Pacific Gas and Electric Company

EPIC Final Report

Program	***Electric Program Investment Charge (EPIC)***
Project	***EPIC 2.27 – Next Generation Integrated Smart Grid Network Management***
Department	*Metering Services and Engineering*
Project Sponsor	Earle Davis
Project Business Lead	Young Nguyen
Contact Info	EPIC_Info@pge.com
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Table of Acronyms (Alphabetized)

AMI	Advanced Metering Infrastructure
AMI Network 1	Vendor 1 AMI Network
AMI Network 2	Vendor 2 AMI Network
AMI Network 3	Vendor 3 AMI Network
ANSI	American National Standards Institute
AP	Access Point
API	Application Programming Interface
CSVS	Cloud Solutions Vendor Service
CC&B	Customer Care and Billing
CEC	California Energy Commission
CPUC	California Public Utilities Commission
D.	Decision
DCU	Data Collecting Unit
EnMS	Enterprise Network Management System
EPIC	Electric Program Investment Charge
ESFT	Enterprise Secure File Transfer
ESM	Enterprise System Monitoring
GIS	Geographic Information System
ID	Identification
IOU	investor-owned utility
IP	Internet Protocol
IPSEC	Internet Protocol Security
IT	Information Technology
KPI	Key Performance Indicator
MDMS	Meter Data Management System
MoM	Manager of Manager
MRO	Meter Reading Office
MTU	Meter Transponder Unit
MySQL	Name of Relational Database Server
NaaS	Network as a Service
PG&E	Pacific Gas and Electric Company

RDS	Relational Data Storage (re: Cloud Solutions Vendor Services)
SCE	Southern California Edison Company
SDG&E	San Diego Gas & Electric Company
SFTP	Secure File Transfer Protocol
SMOC	Smart Meter Operations Center
SNMP	Simple Network Management Protocol
SOAP	Simple Object Access Protocol
TD&D	Technology Demonstration and Deployment
Trap	An asynchronous SNMP protocol alert message
UIQ	Utility IQ
VPN	Virtual Private Network

1 Executive Summary

Pacific Gas and Electric Company (PG&E) Electric Program Investment Charge (EPIC) Project 2.27, *Next Generation Integrated Smart Grid Network Management,* successfully demonstrated a new Advanced Metering Infrastructure (AMI) network management platform concept that integrates independent AMI networks. It demonstrated that such a platform can automatically identify AMI network inefficiencies, and can enable hosting of various PG&E internal and external (customer) applications that leverage AMI network(s) data. This integrated management platform, referred to in the document as a "Manager of Managers" (MoM) platform, has the potential to provide value related to improved safety, reliability, customer satisfaction, and lower costs.

This technology demonstration provides valuable learnings to PG&E as it moves forward with implementation of Enterprise Network Management System (EnMS) platform. PG&E's EnMS vision is a holistic network solution that includes supporting other user groups outside of Smart Meter Operations Center (SMOC) (i.e., Enterprise Network Operating Center, Enterprise System Monitoring (ESM), Asset Management) to better manage the different networks. The future EnMS will include similar functionality to the MoM tool demonstrated in EPIC 2.27 beyond the AMI Network. EPIC 2.27 use cases and learnings are included on PG&E's EnMS deployment road map, including use-case specifications and parameters, flow logic, AMI data retrieving, archiving, and synthesizing in order to automate work processes and improve the management of the AMI networks. Overall, the MoM platform demonstration was a key step towards PG&E's vision to:

- Automatically detect AMI network inefficiencies and failure nodes
- Streamline meter asset management and workflow operations
- Holistically monitor and prioritize AMI network data traffic

In addition, the project demonstrated use-cases which may enhance PG&E's ability to advance the existing AMI network and infrastructure application from a billing-centric to an operations-centric technical solution. As an example, the MoM platform issues Web Service calls to smart meters, collects results and applies rules to identify outliers for field action, while visually displaying all trend data. In another example, PG&E demonstrated the MoM mapping capability to visualize meter/network assets through online mapping applications, and to show device health through color codes. This was accomplished by integrating multiple AMI systems and developing reporting tools that can provide real-time notifications and updates on system conditions. In the future, PG&E envisions growing utilization of its AMI networks and infrastructure in support of hosting customer-driven user applications. Committed to customer satisfaction, this project helped lay foundational learnings for PG&E to potentially offer managed services to customers via meshed networks in the future.

Issues Addressed

It has been demonstrated across the industry that to make significant improvements in day-to-day operations, real-time analytics can be a very effective tool. Rather than waiting for an incident to occur or a customer to report an incident, it is possible that real-time monitoring be integrated with real-time analytics to promptly identify issues and resolve them more quickly than what legacy systems and processes can currently provide. Today, PG&E does not have a fully-integrated network management system that can manage the workflow of different AMI vendors. Without this integration, the different systems must be monitored independently by engineers and analysts in a "swivel chair" fashion, which increases the oversight burden. This is a key obstacle as AMI Smart Grid utilization grows and the need for integration of different AMI vendors becomes more critical. In addition, there is an industry trend, driven by cost-effectiveness, to leverage utility AMI network for non-utility services, such as water meter billing and alert reading. This expansion of utility AMI network usage poses more pressure on present data traffic. With the increase in volume and the frequency of data exchange over the AMI networks, priority based data flow management capabilities are required.

In addition to challenges with independent AMI networks, PG&E's current process for identification of network inefficiencies includes manual labor-intensive processes, which may cause undesirable delays in restoring network performance in affected nodes. For example, a network node failure that occurs today might only be identified by missing read data and subsequent investigation by the SMOC. Upon discovery, the SMOC technician will manually create a Field Order ticket, which initiates the resolution process. This results in delayed actions to restore node failures, which may delay timely detection of alerts—such as a high temperature reading within the SmartMeter™ device which could indicate if a meter requires repair. Therefore, it is important to have sophisticated monitoring that automatically identifies network issues and initiates resolution steps.

To help address these challenges, the goal of this EPIC project was to demonstrate the feasibility of aggregating the management of PG&E's three independent AMI networks via a single management platform. The management platform was required to improve overall operational efficiency and safety through data display, data analytics, and task automation, while maintaining a level of configurability to support new devices and future technologies as they are added to the existing AMI network.

Key Objectives

This project demonstrated a technology solution and concept that can support maximizing the effectiveness of the AMI networks by effectively monitoring the performance of the integrated AMI system, initiating follow-up work orders as needed and tracking them to completion. The management platform key objectives were as follows:

AMI Network Data Aggregation:

- Extract inventory, configuration, and performance data from all three AMI networks using sources and means most suitable to each network; and
- Sync with each network automatically, and in real time where possible.

Improved Display of Network Health and Utilization:

- Present raw or processed Key Performance Indicator (KPI) data indicating the performance of each AMI network on a single display; and
- Present information through a modern, web-based dashboard using maps or graphs, which would facilitate the ability to drill down from a high level overall network view to a single network device or meter.

Process Automation:

- Monitor configurable performance parameters and automatically initiate actions such as raising alarms or creating break/fix tickets.

Support for Future Technologies and Tenants:

- Demonstrate the ability to support new technologies and provide customized visibility to different stakeholders or asset owners other than PG&E.

Key Accomplishments

The following summarizes the key accomplishments of the project:

AMI Network Data Aggregation

- The management platform successfully identified and captured inventory, configuration, and performance data for all three AMI networks, including both networking elements and metering endpoints, thereby enhancing awareness across all of the AMI networks.
- Discovery processes were demonstrated against three distinct data source types: AMI management software web services, direct equipment communication, and flat files. The software web services were performed via Simple Object Access Protocol (SOAP).

Improved Display of Network Health and Utilization

- The management platform user interface, a widget-based dashboard, demonstrated the ability to display a mix of geospatial data, historical trend reports, and real-time performance data;
- User-friendly dashboard navigation facilitates identification of issues at a high level and drilldown to a low level of analysis, which expedites identifying and resolving system issues; and
- Demonstrated display of raw and processed KPI data such as, number of endpoints per AP, radio frequency signal strength of each endpoint, and electric meter temperature data to monitor network health.

Process Automation

- The current semi-automated process for identifying and monitoring electric meter temperature was fully automated, including automatic work order creation and update of the work order based on monitored performance changes.
- A new automated inspection process was implemented for identifying electric meters/current transformers that have been wired incorrectly. This enhancement improved operational efficiency by eliminating manual labor and inaccurate energy usage reading. The project team is currently working with the SMOC to execute this use-case.

Support for Future Technologies and Tenants

- Support for SmartPole meters and Smart streetlight photocell controllers was implemented such that the dashboard can display data distinctly from other standard electric meters; and
- A per-user basis to grant/restrict access to specific user assets via the dashboard was successfully demonstrated.

Key Takeaways

The MoM tool demonstrated an overall view of the capabilities and value of merging different data sources on a real-time basis and providing immediate results that can benefit real-time operations. The following are the key takeaways and lessons learned from this project:

- With an effective tool that merges real-time data of multiple AMI systems, operational displays indicating the status and identifying issues enable better situational awareness across all AMI networks and a more efficient operational response.
- The learnings are applicable to EnMS and future applications that include the need to retrieve, archive, and synthesize performance data to streamline and automate work processes.
- The operational displays present an overall system view, which can be quickly and easily focused on specific areas and identify problems, such as high temperature measurement within the SmartMeter device. This enables a more effective, granular assessment of AMI network elements' performance.
- The ability to automatically identify system issues and automatically generate follow-up action improves the response time, initiating resolution of issues before they lead to equipment failure.

Challenges

The following are key challenges that the project faced:

Scalability:

- While PG&E was successfully able to demonstrate the data aggregation and associated functionality, for this solution to be leveraged at scale an EnMS platform is needed. An EnMS will provide a centralized tool to support different user groups and networks in end-to-end integrated solutions and use-cases that meets business needs. In the end, the EnMS and its specific use-cases will enable modernization of the grid, better management of PG&E assets, reliability, and affordability through improved monitoring and analytics.

