National Grid Case Studies and Corresponding Department Evaluation Objective*

Department Evaluation Objective*	Evaluation Questions	Case Studies that Accomplish Department Evaluation Objective
Grid visibility, command and control during blue sky days	• Did feeder monitors provide Dispatch/ Operations timely visibility of feeder current/voltage to avoid overloads and/or high/low voltages conditions?	• CS1: Improving Contingency Operation with Real-Time Visibility at Marlborough • CS2: Keeping DG Online at Ayer Feeders • CS3: Validating Proper FLISR Operation without Overload in Ayer
Grid visibility, command and control during major events	• Were feeder monitors used to monitor peak loads during major heatwaves?	• CS4: Improving Peak Load Readings at N. Abington
Effectiveness of investments during power surges	• Were feeder monitors useful in investigation of customer power surge complaints?	• CS5: Investigating Power Surge Complaints in Scituate
Effectiveness of investments during distributed generation (DG) backflow instances	• Were feeder monitors used to monitor voltage at circuits with high DG penetration?	• CS6: Monitoring Voltage and DG Backflow in Winchendon
Impacts of investments on DG integration	• Were feeder monitors used to monitor circuit impact of DG and facilitate in DG adoption/operation?	• CS2: Keeping DG Online at Ayer Feeders • CS6: Monitoring Voltage and DG Backflow in Winchendon

* Department Evaluation Objectives are detailed in D.P.U. 21-80/21-81/21-82, Hearing Officer Memorandum at 5 (November 9, 2023).

Source: Guidehouse

Table 3. Unitil Case Studies and Corresponding Department Evaluation Objective*

Department Evaluation Objective*	Evaluation Questions	Case Studies that Accomplish Department Evaluation Objective
Grid visibility, command and control during blue sky days	• Did SCADA improve grid visibility and/or grid operation on blue sky days?	• CS1: SCADA Shortens Outage Duration in Fitchburg
Grid visibility, command and control during major events	• Did SCADA improve grid visibility and/or grid operation on major event days?	• CS2: SCADA Provides Visibility into Grid Conditions during Nor'Easter

* Department Evaluation Objectives are detailed in D.P.U. 21-80/21-81/21-82, Hearing Officer Memorandum at 5 (November 9, 2023).

Source: Guidehouse

Data Management

Guidehouse worked with the EDCs to collect data to complete the 15 M&C Case Studies for the PY 2023 evaluation. Table 4 summarizes data sources used to complete the M&C Case Studies. Section 2.3.1 details each of the data sources.

Table 4. M&C Data Sources

Data Source	Description
2023 Outage management system (OMS) records	OMS records show counts of customers interrupted, fault locations, outage start/end times, devices operated, outage cause, weather conditions, dispatcher/crew comments, and other information relevant to outages.
One Line Diagrams	SCADA one-line circuit diagrams showing circuit topography and locations of GMP M&C and ADA devices
SCADA data	Notifications, alerts, alarms, and interval reporting received from SCADA-enabled devices related to device operations and circuit telemetry.
Customer voltage complaints	Customer voltage complaints by date, and resolution comments recorded by troubleshooters.
Circuits load book	Normal and emergency load carrying capacity of GMP M&C feeders, their current peak loading and forecast

Source: Guidehouse analysis

Key Findings and Recommendations

Findings and recommendations from Guidehouse's PY 2023 evaluation of M&C are summarized for Eversource Case Studies in Table 5, National Grid Case Studies in Table 6, and Unitil Case Studies in Table 7.

Table 5. Eversource Case Studies Key Findings and Recommendations Summary

Case Study	Key Findings	Draft Recommendations
CS1: SCADA Provides Real-Time Information About Outage in Downtown Boston	• Eversource operators in the control center received SCADA alarms in a timely manner from the newly installed M&C device in the 4kV substation. SCADA data showed that the substation breaker had opened in response to a high current (correct and desirable operation). • Eversource control center received a trouble alarm, fault current alarm, and breaker open alarm which were useful information for restoration and for post-hoc analysis.	• General Recommendation Not Applicable to GMP: Eversource crews manually opened the non-remote capable switch in MH22927 to isolate the fault. Eversource may consider adding SCADA to the manual switch in MH22927.
CS2: SCADA Alerts Eversource to an Emergency Outage in Lexington	• In this case of a pole top fire, the GMP-funded 4kV SCADA worked as expected to alert operators of an overcurrent and circuit breaker opening. This timely indication of a circuit outage enabled Eversource to dispatch personnel in a timely manner to respond to the emergency.	• General Recommendation Not Applicable to GMP: To assist in fault location, Eversource may consider installing remote reporting fault indication equipment along the circuit.
CS3: SCADA Gives Early Indication of Faulted Cable at Hyde Park	• 4kV SCADA system worked correctly as expected to alert operators of abnormal conditions in the field. SCADA gave operators early indication of a fault condition and breaker operation, allowing Eversource to dispatch a troubleshooter in a timely manner. Eversource used SCADA to deenergize the hazardous site remotely and rapidly, making the area safe.	• (None)
CS4: On the Hottest Day of the Year, Eversource Used M&C to Maintain Voltage at an Acceptable Level	• Throughout the day on September 7, 2023, when load was at its peak, Eversource operators took corrective action across several substations based on real-time alerts and alarms from GMP SCADA devices, to keep voltage within acceptable limits.	• (None)

Case Study	Key Findings	Draft Recommendations
CS5: SCADA Helps Determine Peak Load in Waltham and Natick	• SCADA readings closely matched the load book, indicating that Eversource used SCADA readings as one of the factors to determine feeder summer peak load. Accurate peak load drives important decisions including whether grid upgrades may be needed to support more load in the future, and whether the circuit can be relied on as emergency backup for neighboring circuits.	• (None)
CS6: Power Quality Monitor Gives Detailed View of Voltage Flickers	• The Power Quality (PQ) monitors are able to catch disturbances at millisecond intervals, capturing data at a higher granularity than standard GMP equipment (e.g., SCADA). The granular PQ data enabled Eversource to investigate if the cause of a university campus's complaint was due to the Eversource system, and whether the level of disturbance is within expected range. Eversource determined that the momentary flickers experienced by the university were within the acceptable PQ range. The PQ monitor allowed Eversource to share detailed data with the university leading to better collaboration, evidence-based investigation, and accurate troubleshooting.	• The PQ Monitor showed that some customer equipment (e.g., building automation systems) can be more sensitive to minor disturbances than is standard in the electronics industry. PQ Monitor alert thresholds were set at industry acceptable standards and did not automatically trigger an alert for the disturbances reported by the university, but did capture the data for analysis. Eversource may consider altering the trigger threshold for the PQ monitor to create an alert for the type of events being experienced by the university.
CS7: DG Integration and Hosting Capacity on 4 kV feeders	• Eversource notes that the 4 kV system has limited ability to interconnect DG without significant upgrades. For the 4 kV feeders that received M&C SCADA investments, Eversource is using SCADA readings to inform hosting capacity (HC) calculations. SCADA inputs included peak load, voltage and minimum light load.	• Eversource should continue to use 4 kV 3-phase SCADA readings to conduct DG interconnection studies and maximize DG hosting capacity at 4 kV feeders in a safe and reliable manner.

Source: Guidehouse

Table 6. National Grid Case Studies Key Findings and Recommendations Summary

Case Study	Key Findings	Draft Recommendations
CS1: Improving Contingency Operation with Near Real-Time Visibility at Marlborough	• The feeder monitors installed at Marlborough provided National Grid control center operators with near real-time visibility into feeder current and voltage, as well as installation health status (communications and relay status). This near real time visibility allowed National Grid to be prepared to respond if any issues had resulted from the contingency operation.	• (None)
CS2: Keeping DG Online at Ayer Feeders	• During a contingency operation where Ayer feeders were carrying extra load, the feeder monitors allowed National Grid to determine with high confidence that contingency switching was safe and reliable, and potential overloads were being avoided. Three-phase loads at all three feeders were kept well below the maximum rating at all times during the period of load transfer. Voltage readings were also observed to stay within acceptable range. • As a result of grid visibility, National Grid was able to maintain all 12 MW of DG online during the period of load transfer.	• (None)
CS3: Validating Proper FLISR Operation without Overload in Ayer	• The feeder monitor readings helped National Grid determine with accuracy that feeder 201W2 did not exceed maximum load ratings while it was carrying additional customers under a FLISR scheme on May 19, 2023.	• National Grid's control center and DC&I may consider setting up automated FLISR/SCADA alarms if load is approaching its limit at any time, including during FLISR operation. Currently, FLISR only does load checks during the initial FLISR reconfiguration. From there it is up to the operators to monitor SCADA and manage the loading. In this case, operators used SCADA to properly manage load and the feeder maximum rating was not exceeded.

Case Study	Key Findings	Draft Recommendations
CS4: Improving Peak Load Readings at N. Abington	• Single-phase readings have a risk of over- or under-stating loading conditions on distribution feeders. The GMP feeder monitor provided three-phase current information throughout 2023. After the GMP feeder monitor was deployed, National Grid learned that the C-phase was most heavily loaded, and that A-phase readings were under-reporting the feeder load. National Grid is using the feeder monitor to determine three-phase load and conduct phase balancing at North Abington. National Grid will also use the feeder monitor readings in the Hanover DG Group Study to study the impact of DG on the feeder.	• National Grid has installed feeder monitors at many locations that lack substation three phase data. National Grid should consider integrating feeder monitor data with other SCADA data and using it for planning purposes on a regular basis. Currently, National Grid is using feeder monitor data for planning purposes on a case-by-case basis, only if needed for studies/analysis.
CS5: Investigating Power Surge Complaints in Scituate	• The case study review demonstrates that the feeder monitor is a useful tool in investigating power surge complaints and ruling out a main line circuit voltage issue. Feeder monitors helped National Grid monitor mainline voltage in near real time and respond quickly when voltage approached limits, e.g., by operating tap changers. On a backup tie where there are no customers to indicate if the line is available, it is useful to have a feeder monitor to provide visibility on whether that backup line is in service.	• (None)

Case Study	Key Findings	Draft Recommendations
CS6: Monitoring Voltage and DG Backflow in Winchendon	• Winchendon circuit 612W1 has high DG interconnected and zero hosting capacity remaining. The feeder monitor was helpful in verifying that voltage stayed within acceptable range throughout the year, including on July 6, 2023, when the most customer voltage complaints were received on this circuit. The feeder monitor confirms National Grid's assessment that the July 6 complaints were due to circuit breaker tripping. • The feeder monitor readings also corroborate National Grid's assessment that the circuit has reached maximum DG hosting capacity (load approaches zero at times). The feeder monitor, being close to the substation, is useful in finely monitoring DG output and maintaining reliable grid operation. The feeder monitor helps National Grid respond quickly if potential backflow conditions arise and take corrective action if necessary.	• Guidehouse recommends National Grid consider using three-phase feeder monitor data to analyze methods of increasing hosting capacity on this circuit (e.g., relay settings).

Source: Guidehouse

Table 7. Unitil Case Studies Key Findings and Recommendations Summary

Case Study	Key Findings	Draft Recommendations
CS1: SCADA Shortens Outage Duration in Fitchburg	• SCADA provided operators with better visibility into the system during an outage event. They learned of the circuit outage immediately, before customer calls. Previously no remote monitoring or control had been available at the substation. Unitil closed the circuit breaker remotely and restored power within 30 seconds, avoiding the need for crew to travel to the substation. Without M&C SCADA, 809 customers would have been without power for an additional 20 minutes while crews travelled to the substation and manually operated the device.	• (None)

Case Study	Key Findings	Draft Recommendations
CS2: SCADA Assists in Restoration During Major Event	• SCADA provided operators with better visibility into the system during a major event, confirming outages identified in OMS based on customer calls. Unitil was unable to find SCADA readings to verify whether operators had issued SCADA commands to remotely control (open/close) the substation circuit breakers. Therefore, remote control via SCADA could not be determined.	• Guidehouse recommends Unitil investigate whether the major event on 3/14/2023 presented an opportunity for using SCADA control, and take steps to utilize SCADA control capability in future substation events.

Source: Guidehouse

1. Introduction to Massachusetts Grid Modernization

This section provides a brief background to the grid modernization evaluation process along with an overview of the Monitoring and Control (M&C) Investment Area and specific M&C evaluation objectives. These are provided for context when reviewing the subsequent sections that address the specific evaluation process and findings.

1.1 Massachusetts Grid Modernization Plan Background

The following subsections summarize the progression of Massachusetts Grid Modernization Plans (GMPs) filed by the three Massachusetts Electric Distribution Companies (EDCs): Eversource, National Grid, and Unitil.

1.1.1 Grid Modernization Term 1 (2018-2021)

On May 10, 2018, the Department issued its Order approving the EDCs' GMPs for 2018-2020 in dockets D.P.U. 15-120/15-121/15-122.[6,7] In the Order, the Department preauthorized grid-facing investments over three years (2018-2020) for each EDC and adopted a three-year (2018-2020) regulatory review construct for preauthorization of grid modernization investments. On May 12, 2020, the Department issued an Order[8] extending the three-year grid modernization plan investment term to a four-year term, which introduced a 2021 program year.

During the GMP term spanning 2018-2021 (hereon referred to as Term 1) 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/ALF)
- Communications/IoT (Comms)
- Workforce Management (WFM)

A certain level of spending for each of these GMP Investment Areas was preauthorized by the Department, with the expectation they would advance the achievement of Department's grid modernization objectives:[9]

- Optimize system performance by attaining optimal levels of grid visibility command and control, and self-healing;
- Optimize system demand by facilitating consumer price responsiveness; and

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

[7] On June 16, 2016, Eversource and National Grid each filed updates to their respective grid modernization plans

[8] D.P.U. 15-120; D.P.U. 15-121; D.P.U. 15-122 (Grid Modernization) Order (1) Extending Current Three-Year Grid Modernization Plan Investment Term; and (2) Establishing Revised Filing Date for Subsequent Grid Modernization Plans (issued May 12, 2020).

[9] D.P.U. 15-120/15-121/15-122, at 106 (2018).

- Interconnect and integrate distributed energy resources (DER).

For Term 1, the Department's preauthorized budget for grid modernization varied by Investment Area and EDC. Eversource originally had the largest preauthorized budget at $133 million, with ADA and M&C representing the largest share ($44 million and $41 million, respectively). National Grid's preauthorized budget was $82.2 million, with ADMS representing over 50% ($48.4 million). Unitil's preauthorized budget was $4.4 million and VVO made up 50% ($2.2 million).

On July 1, 2020, Eversource filed a request for an extension of the budget authorization associated with grid modernization investments.[10] The budget extension, approved by the Department on February 4, 2021,[11] included $14 million for ADA, $16 million for ADMS/ALF, $5 million for Communications, $15 million for M&C, and $5 million for VVO.[12] These values are included in the Eversource total budget by Investment Area in Table 8.

Table 8. Term 1 (2018-2021) Preauthorized Budget, $M

Investment Areas	Eversource	National Grid	Unitil	Total
ADA	$58.00	$13.40	N/A	**$71.40**
ADMS/ALF	$33.00	$48.40	$0.70	**$79.10**
Comms	$23.00	$1.80	$0.84	**$25.60**
M&C	$56.00	$8.00	$0.35	**$64.75**
VVO	$18.00	$10.60	$2.22	**$30.80**
WFM	--	--	$0.30	**$1.00**
2018-2021 Total	**$188.00**	**$82.20**	**$4.41**	**$272.65**

Source: D.P.U. 15-120/15-121/15-122 (2018); D.P.U. 20-74 (2021).

1.1.2 Grid Modernization Term 2 (2022-2025)

On July 2, 2020, the Department issued an Order[13] that triggered further investigation into modernization of the electric grid. In the order, the Department required that the EDCs file a grid modernization plan on or before July 1, 2021. In accordance with this order, the EDCs filed grid modernization plans for a 4-year period spanning 2022-2025 (hereby referred to as Term 2).[14] In these plans, the EDCs outlined continued investment in the areas that received investment during Term 1 (referred to as Track 1 Investment Areas), and investment in new Investment Areas (Track 2 Investment Areas).

Table 9 summarizes the Department pre-authorized Term 2 GMP investment areas, which includes Track 1 and Track 2 investments, and EDC-reported Department objectives that are

[10] Eversource's request for an extension of the budget authorization was docketed as D.P.U. 20-74.

[11] D.P.U. 20-74 (2021).

[12] The Department allowed flexibility to these budgets to accommodate changing technologies and circumstances. For example, EDCs can shift funds across the different preauthorized investments if a reasonable explanation for these shifts is supplied.

[13] Investigation by the Department of Public Utilities on its own Motion into the Modernization of the Electric Grid – Phase Two, D.P.U. 20-69 (2020).

[14] On July 1, 2021, Eversource, National Grid, and Unitil each filed a grid modernization plan with the Department for the period spanning 2022-2025. The Department docketed these plans as D.P.U. 21-80, 21-81, and 21-82, respectively.

addressed by each of the investment areas. Table 10 provides more detail on the new Track 2 grid modernization investments excluding Advanced Metering Infrastructure (AMI).[15]

Table 9. Overview of Term 2 Investment Areas

Investment Area	Term	Description	Department Objectives		
			Optimize System Performance	Optimize System Demand	Integrate DER
Advanced Distribution Automation (ADA)	1 2	National Grid-only investment for Term 2. ADA allows for isolation of outage events with automated restoration of unaffected circuit segments	✓		
Advanced Distribution Management Systems (ADMS)	1 2	New capabilities in real-time system control with investments in developing accurate system models and enhancing Supervisory Control and Data Acquisition (SCADA) and outage management systems (OMS) to control devices for system optimization and provide support for distribution automation and VVO with high penetration of DER.	✓	✓	✓
Advanced Load Flow (ALF)	1 2	Eversource-only investment for Term 2 to integrate, into a single software, both their existing Distributed Generation (DG) tools and customer interconnection portal. Eversource also plans to use a simulation of locational load and generation based on variables such as customer behavior and energy market prices.	✓	✓	✓
Communications/IoT (Comms)	1 2	Fiber middle-mile, field area communications systems and IT	✓	✓	✓

[15] AMI is not included in the scope of evaluation, as there are no Performance Metrics tied to the deployment of AMI during the 2022-2025 GMP Term, and progress of the AMI deployment is projected to be limited during the course of the term.

Investment Area	Term	Description	Department Objectives		
			Optimize System Performance	Optimize System Demand	Integrate DER
Distributed Energy Resources Management System (DERMS)	2	Software that forms the hub of DER management functions and integrates with other applications such as a Demand Response Management System ("DRMS") and ADMS, to create the DERMS Platform. Includes two demonstration projects proposed by National Grid to test new tools, and plans for Unitil to install ground-fault overvoltage protection and make voltage regulator and load tap chamber upgrades (DER Mitigation).	✓	✓	✓
Monitoring and Control (M&C)	1 2	Remote monitoring and control of devices in the substation for feeder monitoring or online devices for enhanced visibility outside the substation	✓		✓
Volt/VAR Optimization (VVO)	1 2	Control of line and substation equipment to optimize voltage, reduce energy consumption, and increase hosting capacity	✓	✓	✓
Workforce Management (WFM)	1 2	Unitil-only investment for Term 2 to improve workforce and asset utilization related to outage management and storm response	✓		

Source: Grid Mod RFP – SOW (Final 8-8-18).pdf; 2022-2025 EDC Grid Modernization Plans; Guidehouse

Table 10. Overview of Term 2, Track 2 Investments

Investment	Investment Area	EDC	Description
Interconnection Automation	**ALF**	**Eversource**	Eversource-only investment for Term 2 to integrate, into a single software, both their existing Distributed Generation (DG) tools and customer interconnection portal.

Investment	Investment Area	EDC	Description
Probabilistic Power Flow Modeling	**ALF**	**Eversource**	Eversource-only investment that can provide simulation of locational load and generation based on variables such as customer behavior and energy market prices.
Distributed Energy Resources Management System	**DERMS**	**All EDCs**	Software that forms the hub of DER management functions and integrates with other applications such as a Demand Response Management System ("DRMS") and ADMS, to create the DERMS Platform.
Dynamic DER Interface	**DERMS**	**Eversource**	This investment will upgrade the existing communication and control capability at Eversource and customer-owned large inverter-based DER facilities. These enhancements will enable the DER assets to be commissioned and integrated into the Company's eECS/ADMS/DERMS control platform to provide real-time monitoring and control capabilities to system operators in support of VVO and other optimization algorithms.
Advanced Short-Term Load Forecasting	**DERMS**	**National Grid**	Improve granular short-term forecasting capabilities to address substation and feeder constraints.
Active Resource Integration	**DERMS**	**National Grid**	Field test a new flexible interconnection option that could enable the Company to accelerate DG interconnections and increase the energy production of DGs per unit of system capacity.
Local Export Power Control	**DERMS**	**National Grid**	Explore the net zero thermal impact capabilities of customer owned Power Control Systems as a tool to lower interconnection costs and expedite interconnection timelines by reducing the need for distribution impact studies for such DER facilities.
DER Mitigation	**DERMS**	**Unitil**	Implement overvoltage protection improvements on the 69 kV side of several distribution substations to mitigate the risk of ground-fault overvoltages. The implementations include modifications to substation and sub-transmission line surge protection, and the addition of voltage transformers and overvoltage relaying schemes where necessary.