AMI Networks Aggregation:

- Aggregating the data from the three AMI vendors across multiple networks was a challenge since each vendor had created their own standards and data model. The aggregation then needed to be combined into a single display system that could be easily utilized by the eventual users. Aggregating the data from the three AMI networks was a key goal for this project, and was accomplished via the MoM dashboard.

AMI Network Updates:

- An additional challenge was the continuous updates from the three AMI systems, which is the standard AMI operating practice. If changes in data are identified/discovered since each AMI vendor processes the data in their own way, it requires PG&E to update the discovery process.

Conclusion

The project successfully demonstrated an integrated, multi-tenant network management system, complete with analytics and visualizations that can support a variety of business operations and processes, such as automated trouble ticketing system, workflow manager, configuration of data sources, and AMI asset management. The tool provides a useful consolidated view of the AMI networks and demonstrates capability to efficiently control operational needs of the AMI network data, such as prioritization and scheduling of certain data processes. This project also provided PG&E with valuable insight into the multi-tenant network management system operational capabilities and implementation challenges. A key challenge was the merging of real-time data from multiple AMI network vendors into one application. Accordingly, learnings from this project informed PG&E's long-term strategy around utilization of AMI for providing customer services.

PG&E sees an opportunity for the implementation of an EnMS platform to develop tools to support user groups beyond SMOC (i.e., Enterprise Network Operating Center, ESM, Asset Management) to better manage the different networks PG&E governs. The platform developed in this project cannot be directly scaled into the EnMS because it would be cost prohibitive to make this head-end the sole dashboard (integration with Geographic Information System (GIS) layers, data sources like Customer Care and Billing (CC&B), Meter Data Management System (MDMS), PG&E ticketing systems) and adds an intermediary layer for AMI data integration into the EnMS. However, the two-use cases developed through this project provided key learnings and are included on PG&Es EnMS deployment roadmap, which will allow for the execution of these applications more quickly and cost effectively then the demonstration application. These learnings include specification development of monitoring points and operating parameters and flow logic functionality and are listed below:

Use Case 1: Developing the fully automated process of identifying meter health
Use Case 2: Identifying electric meter/current transformers that have been wired incorrectly

The EPIC Project 2.27 was a proof of concept to demonstrate that it is possible to integrate three disparate AMI systems into one sole dashboard that can provide an overall system view which can be quickly and easily focused on specific areas to identify problems. It demonstrated that the platform is capable of auto-updating data from the three different sources, monitor configurable performance parameters, prioritize data traffic to manage flow of data over the AMI, and automatically initiate actions such as raising alarms or creating work orders. PG&E plans to continue to champion this effort through continued support and presentations at industry meetings, and to seek further opportunities to continue to evolve and integrate this technical concept into future EnMS or alternate PG&E MoM platform development.

2 Introduction

This report documents the EPIC 2.27 – *Next Generation Integrated Smart Grid Network Management* – project achievements, highlights key learnings from the project that have industry-wide value, and identifies future opportunities for PG&E to leverage this project's learnings.

The California Public Utilities Commission (CPUC) passed two decisions that established the basis for this pilot program. The CPUC initially issued Decision (D.) 11-12-035, *Decision Establishing Interim Research, Development and Demonstrations and Renewables Program Funding Level,*[1] which established the EPIC on December 15, 2011. Subsequently, on May 24, 2012, the CPUC issued D.12-05-037, *Phase 2 Decision Establishing Purposes and Governance for Electric Program Investment Charge and Establishing Funding Collections for 2013-2020,*[2] which authorized funding in the areas of applied research and development, Technology Demonstration and Deployment (TD&D), and market facilitation. In this later decision, CPUC defined TD&D as "the installation and operation of pre-commercial technologies or strategies at a scale sufficiently large and in conditions sufficiently reflective of anticipated actual operating environments to enable appraisal of the operational and performance characteristics and the financial risks associated with a given technology."[3]

The decision also required the EPIC Program Administrators[4] to submit Triennial Investment Plans to cover three-year funding cycles for 2012-2014, 2015-2017, and 2018-2020. On November 1, 2012, in Application 12-11-003, PG&E filed its first triennial EPIC Application at the CPUC, requesting $49,328,000 including funding for 26 TD&D projects. On November 14, 2013, in D.13-11-025, the CPUC approved PG&E's EPIC plan, including $49,328,000 for this program category. Pursuant to PG&E's approved EPIC triennial plan, PG&E initiated, planned and implemented the following project: 2.27 – Next Generation Integrated Smart Grid Network Management. Through the annual reporting process, PG&E kept CPUC staff and stakeholder informed on the progress of the project. The following is PG&E's final report on this project.

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1 http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/156050.PDF.

2 http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/167664.PDF.

3 D.12-05-037, p. 37.

4 PG&E, San Diego Gas & Electric Company (SDG&E), Southern California Edison Company (SCE), and the California Energy Commission (CEC).

3 Project Summary

This project demonstrated a new AMI Network management system to holistically monitor and control the existing AMI networks and infrastructure. The project objective was to evolve AMI from a billing-centric to a full operational solutions platform in the form of a MoM. This innovative solution is designed to help meet evolving customer needs, such as using the existing AMI networks to host customer-driven tenant applications. This project demonstrated an efficient integrated network management system with monitoring and control capabilities to:

- Synthesize display of data from different AMI network assets in one screen, in real time
- Automate the trouble ticketing creation process
- Perform workflow management to prioritize workforce dispatching
- Perform asset management of meter and network equipment regardless of meter or network types
- Support business continuity planning to streamline maintenance and operations

EPIC 2.27's primary goal was to aggregate data from three separately-managed PG&E AMI networks under one management umbrella. This overall management system is expected to drive operational efficiency by eliminating the need for engineers and SMOC technicians to switch among multiple management applications while monitoring and managing these networks. In addition, the centralized management system will allow personnel's technical expertise to be more effectively applied across all networks, and technician onboarding and training to be more time efficient.

Process automation was another goal of this project. PG&E seeks to more quickly identify and rectify issues that at best impact revenue collection and at worst pose a safety risk. As an example, the project automated the process of meters reporting internally measured high temperatures.[5] This automated process was designed to closely monitor and analyze temperature trends, and, if needed, issue work orders. This provides thorough systemwide diagnosis, faster dispatching, and improved oversight to more effectively prevent potential public safety concerns and resolve ongoing high temperature measurement cases.

Finally, in support of PG&E AMI Network as a Service (NaaS) offering, a separate visibility and management layer was designed to allow customized visibility and functionality to separate user (tenant) groups. Network management applications currently provided by the AMI technology vendors are focused primarily on managing the entire network and not on support of specific elements that may be managed by external, third-party user groups.

3.1 Issue Addressed

PG&E has three AMI networks that have independent monitoring systems and data structures with no integration among them. They each have separate processes for dealing with their respective information. Therefore, identifying AMI operational issues—such as data communication, miss-wiring, and meter temperatures, in all AMI networks is time consuming and prone to errors. Yet, timely identification of issues is crucial. For example, identifying a meter temperature before it becomes severe

5 Based on the season: Temperatures above 130°F and 140°F during winter (Nov 1 - Mar 31) and summer (Apr 1 - Oct 31), respectively.

is important from a safety, reliability, customer service, and cost perspective. Furthermore, existing AMI network management systems have limited capabilities to automate oversight and follow-up action, presenting another reason for exploring the MoM platform concept to automate and streamline AMI data workflow. Also, this integrated system is necessary to support many different AMI platform vendors, utilized as part of the AMI Smart Grid. This integrated system needs to facilitate the oversight needed for AMI systems. The improved oversight will lead to improved safety and efficiency.

This project provided a tool that allows users to effectively monitor the performance of all and individual AMI systems, initiate follow-up work orders as needed, and track them to completion. Additional metrics displayed on the dashboard can further improve user experience and efficacy.

3.2 Project Objectives

The project objective was to prove in practice that an integrated AMI Network MoM system is an effective solution concept that can evolve PG&E's current infrastructure to be able to monitor and prioritize data traffic, automate trouble ticketing, dispatch workforce, provide asset management of meter and network equipment, streamline maintenance and operations, and provide the ability to offer managed services to customers.

To accomplish these objectives, the following key functional elements were developed:

- *Discovery Adapters:* New discovery process frameworks and data models were developed to support the retrieval of inventory, configuration, and performance data for all three AMI networks, as well as for PG&E CC&B data.
- *Key Performance Indicator Engine:* As data performance is discovered, it is passed through a process that performs analytics and stores the resulting post-processed data.
- *AMI Network User Interface Enhancements:* Specialized dashboard widgets were created and existing widgets modified to support display of all three AMI network architectures. The dashboard widgets display information at the Network level and enable drill down to a meter module level, as shown below:

  Network -> PG&E Division -> PG&E MRO -> AMI Network Device -> Meter Module

- *Automated Alarm and Ticket Creation Triggers:* As required, support for creating alarms and remote tickets was created based on performance parameters of monitored data.

3.3 Scope of Work and Project Tasks

The scope of work for this project included tasks that support the result of demonstration of an integrated, multi-tenant AMI network management system, with analytics and visualizations that will support a variety of business operations and processes, such as an automated trouble ticketing system, workflow manager, configuration manager, and asset management.

3.3.1 Milestone Tasks

To complete the Scope of Work for the project, the following milestone tasks were created:

- **Milestone 1:** Vendor A delivers requirements documentation for AMI vendor integration. The objective of this project is to integrate, display, and evaluate the data from multiple vendors.

To achieve that, this milestone will provide the requirements for the integration of the data which is a key step.