Source: Source: 2022-2025 EDC Grid Modernization Plans

The Department issued an order approving a preauthorized budget for Track 1 investments on October 7, 2022 and an order approving a preauthorized budget for Track 2 investments on November 30, 2022,[16] in D.P.U. 21-80/21-81/21-82. The preauthorized budget for grid modernization varies by Investment Area and EDC. National Grid has the largest preauthorized budget at $331.8 million, with Communications and VVO representing the largest share ($103 million and $76 million, respectively). Eversource's preauthorized budget is $197.4 million, with

[16] Massachusetts D.P.U. 21-80/D.P.U. 21-81/D.P.U. 21-82 Order on New Technologies and Advanced Metering Infrastructure Proposals issued November 30, 2022.

M&C representing about 50% ($76.3 million). Unitil's preauthorized track one budget is $10.3 million with VVO making up more than 50% ($5.4 million).

Table 11. Term 2 (2022-2025) Preauthorized Budget, $M

Investment Areas	Eversource	National Grid	Unitil	Total
ADA	--	$37.70	--	**$37.70**
ADMS*	$21.90	$61.00	$1.50	**$84.40**
ALF	$5.00	-	-	**$5.00**
Comms	$38.00	$102.80	$0.82	**$141.62**
DERMS	$16.00	$31.00	$1.20	**$48.20**
M&C	$76.30	$4.10	$1.10	**$81.50**
VVO	$40.40	$76.40	$5.40	**$122.20**
WFM	--	--	$0.25	**$0.25**
IT/OT	--	$18.80	--	**$18.80**
Total	***$197.60***	***$331.80***	***$10.27***	***$539.67***

* Given as $1.66M minus DERMS cost from Department Order, Oct. 7, 2022, and calculated from Department Order, Nov. 30, 2022.

Note: The Term 2 preauthorized budget presented excludes Program Management and M&V dollars that were preapproved for each of the three EDCs.

Source: Department Order on Previously Deployed Technologies, D.P.U. 21-80/21-81/21-82 (2022), and Department Order on New Technologies, D.P.U. 21-80/21-81/21-82 (2022).

1.1.3 Evaluation Goals and Objectives

The Department requires a formal evaluation process (including an evaluation plan and evaluation studies) for the EDCs' preauthorized GMP investments. Guidehouse is completing the evaluation to enable a uniform statewide approach and to facilitate coordination and comparability.

The evaluation measures the progress made toward the achievement of Department's grid modernization objectives. It uses the Department-established Performance Metrics, as well as Case Studies that illustrate the performance of specific technology deployments, to help determine if the investments are meeting the Department's GMP objectives.[17]

1.1.4 Metrics for Evaluation

The Department-required evaluation involves Performance Metrics and Case Studies of grid modernizing investments. Case studies apply exclusively to the ADA and M&C investment areas as part of the evaluation to help facilitate understanding of how the technology performs in specific instances (e.g., in remediating the effects of a line outage).

[17] The evaluation of GMP investments no longer includes analysis of Infrastructure Metrics (IMs) per the Order, Hearing Officer Memorandum, D.P.U. 21-80/21-81/21-82 (2023).

1.1.4.1 Performance Metrics

The Performance Metrics assess the performance of all the GMP investments. Table 12 summarizes the Performance Metrics used for the various Investment Areas. This report discusses Performance Metrics that pertain specifically to the M&C Investment Area.

Table 12. Performance Metrics Overview

Metric		Description	Applicable IA	Metric Responsibility*
PM-1	**VVO Baseline**	Establishes a baseline impact factor for each VVO-enabled circuit which will be used to quantify the peak load, energy savings, and greenhouse gas (GHG) impact measures.	VVO	All
PM-2	**VVO Energy Savings**	Quantifies the energy savings achieved by VVO using the baseline established for the circuit against the annual circuit load with the intent of optimizing system performance.	VVO	All
PM-3	**VVO Peak Load Impact**	Quantifies the peak demand impact VVO/CVR has on the system with the intent of optimizing system demand.	VVO	All
PM-4	**VVO Distribution Losses without Advanced Metering Functionality (Baseline)**	Quantifies the improvement that VVO/CVR is providing toward minimizing distribution line losses.	VVO	All
PM-5	**VVO Power Factor**	Quantifies the improvement that VVO/CVR is providing toward maintaining circuit power factors near unity.	VVO	All
PM-6	**VVO – GHG Emissions**	Quantifies the overall GHG impact VVO/CVR has on the system.	VVO	All
PM-7	**Voltage Complaints**	Quantifies the prevalence of voltage-related complaints before and after deployment of VVO investments to assess customer experience, voltage stability under VVO.	VVO	All
PM-8	**Increase in Circuits and Substations with DMS Power Flow and Control Capabilities**	Examines the deployment and data cleanup associated with deployment of ADMS, primarily by counting and tracking the number of circuits and substations per year.	ADMS/ ALF	All
PM-9	**Control Functions Implemented by Circuit**	Examines the control functions of DMS power flow and control capabilities, focused on the control capabilities including VVO-CVR and FLISR.	ADMS/ ALF	All

Metric		Description	Applicable IA	Metric Responsibility*
PM-10	**Numbers of Customers that benefit from GMP funded Distribution Automation Devices**	Shows the progress of ADA investments by tracking the number of customers that have benefitted from the installation of ADA devices.	ADA	NG
PM-ES-1	**Advanced Load Flow – Percent Milestone Completion**	Examines the fully developed ALF capability across Eversource's circuit population.	ADMS/ ALF	ES
PM-UTL1	**Customer Minutes of Outage Saved per Circuit**	Tracks time savings from faster AMI outage notification than customer outage call, leading to faster outage response and reduced customer minutes of interruption.	M&C	UTL
PM-NG-1	**Main Line Customer Minutes of Interruption Saved**	Measures the impact of ADA investments on the customer minutes of interruption (CMI) for main line interruptions. Compares the CMI of GMP ADA-enabled circuits to the previous 3-year average for the same circuit.	ADA	NG

PM = Performance Metric, IA = Investment Area, ES = Eversource, NG = National Grid, UTL = Unitil

* Column indicates which EDC is responsible for calculating each metric, for statewide metrics, all EDCs are responsible

Source: Stamp Approved Performance Metrics outlined in D.P.U. 21-80/21-81/21-82 (2024).

1.1.4.2 Case Studies

The impacts of GMP devices on system reliability metrics can be difficult to discern due to the range of factors that affect these metrics. Storm conditions, vehicle accidents and other factors drive reliability from year to year. This is especially likely if the device has less than several full years of operation to affect the metric.

Guidehouse, in consultation with the EDCs, developed a case study approach to provide more insight into the actual operation of the GMP devices and to illustrate how these investments provide customer reliability and operational benefits. The case studies help to illustrate the benefits provided by GMP devices during outages and other events. This approach investigates outage events on specific circuits where the GMP equipment was used to address the 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.

1.2 M&C Investment Area Overview

As a part of the grid modernization efforts, the EDCs are making investments to advance their M&C capabilities and enhance network visibility, with the goal of delivering optimized system performance, higher reliability, and greater DER integration. Table 13 summarizes the preauthorized budget for the M&C Investment Area for the first and second GMP terms.

Table 13. GMP Preauthorized Budget for M&C, $M

Period	Eversource	National Grid	Unitil	Total
Term 1 (2018 – 2021)	$56.00	$8.00	$0.35	**$64.75**
Term 2 (2022 – 2025)	$76.30	$4.10	$1.10	**$81.50**

Source: Department Order, May 10, 2018, Eversource filing "GMP Extension and Funding Report," July 1, 2020, Department Order, October 7, 2022, and Department Order, November 30, 2022 under docket 21-80, 21-81, and 21-82.

The following subsection discusses EDC-specific approaches to M&C.

1.2.1 EDC Approach to M&C

Each EDC has a unique approach to their M&C Investment Area. Throughout Term 1, Eversource and Unitil were focused on expanding SCADA on substations and distribution networks, while National Grid had focused on deploying feeder monitors on its distribution network. Unitil had an additional investment focused on integrating its advance metering infrastructure (AMI) data with its outage management system (OMS).

In Term 2, Eversource elected to continue its investment in both Substation Automation and Power Quality Monitoring, with National Grid continuing its deployment of mainline feeder monitors and Unitil continuing its AMI-OMS integration and further deploying its SCADA on substations and reclosers.

1.2.1.1 Eversource Overview of GMP Deployment Plan

Eversource's M&C Term 1 Investment Area goals and objectives included:

- Increasing the amount of data that is collected by the existing SCADA system for enhanced analytical capabilities (e.g., load flow analysis); and
- Increasing reliability by enabling crew dispatch to remotely isolate faulted cable sections, restoring power to customers.

Moving into Term 2, Eversource's M&C goals and objectives included:

- Ramping up its Substation Automation program by replacing older relay technology with current microprocessor relay technology for 190 additional feeders at bulk substations across Massachusetts. These relays will be equipped with incremental remote monitoring capability to enable more timely engineering analysis of system events.
- Continuing to add relays with remote telemetry to 55 high priority 4 kV feeders in eastern Massachusetts.
- Ramping up its Power Quality Monitoring program to provide remote access and storage of continuous power quality data so that detailed information from disturbance events can be evaluated by Eversource Distribution Engineering, System Planning, and Protection and Controls Engineering

To achieve these goals, Eversource is deploying a range of M&C devices on its distribution network. Table 14 details the technologies and devices that are being implemented as part of Eversource's M&C Investment Area.

Table 14. Devices and Technologies Deployed Under Eversource M&C Investment

Device/ Investment Type	Description	Term
Microprocessor relays*	Includes advanced overcurrent protection, pushbutton controls for the breakers, safety hot line tagging, reclosing, breaker failure, and under-frequency load-shedding schemes.	1 2
4 kV Circuit Breaker SCADA*	Provides real-time visibility to loading conditions on the 4 kV circuits that are among the most heavily loaded on Eversource's distribution system.	1 2
Recloser SCADA	Addition of communications capability so the device can be centrally monitored and controlled from the dispatch center.	1
Padmount Switch SCADA	Addition of a radio package to enable communications and central monitoring.	1
Network Protector SCADA	Provides real-time network load data and additional telemetric information.	1
Power Quality Monitors	Provides remote access and storage of power quality meter data for Eversource system planning, protection, and controls engineering to evaluate disturbance events and share information with customers.	1 2

* Within Term 2, Microprocessor relays and 4 kV Circuit Breaker SCADA are aggregated and reported together as "Substation Automation"

Source: Guidehouse analysis of GMP Annual Reports and EDC Data

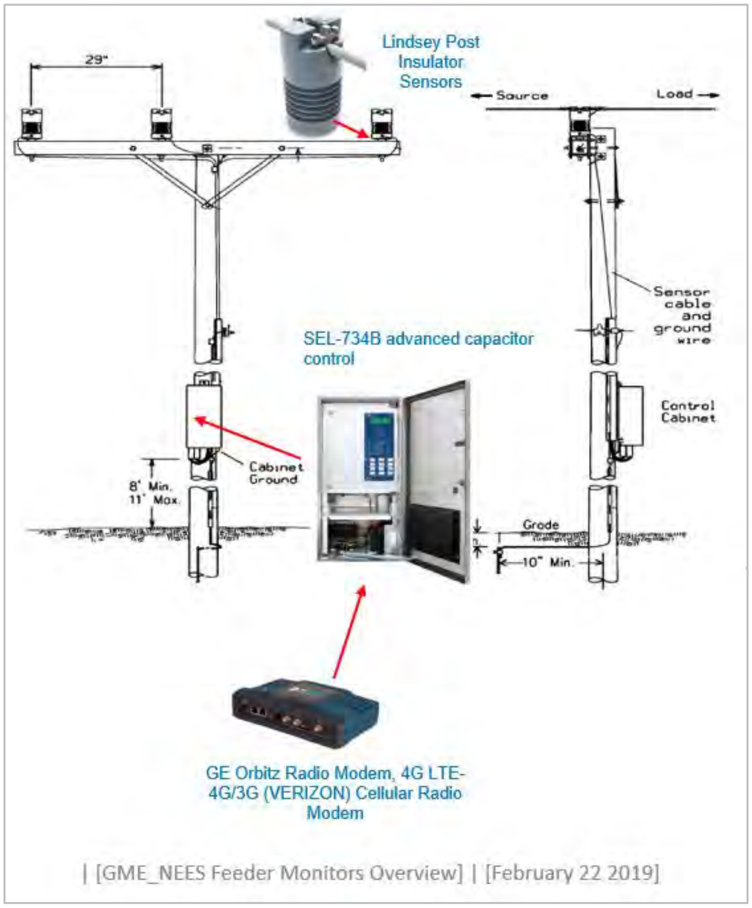
1.2.1.2 National Grid Overview of GMP Deployment Plan

National Grid's Term 1 and Term 2 M&C Investment Area goals and objectives include:

- Provide critical data for operations and distribution designers by providing near real-time voltage, current, and power monitoring information to the operations control center; and
- Focus on overhead feeders within the distribution system and substations with minimal to no existing SCADA.

The achieve these goals, National Grid has installed interval power monitoring devices on overhead feeders within its distribution system. The feeder monitors are installed outside the substation fence for increased visibility. Information is transmitted cellularly every 5 minutes. Figure 1 shows a detailed schematic of how the EDC is implementing the technology. Each circuit location includes three sensors (one per phase) and one control box that houses a relay with a communications package.[18]

Figure 1. Feeder Monitor Schematic



Source: National Grid

As described in Table 15, National Grid's Term 2 M&C investments focus solely on the continued deployment of feeder monitor projects. Achieving stated GMP goals will require interval monitoring on all primary distribution feeders, at least at the head of the feeder (i.e., at or near the substation) to ensure compliance with voltage and protection requirements as customer DER adoption grows. National Grid stated in its 2022-2025 GMP that it will be dedicating $4.1 million during the Term 2 period to its feeder monitor program.

Table 15. Devices and Technologies Deployed Under National Grid M&C Investment

Device/ Investment Type	Description	Term
Feeder Monitors	Installation of interval power monitoring devices on feeders where National Grid does not have distribution information.	1 2

Source: Guidehouse analysis of GMP Annual Reports and EDC Data

1.2.1.3 Unitil Overview of GMP Deployment Plan

Unitil's M&C Term 1 Investment Area goals and objectives included the following:

- Provide remote monitoring of conditions on the electric system (e.g., voltage, current);

- Provide remote control of equipment and functions (e.g., circuit breakers/reclosers, transformer load tap changers, capacitor banks);
- Enable technologies required for other GMP projects (e.g., ADMS/ALF, VVO); and
- Improve integration of outage information from meters into the OMS outage prediction engine to enhance outage prediction process, reduce false positives, and enhance outage location detection.

To achieve these goals, Unitil is implementing substation SCADA and AMI data integration with their OMS. In Term 2, Unitil will continue both investments: substation SCADA rollout as well as continued AMI/OMS integration, which are described in Table 16.

Table 16. Devices and Technologies Deployed Under Unitil M&C Investment

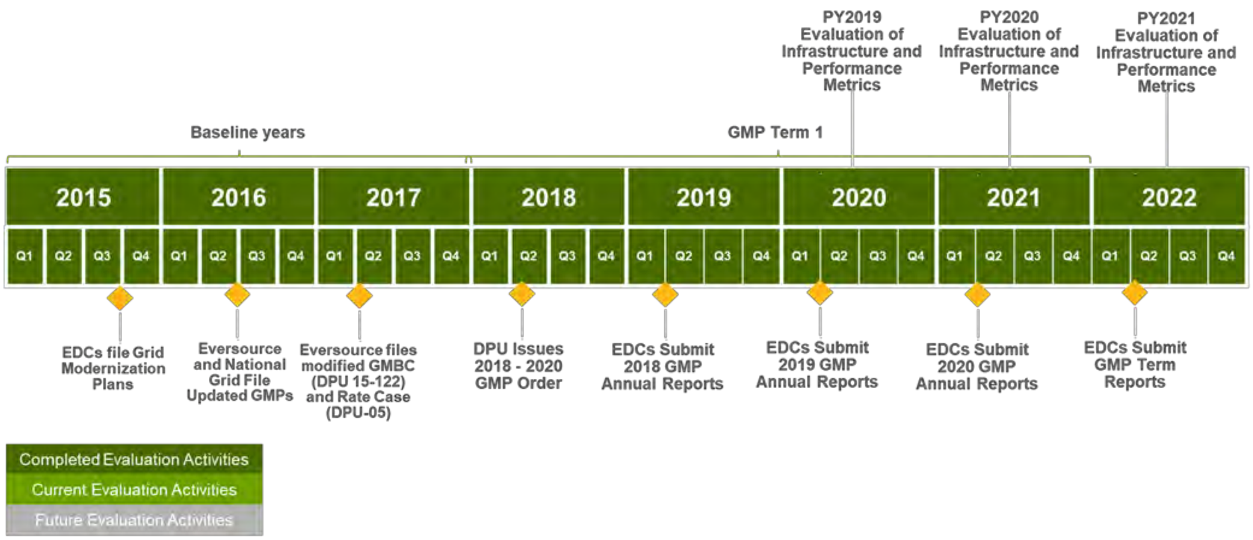
Device/ Investment Type	Description	Term
Substation SCADA	The installation and interconnection of a SCADA terminal unit, the establishment of communications between the terminal unit and the remotely located SCADA master system, and the associated programming to implement desired functions.	1 2
Recloser SCADA	Addition of communications capability so the device can be centrally monitored and controlled from the dispatch center.	1 2
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.	1 2

Source: Guidehouse analysis of GMP Annual Reports and EDC Data

2. M&C Evaluation Process

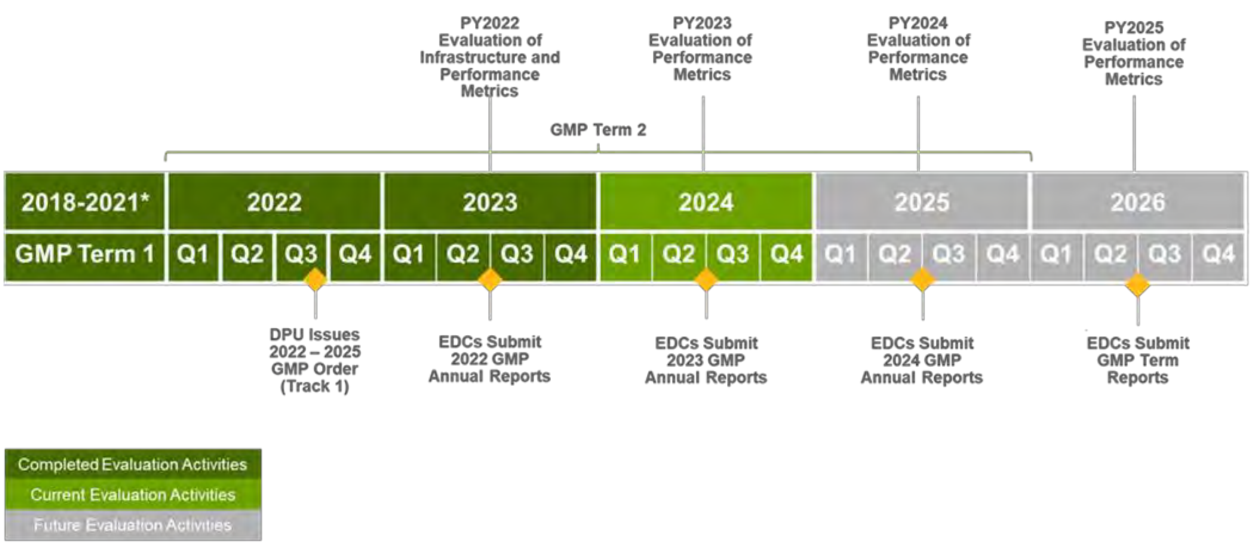
This section presents a high-level overview of the Guidehouse methodologies for the evaluation of Infrastructure and Performance Metrics as well as Case Studies. Figure 2 highlights the Term 1 filing background and timeline of the GMP Order and the evaluation process, and Figure 3 indicates the expected timeline for Term 2.

Figure 2. M&C Evaluation Timeline Term 1



Source: Guidehouse review of the Department orders and GMP process

Figure 3. M&C Evaluation Timeline Term 2



Note: M&C Evaluation Timeline for Term 2 does not incorporate Term 1 evaluations completed in 2022.

Source: Guidehouse review of the Department orders and GMP process

2.1 M&C Evaluation Objectives

This evaluation focuses on the effectiveness of the Department preauthorized M&C investments for each EDC towards meeting the Department's grid modernization objectives.[19] Evaluation will focus on the first and third objectives: "(1) optimize system performance by attaining optimal levels of grid visibility, command and control…" and "(3) interconnect and integrate distributed energy resources."

Table 17 illustrates the key Performance Metrics and Case Studies relevant for the M&C evaluation. The PMs are intended to measure the improvements in reliability that can be attributed to M&C investments. However, as the number of metrics pertaining to the M&C investment area is limited, Case Studies are intended to provide a more detailed exploration of investment performance.

Table 17. M&C Evaluation Metrics

Metric	M&C Evaluation Metrics[20]	ES	NG	UT
PM-UTL-1	Customer Minutes of Outage Saved per Circuit			✓
Other	Case Studies to evaluate each investment per its objectives as stated by the EDC, including:	✓	✓	✓
	• M&C operations that improved reliability	✓		✓
	• M&C use for DG monitoring, voltage/PQ monitoring and system disturbance	✓	✓	
	• M&C use for load balancing	✓	✓	

Source: Guidehouse Stage 3 Evaluation Plan filed February 7, 2024

The EDCs provided the data supporting Performance Metrics and Case Studies to the evaluation team. Section 3 through Section 5 present the results from the Case Study analysis.

2.2 Performance Metrics Analysis

Table 18 describes the Performance Metrics relevant to the M&C investment area. Due to a Department Order[21] that requested customer average interruption duration and frequency analyses be excluded from evaluation in PY 2023, PM-12 and PM-13 are not assessed in this report.