  - Deploy Base MoM Platform on Cloud Solutions Vendor Service (CSVS) cloud solutions platform
  - Develop Application Programming Interfaces (API) and flat files for each of the three AMI vendor networks

- **Milestone 2:** Vendor A demonstrates and delivers documentation for developed interfaces. Once the integration requirements are achieved, the next step is to develop and demonstrate the integration and interface.
  - Generate Data Model for Inventory/Configuration Tracking
  - Generate Custom Comm Views
  - Generate Custom Power Capacity Views
  - Generate Custom Fault/Alert Views
- **Milestone 3:** Vendor A demonstrates and delivers documentation for developed views. This project's end product is the actual displays that will provide the users the expected value, such as performance monitoring and issues identified in the AMI systems. This milestone will describe the different displays, implementation and test plan.
  - Work with PG&E to Develop System Test Plan
  - Datafill and Test Inventory Model Completeness
  - Datafill and Test Electric Meter Interfaces
  - Datafill and Test Gas Meter Interfaces
  - Datafill and Test Streetlight Vision Interfaces

Software development performed in Milestones 2 and 3 were organized into seven 2-week agile development sprints.

4 Project Activities, Results, and Findings

The EPIC 2.27 project demonstration was accomplished by leveraging the MoM platform that was deployed in a CSVS cloud environment. This environment was connected to PG&E's lab network (TicNet) such that it could directly connect over an Internet Protocol Security Virtual Private Network (VPN) to both Vendor 1's (electric SmartMeter AMI vendor) instance of Utility IQ (UIQ)[6] for the lab and the Vendor 1's lab hardware deployed in the Fremont test facility. In addition, a secure flat file repository was established on PG&E's Enterprise Secure File Transfer for the purpose of hosting the flat files required for discovery during the project. The MoM database used for the project was an CSVS Relational Data Storage instance of MySQL. This is shown in Figure 1.

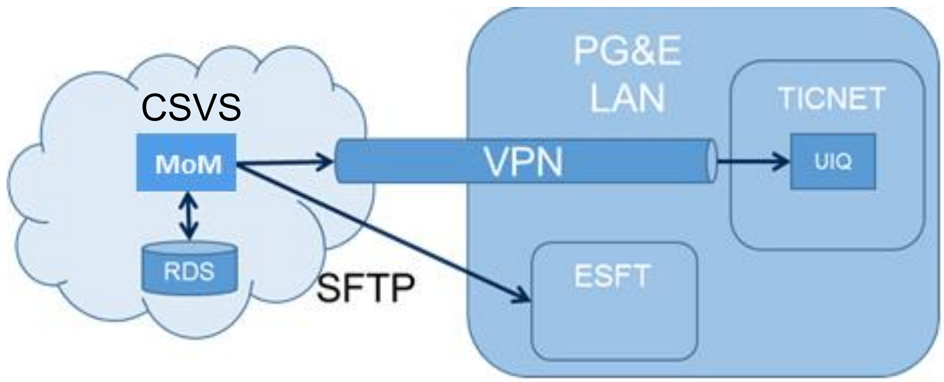


Figure 1. High Level Network Diagram

4.1 Technical Results and Findings – AMI Network Data Aggregation

To achieve a key value of this project, multiple AMI systems needed to be integrated in a manner that would provide access to the applicable data including real time updates. In order to be able to model all three AMI networks in the MoM platform, a multitude of discovery processes had to be created to pull data from the appropriate source for each network, element, and data type. A summary of the different sources for each is shown in Table 1.

4.1.1 Technical Development and Methods

To fulfill the required discovery needs, two new discovery adaptors were created for discovery from a SOAP Web Service and from flat files. Details of each are as follows:

- SOAP Web Service Discovery – This adaptor was used for making calls to the UIQ SOAP Web Service to initiate SOAP requests, to check the status of SOAP requests, and to pull back the results of SOAP requests; and
- Flat File Discovery – This adaptor was used for all other non-SOAP discovery for which flat files that contained source data were generated.

6 Utility IQ (UIQ) is a software application used by PG&E to monitor, configuration and control of SmartMeters.

Table 1. Discovered Data Types and Sources

Network	Element Type	Data Type	Source
AMI Network 3	Vendor 3 Electric Module	Inventory	ESFT (CC&B)
		Configuration	ESFT (VA File)
		Performance	ESFT (PRN File)
AMI Network 2	Vendor 2 Gas Module	Inventory	ESFT (CC&B)
		Configuration	N/A
		Performance	ESFT (MTU Transmissions)
	Vendor 2 DCU	Inventory	ESFT (DCU Tables)
		Configuration	ESFT (DCU Commands)
		Performance	ESFT (DCU Call Data, DCU Messages)
AMI Network 1	Vendor 1 Electric Module	Inventory	ESFT (CC&B)
		Configuration	UIQ AMR (Device Export)
		Performance	UIQ WS (C12.19, Interval Read) UIQ AMR (Network Summary) UIQ NEM (NodeQ 0)
	Vendor 1 Streetlight	Inventory	ESFT (CC&B)
		Configuration	UIQ AMR (Device Export)
		Performance	UIQ WS (Interval Read)
	Vendor 1 AP	Inventory	UIQ AMR (Device Export)
		Configuration	UIQ AMR (Device Export)
		Performance	UIQ NEM (WAN Util, NAN Util, Meters by AP, Hop Counts by AP)

Once the above mentioned adapters were developed, each then had to be configured to properly discover each of the data types and then process them as necessary. For inventory data, new elements found in source files were added automatically to the system. For configuration data, configuration changes to existing elements were updated and changes logged to the configuration change log.

In addition to the new discovery adaptors, a mechanism for calculating and storing KPI data was also added, ready for execution following any discovery process. All of the added support for the two new discovery mechanisms and KPI calculation were implemented such that new data types can be added at runtime within the application.

4.1.2 Challenges

The main challenge was experienced during the process of building one data model representing different AMI networks, primarily because of the unique structure of each AMI network and differences in their associated data models. This challenge was addressed by the MoM discovery mechanism, which is flexible to configure on the fly and can rapidly be adapted to support new element types as they are introduced. Discovery of all required portions of all three AMI networks was possible due to the two newly-developed adaptors and proper configuration for each type of data.

4.1.3 Observations

During the test phase, some basic testing was performed to validate the availability of performance and configuration data, required by the EnMS platform. The availability of data of interest was verified by direct database query. In a production environment, this data would be made available through a formal RESTful API that would be added to the MoM platform through future development. The net results from this project indicated that despite the challenges, the data integration was successful.

4.2 Technical Results and Findings – Improved Display of Network Health and Utilization

The final deliverable intended for the users was a combination of easily used displays that would enhance the monitoring and operations of the AMI systems. Operational performance would be more effectively monitored and issues would be identified proactively, thereby enhancing performance and safety.

As defined by the project requirements, focus was on the network navigation and data visualization to improve upon the existing display of network health and utilization information.

Navigation Requirements: Stipulated view of information at a high (Network-wide) level, including ability to highlight problem areas, and drill down into each area to view the specific underlying AMI networking devices or meter modules. The MoM platform has a data model that supports a hierarchical network structure, which was configured to work with PG&E's three AMI networks.

Network Health and Utilization Requirements: Called out many specific metrics for evaluating the AMI networks along three main categories:

- Network Health
- Network Utilization
- Endpoint Health

The MoM platform dashboard is "widget"-based, such that widgets can be arranged and sized through configuration. Widget content is also configurable to show map-based information, line charts, bar charts, etc. This feature was leveraged to quickly display many of the required performance metrics.

4.2.1 Technical Development and Methods

Hierarchical Network Data Model: To facilitate the required network navigation, the MoM dashboard was divided into five "Views," organized into a hierarchical tree structure. As shown in Figure 2, this structure is used to guide navigation from the highest to the lowest hierarchical level. The highest hierarchical level is called "Network," which aggregates data across all elements of all three AMI networks down to the individual "Meter Module" level. Below the highest level are the two lower levels, first the 18 PG&E Divisions followed by the 83 Meter Reading Offices (MRO). Both layers can be configured arbitrarily, but configuration must represent logical breakdowns of the total coverage into smaller groups of elements, typically based on geography. The layer below the MROs is where the AMI networking elements (Access Points (AP), Data Collecting Units (DCU)) appear as they have a "Parent" or one-too-many relationship to the meter modules, which appear in the layer directly below them. Meter module elements not currently communicating through a parent are assigned to a "dummy" element and are highlighted and grouped together by default.

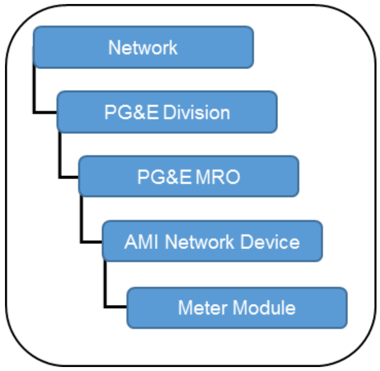


Figure 2. View Hierarchy

By default, in the MoM application, the Views can be navigated by a Tree View widget. A screenshot of the Tree View navigation widget is shown in Figure 3.

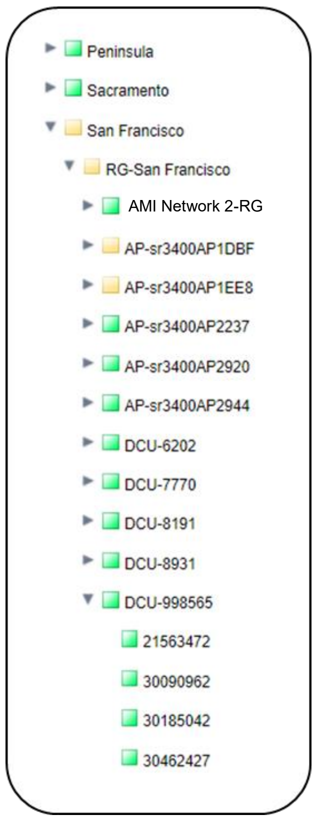


Figure 3. Tree Navigation Widget

The colored squares preceding the branch name indicate the aggregate alarm status of the branch. The alarm severity and color meanings are as listed below:

- Critical: Red – need immediate attention (i.e., critical hot socket detection, temp > 190 degree F and need attention within 24 hours).
- Major: Amber – need attention but can wait (i.e., hot socket detection, temp >170F but < 190F).