[19] D.P.U. 15-120/15-121/15-122, at 106 (2018). The Department's grid modernization objectives include "(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. Id.

[20] Note: to the degree that the *performance metrics* are modified or augmented during the stakeholder input process, Guidehouse will work with the EDCs to incorporate the new metrics into an updated evaluation plan.

[21] D.P.U. 21-80/21-81/21-82, Hearing Officer Memorandum at 4 (November 9, 2023).

Table 18. M&C Performance Metrics Overview

Performance Metric		EDC	Description
PM-UTL1	Customer Minutes of Outage Saved per Circuit	UTL	Tracks time savings from faster AMI outage notification than customer outage call, leading to faster outage response and reduced customer minutes of interruption.

Source: Stamp Approved Performance Metrics, February 1, 2024

PM-UTL1 tracks the time savings realized from faster AMI outage notification compared customer outage call. The metric seeks to quantify the impacts of Unitil's OMS/AMI integration through the reduced customer of minutes of interruption.

Unitil re-evaluated its OMS/AMI integration process in PY 2022 after its primary vendor discontinued support for Landis & Gyr PLX technology. Unitil issued an RFP to assess vendor options in December 2022. In 2023, Unitil determined it would move forward with Landis & Gyr, and will use a new communications technology using a combination of radio frequency and cellular in lieu of PLX. Unitil will continue progress towards building out the OMS/AMI integration in 2024, with planned completion in either 2025 or 2026. Given that the OMS/AMI integration has not been completed, this metric cannot yet be analyzed and is thus not included in this evaluation report.

2.3 Case Study Analysis

Guidehouse, in consultation with the EDCs, developed a Case Study approach to provide more insight into the actual operation of the GMP devices and to illustrate how these investments provide customer reliability and operational benefits. The impacts of GMP devices on system reliability metrics can be difficult to discern due to the range of factors that affect these metrics including storm conditions. 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.

This evaluation features 15 case studies for the M&C investment area: seven for Eversource, six for National Grid, and two for Unitil. The number of M&C case studies (15) is higher than prior evaluation years per Department direction.[22] The Department also directed that the evaluation process document the case study selection process in greater detail, which is done in the Case Study chapters for each EDC.

At the direction of the Department,[23] the case studies in this report explore a variety of use cases of M&C, including support in grid visibility and control, load balancing for system operation, facilitation of DER integration, voltage and power surge monitoring, DG backflow monitoring, and effectiveness during major events. Guidehouse acknowledges stakeholder and EDC comments stating case studies be made less technical and more user-friendly.[24] In

[22] D.P.U. 21-80/21-81/21-82, Hearing Officer Memorandum at 5 (November 9, 2023).

[23] D.P.U. 21-80/21-81/21-82, Hearing Officer Memorandum at 5 (November 9, 2023).

[24] Joint Comments of Massachusetts Electric Company and Nantucket Electric Company each d/b/a National Grid, NSTAR Electric Company D/B/A Eversource Energy, and Fitchburg Gas and Electric Light Company d/b/b Unitil on Metrics, and New Metrics Proposals, D.P.U. 21-80, 21-81 and 21-82, p. 4.

response, Guidehouse has updated the case study format to include high level summaries and made them more accessible to a broader audience.

Table 19 includes research questions that have been investigated during each evaluation. The research questions shape the evaluation approach used to determine the effectiveness of the M&C investments (i.e., equipment, software, technology) to improve reliability and accomplish the Department grid modernization objectives.

Table 19. Evaluation Research Questions

Department Case Study Objective	Research Question
Grid visibility, command and control during blue sky days	• Did SCADA provide Dispatch/Operations timely visibility of grid events/emergencies?
Grid visibility, command and control during major events	• Did M&C provide real-time actionable information to Dispatch/Operations during major events or peak load days? Was corrective action taken? • Was M&C used for peak load monitoring or management on heavily loaded circuits?
Effectiveness of investments for DER integration including risk of backflow	• Was M&C used to facilitate DG integration or DG operation, including managing risk of voltage fluctuations or backflow? • Was M&C used to determine circuit hosting capacity or conduct DG interconnection studies?
Impacts of investments on DER integration	• Are 3-phase SCADA readings being used to facilitate DG integration or DER operation?
Effectiveness of Investments during power surges	• Was M&C used to monitor voltage and troubleshoot customer power quality or power surge complaints?

Source: Guidehouse Stage 3 Evaluation Plan submitted to EDCs on February 7, 2024 with updates

2.3.1 Case Study Data Sourcing and Management

Guidehouse requested and used a combination of the following data from EDCs in order to perform case studies:

- Outage management system (OMS) records for circuits where GMP-funded M&C devices have been commissioned in the GMP period. The OMS records show customer counts, fault locations, outage start/end times, devices operated, outage cause, weather conditions, and other information relevant to outages.
- Written comments by dispatchers and crews elaborating the cause of the outage and actions taken in response.
- SCADA one-line circuit diagrams showing circuit topography and locations of GMP M&C and ADA devices.
- Notifications, alerts and alarms received from SCADA-enabled devices related to device operations and circuit telemetry.

- Follow-up conversations with EDCs to understand the sequence of events, corrective actions taken and estimate benefit or time savings resulting from GMP investments.
- For M&C case studies not involving outages, Guidehouse requested supplemental information from EDCs including circuit peak loads, voltage complaints, samples of data reported by GMP M&C devices, circuit conditions where the GMP device was installed, documentation of how the data was used in EDC analysis, and EDC actions taken in response to the analysis.

Specific datasets and analysis approaches were applied to each EDC and each case study, as described in EDC-specific Case Study Section 3, Section 4, and Section 5.

3. Eversource M&C Case Studies

3.1 Overview of Eversource M&C Case Studies

Eversource's Term 2 M&C investments include Substation Automation (comprising deploying substation SCADA capabilities and microprocessor relays) and power quality monitors. The evaluation of Substation Automation investments focuses on the 4 kV portions of the Substation Automation program. The 4 kV system represents some of Eversource's older infrastructure with limited existing visibility in grid performance. GMP Substation Automation investment funds were targeted to improve grid visibility and control of the 4 kV substations.

The evaluation features seven M&C Case Studies for Eversource, which focus on a host of M&C functions and a variety of use cases addressing specific M&C objectives and Department evaluation objectives.[25] Case Studies that were selected to demonstrate each Department Objective are outlined in Table 20 below.

Table 20. Eversource Case Studies and Corresponding Department Evaluation Objective*

Department Evaluation Objective*	Evaluation Questions	Case Studies that Accomplish Department Evaluation Objective
Grid visibility, command and control during blue sky days	• Did SCADA provide Dispatch/ Operations timely visibility of grid events/emergencies?	• CS1: SCADA Provides Real-Time Information about Outage in Downtown Boston • CS2: SCADA Alerts Eversource to an Emergency Outage in Lexington
Grid visibility, command and control during major events	• Did M&C provide real-time actionable information to Dispatch/Operations during major events or peak load days? Was corrective action taken? • Was M&C used for peak load monitoring or management on heavily loaded circuits?	• CS3: SCADA Gives Early Indication of Faulted Cable at Hyde Park • CS4: On the hottest day of the year, Eversource used M&C to maintain voltage at acceptable level • CS5: SCADA Helps Determine Peak Load in Waltham and Natick
Effectiveness of investments in detecting power surges	• Was M&C used to monitor voltage and troubleshoot customer power quality or power surge complaints?	• CS6: Power Quality Monitor Gives Detailed View of Voltage Flickers • CS4: On the hottest day of the year, Eversource used M&C to maintain voltage at acceptable level
Impacts of investments on DG integration	• Was M&C used to facilitate DG integration or DG operation,	• CS7: DG Integration on 4 kV Circuits

25 D.P.U. 21-80/21-81/21-82, Hearing Officer Memorandum at 5 (November 9, 2023).

Department Evaluation Objective*	Evaluation Questions	Case Studies that Accomplish Department Evaluation Objective
	including managing risk of voltage fluctuations or backflow? • Was M&C used to determine circuit hosting capacity or conduct DG interconnection studies?	

* Department Evaluation Objectives are detailed in D.P.U. 21-80/21-81/21-82, Hearing Officer Memorandum at 5 (November 9, 2023).

Source: Guidehouse

3.2 Eversource Case Study Selection and Analysis

The selection approach was tailored to each Department GMP objective, Department evaluation objective, each device type, and based on data made available by Eversource. The selection process for Eversource Case Studies is described below, organized by each evaluation objective.

3.2.1 Grid visibility, command and control during power interruptions

The Case Study selection process was designed to evaluate whether SCADA provided Dispatch/ Operations timely visibility into grid events/emergencies. The grid events and emergencies were selected in the following manner, based on a dataset of all 2023 distribution grid interruption events requested from Eversource:

OMS Analysis

1. Starting from the 2023 OMS dataset for Eversource outages, Guidehouse filtered to circuits with 4 kV operating voltage where limited SCADA visibility existed before GMP and where substation SCADA had been commissioned before 2023.
2. Further filtered by isolating device type: Breaker or recloser. Breaker and recloser operations should be captured in SCADA and be visible to operators. This resulted in 44 candidate outage events.
3. To further down-select outage events for potential Case Studies, Guidehouse filtered outages that affected more than 200 customers to prioritize events with higher customer impact. The result was five unique outage events.
4. Guidehouse further excluded an outage event from late December 2023 for which OMS data was still being vetted and finalized by Eversource at the time of evaluation.
5. Guidehouse excluded an outage involving loss of bus section on Station 34 for which insufficient information on the cause of the outage was available to complete a Case Study

This process resulted in three Case Study events (two blue sky, one major event) as follows:

- Case Study 1 – SCADA Provides Real-Time Information about Outage in Downtown Boston (normal weather/blue sky day);
- Case Study 2 – SCADA Alerts Eversource to an Emergency Outage in Lexington (major event day); and

- Case Study 3 – SCADA Gives Early Indication of Faulted Cable at Hyde Park (normal weather/blue sky day).

For these selected Case Studies, analysis was performed as follows:

SCADA Analysis

- Guidehouse reviewed the full-year of 2023 SCADA data (comprising of alerts, alarms and exception reporting) for all 4 kV SCADA devices that were put in service before mid-2023.
- For selected Case Study outages, Guidehouse corroborated timing of SCADA alerts/alarms with OMS outage start/end times to ensure SCADA provided timely information to Eversource.
- Guidehouse requested one-line diagrams and used OMS records for the selected Case Studies to determine outage restoration steps.

3.2.2 Grid visibility, command and control during Major Events – Voltage Monitoring

A potential benefit of the grid visibility afforded by M&C is a better ability to maintain voltage at acceptable levels during heatwaves. Guidehouse designed an approach focusing on the hottest day of 2023 (September 7)[26] and examining whether GMP SCADA readings had been useful in maintaining voltage within acceptable levels.

The Case Study analysis approach was designed to answer the following evaluation questions shown in Table 21:

Table 21. Eversource Case Studies Major Events Analysis Approach

Evaluation Questions	Analysis Approach
(1) Did M&C provide real-time voltage data to Dispatch during the hottest day of 2023 (September 7)? (2) Did M&C record any high or low voltage instances? (3) If so, did Eversource take corrective action?	• To evaluate (1) Guidehouse examined all SCADA alerts and alarms recorded at 23 Eversource 4 kV SCADA substations on September 7, 2023 • To evaluate (2), Guidehouse selected substations where high and low voltages were recorded by SCADA and alerts were issued to dispatchers. Result: 2 substations (Station 53 and Station 455) • To evaluate (3), Guidehouse checked whether any corrective actions were logged in SCADA at the substations above (e.g., tap changer operation) and whether voltage conditions had improved after.

Source: Guidehouse

[26] According to NOAA data at https://www.weather.gov/wrh/Climate?wfo=box (Accessed May 31, 2024), September 7, 2023, had the hottest maximum temperature in Boston in 2023.

The two substations resulting from above analysis process are included in Case Study 4: Station 53 (Downtown Boston) and Station 455 (Framingham).

3.2.3 Grid visibility, command and control during major event – Peak Load

Peak load readings are important in key decision making, including whether a circuit is approaching its maximum rating and requires upgrades to support additional customer load. Accurate peak load determination is a key benefit of M&C, especially during peak load days that typically occur during heatwaves.

To evaluate this objective, Guidehouse designed an approach to examine whether GMP SCADA readings had been used to update circuit peak loads in the 'load book', which maintains accurate up to date information on a circuit's load carrying capability. The Case Study analysis approach was designed to answer the following evaluation questions shown in Table 22:

Table 22. Eversource Case Studies Peak Load Analysis Approach

Evaluation Question	Analysis Approach
(1) Were any of the M&C 4 kV circuits approaching capacity (i.e., are heavily loaded) according to the 2023 load book? (2) Did Eversource use 3-phase SCADA readings to update peak load values for those circuits?	• To test (1), Guidehouse requested Eversource's circuit 'load book' and filtered for heavily loaded 4 kV circuits (>80% of summer normal rating) that had received GMP SCADA investment. Result: 2 circuits (in Waltham and Natick) • To evaluate (2), Guidehouse requested SCADA screenshots for those 2 circuits showing load readings taken during peak times. Guidehouse compared SCADA readings against the load book information.

Source: Guidehouse

The resulting two circuits are included in Case Study 5: SCADA Helps Determine Peak Load in Waltham and Natick

3.2.4 Impacts of investments on DG Integration

To evaluate the use of Eversource's M&C investments on DER integration and identify potential DG integration Case Studies, Guidehouse used the following selection process:

1. Used Eversource Massachusetts Hosting Capacity Map to identify 4 kV circuits with high levels of interconnected DG and constrained hosting capacity;
2. For 4 kV circuits with constrained hosting capacity identified above, Guidehouse asked Eversource for evidence on SCADA readings being used as input to:
   a) calculate hosting capacity;
   b) anticipate DG grid impact (such as backflow); and/or
   c) improve DG interconnection process.

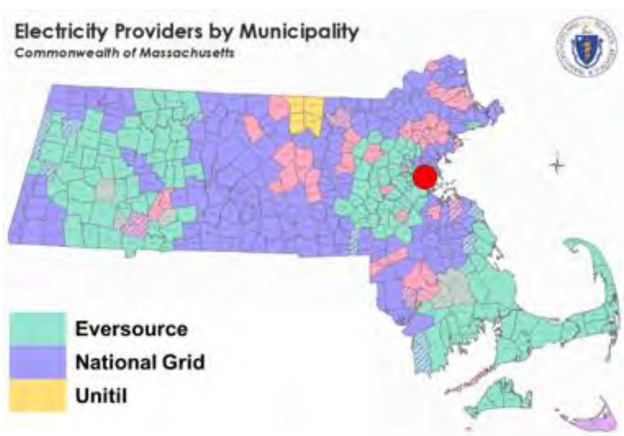
This process resulted in one DG integration Case Study spanning a number of 4 kV circuits, Case Study 7: DG Integration and Hosting Capacity on 4 kV Feeders.

3.2.5 Effectiveness of investments in detecting power surges

To identify potential Case Studies that satisfy the Department's evaluation objective of illustrating the effectiveness of M&C investments to detect power surge instances, Guidehouse focused its evaluation on the effectiveness of a GMP funded power quality monitor commissioned by Eversource.

Eversource had commissioned advanced power quality (PQ) monitoring equipment in January 2021 using GMP funds at the substation STA819 that supplies a university campus in Cambridge, Massachusetts. The PQ monitor capable of capturing disturbances at millisecond intervals, which is at a much higher granularity than standard M&C equipment such as SCADA. This equipment would help Eversource investigate disturbances reported by the university to determine if they was caused by the Eversource system and propose potential solutions. This technology has not been evaluated from PY 2019 through PY 2022 for Eversource, Guidehouse selected the PQ monitor at the university to evaluate its effectiveness in PQ monitoring. This resulted in one Case Study, Case Study 6: Power Quality Monitor Gives Detailed View of Voltage Flickers.

3.3 Case Study 1: SCADA Provides Real-Time Information about Outage in Downtown Boston



Event Date Time

January 29, 2023, 10:44 pm

Event Classification

Normal Weather

Cause

Underground Conductor Failure

Affected Feeders

4910

Number of Customers Restored

Ckt 4910: 789 customers (139 minutes), 9 customers (171 minutes), 135 customers (353 minutes)

Source: Guidehouse (map from https://www.mass.gov/doc/electricity-providers/download, Accessed May 31, 2024)

3.3.1 Description

Eversource used GMP funds to modernize a 4 kV underground circuit serving 939 customers in the vicinity of Beacon Street and Massachusetts Avenue in the City of Boston, Massachusetts. Investments included SCADA visibility at the 4 kV substation which previously had limited (single-phase voltage) visibility. The investments also included replacing obsolete underground, oil-filled switches with SCADA-controlled, vacuum fault interrupters (VFI) as part of ADA, though ADA investments are not being evaluated this year. The M&C and ADA devices were used together to restore the outage in Boston.

On January 29 at 10:44pm, Eversource operators in the control center received SCADA alarms, shown in Figure 4, from the newly installed M&C device in the 4 kV substation. The alarm was triggered by high current indicating a fault condition. SCADA data showed that the substation breaker had opened in response to the event, a correct and desirable operation.

Figure 4. SCADA Alerts Received During Outage in Downtown Boston

SCADA Alerts Received at 10:44 pm:

801	01/29/2023 22:44:14s	(049D) GENERAL ALM ALARM	P2 DIGITAL
802	01/29/2023 22:44:14s	(049D) RTU NETWORK ANN B123 TRBL ALARM	P2 DIGITAL
803	01/29/2023 22:44:15s	(049D) 49-10 4KV PHC AMP IN SATURATION UNREASONABLE VALUE 3842.0 LIMIT VALUE 600.0	UNREAS
804	01/29/2023 22:44:15s	(049D) 49-10 4KV NEU AMP IN SATURATION UNREASONABLE VALUE 3744.0 LIMIT VALUE 600.0	UNREAS
805	01/29/2023 22:44:20s	(049D) BKR 49-10 OPEN	P1 DIGITAL

Outage Start Time Recorded as 10:44 pm:

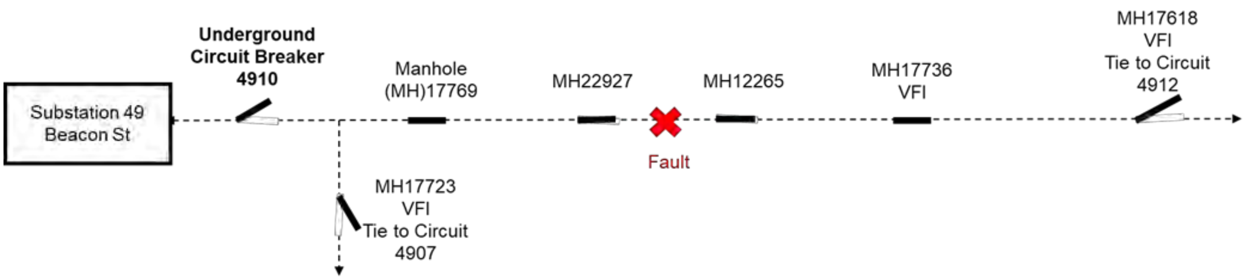
DEENDATETIME	RESTOREDDATETI	ACT_CUST_OI	A_ACT_CUST_	DURATIONM	DURATIONM
1/29/23 10:44 PM	1/30/23 1:03 AM	789	789	139	2:18:05
1/29/23 10:44 PM	1/30/23 1:35 AM	9	9	171	2:50:15
1/29/23 10:44 PM	1/30/23 4:37 AM	135	135	353	5:52:07
1/29/23 10:44 PM	1/30/23 1:03 AM	1	1	139	2:18:05

Source: Eversource

3.3.2 Outage Restoration Steps

Figure 5 provides a one-line diagram of the Station 49's underground circuit 4910. Outage restoration steps undertaken on January 29 and January 30 are summarized thereafter.

Figure 5. One Line Schematic Diagram of Circuit 4910



Source: Guidehouse analysis of 2023 EDC data

1. Upon discovering the 10:44pm outage on January 29, Eversource operators directed troubleshooters to specific manholes as indicated by field fault indication reports. When the crews arrived on site, they found a car parked on the manhole which had to be moved. Crews pumped water out of the manhole and found underground conductor had blown between MH22927 (Manhole #22927) and MH12265 (indicated as "Fault" in Figure 5).
2. Eversource crews manually opened the non-remote capable switch in MH22927 to isolate the fault. Eversource operator remotely opened the VFI in MH17736 and remotely closed the VFI tie switch in MH17618 at 1:03 am on January 30, restoring a section of the circuit and picking up 789 customers.
3. The Eversource operator also remotely closed circuit breaker 4910 at 1:35 am on January 30, restoring nine customers. Crews performed repairs restoring remaining 135 customers at 4:37 am on January 30.

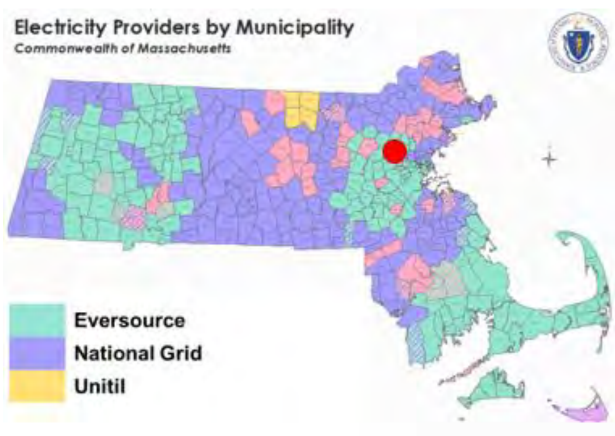
3.3.3 Key Findings

Eversource operators in the control center received SCADA alarms in a timely manner from the newly installed M&C device in the 4 kV substation. SCADA data showed that the substation breaker had opened in response to a high current (correct and desirable operation). The Eversource control center received a trouble alarm, fault current alarm, and breaker open alarm, which were useful for restoration and for post-hoc analysis.