- Minor: Yellow – Need to check temperature hourly (i.e., temp>140°F but <170°F)
- Clear: Green – Temperature is back to normal (i.e., temp <140°F)

Data Visualization: The required data visualizations had to be distributed across each of the Views corresponding to an appropriate level of drilldown into the network. Within each View, decisions were then made about how many and which types of widgets should be displayed. The main categories of *Network Health, Network Utilization, and Endpoint Health* were distributed across the Views as follows:

- **Network:** Network Health (Overall)
- **PG&E Division:** Network Utilization (Division)
- **PG&E MRO:** Network Utilization (MRO)
- **AMI Network Device:** Network Health (Device)
- **Meter Module:** Endpoint Health

4.2.1.1 Network View

Figure 4 is the topmost level view, displayed to all users as they log into the dashboard. The Network View has been configured to give users a health summary overview of all three AMI networks across multiple metrics. This view highlights, as configured, areas of interest or potential problems, and guides the user to the portions of the networks where they should focus their attention. A more detail view of the multiple sections is provided in Figure 5 through Figure 10.

4.2.1.2 Network Map Widget (Showing MRO Boundaries)

This network map in Figure 5 shows the individual boundaries of the PG&E MROs. The MROs are color-highlighted by the aggregated alarm status of all elements within the boundary.

4.2.1.3 Division Overview Widget

The widget in Figure 6 gives a summary of alarm and ticket status per PG&E Division. It displays active alarms, open tickets, and dispatched tickets.

4.2.1.4 Network Health Widgets

There are three bar charts (Figure 7, Figure 8, and Figure 9), each displaying the overall aggregated health of each of the three AMI networks based on one or more selected KPIs. For example, Figure 7 shows AMI Network 3 health status, representing the percentage of meters that reported successfully on a given day.

AMI Network 2 health, presented in Figure 8, represents the number of successful calls of DCUs and DCUs with unloaded battery voltage > 12 V.

AMI Network 1 health, shown in Figure 9, represents the percentage of APs that have fewer than 10,000 primary meters and hop counts less than 6. All health metrics per network are configurable at runtime.

4.2.1.5 Network Population Widget

A report showing the breakdown of the networks technology type was also included here in Figure 10 for reference.

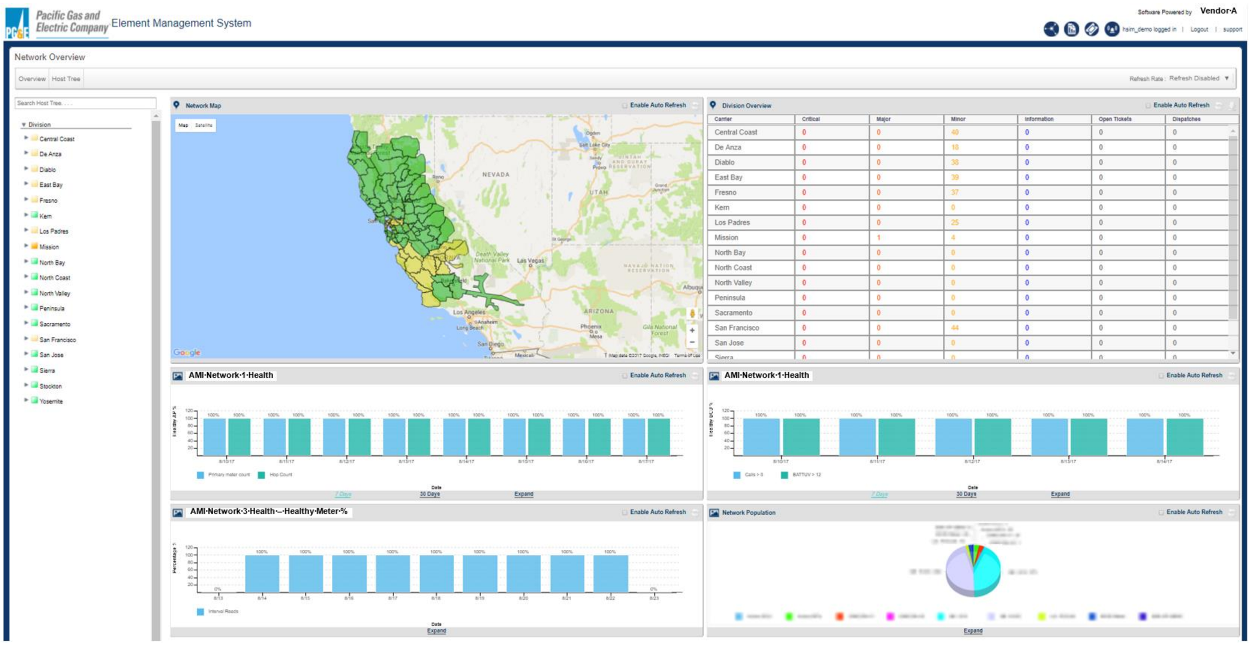


Figure 4. Network View

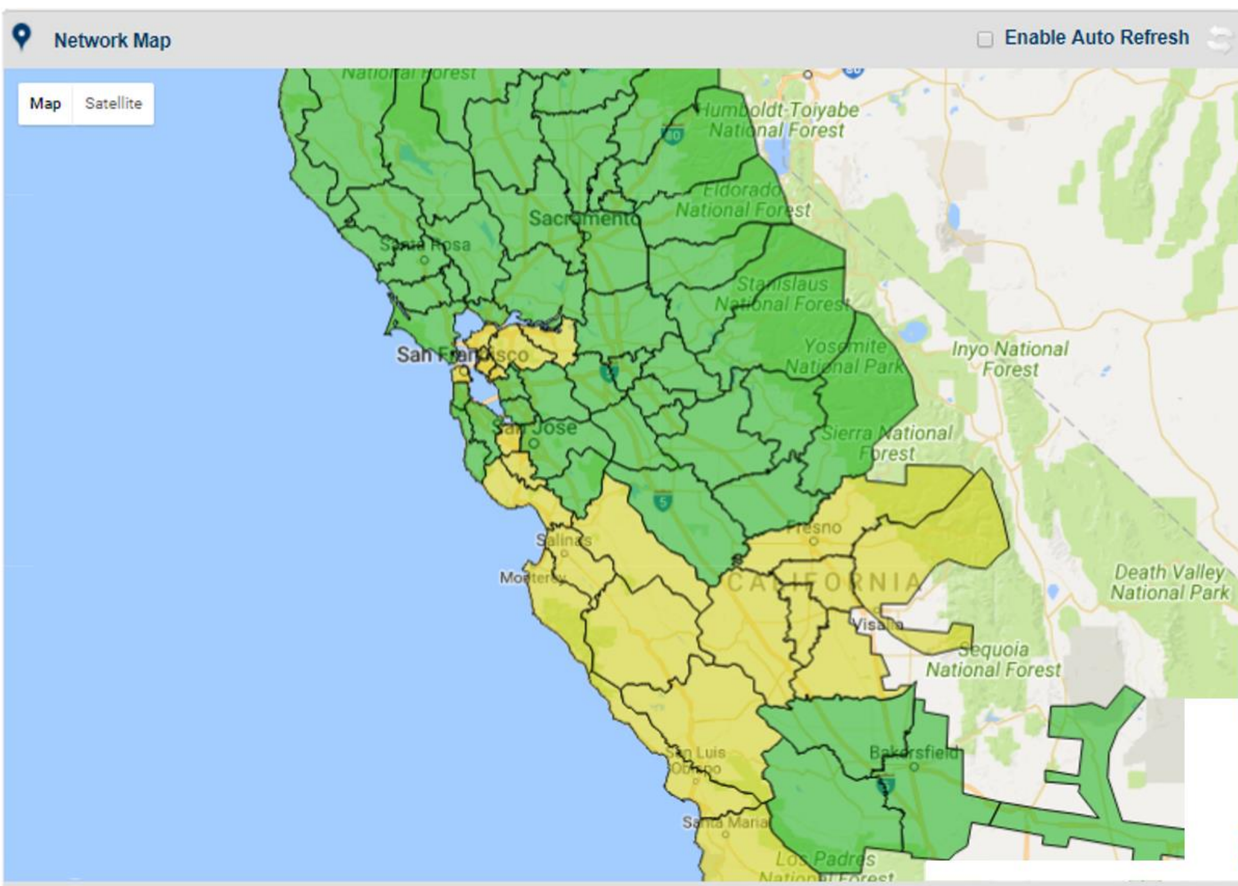
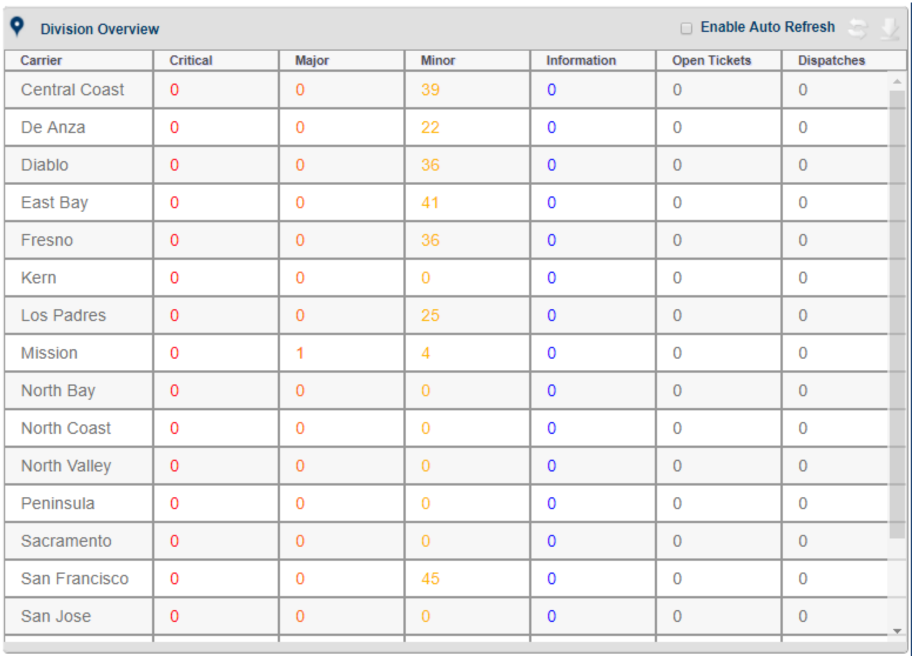