Recommendation:

Eversource crews manually opened the non-remote capable switch in MH22927 to isolate the fault. Eversource may consider adding SCADA to the manual switch in MH22927 for faster restoration. Note that this is a general recommendation and is not applicable to GMP M&C.

3.4 Case Study 2: SCADA Alerts Eversource to an Emergency Outage in Lexington



Source: Guidehouse (map from https://www.mass.gov/doc/electricity-providers/download, Accessed May 31, 2024)

Event Date Time

December 1, 2023

Event Classification

Normal Weather (Rainy Evening)

Cause

Fault in Manhole

Circuits Affected

3407

3.4.1 Description

On December 1, 2023, at 10:21 pm, a rainy evening in Lexington, Massachusetts, Eversource operators received a SCADA alarm, shown in red in Figure 6, that a 4 kV circuit breaker had locked open in Station 34.

Figure 6. SCADA Alerts Received During Outage in Lexington

SCADA Alerts Received:

12/01/2023 19:31:55s	(034D) 351-1377 14KV PH2 KV RET TO NRM 14.4 < Hi Lim: 14.5	P4 ANALO	S_WLTHM
12/01/2023 22:21:57s	(034) XFMR 14D MISC NORMAL with MCD	P2 DIGITA	S_WLTHM
12/01/2023 22:21:57s	(034D) BKR 34-07 OPEN	P1 DIGITA	S_WLTHM
12/01/2023 22:52:38s	(034D) BKR 34-07 RECL C/O OFF	P2 DIGITA	S_WLTHM
12/01/2023 22:52:38s	(034D) BKR 34-07 RECL OFF	P2 DIGITA	S_WLTHM
12/02/2023 03:24:08s	(034D) BKR 34-08 RECL C/O OFF	P2 DIGITA	S_WLTHM
12/02/2023 03:24:08s	(034D) BKR 34-08 RECL OFF	P2 DIGITA	S_WLTHM

Source: Eversource data

As a result of the breaker lockout, all 318 customers served by the circuit 3407 had lost power. In response, Eversource dispatched troubleshooters to check the substation breaker and patrol the area for a fault. While enroute, Eversource received a Fire Department report of a pole top fire on Grant Street in Lexington. (The circuit consists of both underground and overhead segments).

When Eversource personnel arrived at the substation, they noticed smoke in the substation basement in addition to the pole top fire. Troubleshooters suspected a fault in a manhole, but a neighboring circuit needed to be deenergized to allow for inspection, as the two circuits overlapped in the manhole. After a four-hour outage, all customers were restored at 2:29am.

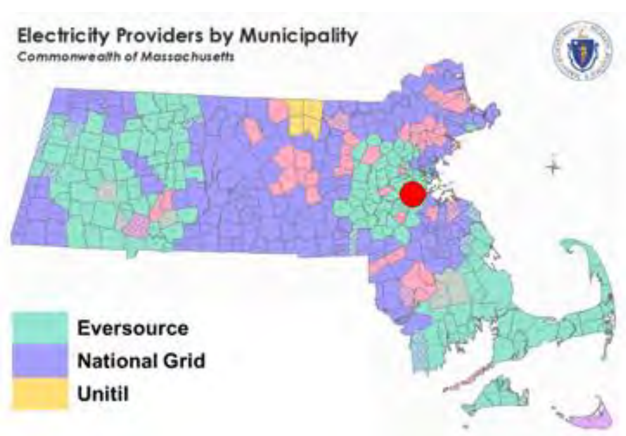
3.4.2 Key Findings

In this case of a pole top fire, the GMP-funded 4 kV SCADA worked as expected to alert operators of an overcurrent and circuit breaker opening. This timely indication of a circuit outage enabled Eversource to dispatch personnel in a timely manner to respond to the emergency.

Recommendation:

To assist in fault location, Eversource may consider installing remote reporting fault indication equipment along the circuit. Note that this is a general recommendation and is not applicable to GMP M&C.

3.5 Case Study 3: SCADA Gives Early Indication of Faulted Cable at Hyde Park



Event Date Time

September 16, 2023

Event Classification

Excludable Major Event - Hurricane Lee

(The outage itself is not excludable as it occurred hours after the Hurricane on September 15)

Cause

Overload, High Current due to underground fault

Substations

Station 60

Source: Guidehouse (map from https://www.mass.gov/doc/electricity-providers/download, Accessed May 31, 2024)

3.5.1 Description

This event occurred in the aftermath of Hurricane Lee which passed through Eastern Massachusetts on September 15-16, 2023. In the afternoon of September 16, Eversource operators received trouble alarms from the 4 kV substation SCADA at Station 60 serving Hyde Park in the City of Boston, Massachusetts. SCADA alerts, shown in Figure 7, on September 16 showed that circuit breaker 60-06 had opened due to a high current value at 12:46pm, which is an indication of faulted equipment. The breaker then closed after current returned to normal. To investigate, Eversource dispatched a troubleshooter, who later reported a manhole smoking and arcing on arrival.

Eversource operators responded to the emergency by remotely deenergizing the circuit using GMP SCADA at 1:40pm on September 16, making the area safe. Eversource determined the cause to be a faulted multiple splice in a manhole.

Figure 7. SCADA Alerts Received in Aftermath of Hurricane Lee

SCADA Alerts Received at 12:47 pm:

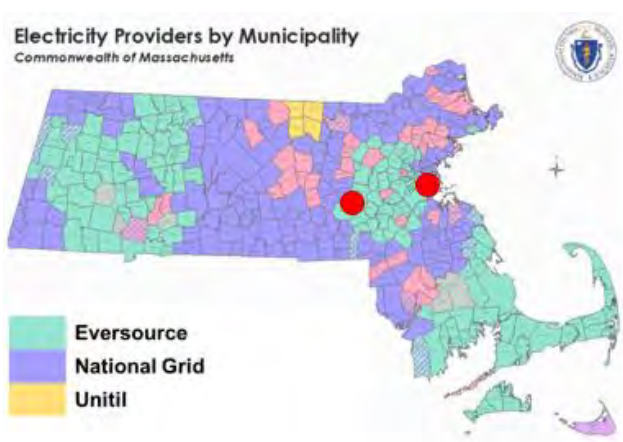
09/16/2023 12:46:50d	(060) 60-06 1929/8 TRBL ALARM	P2 DIGITAL
09/16/2023 12:47:19d	(060) BKR 60-06 4KV OPEN with MCD	P1 DIGITAL
09/16/2023 12:47:20d	(060) 60-06 4KV NEU AMP IN SATURATION UNREASONABLE VALUE 2915.0 LIMIT VALUE 600.0	UNREAS
09/16/2023 12:47:20d	(060) 60-06 4KV PHC AMP IN SATURATION UNREASONABLE VALUE 2963.0 LIMIT VALUE 600.0	UNREAS
09/16/2023 12:47:40d	(060) 60-06 1929/8 TRBL ALARM	P2 DIGITAL
09/16/2023 12:47:49d	(060) BKR 60-06 4KV CLOSE	P1 DIGITAL
09/16/2023 13:40:10d	(060) BKR 60-06 4KV OPEN CTRL ISSUED BY E010819	CONTROL
09/16/2023 13:40:11d	(060) BKR 60-06 4KV OPEN By E010819	P1 DIGITAL
09/16/2023 13:40:14d	(060) 60-06 1929/8 TRBL ALARM	P2 DIGITAL

Source: Eversource

3.5.2 Key Findings

The 4 kV SCADA system worked correctly as expected to alert operators of abnormal conditions in the field. SCADA gave operators early indication of a fault conditions and breaker operation, allowing Eversource to dispatch a troubleshooter in a timely manner. Eversource used SCADA to deenergize the hazardous site remotely and make the area safe.

3.6 Case Study 4: On the hottest day of the year, Eversource used M&C to maintain voltage at acceptable level



Source: Guidehouse (map from https://www.mass.gov/doc/electricity-providers/download, Accessed May 31, 2024)

Event Date Time

September 7, 2023

Event Classification

Hottest Day of the Year

Cause

Voltage Sags and Swells due to Peak Load Conditions

Substations

Station 53, Station 488, Station 455

3.6.1 Description

On September 7, 2023, the hottest day of the year in Massachusetts, Eversource operators responded to voltage alerts and operated devices to return voltage to normal conditions across several substations.

At Station 53 (Downtown Boston), a SCADA alarm was received at 5:04am on September 7, indicating voltage was 113.7V, which was below minimum acceptable threshold of 114V. Using SCADA control, operators operated transformer tap changer to increase voltage back to an acceptable level. Also, using SCADA control, the operator closed the substation capacitor bank to increase voltage. As reported by SCADA, voltage increased to 116VAC.

Another SCADA alarm was received at 12:29pm indicating voltage was 115.9V, which was below minimum threshold of 116V. Using SCADA control, an operator operated the transformer tap changer to increase voltage to an acceptable level.

A SCADA alarm was also received at 6:04pm indicating that voltage was 120.6V, approaching maximum threshold of 121V. Using SCADA control, an operator opened the substation capacitor bank to decrease voltage to an acceptable level.

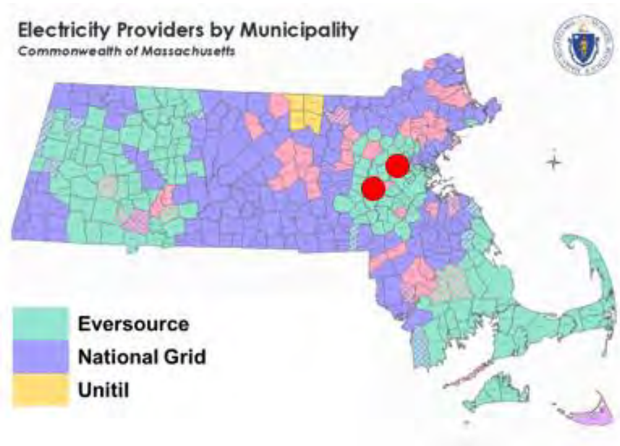
At Station 455 (Framingham), a SCADA alarm received at 12:10am on September 7 indicated that bus voltage was exceeding the high limit of 14.2 kV. Using SCADA control, an operator operated the transformer tap changer to adjust voltage to an acceptable level.

3.6.2 Key Findings

Without M&C SCADA, Eversource had limited (single-phase voltage) visibility on 4 kV circuits, making it difficult to respond to high and low voltage conditions. Now Eversource operators get real-time alarms if voltage on any of the three phases on its 4 kV system deviates outside acceptable voltage range. Throughout the day, Eversource operators responded to voltage alerts and operated devices to return voltage to normal conditions.

Eversource operators took corrective action based on real-time alerts and alarms from GMP SCADA devices, to keep voltage within acceptable limits on the hottest day of the year when load was at its peak.

3.7 Case Study 5: SCADA Helps Determine Peak Load in Waltham and Natick



Source: Guidehouse (map from https://www.mass.gov/doc/electricity-providers/download, Accessed May 31, 2024)

Event Classification

Summer peak load

Cause

Heatwave

Circuits Affected

3408 Waltham and 2302 Natick

3.7.1 Description

Peak load is an important metric in distribution grid operation and planning. Peak load readings reveal how much reserve current-carrying capacity is available at a location. It drives decisions on whether grid equipment may approach maximum rating on peak days, whether grid upgrades are needed to carry more load in the future, and whether the circuit can be relied on as emergency backup for neighboring circuits, among other decisions.

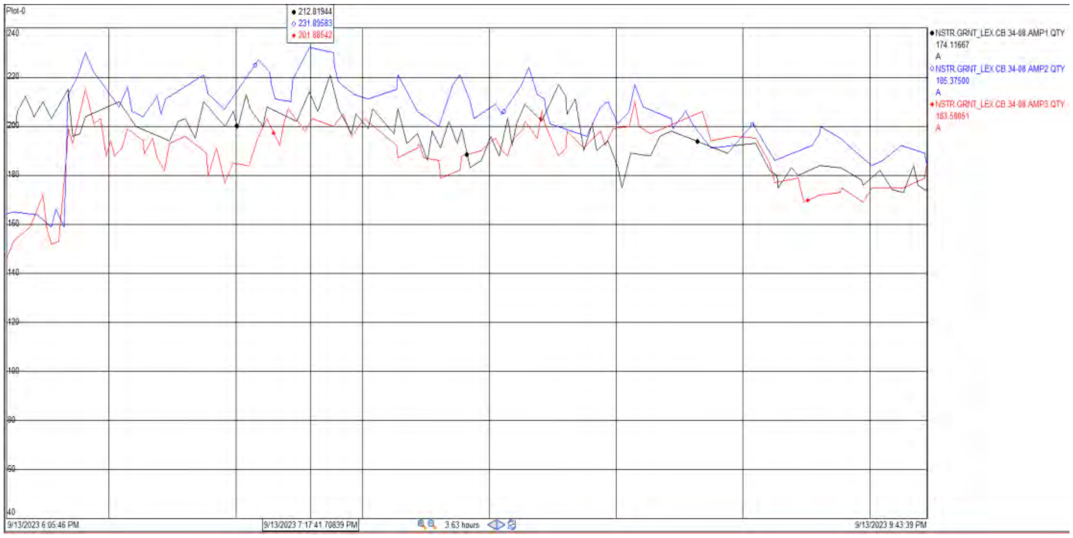
Previously before GMP investment, Eversource had single phase readings available. To get three-phase readings, Eversource engineers would ask a station operator to record load readings in the field during a heatwave. However, during a heatwave event, taking readings would not be top priority. The readings would often be written on paper and not coincide with the true peak (hour/minute); often the reads would be taken at off hours or during the night.

3.7.1.1 Waltham

To evaluate the impact of GMP SCADA on peak load readings, Guidehouse reviewed Eversource's 'load book', which maintains accurate up to date information on a circuit's load carrying capability, for feeder peak load at circuit 3408 in Waltham, a heavily loaded feeder. Guidehouse found that SCADA recorded the highest reading of the year on September 13, 2023, at 7:17pm. Without SCADA, peak readings would be less precise, and planning engineers would have had to rely on hand-written readings from the field.

SCADA data is shown in Figure 8, compared to peak load according to Eversource's 'load book' in Figure 9.

Figure 8. Waltham 3-Phase SCADA Readings from the peak time in 2023.



Source: Eversource

Figure 9. Eversource's Load Book Noting the Peak Load in 2023

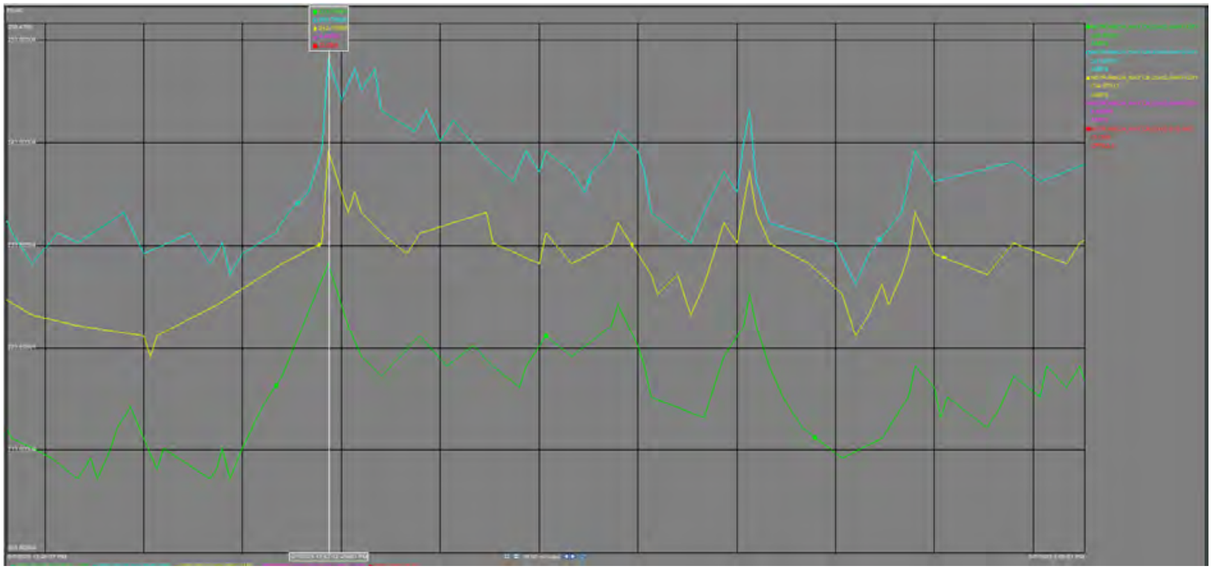
CIRCUIT	FEED SOURCE	WIRE CABLE SIZE	SUMMER NORMAL RATING	SUMMER EMERGENCY RATING	WINTER NORMAL RATING	WINTER EMERGENCY RATING	2023 SUMMER PEAK	2023 WINTER PEAK	2023 YEAR PEAK	2023 YEAR % of SN
3408	STA034	350	250	300	275	300	211	113	211	84%

Source: Eversource

3.7.1.2 Natick

To evaluate the impact of GMP SCADA on peak load readings, Guidehouse also reviewed Eversource's 'load book' for feeder peak load at circuit 2302 in Natick, another heavily loaded feeder. Guidehouse found that SCADA recorded the highest reading of the year on May 7, 2023, at 12:52pm. Without SCADA, peak readings would be less precise, and planning engineers would have had to rely on field reports taken manually, not always taken at the peak time. SCADA data is shown in Figure 10, which was compared to peak load according to Eversource's 'load book' in Figure 11.

Figure 10. Natick 3-Phase SCADA Readings from the Peak Time in 2023



Source: Eversource

Figure 11. Eversource's Load Book Noting the Peak Load in 2023.

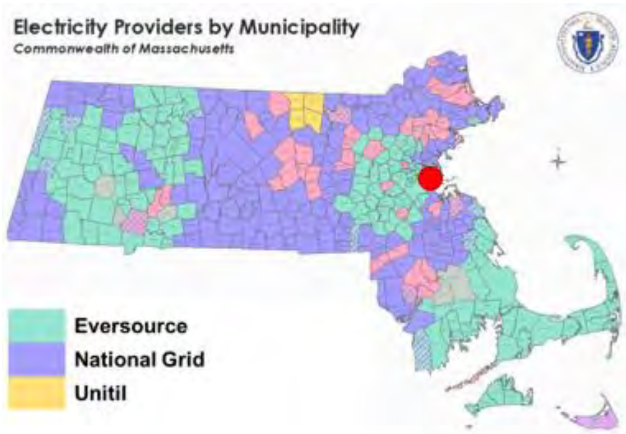
CIRCUIT	FEED SOURCE	WIRE CABLE SIZE	SUMMER NORMAL RATING	SUMMER EMERGENCY RATING	WINTER NORMAL RATING	WINTER EMERGENCY RATING	2023 SUMMER PEAK	2023 WINTER PEAK	2023 YEAR PEAK	2023 YEAR % of SN
2302	STA023	350	300	300	300	300	242	164	242	81%

Source: Eversource

3.7.2 Key Findings

SCADA readings closely matched the load book, indicating that Eversource used SCADA readings as one of the factors to determine feeder summer peak load. Accurate peak load drives important decisions including whether grid upgrades may be needed to support more load in the future, and whether the circuit can be relied on as emergency backup for neighboring circuits.

3.8 Case Study 6: Power Quality Monitor Gives Detailed View of Voltage Flickers



Source: Guidehouse (map from https://www.mass.gov/doc/electricity-providers/download, Accessed May 31, 2024)

Event Date Time

May 15, 2023

Event Classification

Normal Weather

Cause

Power Quality Disturbance Due to Momentary (Cable Fault)

Duration of Disturbance

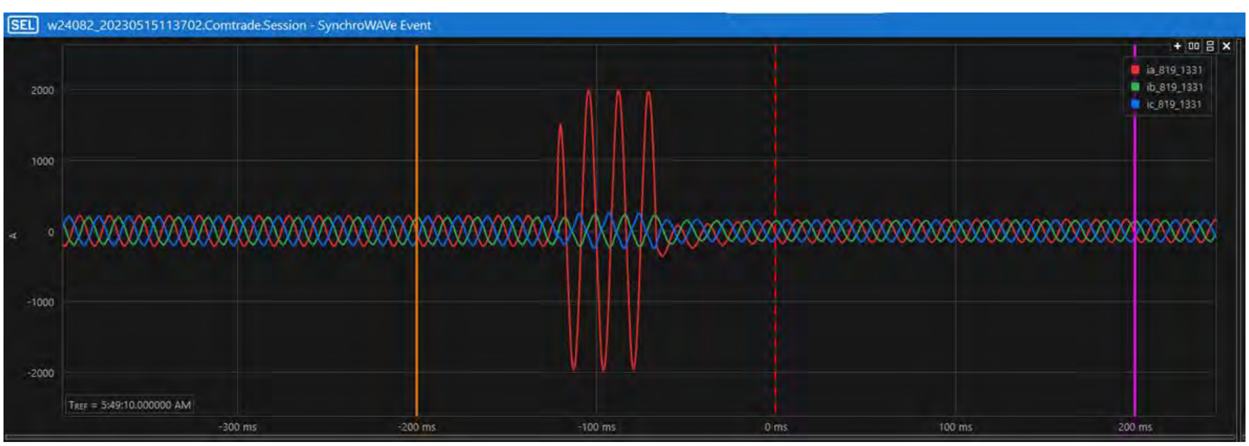
0.06 seconds (4/60th of a second)

3.8.1 Description

A university campus in Cambridge was experiencing power quality issues on its main campus during PY 2023. The university reported that building fire alarms and automation alarms went off (malfunctioned) on May 15, 2023 due to momentary power quality disturbance. Eversource could not troubleshoot these events using standard grid monitoring equipment alone. Eversource determined these voltage disturbances were occurring at the sub-second level.

Eversource had installed advanced power quality monitoring equipment using GMP funds at the substation supplying the university (STA819) in January 2021. The PQ monitor is able to catch disturbances at millisecond intervals, helping Eversource investigate if the cause of the disturbance was the Eversource system and the level of disturbance. Eversource used the GMP PQ Monitor to generate the waveform for the May 15, 2023 voltage event shown in Figure 12.

Figure 12. GMP PQ Monitor Generated Waveform for the May 15, 2023, Voltage Event

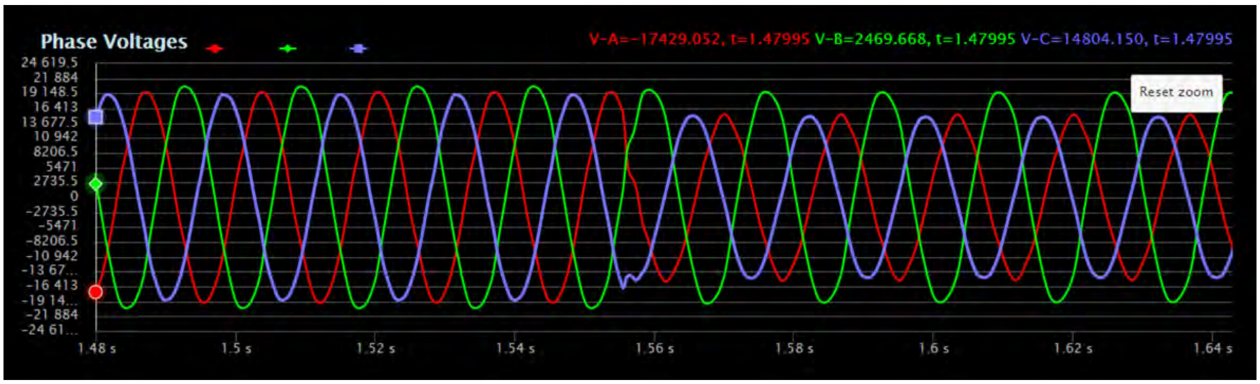


Source: Eversource

Eversource determined the voltage was within the acceptable range of the CBEMA curve.[27] Eversource further determined the relay coordination system had worked as expected to clear the fault in 4 cycles (4/60ths of a second).

The Power Quality Monitor was also used to generate a similar waveform for another power quality event reported on March 8, 2021, shown in Figure 13.

Figure 13. GMP PQ Monitor Generated Waveform for the March 8, 2021, Voltage Event



Source: Eversource

PQ data shows voltage had dipped 27% for 0.44 seconds. Eversource determined the voltage was within the acceptable range of the CBEMA curve.[28] Eversource further determined the fault had been cleared by the Eversource relay coordination system in 1.2 seconds as expected.

3.8.2 Key Findings

The PQ monitors are able to catch disturbances at millisecond intervals, capturing data at a higher granularity than standard GMP equipment (e.g., SCADA). The granular PQ data enabled Eversource to investigate if the cause of the customer complaint was due to the Eversource system, and whether the level of disturbance is within expected range. Eversource determined that the momentary flickers experienced by the university campus were within the acceptable PQ range. The PQ monitor allowed Eversource to share detailed data with the customer leading to better collaboration, evidence-based investigation, and accurate troubleshooting.

Recommendation:

Some customer equipment (e.g., building automation systems) can be more sensitive to minor disturbances than is standard in the electronics industry.[29] PQ Monitor alert thresholds were set at industry acceptable standards and did not automatically trigger an alert for the disturbances reported by the university campus, but did capture the data for analysis. Eversource may

[27] Computer Business Equipment Manufacturers Association Specification for computer and electronics manufacturers; Adapted from IEEE Standard 446

[28] Ibid.

[29] Computer Business Equipment Manufacturers Association Specification for computer and electronics manufacturers; Adapted from IEEE Standard 446

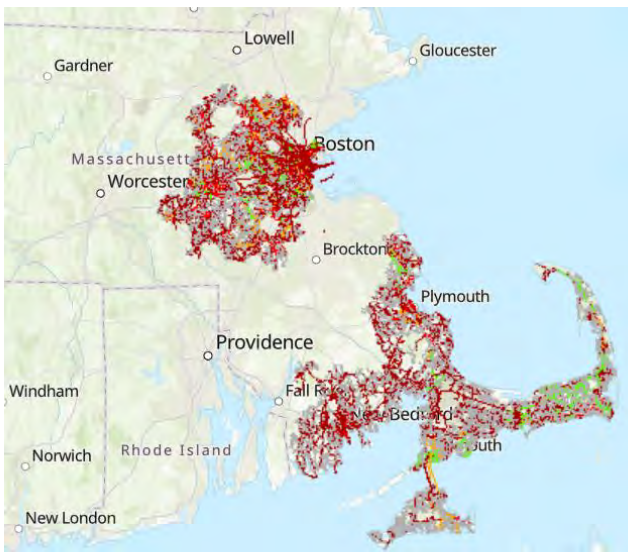
consider altering the trigger threshold for the PQ monitor to create an alert for the type of events being experienced by the university.

3.9 Case Study 7: DG Integration and Hosting Capacity on 4 kV Feeders

3.9.1 Description

Guidehouse used Eversource's Massachusetts hosting capacity map[30] to evaluate whether three-phase SCADA readings are being leveraged to calculate more accurate DG hosting capacity and/or estimate DG grid impacts on 4 kV circuits. As shown in Figure 14, Eversource's publicly available hosting capacity maps present, in red/green hues, how much DG capacity each circuit (or section of a circuit) can accommodate with limited grid upgrades.

Figure 14. Snapshot of Eversource's Eastern Massachusetts Hosting Capacity Map



Source: Eversource DG Hosting Capacity – External Map Viewer EMA (https://eversource.maps.arcgis.com/apps/webappviewer/index.html?id=7b13d31f908243e49406f198b359aa71, Accessed May 10, 2024)

Since only one section of the circuit can be looked up at a time, and data cannot be downloaded from the Eversource hosting capacity site, Guidehouse selected a randomized sample of seven 4 kV circuits and 19 sections. Table 23 presents the hosting capacity results of this search.

Table 23. Sample of Eversource's 4 kV Circuit Section Hosting Capacities from Map

Circuit	Section ID	Hosting Capacity (MW)
5901	700000007345910	0.05
5901	700000007424374	0.40
5901	700000007424375	0.05
5901	700000007424376	0.05

[30] Massachusetts Hosting Capacity Map (https://www.eversource.com/content/residential/about/doing-business-with-us/interconnections/massachusetts/hosting-capacity-map)

Circuit	Section ID	Hosting Capacity (MW)
5901	700000001448288	0.40
5901	700000001448289	0.40
5901	700000001448292	0.40
5901	700000001448293	0.40
5901	700000001937024	0.40
5901	700000001937025	0.40
488-H6	400000007435566	1.00
488-H6	400000007435564	1.00
488-H6	400000002786049	1.00
488-H6	400000002786050	1.00
488-H6	400000002786051	1.00
488-H6	400000002786053	1.00
488-H6	400000002786054	1.00
488-H6	400000002786055	1.00
488-H6	400000002786056	1.00
488-H6	400000002786033	1.00
23-H1	700000000919120	0.05
23-H1	700000000888522	0.20
2408	700000001498440	0.05
2408	700000001407740	0.20
240-H1	100000000293395	0.05
240-H2	400000007568048	0.05
240-H2	320000000121573	1.00
240-H3	100000000148242	0.05
240-H3	100000000498103	0.20

Source: Guidehouse Compilation of Eversource Hosting Capacity Map (https://www.eversource.com/content/residential/about/doing-business-with-us/interconnections/massachusetts/hosting-capacity-map, Accessed May 30, 2024)

The 4 kV hosting capacity values for 3-phase sections were seen to range between 0.2 MW and 1 MW for the sample observed. An example of the attributes of a three-phase section of Eversource's Station 23 is shown in Figure 15. For single-phase sections, the hosting capacity is defaulted to 50kW. An example of the attributes of a single-phase section of Eversource's Station 240 is shown in Figure 16.

Figure 15. Example of Eversource's Hosting Capacity Attribute Table for a Single-Phase Section of Station 23

Location Hosting Capacity(MW)	0.05
Section ID	700000000919120
Operating Voltage	4.16
Circuit Name	23-H1
Bulk Circuit Name	23-1345H
Distribution Substation Name	STA_023 Natick
Distribution Substation Voltage(kV)	13.8/4.16
Distribution Substation Rating (MVA)	66.00
Bulk Substation Name	STA_240 Framingham
Bulk Substation Voltage(kV)	115/13.8
Bulk Substation Rating (MVA)	66.00
Bulk Sub Hosting Capacity(MW)	51.20
Circuit DER Online(kW)	1565.00
Circuit DER In Queue(kW)	62.00
Current ASO Studies	Lvl 0/1:0 ; Lvl 3 In Study:0 ; Lvl 3 In Queue:0
Circuit Feeds Secondary Network Customers	N
Circuit Rating (Amp)	465.00
3V0 Status	N
Date Last Updated	05/13/2024, 06:05 AM

Source: Eversource DG Hosting Capacity – External Map Viewer EMA Circuit Viewer Results (https://eversource.maps.arcgis.com/apps/webappviewer/index.html?id=7b13d31f908243e49406f198b359aa71, Accessed May 30, 2024)

Figure 16. Example of Eversource's Hosting Capacity Attribute Table for a Three-Phase Section of Station 240

Location Hosting Capacity(MW)	1.00
Section ID	320000000121573
Operating Voltage	4.16
Circuit Name	240-H2
Bulk Circuit Name	240-H2
Distribution Substation Name	N/A
Distribution Substation Voltage(kV)	N/A
Distribution Substation Rating (MVA)	
Bulk Substation Name	STA_240 Framingham
Bulk Substation Voltage(kV)	115/13.8
Bulk Substation Rating (MVA)	66.00
Bulk Sub Hosting Capacity(MW)	51.20
Circuit DER Online(kW)	960.00
Circuit DER In Queue(kW)	43.00
Current ASO Studies	Lvl 0/1:0 ; Lvl 3 In Study:0 ; Lvl 3 In Queue:0
Circuit Feeds Secondary Network Customers	
Circuit Rating (Amp)	365.00
3V0 Status	N
Date Last Updated	05/13/2024, 06:05 AM

Source: Eversource DG Hosting Capacity – External Map Viewer EMA Circuit Viewer Results (https://eversource.maps.arcgis.com/apps/webappviewer/index.html?id=7b13d31f908243e49406f198b359aa71, Accessed May 30, 2024)

3.9.2 Key Findings:

Eversource notes that the 4 kV system has limited ability to interconnect DG without significant upgrades. For the 4 kV feeders that received M&C SCADA investments, Eversource is using

SCADA readings to inform HC calculations. Inputs included peak load, voltage and minimum light load.

Recommendation:

Eversource should continue to use 4 kV 3-phase SCADA readings to conduct DG interconnection studies and maximize DG hosting capacity at 4 kV feeders in a safe and reliable manner.

3.10 Eversource Key Findings and Recommendations

Table 24 presents the key findings and recommendations for each of the seven Eversource M&C Case Studies evaluated by Guidehouse for PY 2023.

Table 24. Eversource Case Studies Findings and Recommendations Summary

Case Study	Findings	Draft Recommendations
CS1: SCADA Provides Real-Time Information About Outage in Downtown Boston	• Eversource operators in the control center received SCADA alarms in a timely manner from the newly installed M&C device in the 4 kV substation. SCADA data showed that the substation breaker had opened in response to a high current (correct and desirable operation). • Eversource control center received a trouble alarm, fault current alarm, and breaker open alarm which were useful information for restoration and for post-hoc analysis.	• General Recommendation Not Applicable to GMP: Eversource crews manually opened the non-remote capable switch in MH22927 to isolate the fault. Eversource may consider adding SCADA to the manual switch in MH22927.
CS2: SCADA Alerts Eversource to an Emergency Outage in Lexington	• In this case of a pole top fire, the GMP-funded 4 kV SCADA worked as expected to alert operators of an overcurrent and circuit breaker opening. This timely indication of a circuit outage enabled Eversource to dispatch personnel in a timely manner to respond to the emergency.	• General Recommendation Not Applicable to GMP: To assist in fault location, Eversource may consider installing remote reporting fault indication equipment along the circuit.

Case Study	Findings	Draft Recommendations
CS3: SCADA Gives Early Indication of Faulted Cable at Hyde Park	• 4 kV SCADA system worked correctly as expected to alert operators of abnormal conditions in the field. SCADA gave operators early indication of a fault conditions and breaker operation, allowing Eversource to dispatch a troubleshooter in a timely manner. Eversource used SCADA to deenergize the hazardous site remotely and rapidly, making the area safe.	• (None)
CS4: On the Hottest Day of the Year, Eversource Used M&C to Maintain Voltage at an Acceptable Level	• Throughout the day on September 7, 2023, when load was at its peak, Eversource operators took corrective action across several substations based on real-time alerts and alarms from GMP SCADA devices, to keep voltage within acceptable limits.	• (None)
CS5: SCADA Helps Determine Peak Load in Waltham and Natick	• SCADA readings closely matched the load book, indicating that Eversource used SCADA readings as one of the factors to determine feeder summer peak load. Accurate peak load drives important decisions including whether grid upgrades may be needed to support more load in the future, and whether the circuit can be relied on as emergency backup for neighboring circuits.	• (None)
CS6: Power Quality Monitor Gives Detailed View of Voltage Flickers	• The Power Quality (PQ) monitors are able to catch disturbances at millisecond intervals, capturing data at a higher granularity than standard GMP equipment (e.g., SCADA). The granular PQ data enabled Eversource to investigate if the cause of the customer (Harvard) complaint was due to the Eversource system, and whether the level of disturbance is within expected range. Eversource determined that the momentary flickers experienced by the university campus were within the acceptable PQ range. The PQ monitor allowed Eversource to share detailed data with Harvard leading to better collaboration, evidence-based investigation, and accurate troubleshooting.	• The PQ Monitor showed that some customer equipment (e.g., building automation systems) can be more sensitive to minor disturbances than is standard in the electronics industry. PQ Monitor alert thresholds were set at industry acceptable standards and did not automatically trigger an alert for the disturbances reported by the university, but did capture the data for analysis. Eversource may consider altering the trigger threshold for the PQ monitor to create an alert for the type of events being experienced by the university.

Case Study	Findings	Draft Recommendations
CS7: DG Integration and Hosting Capacity on 4 kV feeders	• Eversource notes that the 4 kV system has limited ability to interconnect DG without significant upgrades. For the 4 kV feeders that received M&C SCADA investments, Eversource is using SCADA readings to inform hosting capacity (HC) calculations. SCADA inputs included peak load, voltage and minimum light load.	• Eversource should continue to use 4 kV 3-phase SCADA readings to conduct DG interconnection studies and maximize DG hosting capacity at 4 kV feeders in a safe and reliable manner.

Source: Guidehouse

4. National Grid M&C Case Studies

4.1 Overview of National Grid M&C Case Studies

National Grid's M&C investments include interval power monitoring devices on overhead feeders located on its distribution system. The feeder monitors are installed outside the substation fence for increased visibility of feeder main line current, voltage, and other parameters. Information from the monitors is transmitted via the cellular network every five minutes and is displayed in the Operations Control Center (OCC).

Six Case Studies were selected to address specific M&C objectives and Department directives. Case Studies that were selected to demonstrate each Department Objective are outlined in Table 25 below. Taken together, the Case Studies demonstrate a host of M&C functions, a variety of use cases and a range of levels of utilization of the technology.

Table 25. National Grid Case Studies and Corresponding Department Evaluation Objective*

Department Evaluation Objective*	Evaluation Questions	Case Studies that Accomplish Department Evaluation Objective
Grid visibility, command and control during blue sky days	• Did feeder monitors provide Dispatch/ Operations timely visibility of feeder current/voltage to avoid overloads and/or high/low voltages conditions?	• CS1: Improving Contingency Operation with Real-Time Visibility at Marlborough • CS2: Keeping DG Online at Ayer Feeders • CS3: Validating Proper FLISR Operation without Overload in Ayer
Grid visibility, command and control during major events	• Were feeder monitors used to monitor peak loads during major heatwaves?	• CS4: Improving Peak Load Readings at N. Abington
Effectiveness of investments during power surges	• Were feeder monitors useful in investigation of customer power surge complaints?	• CS5: Investigating Power Surge Complaints in Scituate
Effectiveness of investments during distributed generation (DG) backflow instances	• Were feeder monitors used to monitor voltage at circuits with high DG penetration?	• CS6: Monitoring Voltage and DG Backflow in Winchendon

Department Evaluation Objective*	Evaluation Questions	Case Studies that Accomplish Department Evaluation Objective
Impacts of investments on DER integration	• Were feeder monitors used to monitor circuit impact of DG and facilitate in DG adoption/operation?	• CS3: Keeping DG Online at Ayer Feeders • CS6: Monitoring Voltage and DG Backflow in Winchendon

* Department Evaluation Objectives are detailed in D.P.U. 21-80/21-81/21-82, Hearing Officer Memorandum at 5 (November 9, 2023).

Source: Guidehouse

4.2 National Grid Case Study Selection and Analysis

The selection approach was tailored to each Department GMP objective, Department evaluation objective, each device type, and the data made available by National Grid. The selection process for National Grid Case Studies is described below, organized by each objective.

4.2.1 Grid visibility, command and control

National Grid's feeder monitors are designed to provide visibility into main-line current and voltage as well as circuit conditions (e.g., phase imbalance, momentary faults, power factor). Both ADA and M&C investments include feeder monitors, but their intended uses are different:

- The feeder monitors funded from ADA funds are used in outage restoration and facilitating FLISR operation.
- The feeder monitors funded from M&C funds are primarily used to monitor circuit conditions (such as load, voltage) and for planning for grid operations and contingencies.

With this in mind, M&C Case Studies were designed to showcase grid contingency planning, load management, and voltage monitoring functions rather than outage restoration. More information on how ADA FLISR schemes are used to facilitate outage restoration is provided in Case Studies contained in the PY 2023 ADA Evaluation Report.

To showcase grid contingency planning, load management, and voltage monitoring functions, National Grid was asked to provide instances where contingency circuit switching had taken place in 2023 on feeders with M&C feeder monitors. Three instances were provided: one in Marlborough in November 2023, and two in Ayer in June 2023. This resulted in three Case Studies:

1. Case Study 2: Improving Contingency Operation with Real-Time Visibility at Marlborough
2. Case Study 3: Keeping DG Online at Ayer Feeders
3. Case Study 4: Validating Proper FLISR Operation without Overload in Ayer

To perform those Case Studies, Guidehouse:

1. Requested feeder monitor data readings to verify the data had been visible to Dispatch/Operations at the time of the event;

2. Investigated whether feeder monitor data had been useful in grid operational decision making and, if so, which specific decision-making processes had benefited from feeder monitor data; and
3. Held follow-up discussions to discern the impact of feeder monitors and determine what would have happened in the absence of feeder monitors.

4.2.2 Grid visibility, command and control during major event – Peak Load

Peak load readings are important in key decision making including whether a circuit is approaching its maximum rating, which could require system upgrades to support additional customer load. Accurate peak load determination is a key benefit of M&C especially during peak load days that typically occur during heatwaves.

One of the M&C evaluation objectives was to determine whether feeder monitors had been used to inform and improve peak load calculations, especially for heavily loaded circuits. To select heavily loaded circuits, Guidehouse's initial approach was to request National Grid's 'load book' and evaluate the use of feeder monitors on heavily loaded circuits – similar to the approach followed for Eversource Case Studies.

However, Guidehouse learned that National Grid is generally not using feeder monitor readings for peak load purposes except in a handful of cases. National Grid offered three specific circuits where feeder monitors had been used to improve peak load accuracy and phase balancing. For two of those three circuits, load balancing had been performed in 2021 and 2022 and they were not deemed candidates for PY 2023 evaluation. One circuit at North Abington was selected for a case study. Whereas two National Grid peak load Case Studies had been targeted in PY 2023 evaluation, one load Case Study was performed. Guidehouse has recommended more systematic use of feeder monitors for peak load readings wherever feeder monitor data is available.

The National Grid peak load Case Study analysis was approached as shown in Table 26.