Figure 5. Network Map With MRO Boundaries



Carrier	Critical	Major	Minor	Information	Open Tickets	Dispatches
Central Coast	0	0	39	0	0	0
De Anza	0	0	22	0	0	0
Diablo	0	0	36	0	0	0
East Bay	0	0	41	0	0	0
Fresno	0	0	36	0	0	0
Kern	0	0	0	0	0	0
Los Padres	0	0	25	0	0	0
Mission	0	1	4	0	0	0
North Bay	0	0	0	0	0	0
North Coast	0	0	0	0	0	0
North Valley	0	0	0	0	0	0
Peninsula	0	0	0	0	0	0
Sacramento	0	0	0	0	0	0
San Francisco	0	0	45	0	0	0
San Jose	0	0	0	0	0	0

Figure 6. Division Alarm and Ticket Overview

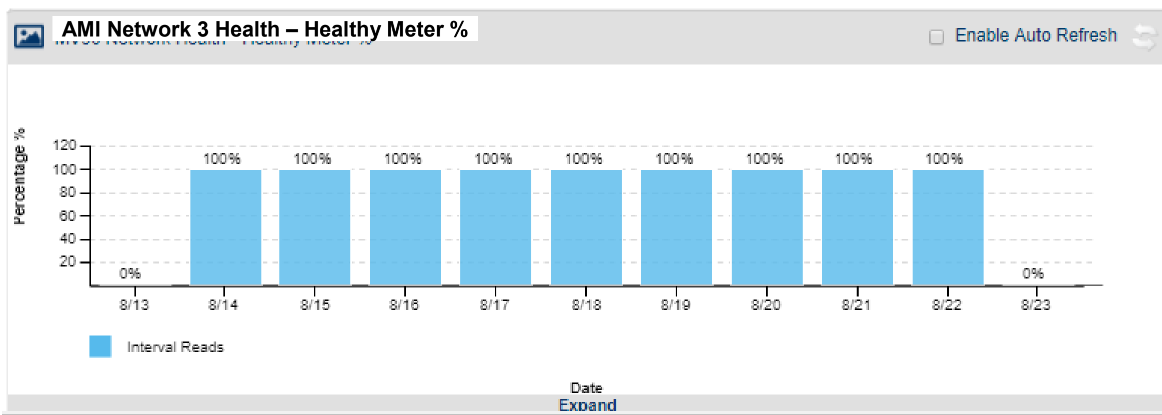


Figure 7. AMI Network 3 Health Trend Report

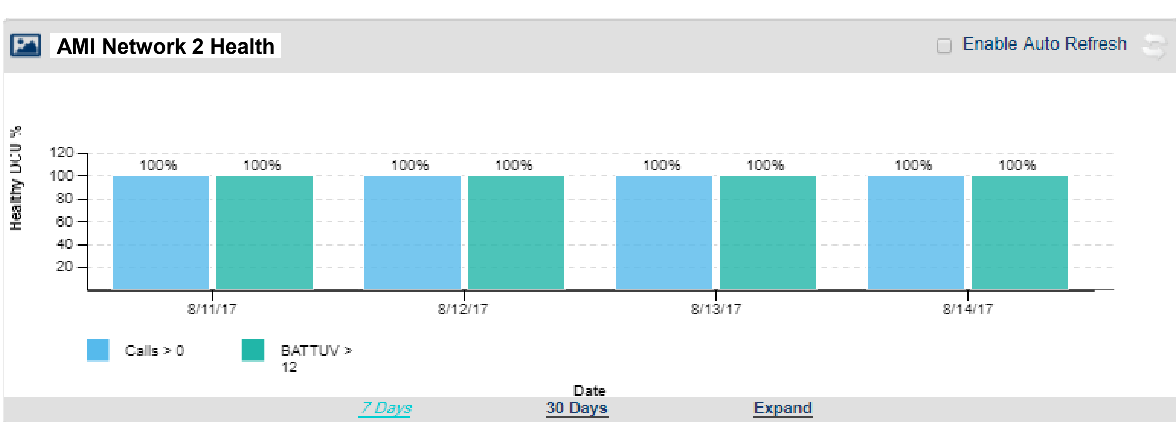


Figure 8. AMI Network 2 Health Trend Report

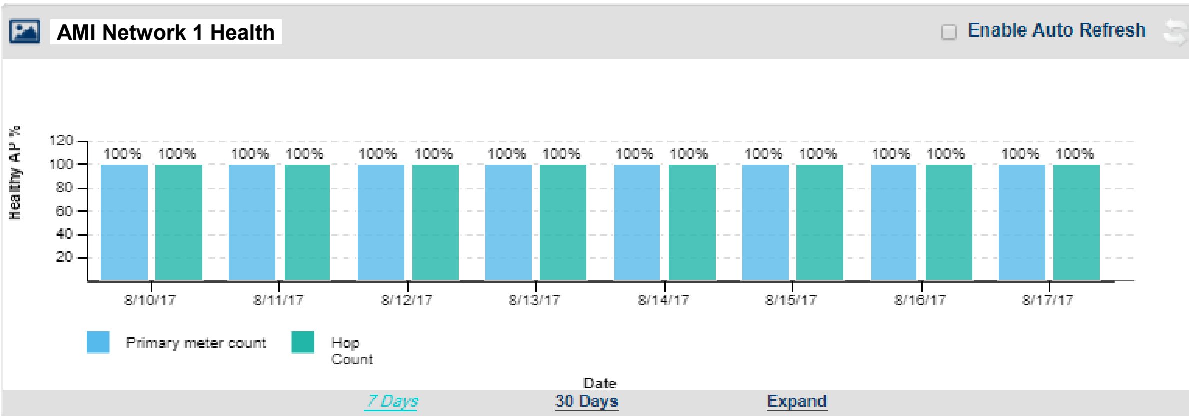


Figure 9. AMI Network 1 Health Trend Report

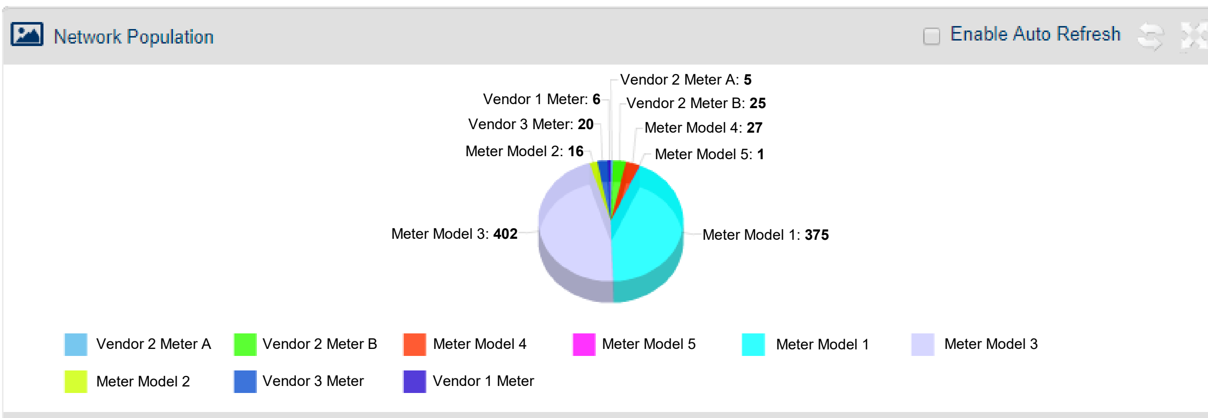


Figure 10. Network Population Report

4.2.1.6 Division View

As shown in Figure 11, by clicking on a PG&E Division name from the Tree Navigation Pane or in the Division Overview widget, the dashboard focus drills into that single Division. All widgets displayed will only show data as it pertains to the portions of each network within that Division. An expanded view is provided in Figure 12 through Figure 17.

4.2.1.7 Network Map Widget (Showing Devices and KPI Filters)

This widget, shown in Figure 12, facilitates the display of all managed network element types and allows for colored highlighting of the elements by either alarm status or performance of a selected KPI. This allows for visual correlation of problems across network and KPI types. The user can select which elements display alarm status and which display KPI performance.