Table 26. National Grid Peak Load Case Study Analysis Approach

Evaluation Question	Analysis Approach
(1) Were any of the M&C circuits approaching capacity (are heavily loaded) according to the 2023 load book? (2) Did National Grid use three-phase feeder monitor readings to update peak load values for those circuits?	• National Grid proposed three circuits where feeder monitors had been used for load readings. To evaluate (1), one circuit was selected where feeder monitor had been used for peak load readings in 2023. • To evaluate (2), Guidehouse requested SCADA data showing load readings taken during peak times. • The result was Case Study 4: Improving Peak Load Readings at North Abington

Source: Guidehouse

4.2.3 Impacts of Investments on DG Integration and Monitoring DG Backflow

To evaluate the use of feeder monitors on DG integration at National Grid, Guidehouse used the following selection process:

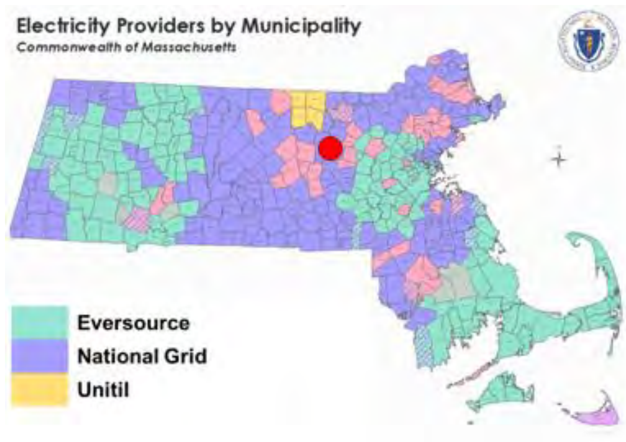
1. Guidehouse used National Grid's Massachusetts Hosting Capacity Map to identify circuits with high levels of interconnected DG and constrained hosting capacity, that had also received M&C feeder monitor investments in 2023 or earlier.
2. For circuits with constrained hosting capacity and M&C investment identified in 1 above, Guidehouse selected the circuit with the highest number of voltage complaints. The rationale was that voltage fluctuations are a common concern on circuits with high DG, and feeder monitors improve visibility of main line voltage.
3. For the circuit selected in 2, Guidehouse asked National Grid for SCADA voltage and current interval readings. The SCADA data was used to examine whether feeder monitors were used as an input to:
    a) inform hosting capacity calculation;
    b) monitor/avoid DG backflow; and/or
    c) monitor/avoid potential voltage impacts of high DG penetration.

This process resulted in one DG integration Case Study, Case Study 6: Monitoring Voltage and DG Backflow in Winchendon.

4.2.4 Effectiveness of Investments during Power Surges

To evaluate the use of feeder monitors for detecting, correcting, or avoiding power surges, Guidehouse requested National Grid to provide customer voltage complaints, by feeder, for 2023. The Scituate feeder 07-915W36 was found to have the highest number of voltage complaints (36) of any M&C feeder, and also had the highest number of power surge complaints (5). The circuit 07-915W36 was selected for a Case Study to evaluate the effectiveness of feeder monitors in troubleshooting power surge complaints.

4.3 Case Study 1: Improving Contingency Operation with Real-Time Visibility at Marlborough



Source: Guidehouse (map from https://www.mass.gov/doc/electricity-providers/download, Accessed May 31, 2024)

Event Date Time

November and December, 2023

Event Classification

Normal Weather

Cause

Planned transmission event

Affected Feeders

310W3, 310W4, 310W5, 310W6, 311W1, 311W2 311W3, 311W4, 311W5 & 311W6

4.3.1 Description

National Grid needed to perform transmission line work in November 2023, for which several Marlborough circuits had to be supplied from an alternate source. In addition, National Grid needed to perform a breaker replacement project at the Marlborough substation from December 2023 to May 2024, for which offloading was necessary. National Grid planned to minimize the customer impact while ensuring that the feeders carrying extra load would not get overloaded, as overloading can cause equipment damage leading to outages.

4.3.2 Benefits of GMP Feeder Monitor

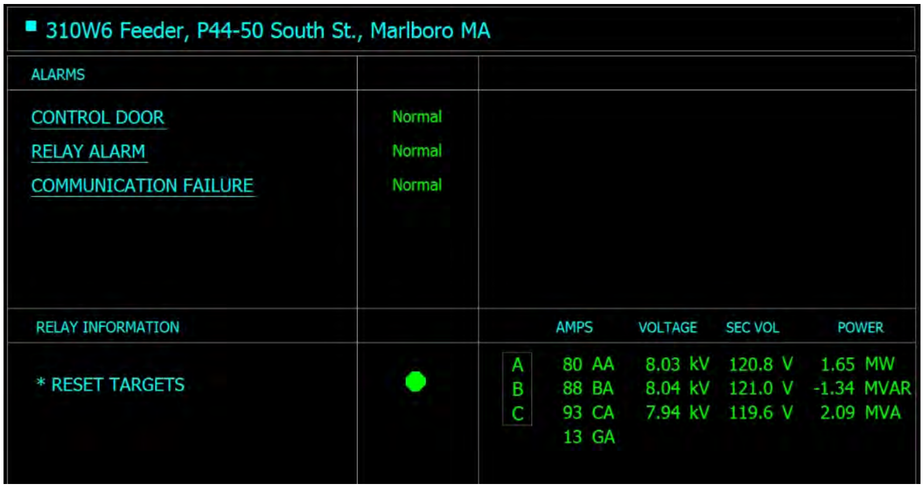
Without feeder monitors, National Grid had to rely on limited single-phase SCADA analogs from the substation which do not show precise load conditions along the feeder to make decisions on contingency load carrying configurations. In addition, National Grid had to rely on limited monthly load readings taken manually. Without near real time feeder visibility, potential overload and damage to equipment could result.

With feeder monitors, National Grid can monitor real-time load conditions to make sure that contingency switching is not overloading the feeder. Real time load visibility allows better decision making and quick reaction if overload does arise during the day, reducing the likelihood of outages and of damage to equipment due to overloading.

4.3.3 Key Findings and Recommendations

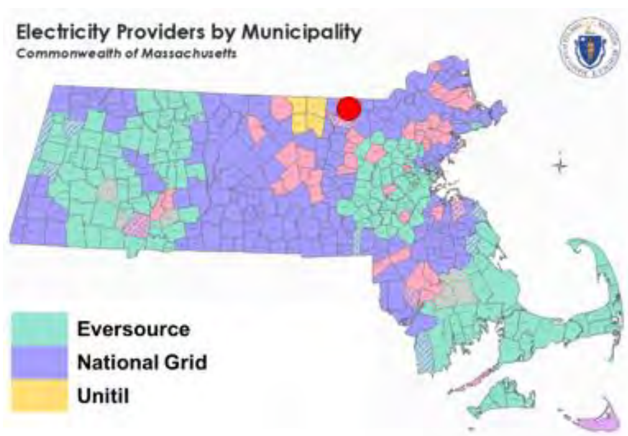
The feeder monitors installed at Marlborough provided National Grid control center operators with near real-time visibility into feeder current and voltage, as well as installation health status (communications and relay status). This real time visibility, as shown in Figure 17, allowed National Grid to be prepared to respond if any issues had resulted from the contingency operation.

Figure 17. Visibility into Feeder Current and Voltage in Marlborough



Source: National Grid

4.4 Case Study 2: SCADA Helps Keep DG Online at Ayer Feeders



Source: Guidehouse (map from https://www.mass.gov/doc/electricity-providers/download, Accessed May 31, 2024)

Event Date Time

5/14-6/2, 2023

Event Classification

Normal weather

Cause

Planned transmission outage

Feeders

201W2, 201W3, and 201W4

4.4.1 Description

National Grid had to perform planned work between May 14 and June 2, 2023, on the L138 transmission line feeding the Laurel Circle substation. Feeders 227W1 and 227W3 had to be supplied by an alternate source, i.e., the Ayer feeders 201W2, 201W3, and 201W4 had to carry additional load.

4.4.2 Benefits of GMP Feeder Monitor

- Without the feeder monitor, National Grid had limited SCADA in the Ayer substation to make contingency decisions on whether additional load would overload and damage the Ayer feeders. Now, National Grid has near real-time feeder monitor readings to monitor load and respond immediately if an overload was approaching.

- In addition, National Grid was able to keep all the DG (approximately 12 MW) on those feeders online during that period.

4.4.3 Key Findings and Recommendations:

Feeder monitors gave National Grid near real time visibility into feeder load conditions. The feeder monitors allowed National Grid to determine with high confidence that contingency switching was safe and reliable, and potential overloads were being avoided.

National Grid was able to maintain all 12MW of DG online during the period of load transfer. As shown in Table 27, three-phase loads at all three feeders were kept well below the maximum rating (493 Amperes) at all times during the period of load transfer. Voltage readings were also observed to stay within acceptable range.

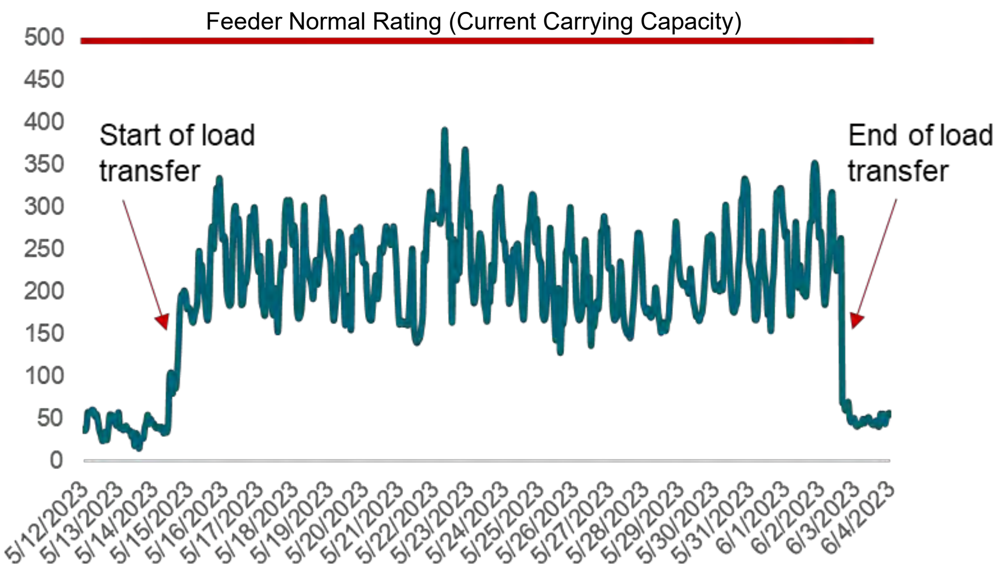
Table 27. National Grid Ayer Feeder Monitor Readings

Feeder	Maximum Load Reading on Feeder Monitor Observed 5/12-6/4/23 (A)	Normal Rating (A)	Emergency Rating (A)
201W2	322	493	515
201W3	310	493	515
201W4	391	493	515

Source: Guidehouse analysis

As an example, 201W4 A-phase readings are shown in Figure 18.

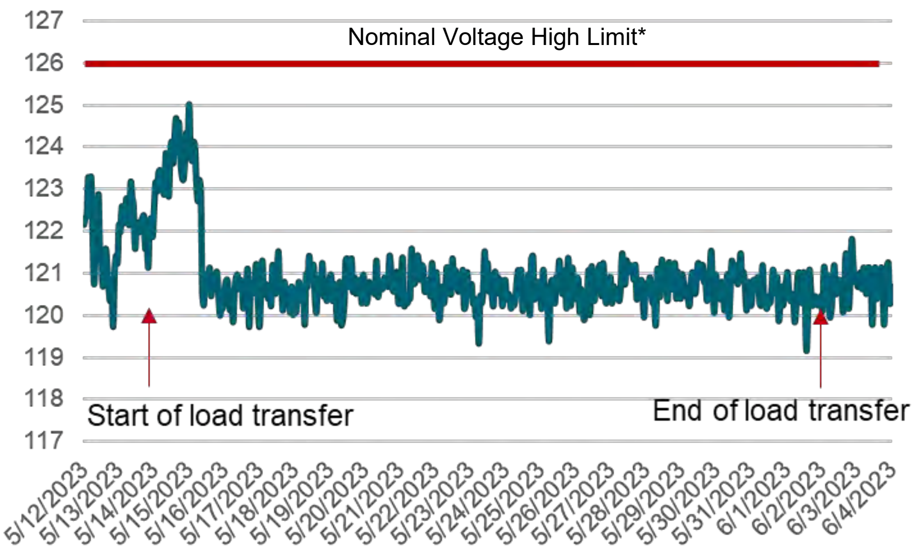
Figure 18. Feeder Monitor 201W4 Current Readings A-Phase (Amperes)



Source: Guidehouse (data from National Grid)

Though the lightly loaded C-phase crept up, as shown in Figure 19, it stayed within acceptable limits. The feeder monitors provided accurate voltage readings that were useful in monitoring feeder voltage. No customer voltage complaints were received on the three Ayer feeders during the period of load transfer.

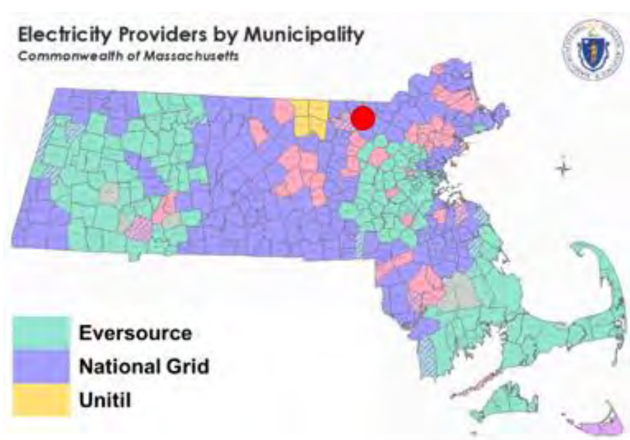
Figure 19. Feeder Monitor 201W2 Voltage Readings C-Phase (Volts)



* Massachusetts limits are based on voltage guidelines in ANSI C84.1−2016

Source: Guidehouse (data from National Grid)

4.5 Case Study 3: SCADA Validated Proper FLISR Operation without Overload in Ayer



Event Date Time

May 19, 2023

Event Classification

Normal weather

Cause

tree limb on main line

Feeder

201W2

Source: Guidehouse (map from https://www.mass.gov/doc/electricity-providers/download, Accessed May 31, 2024)

4.5.1 Description

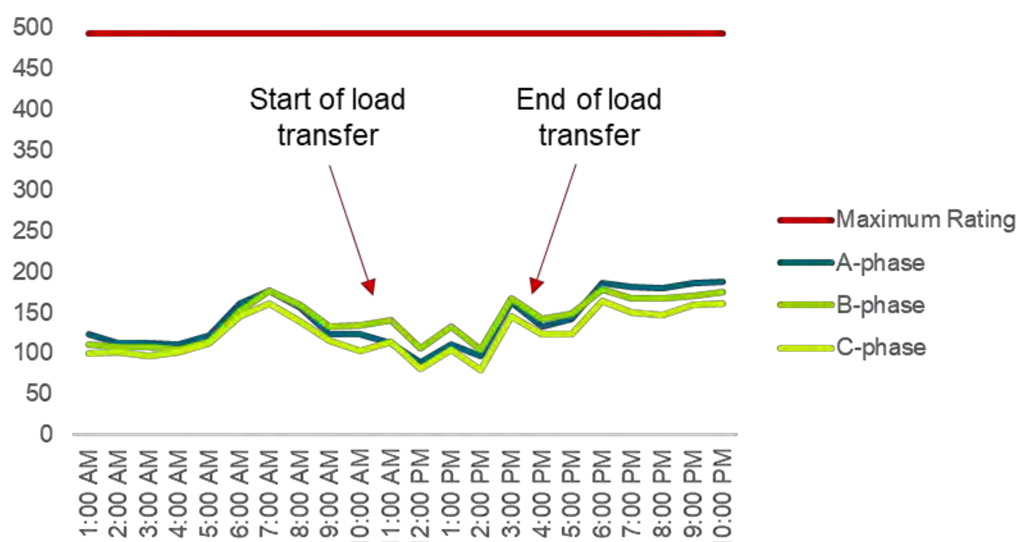
On May 19, 2023, at 10:26am, a tree fell on overhead lines causing a circuit breaker lockout on feeder 216W6. It triggered the FLISR scheme to operate, closing a tie with the Ayer feeder 201W2. The feeder 201W2 now carried 594 additional customers from feeder 216W6. 201W2 was already in abnormal configuration due to a transmission line outage (Case Study 2 above). The repairs lasted almost 5 hours and were completed after 3pm – meaning 201W2 remained in abnormal configuration through peak afternoon hours.

There was a risk that 201W2 might get overloaded as load peaked in the afternoon hours. FLISR only does load checks during the initial FLISR reconfiguration. From there it is up to the Operators to manage the loading. It is the expectation that if a FLISR operation causes a feeder to become loaded between its summer normal and summer emergency rating then Operations will immediately begin taking steps to further switch load to bring the feeder below its summer normal rating. Likewise, there is a risk that the feeder creeps back above the summer normal rating in the evening as PV output slows down and unmasks further load; that would also be up to the human operators to manage.

4.5.2 Benefits of GMP Feeder Monitor

The feeder monitor on the Ayer 201W2 feeder provided near real time visibility to the control center which allowed operators to monitor load as peak time approached and take proper action if necessary. The feeder monitor allowed National Grid to monitor in near real time if contingency switching was safe and reliable, avoiding a potential overload situation as shown in Figure 20. The 4MW DG connected on 201W2 contributed to lowering overall circuit load.

Figure 20. Feeder Monitor 201W2 Hourly Current Readings on May 19, 2023 (Amperes)



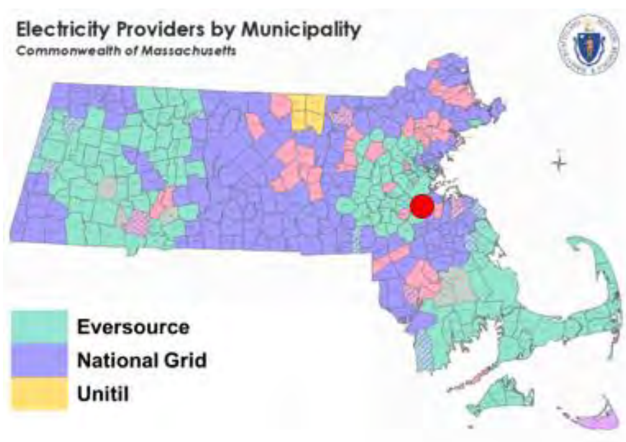
Source: Guidehouse (data from National Grid)

4.5.3 Key Findings and Recommendations

The feeder monitor readings helped National Grid determine with accuracy that feeder 201W2 did not exceed maximum load ratings while it was carrying additional customers under a FLISR scheme on May 19, 2023.

FLISR only does load checks during the initial FLISR reconfiguration. From there it is up to the operators to monitor SCADA and manage the loading. In this case, operators used SCADA to properly manage load and the feeder maximum rating was not exceeded. However, National Grid's control center and DC&I may consider setting up automated FLISR/SCADA alarms if load is approaching its limit at any time, including during FLISR operation.

4.6 Case Study 4: Improving Peak Load Readings at N. Abington



Source: Guidehouse (map from https://www.mass.gov/doc/electricity-providers/download, Accessed May 31, 2024)

Event Date Time

7/12/23 and 9/7/23

Event Classification

Peak load

Cause

Hottest days of 2023

Affected Feeders

99W63

4.6.1 Description

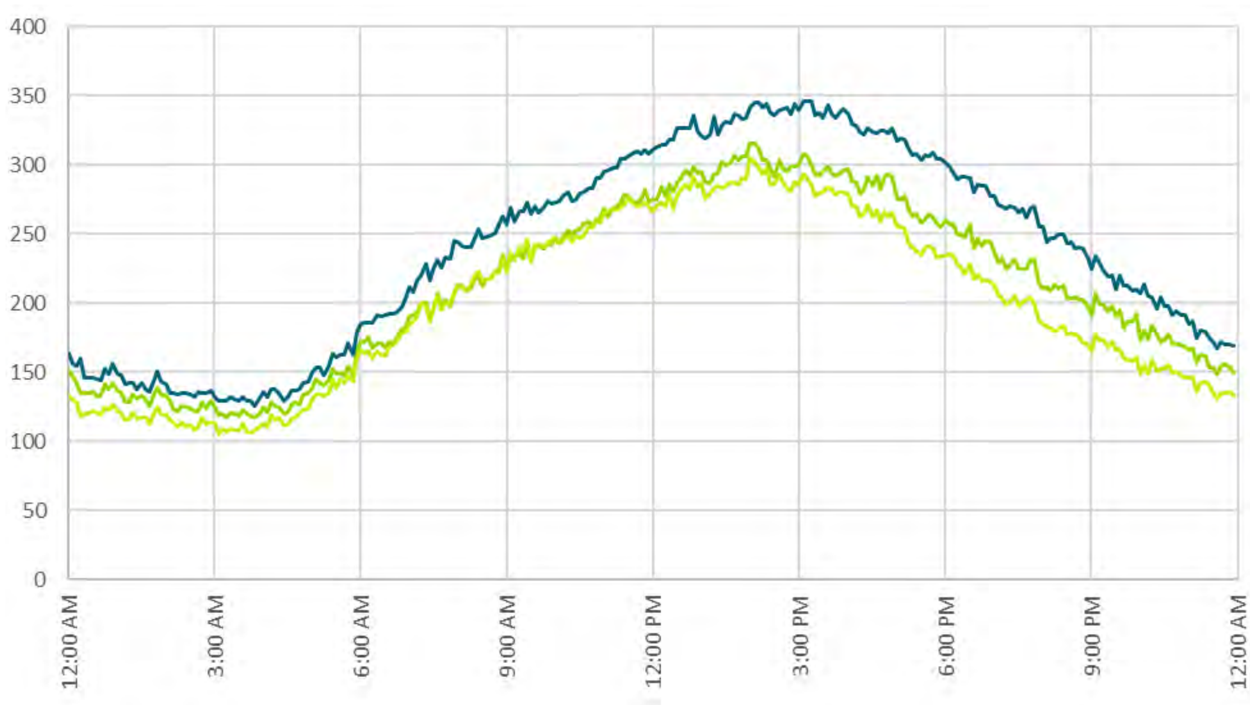
National Grid's North Abington Substation has only single-phase current and voltage readings for each feeder. National Grid installed a feeder monitor on feeder 99W63 which records three-phase, 5-minute interval readings for the feeder. Guidehouse requested feeder monitor interval load readings for the year of 2023. Analysis shows the feeder monitor recorded peak readings on July 12, 2023, and September 7, 2023, as shown in Figure 21 and Figure 22, respectively.

Figure 21. Snapshot of 99W63 Feeder Monitor Readings During one of the Peak Times in 2023

	APH AMPS.MQ	APH AMPS.MV	BPH AMPS.MQ	BPH AMPS.MV	CPH AMPS.MQ	CPH AMPS.MV
12-Jul-23 13:30:00	TE.INV	308	TE.INV	302	TE.INV	334
12-Jul-23 13:35:00	TE.INV	312	TE.INV	308	TE.INV	**351**
12-Jul-23 13:40:00	TE.INV	314	TE.INV	300	TE.INV	340
12-Jul-23 13:45:00	TE.INV	315	TE.INV	307	TE.INV	341

Source: National Grid

Figure 22. Three-Phase 99W63 Feeder Monitor Load Readings (Amperes) on September 7, one of the Peak Days in 2023



Source: Guidehouse analysis of National Grid data

4.6.2 Benefits of GMP Feeder Monitor

Prior to deploying a feeder monitor, station reads for North Abington feeder 99W63 had been single-phase and were reading the A-phase only. After the GMP feeder monitor was deployed, National Grid learned that the C-phase was most heavily loaded, and A-phase readings were under-reporting feeder load. This ultimately improved the accuracy of grid visibility for feeder 99W63.

Using feeder monitor readings, National Grid learned that substation load readings had been mis-scaled and were under-reporting feeder load. With the feeder monitor, National Grid was able to correctly determine feeder load during normal and peak times, improving grid visibility and planning.

With accurate three-phase peak load readings, National Grid can make better decisions about whether upgrades are needed to increase load carrying capacity at this feeder on normal and peak days. National Grid plans to perform load-balancing to balance load on the three phases due to its discovery of significant imbalance between the A-phase and C-phase. In addition, National Grid plans to use the three-phase, granular SCADA data from the feeder monitor in the Hanover DG Group Study to better understand DG impacts.

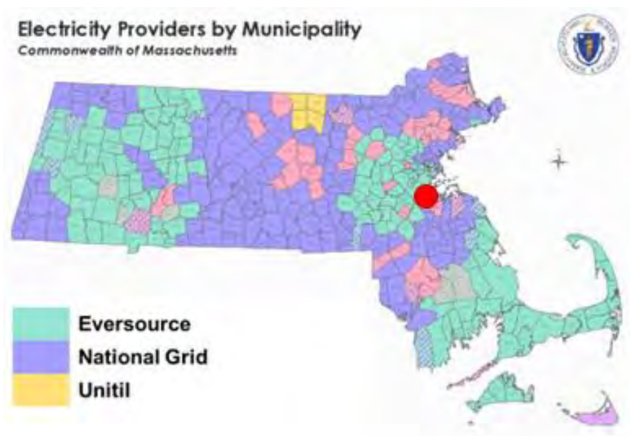
4.6.3 Key Findings and Recommendations

Single-phase readings have a risk of over- or under-stating loading conditions on distribution feeders. The GMP feeder monitor provided three-phase current information throughout 2023.

After the GMP feeder monitor was deployed, National Grid learned that the C-phase was most heavily loaded, and that A-phase readings were under-reporting the feeder load. National Grid is using the feeder monitor to determine three-phase load and conduct phase balancing at North Abington. National Grid will also use the feeder monitor readings in the Hanover DG Group Study to study the impact of DG on the feeder.

National Grid has installed feeder monitors at many locations that lack substation three phase data. National Grid should consider integrating feeder monitor data with other SCADA data and using it for planning purposes on a regular basis. Currently, National Grid is using feeder monitor data for planning purposes on a case-by-case basis, only if needed for studies/analysis.

4.7 Case Study 5: Investigating Power Surge Complaints in Scituate



Source: Guidehouse (map from https://www.mass.gov/doc/electricity-providers/download, Accessed May 31, 2024)

Event Date Time

7/20/23, 8/7/23 and 9/7/23

Event Classification

Power Surge Complaints

Cause

TBD

Feeder

07-915W36

4.7.1 Description

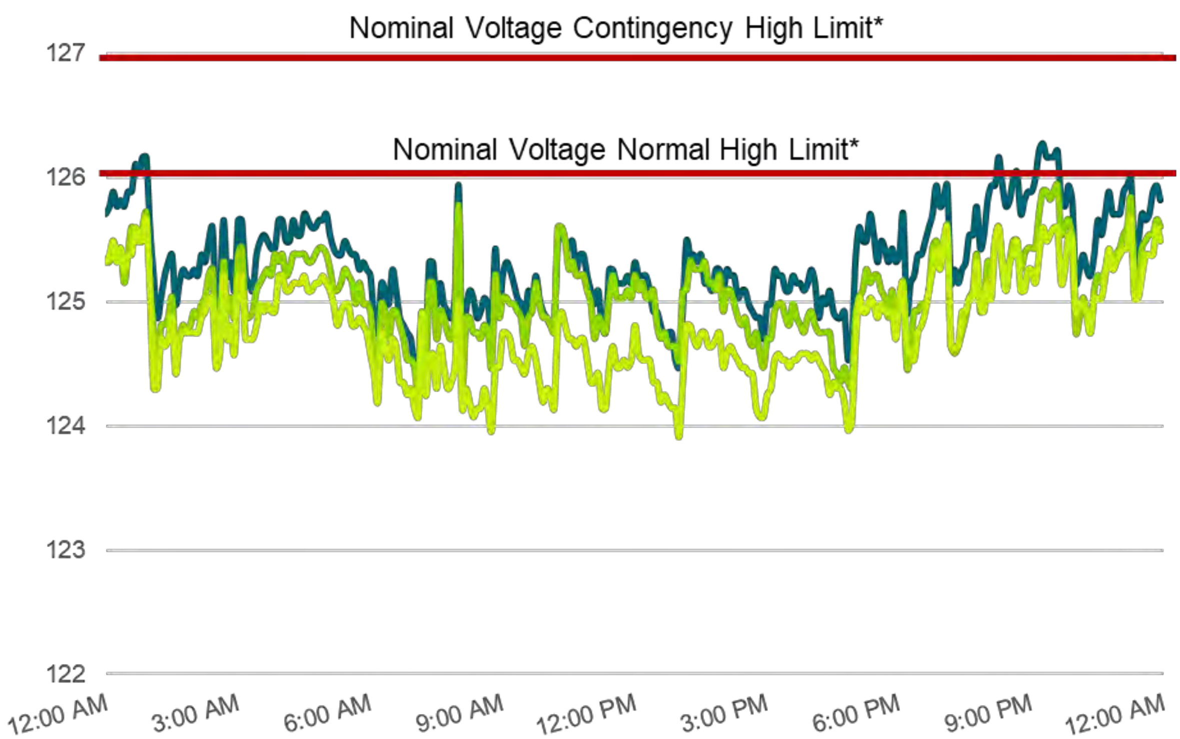
The feeder 07-915W36 in Scituate had the highest number of power surge complaints in 2023 (complaints noted on 1/05, 7/17, 7/20, 8/07, 9/07). The feeder also had 31 other voltage complaints including flickering lights, nearly all in the summer months (though nine were repeat callers).

Guidehouse requested feeder monitor current and voltage readings from July to September of 2023. The objective was to evaluate whether the feeder monitor readings are useful in determining whether the power surges were a main line circuit issue (which would be visible to the feeder monitor), or if not, a localized issue (e.g., open neutral, loose wire or transformer problem affecting a small number of customers).

4.7.2 Key Findings and Recommendations

Throughout the summer, voltage stayed within acceptable ranges including during heatwaves and during the days when most voltage and power surge complaints were received. As shown in Figure 23, on July 20, 2023, voltage reached its highest value (126.2 V) approaching contingency for a few minutes and was brought back down within minutes. National Grid responded quickly to decrease voltage to acceptable level.

Figure 23. Three-phase Feeder Voltage Readings (in Volts) on July 20, 2023



* Massachusetts limits are based on voltage guidelines in ANSI C84.1−2016

Source: Guidehouse (data from National Grid)

The case study review demonstrates that the feeder monitor is a useful tool in investigating power surge complaints and ruling out a main line circuit voltage issue. National Grid troubleshooters confirmed that a local pole-top transformer had a faulty connection causing voltage fluctuations for a set of customers served by the transformer. Troubleshooters also diagnosed several customer electrical issues inside their residences.

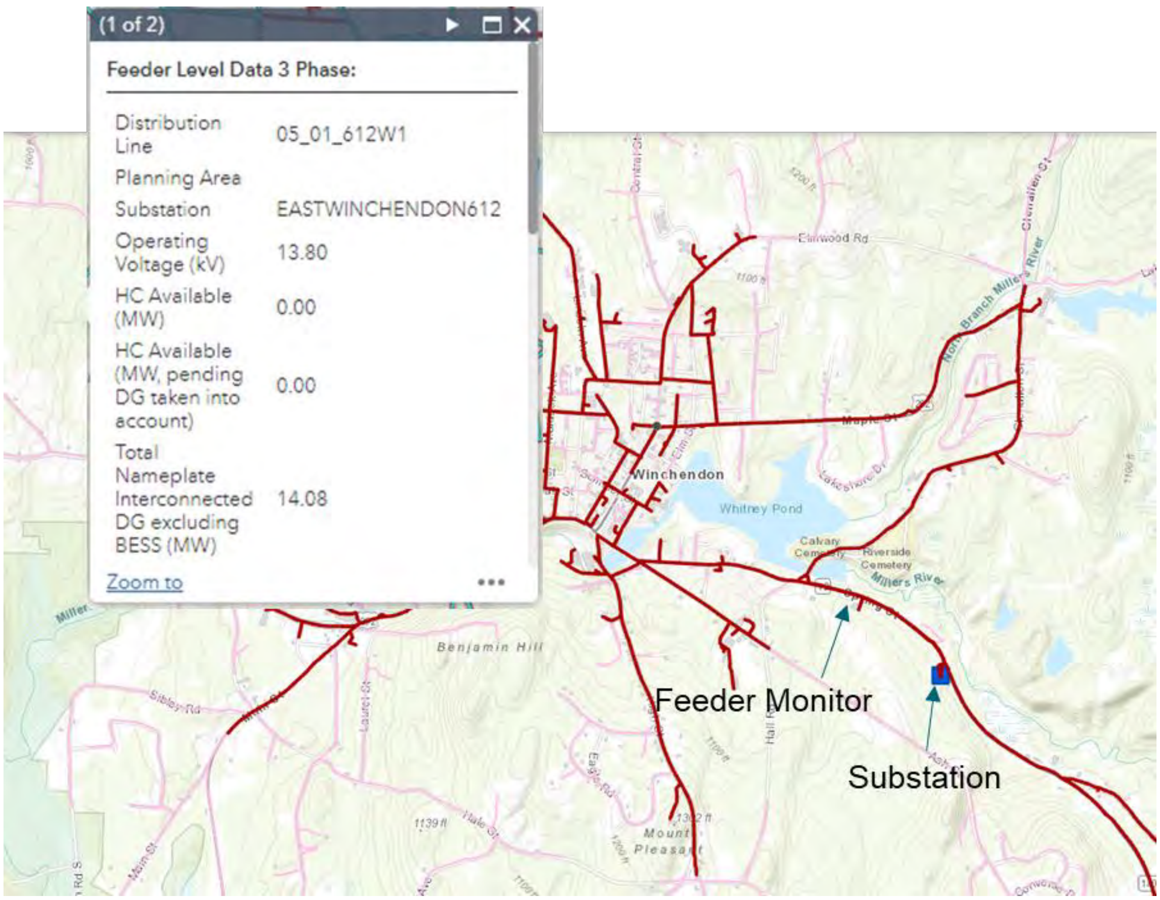
Overall, feeder monitors helped National Grid monitor mainline voltage in near real time and respond quickly when voltage approached limits, e.g., by operating tap changers. On a backup tie where there are no customers to indicate if the line is available, it is useful to have a feeder monitor to provide visibility on whether that backup line is in service.

4.8 Case Study 6: Monitoring Voltage and DG Backflow in Winchendon

4.8.1 Description

M&C investments can help monitor potential adverse impacts of high DG on a distribution circuit. Those impacts may include reverse power flow (which legacy substation relays are not typically designed for) and associated relay control and protection issues. High DG can also cause voltage to vary outside acceptable ranges. To evaluate the use of feeder monitors for DG monitoring and integration, Guidehouse selected a circuit with high DG as well as indications, from customer voltage complaints, of potential adverse impacts that the feeder monitor could help troubleshoot.

The feeder 01-612W1 in Winchendon is among the most constrained in DG hosting capacity with zero MW hosting capacity remaining on the circuit (snapshot below). 14 MW of solar and battery storage units are connected to this 13.8 kV feeder. The feeder also received the second highest voltage complaints of any National Grid GMP M&C circuit in 2023. 28 complaints were received of fluctuating voltage (though 15 were duplicate callers).



Source: Snapshots from National Grid Massachusetts Hosting Capacity Map

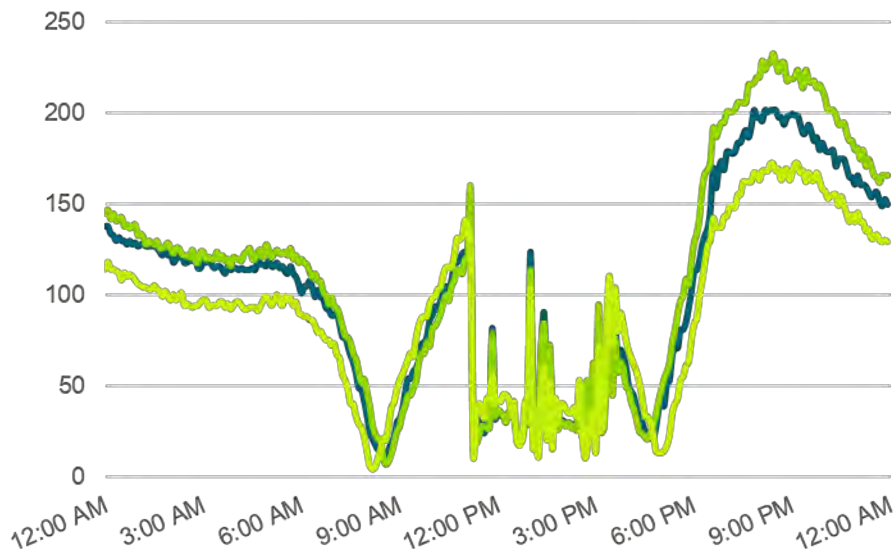
Guidehouse requested feeder monitor voltage data to verify whether the data provided useful information about DG impacts on the circuit and its customers. Guidehouse received 5-minute interval data from this feeder monitor showing 3-phase current and voltage throughout the year of 2023.

4.8.2 Analysis and Observations

4.8.2.1 DG Backflow and Current

Current stayed within acceptable range for all three phases throughout the year (no overloading). Current approached very low values (less than 10 Amperes) often, most often in the summer. For instance, see the load readings on July 6, 2023, in Figure 24. Zero current values were not observed, except during the period July 14-24, 2023, when the circuit was most likely in abnormal switching configuration. The feeder monitor is right outside the substation meaning little to no load between the substation and the feeder monitor.

Figure 24. Three-Phase Load Readings from the Feeder Monitor on 612-W1 on July 6, 2023



Source: Guidehouse analysis of National Grid data

While no backflow was observed, a risk of backflow exists during periods of high DG output - i.e., the DG on this circuit generated enough current at times to carry almost the entire load on this circuit.

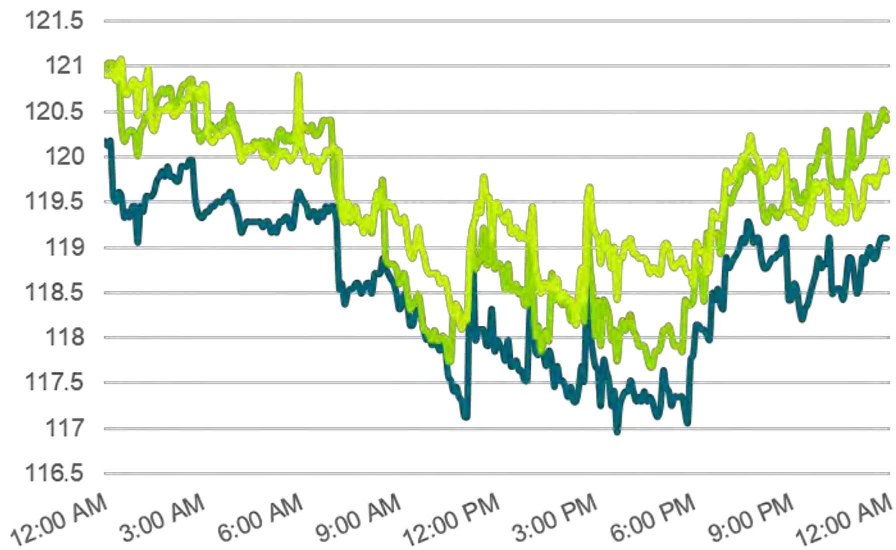
Guidehouse determined that the feeder monitor readings corroborate National Grid's estimation that the circuit has reached maximum DG hosting capacity. For a feeder where distributed generation is close to maximum capacity, the feeder monitor is useful in finely monitoring DG output and maintaining reliable grid operation. The feeder monitor helps National Grid respond quickly if current is approaching zero and take corrective action if necessary.

4.8.2.2 Voltage

28 customer complaints were received from this circuit, 17 of which occurred in the summer months, and nine of which were received in a single day, July 6, 2023. Complaints indicated flickering lights, fluctuating voltage, partial power, and power going on and off.

Feeder monitor data shows that throughout the year 2023, main line circuit voltage on all three phases stayed within acceptable range, including on July 6 when the most voltage complaints were received. Voltage data for July 6, 2023, is shown in Figure 25.

Figure 25. Three-Phase Voltage Readings from the Feeder Monitor on 612-W1 on July 6, 2023*



*Nominal Voltage High Limit is 126V in Massachusetts

Source: Guidehouse analysis of National Grid data

The feeder monitor provided useful information to help the utility rule out mainline circuit voltage issues while troubleshooting customer voltage complaints. Troubleshooters confirmed that the customer complaints on July 6, 2023, were due to a circuit breaker opening and closing repeatedly and causing momentary interruptions.

4.8.3 Key Findings and Recommendations

Voltage stayed within acceptable range throughout the year, including on July 6, 2023, when the most voltage complaints were received. The feeder monitor readings corroborate National Grid's assessment that the July 6 complaints were due to circuit breaker tripping.

Load approaches zero often which indicates a risk of backflow. It corroborates National Grid's determination that hosting capacity is zero. The feeder monitor, being close to the substation, is useful in finely monitoring DG output and maintaining reliable grid operation. The feeder monitor helps National Grid respond quickly if potential backflow conditions arise and take corrective action if necessary.

Guidehouse recommends National Grid consider using three-phase feeder monitor data to analyze methods of increasing hosting capacity on this circuit (e.g., relay settings).

4.9 National Grid Key Findings and Recommendations

Table 28 summarizes the key findings and Guidehouse's recommendations for each of the six National Grid Case Studies.

Table 28. National Grid Case Studies Findings and Recommendations Summary

Case Study	Findings	Draft Recommendations
CS1: Improving Contingency Operation with Near Real-Time Visibility at Marlborough	• The feeder monitors installed at Marlborough provided National Grid control center operators with near real-time visibility into feeder current and voltage, as well as installation health status (communications and relay status). This near real time visibility allowed National Grid to be prepared to respond if any issues had resulted from the contingency operation.	• (None)
CS2: Keeping DG Online at Ayer Feeders	• During a contingency operation where Ayer feeders were carrying extra load, the feeder monitors allowed National Grid to determine with high confidence that contingency switching was safe and reliable, and potential overloads were being avoided. Three-phase loads at all three feeders were kept well below the maximum rating at all times during the period of load transfer. Voltage readings were also observed to stay within acceptable range. • As a result of grid visibility, National Grid was able to maintain all 12 MW of DG online during the period of load transfer.	• (None)
CS3: Validating Proper FLISR Operation without Overload in Ayer	• The feeder monitor readings helped National Grid determine with accuracy that feeder 201W2 did not exceed maximum load ratings while it was carrying additional customers under a FLISR scheme on May 19, 2023.	• National Grid's control center and DC&I may consider designing FLISR/SCADA alarms if load is approaching its limit at any time, including during FLISR operation. Currently, FLISR only does load checks during the initial FLISR reconfiguration. From there it is up to the operators to monitor SCADA and manage the loading. In this case, operators used SCADA to properly manage load and the feeder maximum rating was not exceeded.