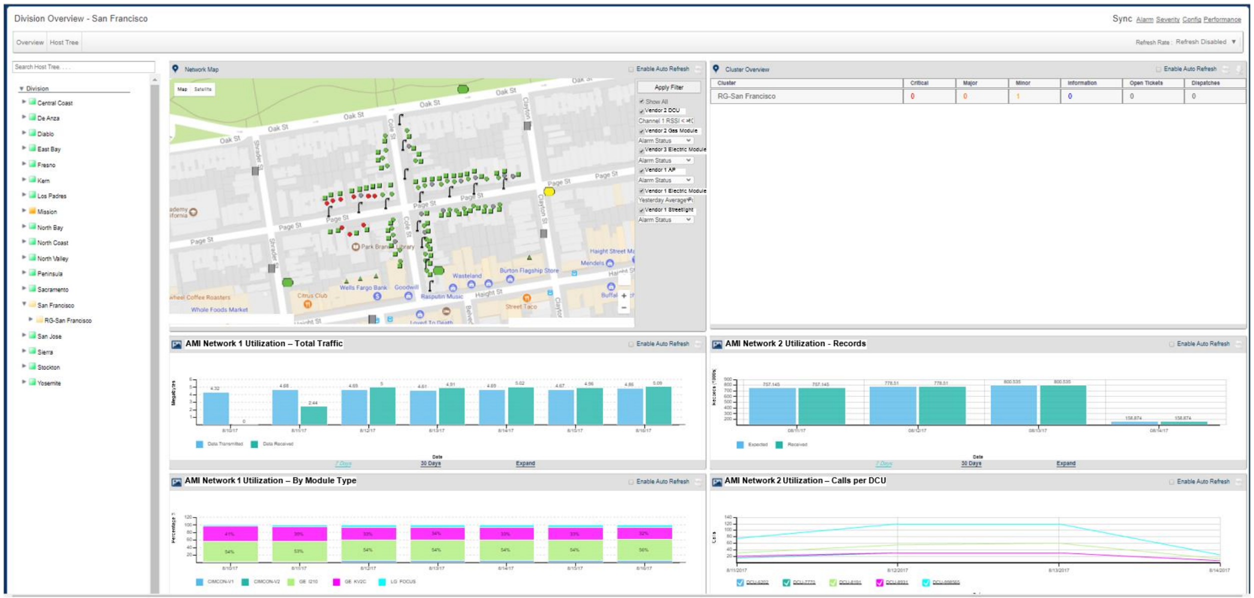


Figure 11. Division View

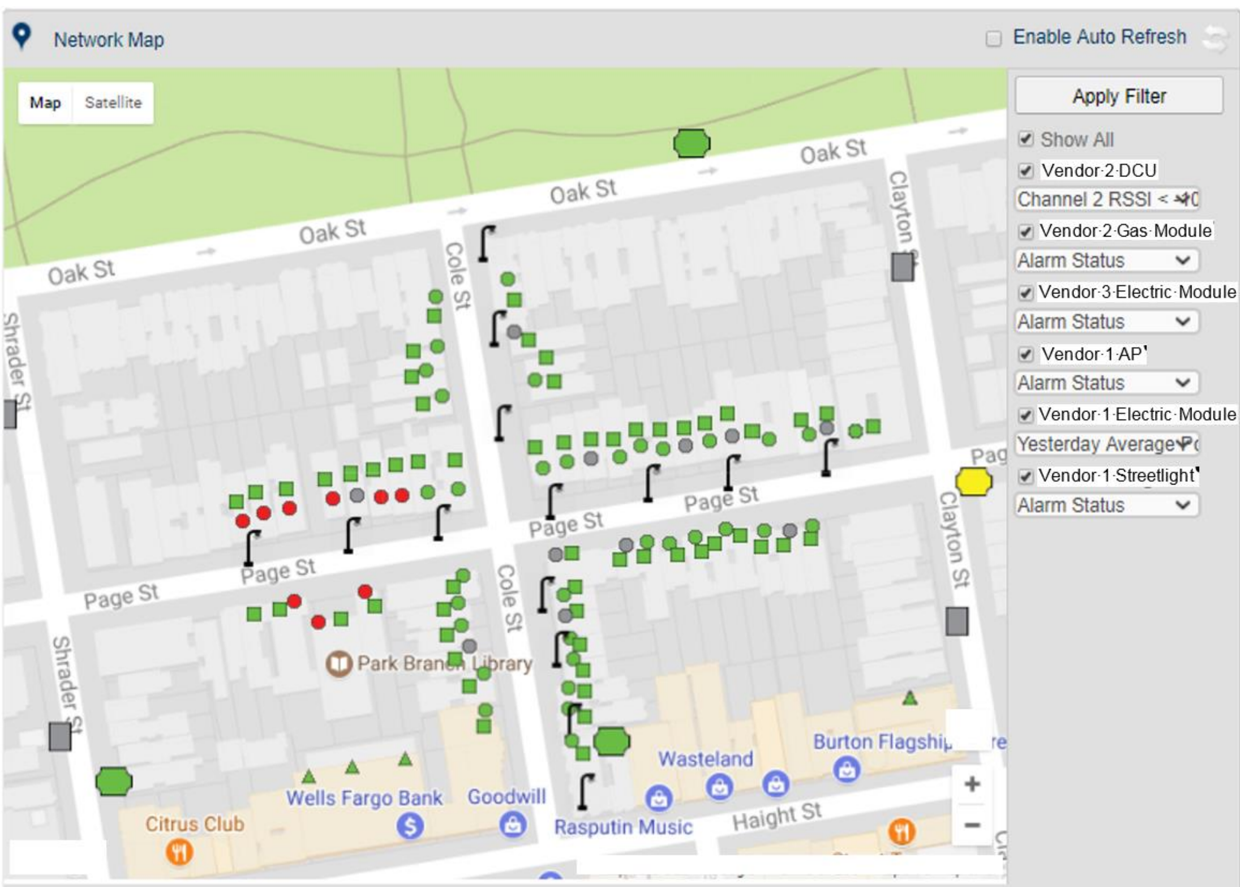
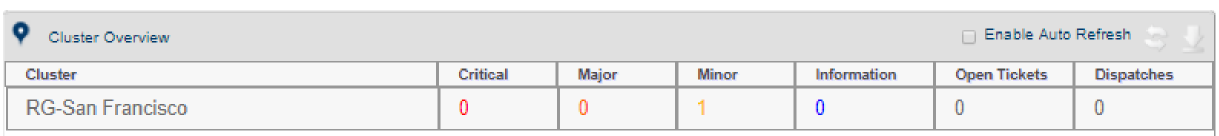


Figure 12. Network Map With KPI Selectors

4.2.1.8 Meter Reading Office Overview

The previous alarm and ticket widget overview summary (shown previously in Figure 6) is grouped per Division. It is later revised and replaced by summary per Division with summary per MRO to better facilitate drilldown first into problem divisions, then problem MROs of the Division. This is shown in Figure 13.


Cluster Overview
Enable Auto Refresh

Cluster	Critical	Major	Minor	Information	Open Tickets	Dispatches
RG-San Francisco	0	0	1	0	0	0

Figure 13. MRO Cluster Alarm and Ticket Overview

4.2.1.9 Network Utilization

For AMI Network 1 and AMI Network 2, two customized reports of network utilization are presented in Figure 14 through Figure 17.

Figure 14 shows Electric AMI Network Utilization Trend. It displays the total data transmitted across all Aps in megabytes during a given day and the total data received.

Figure 15 shows Electric AMI Network Utilization % Per Module Type. It shows a daily trend of the percentage of total AMI network traffic contributed by each meter type.

Figure 16 shows Vendor 2 Network Utilization by Call Records Report. The report shows the total number of call records both expected and received across all DCUs in AMI Network 2.

Figure 17 shows Gas AMI Network Utilization by Calls Report. It displays the total number of calls per day per DCU in the PG&E Division.