Case Study	Findings	Draft Recommendations
CS4: Improving Peak Load Readings at N. Abington	• Single-phase readings have a risk of over- or under-stating loading conditions on distribution feeders. The GMP feeder monitor provided three-phase current information throughout 2023. After the GMP feeder monitor was deployed, National Grid learned that the C-phase was most heavily loaded, and that A-phase readings were under-reporting the feeder load. National Grid is using the feeder monitor to determine three-phase load and conduct phase balancing at North Abington. National Grid will also use the feeder monitor readings in the Hanover DG Group Study to study the impact of DG on the feeder.	• National Grid has installed feeder monitors at many locations that lack substation three phase data. National Grid should consider integrating feeder monitor data with other SCADA data and using it for planning purposes on a regular basis. Currently, National Grid is using feeder monitor data for planning purposes on a case-by-case basis, only if needed for studies/analysis.
CS5: Investigating Power Surge Complaints in Scituate	• The case study review demonstrates that the feeder monitor is a useful tool in investigating power surge complaints and ruling out a main line circuit voltage issue. Feeder monitors helped National Grid monitor mainline voltage in near real time and respond quickly when voltage approached limits, e.g., by operating tap changers. On a backup tie where there are no customers to indicate if the line is available, it is useful to have a feeder monitor to provide visibility on whether that backup line is in service.	• (None)

Case Study	Findings	Draft Recommendations
CS6: Monitoring Voltage and DG Backflow in Winchendon	• Winchendon circuit 612W1 has high DG interconnected and zero hosting capacity remaining. The feeder monitor was helpful in verifying that voltage stayed within acceptable range throughout the year, including on July 6, 2023, when the most customer voltage complaints were received on this circuit. The feeder monitor confirms National Grid's assessment that the July 6 complaints were due to circuit breaker tripping. • The feeder monitor readings also corroborate National Grid's assessment that the circuit has reached maximum DG hosting capacity (load approaches zero at times). The feeder monitor, being close to the substation, is useful in finely monitoring DG output and maintaining reliable grid operation. The feeder monitor helps National Grid respond quickly if potential backflow conditions arise and take corrective action if necessary.	• Guidehouse recommends National Grid continue to use three-phase feeder monitor data to analyze methods of increasing hosting capacity on this circuit (e.g., relay settings).

Source: Guidehouse

5. Unitil M&C Case Studies

5.1 Overview of Unitil M&C Case Studies

Unitil's M&C investment introduces SCADA visibility and control functions to substations that previously lacked remote visibility and control functions. Two Case Studies were selected for Unitil for the PY 2023 evaluation and are shown in Table 29. The Case Studies both address the Department's Grid Modernization objective of grid visibility, command and control.

Table 29. Unitil Case Studies and Corresponding Department Evaluation Objective*

Department Evaluation Objective*	Case Studies that Accomplish Department Evaluation Objective
Grid visibility, command and control during blue sky days	• CS1: SCADA Shortens Outage Duration in Fitchburg
Grid visibility, command and control during major events	• CS2: SCADA Provides Visibility into Grid Conditions during Nor'Easter

* Department Evaluation Objectives are detailed in D.P.U. 21-80/21-81/21-82, Hearing Officer Memorandum at 5 (November 9, 2023).

Source: Guidehouse

5.2 Unitil Case Study Selection and Analysis

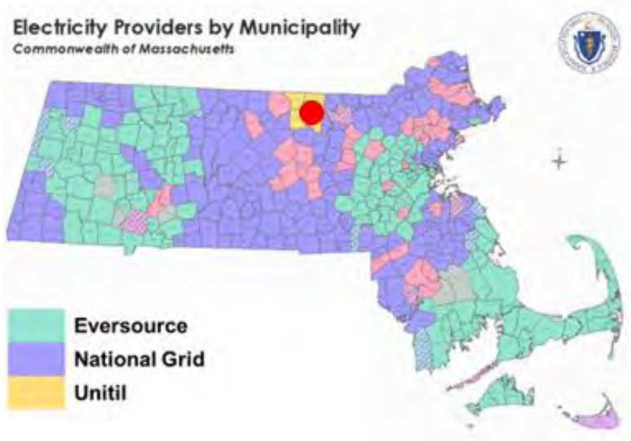
The Case Study selection process was designed to evaluate whether SCADA improved grid visibility and/or grid operation. Two grid events were selected using the following process, based on a dataset of all 2023 distribution grid interruption events provided by Unitil:

1. Starting from the 2023 OMS dataset for outages, Guidehouse filtered for outages in locations where SCADA had been commissioned before 2023 (Townsend, Lunenberg, Rindge Road and Beech Street).
2. Further filtered for outages where a substation device had operated, excluding outages that had occurred at the secondary level and would not be recorded by Substation SCADA.
3. The result was four unique outage events: an excludable major event from a March 2023 nor'easter; and three events on blue sky days, one of which had already been the subject of a Case Study in the PY 2022 M&C evaluation report.
4. The major event from March 2023 and one of the other two events were chosen for Case Studies in PY 2023 evaluation.

For these selected Case Studies, analysis was performed as follows:

- Guidehouse reviewed SCADA data (consisting of alerts, exceptions and control commands) for each event, and compared them to OMS data for corroboration; and
- Guidehouse held follow-up discussions with Unitil to verify restoration steps and understand the time savings due to remote commands where applicable.

5.3 Case Study 1: SCADA Shortens Outage Duration in Fitchburg



Source: *Guidehouse (map from https://www.mass.gov/doc/electricity-providers/download, Accessed May 31, 2024)*

Event Date Time

June 1, 2023, 11:45 pm

Event Classification

Normal Weather

Cause

Tree Contact – Broken Tree Limb

Affected Feeders

F35W36

Number of Customers Restored

809

5.3.1 Description

Unitil used GMP funds to install SCADA at the Rindge Road substation. Previously, the substation lacked remote monitoring and control capability. On June 1, 2023, at 11:45 pm, Unitil operators in the control center received SCADA alarms from the M&C device in the Rindge Road substation. The alerts, as shown in Figure 26, stated that all three phases of the feeder F35W36 had lost power due to circuit breaker lockout. 809 customers were out of power. OMS outage start time was 11:47pm, indicating the SCADA alarm arrived two minutes earlier than the customer call.

Figure 26. SCADA Alarms Received During Outage in Fitchburg

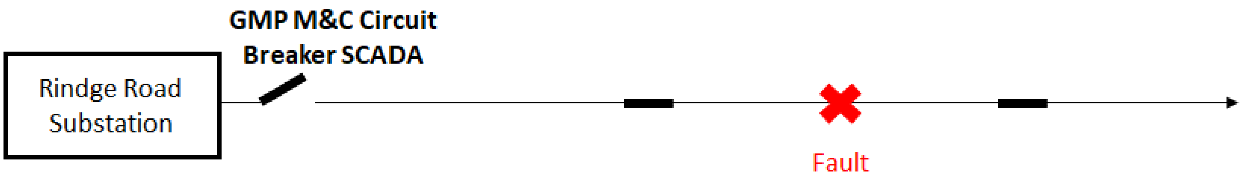
Date	Time	St Desc	Pt Desc	Status Pair/Limit	Message
6/1/2023	23:45:36:129	RINDGE ROAD	F35W36 BREAKER STATUS C	OPENED	F35W36 BREAKER STATUS C OPENED
6/1/2023	23:45:36:129	RINDGE ROAD	F35W36 BREAKER STATUS B	OPENED	F35W36 BREAKER STATUS B OPENED
6/1/2023	23:45:36:129	RINDGE ROAD	F35W36 BREAKER STATUS A	OPENED	F35W36 BREAKER STATUS A OPENED

Source: Unitil

5.3.2 Outage Restoration Steps

Unitil crews were dispatched at 11:52pm and arrived on the scene at 12:17 am. They found a tree limb had taken down two phases at Pole 71 on Ashby State Road (fault location in Figure 27). Crew cleared the tree and re-attached the overhead phase lines to the pole. Crews finished work at 1:37am. No fault isolation was performed during the restoration. However, Unitil believes that fault isolation was not warranted for damage of this extent; opening taps would have required an additional crew and possibly lengthened outage duration for some customers.

Figure 27. Rindge Road Substation One-Line Diagram



Source: Guidehouse analysis of 2023 EDC data

When repairs were complete, crews requested the control center to remotely close the circuit breaker and restore power to the circuit. Operators issued the SCADA command at 1:34pm and the command was completed successfully within 30 seconds, as seen in Figure 28 below.

Figure 28. SCADA Records from Outage Event on June 1, 2023

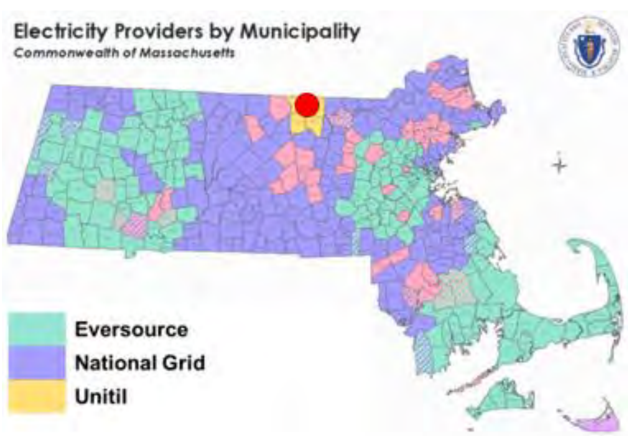
Date	Time	St Desc	Pt Desc	Status Pair/Limit	Message
6/2/2023	1:34:00 AM	RINDGE ROAD	F35W36 OPEN/CLOSE	CLOSE	*CONTROL* Command Issued by Operator: CED @ D#8
6/2/2023	1:34:00 AM	RINDGE ROAD	F35W36 OPEN/CLOSE	CLOSE	*CONTROL* Control Completed CED @ D#8
6/2/2023	01:34:29:892	RINDGE ROAD	F35W36 BREAKER STATUS C	CLOSED	F35W36 BREAKER STATUS C CLOSED
6/2/2023	01:34:29:892	RINDGE ROAD	F35W36 BREAKER STATUS B	CLOSED	F35W36 BREAKER STATUS B CLOSED
6/2/2023	01:34:29:892	RINDGE ROAD	F35W36 BREAKER STATUS A	CLOSED	*CONTROL* Solicited Status Change

Source: Unitil

5.3.3 Key Findings

SCADA provided operators with better visibility into the system. They learned of the circuit outage immediately, before customer calls. Previously no remote monitoring or control had been available at the substation. Unitil closed the circuit breaker remotely and restored power within 30 seconds, avoiding the need for crew to travel to the substation. Without M&C SCADA, these 809 customers would have been without power for an additional 20 minutes while crews travelled to the substation and manually operated the device.

5.4 Case Study 2: SCADA Assists in Restoration During Major Event



Event Date Time

March 14, 2023

Event Classification

Major event: nor'easter, snow, wind

Cause

Tree contact with transmission structure

Substations Affected

Lunenberg, Townsend, West Townsend and Pleasant Street

Source: Guidehouse (map from https://www.mass.gov/doc/electricity-providers/download, Accessed May 31, 2024)

5.4.1 Description

On March 14, 2023, a nor'easter brought 20 inches of snow to Fitchburg, Massachusetts. At 5:48am a tree made contact with a transmission structure and damaged two transmission lines (08 and 09) causing an outage to four Unitil substations. Townsend and Lunenberg substations had GMP SCADA and are evaluated in this Case Study; West Townsend and Pleasant St substations did not have GMP SCADA.

Crews arrived on scene at about 6am and performed repairs throughout the day, restoring power to the substations after 10pm.

5.4.2 Key Findings and Recommendations

SCADA readings showed the status of circuit breaker lockout or close at times that closely matched OMS. Visibility into circuit breaker energized status is valuable during a major event while crews are patrolling and performing repairs on downstream damage. Visibility into circuit breaker energized status was not available on substations without M&C.

SCADA provided operators with better visibility into the system during a major event, confirming outages identified in OMS based on customer calls. Unitil was unable to verify whether SCADA was used to remotely control the substation circuit breakers and restore any customers. Guidehouse recommends Unitil investigate whether there was an opportunity to use SCADA control during the major event on March 14, 2023 to restore customers sooner.

5.5 Unitil Key Findings and Recommendations

Table 30 summarizes the key findings and Guidehouse's recommendations for each of the two Unitil Case Studies.

Table 30. Unitil Case Studies Findings and Recommendations Summary

Case Study	Findings	Draft Recommendations
CS1: SCADA Shortens Outage Duration in Fitchburg	• SCADA provided operators with better visibility into the system during an outage event. They learned of the circuit outage immediately, before customer calls. Previously no remote monitoring or control had been available at the substation. Unitil closed the circuit breaker remotely and restored power within 30 seconds, avoiding the need for crew to travel to the substation. Without M&C SCADA, 809 customers would have been without power for an additional 20 minutes while crews travelled to the substation and manually operated the device.	• (None)
CS2: SCADA Assists in Restoration During Major Event	• SCADA provided operators with better visibility into the system during a major event, confirming outages identified in OMS based on customer calls. Unitil was unable to find SCADA readings to verify whether operators had issued SCADA commands to remotely control (open/close) the substation circuit breakers. Therefore, remote control via SCADA could not be determined.	• Guidehouse recommends Unitil investigate whether the major event on 3/14/23 presented an opportunity for using SCADA control and take steps to utilize SCADA control capability in future substation events.

Source: Guidehouse

6. Key Findings and Recommendations

Key Findings and Recommendations from Guidehouse's PY 2023 evaluation of M&C are summarized for Eversource Case Studies in Table 31, National Grid Case Studies in Table 32, and Unitil Case Studies in Table 33.

Table 31. Eversource Case Studies Key Findings and Recommendations Summary

Case Study	Key Findings	Draft Recommendations
CS1: SCADA Provides Real-Time Information About Outage in Downtown Boston	• Eversource operators in the control center received SCADA alarms in a timely manner from the newly installed M&C device in the 4 kV substation. SCADA data showed that the substation breaker had opened in response to a high current (correct and desirable operation). • Eversource control center received a trouble alarm, fault current alarm, and breaker open alarm which were useful information for restoration and for post-hoc analysis.	• General Recommendation Not Applicable to GMP: Eversource crews manually opened the non-remote capable switch in MH22927 to isolate the fault. Eversource may consider adding SCADA to the manual switch in MH22927.
CS2: SCADA Alerts Eversource to an Emergency Outage in Lexington	• In this case of a pole top fire, the GMP-funded 4 kV SCADA worked as expected to alert operators of an overcurrent and circuit breaker opening. This timely indication of a circuit outage enabled Eversource to dispatch personnel in a timely manner to respond to the emergency.	• General Recommendation Not Applicable to GMP: To assist in fault location, Eversource may consider installing remote reporting fault indication equipment along the circuit.
CS3: SCADA Gives Early Indication of Faulted Cable at Hyde Park	• 4 kV SCADA system worked correctly as expected to alert operators of abnormal conditions in the field. SCADA gave operators early indication of a fault conditions and breaker operation, allowing Eversource to dispatch a troubleshooter in a timely manner. Eversource used SCADA to deenergize the hazardous site remotely and rapidly, making the area safe.	• (None)
CS4: On the Hottest Day of the Year, Eversource Used M&C to Maintain Voltage at an Acceptable Level	• Throughout the day on September 7, 2023, when load was at its peak, Eversource operators took corrective action across several substations based on real-time alerts and alarms from GMP SCADA devices, to keep voltage within acceptable limits.	• (None)

Case Study	Key Findings	Draft Recommendations
CS5: SCADA Helps Determine Peak Load in Waltham and Natick	• SCADA readings closely matched the load book, indicating that Eversource used SCADA readings as one of the factors to determine feeder summer peak load. Accurate peak load drives important decisions including whether grid upgrades may be needed to support more load in the future, and whether the circuit can be relied on as emergency backup for neighboring circuits.	• (None)
CS6: Power Quality Monitor Gives Detailed View of Voltage Flickers	• The Power Quality (PQ) monitors are able to catch disturbances at millisecond intervals, capturing data at a higher granularity than standard GMP equipment (e.g., SCADA). The granular PQ data enabled Eversource to investigate if the cause of a university campus's complaint was due to the Eversource system, and whether the level of disturbance is within expected range. Eversource determined that the momentary flickers experienced by Harvard were within the acceptable PQ range. The PQ monitor allowed Eversource to share detailed data with the university leading to better collaboration, evidence-based investigation, and accurate troubleshooting.	• The PQ Monitor showed that some customer equipment (e.g., building automation systems) can be more sensitive to minor disturbances than is standard in the electronics industry. PQ Monitor alert thresholds were set at industry acceptable standards and did not automatically trigger an alert for the disturbances reported by the university, but did capture the data for analysis. Eversource may consider altering the trigger threshold for the PQ monitor to create an alert for the type of events being experienced by the university.
CS7: DG Integration and Hosting Capacity on 4 kV feeders	• Eversource notes that the 4 kV system has limited ability to interconnect DG without significant upgrades. For the 4 kV feeders that received M&C SCADA investments, Eversource is using SCADA readings to inform hosting capacity (HC) calculations. SCADA inputs included peak load, voltage and minimum light load.	• Eversource should continue to use 4 kV 3-phase SCADA readings to conduct DG interconnection studies and maximize DG hosting capacity at 4 kV feeders in a safe and reliable manner.

Source: Guidehouse

Table 32. National Grid Case Studies Key Findings and Recommendations Summary

Case Study	Key Findings	Draft Recommendations
CS1: Improving Contingency Operation with Near Real-Time Visibility at Marlborough	• The feeder monitors installed at Marlborough provided National Grid control center operators with near real-time visibility into feeder current and voltage, as well as installation health status (communications and relay status). This near real time visibility allowed National Grid to be prepared to respond if any issues had resulted from the contingency operation.	• (None)
CS2: Keeping DG Online at Ayer Feeders	• During a contingency operation where Ayer feeders were carrying extra load, the feeder monitors allowed National Grid to determine with high confidence that contingency switching was safe and reliable, and potential overloads were being avoided. Three-phase loads at all three feeders were kept well below the maximum rating at all times during the period of load transfer. Voltage readings were also observed to stay within acceptable range. • As a result of grid visibility, National Grid was able to maintain all 12 MW of DG online during the period of load transfer.	• (None)
CS3: Validating Proper FLISR Operation without Overload in Ayer	• The feeder monitor readings helped National Grid determine with accuracy that feeder 201W2 did not exceed maximum load ratings while it was carrying additional customers under a FLISR scheme on May 19, 2023.	• National Grid's control center and DC&I may consider setting up automated FLISR/SCADA alarms if load is approaching its limit at any time, including during FLISR operation. Currently, FLISR only does load checks during the initial FLISR reconfiguration. From there it is up to the operators to monitor SCADA and manage the loading. In this case, operators used SCADA to properly manage load and the feeder maximum rating was not exceeded.

Case Study	Key Findings	Draft Recommendations
CS4: Improving Peak Load Readings at N. Abington	• Single-phase readings have a risk of over- or under-stating loading conditions on distribution feeders. The GMP feeder monitor provided three-phase current information throughout 2023. After the GMP feeder monitor was deployed, National Grid learned that the C-phase was most heavily loaded, and that A-phase readings were under-reporting the feeder load. National Grid is using the feeder monitor to determine three-phase load and conduct phase balancing. National Grid will also use the feeder monitor readings in the Hanover DG Group Study to study the impact of DG on the feeder.	• National Grid has installed feeder monitors at many locations that lack substation three phase data. National Grid should consider integrating feeder monitor data with other SCADA data and using it for planning purposes on a regular basis. Currently, National Grid is using feeder monitor data for planning purposes on a case-by-case basis, only if needed for studies/analysis.
CS5: Investigating Power Surge Complaints in Scituate	• The case study review demonstrates that the feeder monitor is a useful tool in investigating power surge complaints and ruling out a main line circuit voltage issue. Feeder monitors helped National Grid monitor mainline voltage in near real time and respond quickly when voltage approached limits, e.g., by operating tap changers. On a backup tie where there are no customers to indicate if the line is available, it is useful to have a feeder monitor to provide visibility on whether that backup line is in service.	• (None)

Case Study	Key Findings	Draft Recommendations
CS6: Monitoring Voltage and DG Backflow in Winchendon	• Winchendon circuit 612W1 has high DG interconnected and zero hosting capacity remaining. The feeder monitor was helpful in verifying that voltage stayed within acceptable range throughout the year, including on July 6, 2023, when the most customer voltage complaints were received on this circuit. The feeder monitor confirms National Grid's assessment that the July 6 complaints were due to circuit breaker tripping. • The feeder monitor readings also corroborate National Grid's assessment that the circuit has reached maximum DG hosting capacity (load approaches zero at times). The feeder monitor, being close to the substation, is useful in finely monitoring DG output and maintaining reliable grid operation. The feeder monitor helps National Grid respond quickly if potential backflow conditions arise and take corrective action if necessary.	• Guidehouse recommends National Grid consider using three-phase feeder monitor data to analyze methods of increasing hosting capacity on this circuit (e.g., relay settings).

Source: Guidehouse

Table 33. Unitil Case Studies Key Findings and Recommendations Summary

Case Study	Key Findings	Draft Recommendations
CS1: SCADA Shortens Outage Duration in Fitchburg	• SCADA provided operators with better visibility into the system during an outage event. They learned of the circuit outage immediately, before customer calls. Previously no remote monitoring or control had been available at the substation. Unitil closed the circuit breaker remotely and restored power within 30 seconds, avoiding the need for crew to travel to the substation. Without M&C SCADA, 809 customers would have been without power for an additional 20 minutes while crews travelled to the substation and manually operated the device.	• (None)

Case Study	Key Findings	Draft Recommendations
CS2: SCADA Assists in Restoration During Major Event	• Unitil was unable to find SCADA readings to verify whether operators had issued SCADA commands to remotely control (open/close) the substation circuit breakers. Therefore, remote control via SCADA could not be determined.	• Guidehouse recommends Unitil investigate whether the major event on 3/14/23 presented an opportunity for using SCADA control and take steps to utilize SCADA control capability in future substation events.

Source: Guidehouse

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