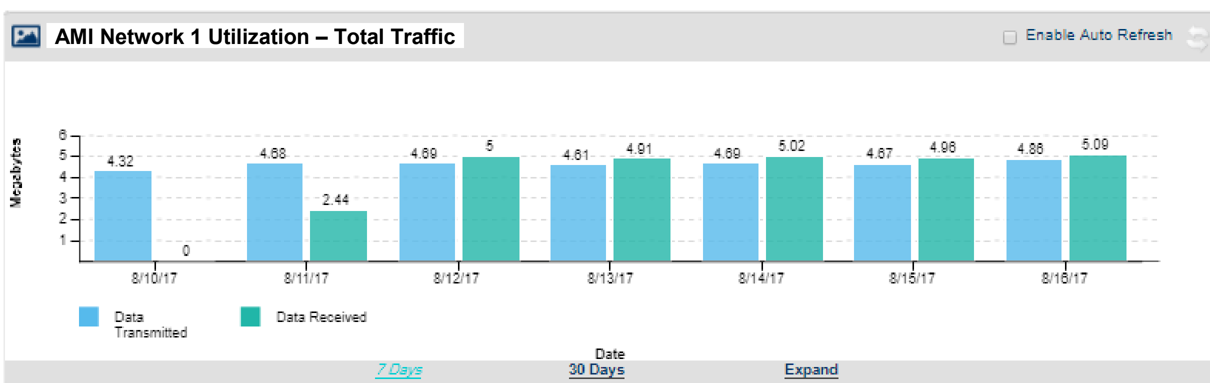


Figure 14. AMI Network 1 Utilization Trend Report

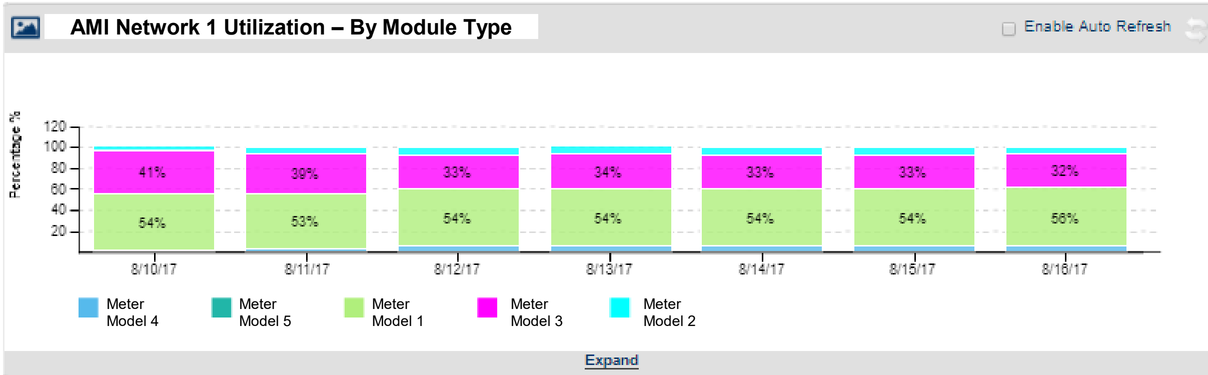


Figure 15. AMI Network 1 Utilization % Per Module Type

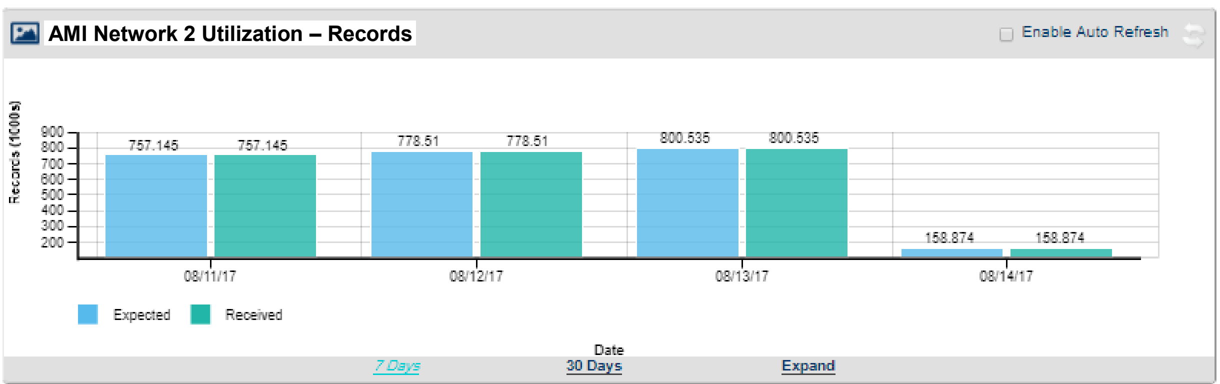


Figure 16. AMI Network 2 Utilization by Call Records Report

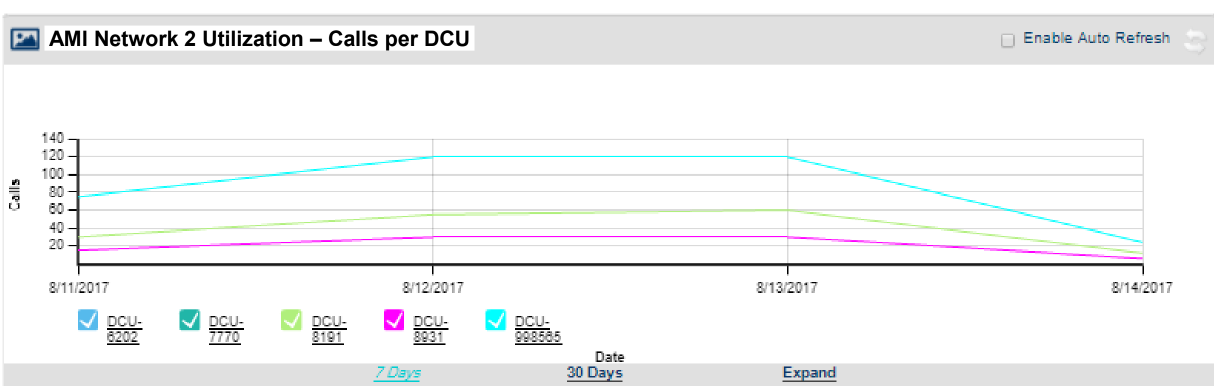


Figure 17. AMI Network 2 Network Utilization by Calls Report

4.2.1.10 Meter Reading Office View

The view shown in Figure 18 was chosen to have the same map and network utilization graph widgets as seen on the Division View, but with new alarm and ticket summary widgets that present more information about the occurring problems and already dispatched work orders. A more detailed view is provided for new displays, in Figure 19 and Figure 20.

4.2.1.11 MRO Alarm Summary

Figure 19 shows a list of all elements with current alarms and their severity within the MRO. By clicking on the widget, additional information is shown about when the alarm occurred, detailed description of the alarm, and suggested remedy for the alarm.

4.2.1.12 MRO Ticket Summary

The widget shown in Figure 20 provides summary information for all currently open tickets for elements within this MRO and the associated ticket status.

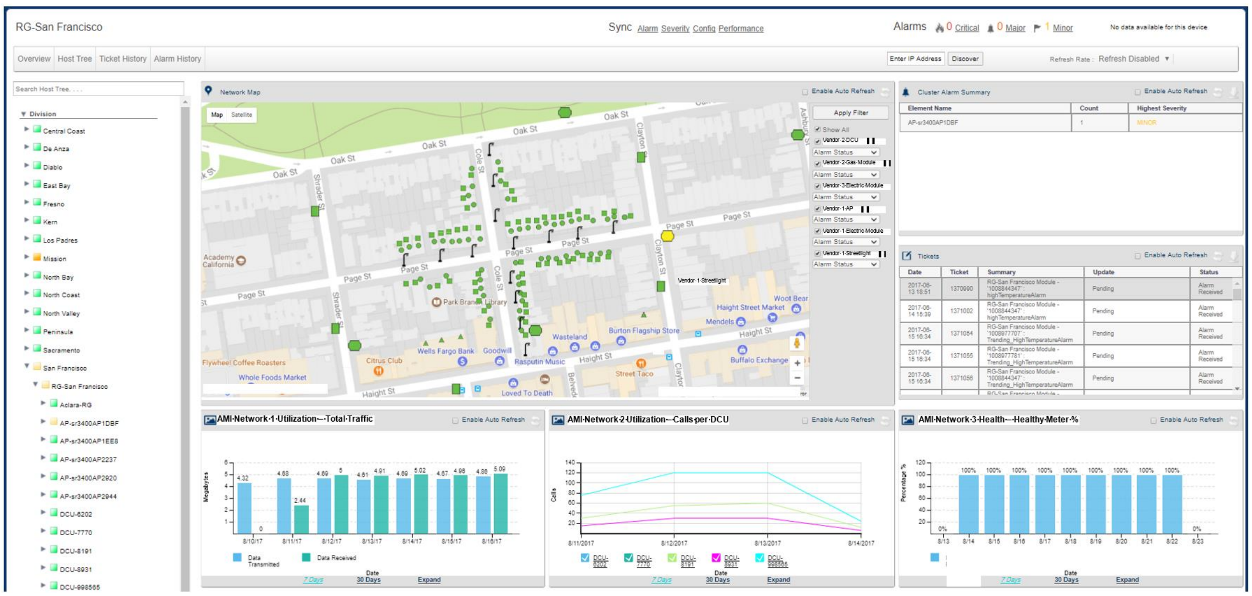


Figure 18. MRO View

Cluster Alarm Summary   Enable Auto Refresh

Element Name	Count	Highest Severity
AP-sr3400AP1DBF	1	MINOR
1008977781	1	MINOR
1008977707	1	MINOR
1008977780	1	MINOR
1009914861	1	MINOR
1009914862	1	MINOR

Figure 19. MRO Alarm Summary

Tickets   Enable Auto Refresh

Date	Ticket	Summary	Update	Status
2017-06-13 18:51	1370990	RG-San Francisco Module - '1008844347' : highTemperatureAlarm	Pending	Alarm Received
2017-06-14 15:39	1371002	RG-San Francisco Module - '1008844347' : highTemperatureAlarm	Pending	Alarm Received
2017-06-15 16:34	1371054	RG-San Francisco Module - '1008977707' : Trending_HighTemperatureA	Pending	Alarm Received
2017-06-15 16:34	1371055	RG-San Francisco Module - '1008977781' : Trending_HighTemperatureA	Pending	Alarm Received
2017-06-15 16:34	1371056	RG-San Francisco Module - '1008844347' : Trending_HighTemperatureA	Pending	Alarm Received
2017-06-		RG-San Francisco		Alarm

Figure 20. MRO Ticket Summary

4.2.1.13 AMI Network Device View

Similar to the MRO View, alarm and ticket summary widgets remain along with a map showing both the Network Device and the elements "parented" to it. As shown in Figure 21, two new widgets showing "Performance" and "Configuration" parameters were added. The data shown in these two widgets are updatable from the devices in real time where supported by the end device. In addition, six new performance plots were added to show performance metric trends over time. A more detailed view of the new plots are displayed in Figure 32 through Figure 35, which are in the Appendix (Section A.1).

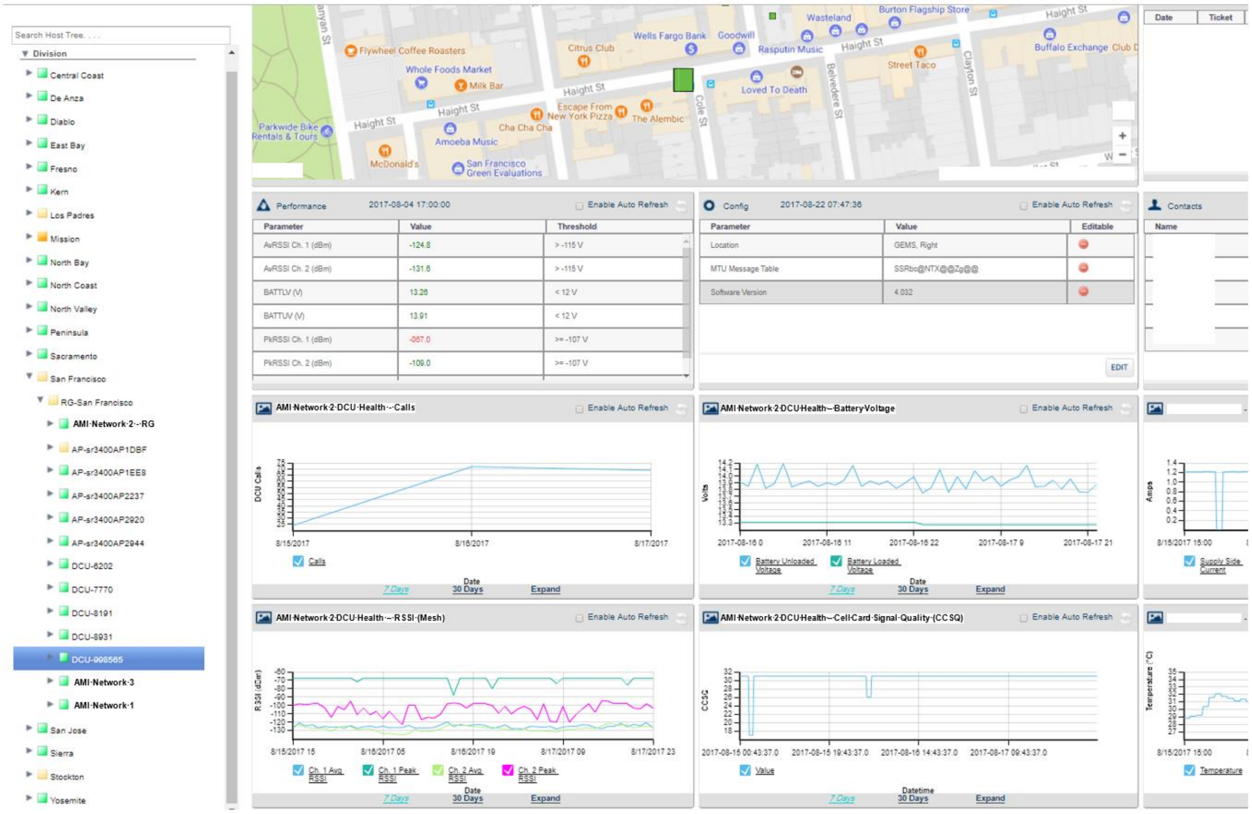


Figure 21. AMI Network Device View

4.2.1.14 <u>Meter Module View</u>

Similar to the AMI Network Device View, the Meter Module View (Figure 22) Performance, Config widgets, and Performance Trend report widgets have been updated with parameters relative to meters. For electric meters, real-time discovery is performed following the American National Standards Institute (ANSI) standard C12.19 and adapted based on the meter manufacturer (Meter Model 1, Meter Model 2, Meter Model 3, etc.). This is shown in Figure 22. A more detailed view is provided in Figure 36 through Figure 40 the Appendix (Sections A.3 and A.4).

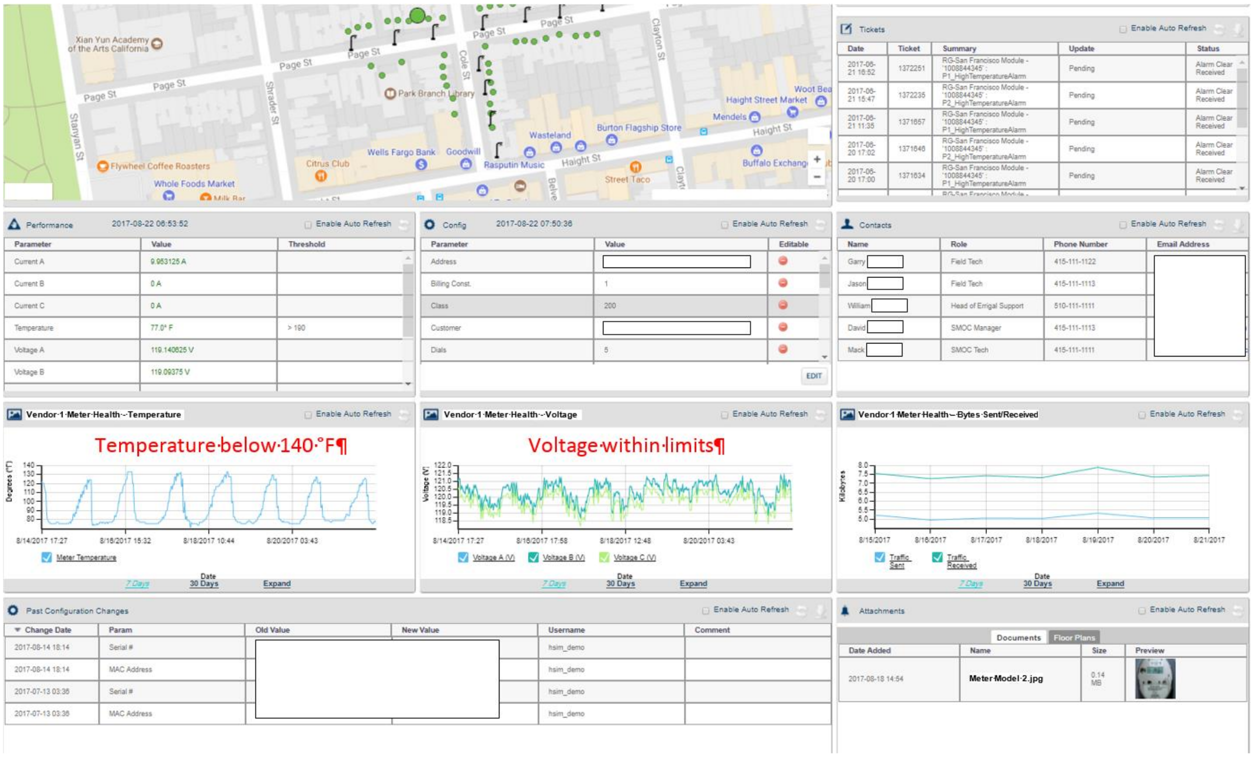


Figure 22. Meter Module View

4.2.2 Challenges

Dynamic Network Relationships: Due to the dynamic nature of the association of meter modules to aggregating AMI network devices (APs, DCUs), meter modules' "parent" devices are updated every time that information is re-discovered from the network itself. This results in continuous data flow that must be quickly processed and formatted. This poses a challenge on system performance.

Meter Vendor-Specific Discovery: Even when standard metering protocols are used, such as ANSI C12.19, each meter vendor records data in their own unique way which requires post-processing in order to be able to interpret the raw data. The existing AMI network management software offers no functionality for translating the raw hex data of ANSI C12.19 requests. Therefore, an external software is required for data translation on a per-vendor basis.

4.2.3 Observations

The MoM platform's configurable dashboard user interface showed that it can be customized rapidly to present a diverse set of information across all of the networking devices and metering endpoints of PG&E's three AMI networks.

The challenges that were overcome are what provide significant value. For example, the capability of utilizing, displaying, and evaluating real time data updates provides important information to the users.

4.3 Technical Results and Findings – Process Automation

Providing displays related to overall performance is important, but providing specific use cases that address legacy operational issues for real time data gathering and evaluation enhances that value.

The tools described below provide specific value but also provide a demonstration of how newly gathered data can help resolve operational issues that may have been difficult in the past. In some cases, those problems may not be identified until the problem is significant which can have an impact on safety and cost effectiveness. For example, issues such as data communication or high temperature meter sockets can be identified and resolved sooner. Previously, they may not have been identified until the problem became more severe.

The project implemented a use case for "High Temperature Sockets," where the management platform monitors the temperature of individual electric meters and performs automated actions based on the reported meter temperature. There is a similar process currently performed by SMOC, but that process has some manual steps that could benefit from formalization of an automated process. The goal is to identify potential safety issues related to meter temperature and initially trigger an hourly "trending" process to collect more granular temperature data. If the temperature continues to increase to an unsafe level, a trouble ticket is created to repair or replace the meter. The alarm-handling and automatic alarm-based trouble ticket creation standard in the MoM platform was utilized to implement the requirements, but additional development and configuration was performed to support the required hourly trending and alarm generation.

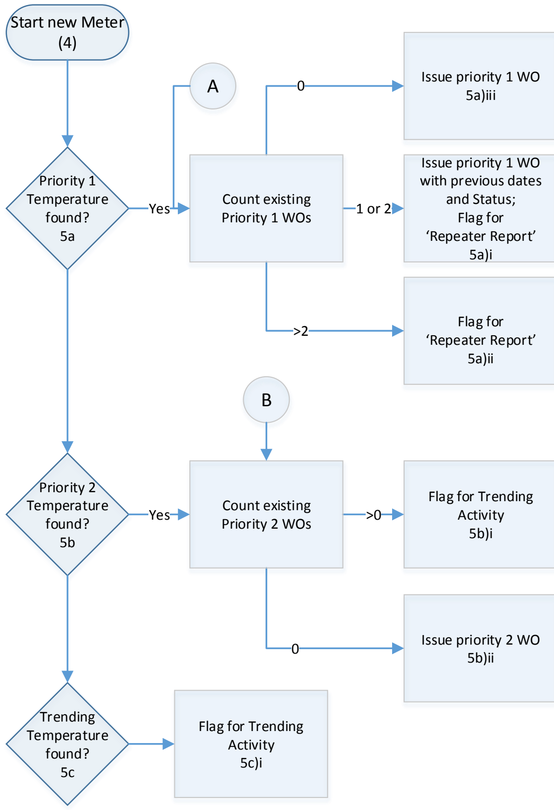
An additional use case for detecting incorrectly-wired meters was also implemented. By monitoring voltage information, incorrectly wired meters can be detected and resolved more quickly, thereby avoiding a potentially long-term billing issue. The detection was based on a single read of diagnostic registers.

These two use cases build on *EPIC 1.14 – Next Generation SmartMeter™ Telecom Network Functionalities* work by demonstrating targeted applications in identifying SmartMeter operational and maintenance issues autonomously and creating break/fix tickets. EPIC 1.14 developed a dashboard that can display outage restorations for meters in real time and identify nested outages displayed on a map. From the learnings of EPIC 1.14, PG&E developed recommendations to improve PG&Es SmartMeter system for its existing outage reporting and notification system.

4.3.1 Technical Development and Methods

In support of all the required functionality in the use cases, and internal Simple Network Management Protocol (SNMP) Meter Information Base was configured with an SNMP Trap to communicate the affected meter identification, alarm severity, alarm identifier, etc. The MoM platform was also configured with a trap rule to trigger ticket creation or status update of an existing ticket in a pre-defined MoM Ticketer workflow, "Temperature Alarm."

High Temperature Sockets: Figure 23 presents this use case flow chart, including information regarding the three temperature thresholds required in summer and winter as well as the activation of the ongoing temperature trending as long as the high temperature limits are exceeded.



Temperatures for Proof of Concept	Winter (Nov 1 → Mar 31)	Summer (Apr 1 → Oct 31)
High Temperature	> 130F	>140F
Priority 1 Temp.	>180F	>190F
Priority 2 Temp	>160F but <180F	>170F but < 190F
Trending Temp	>130F but <160F	>140F but <170F

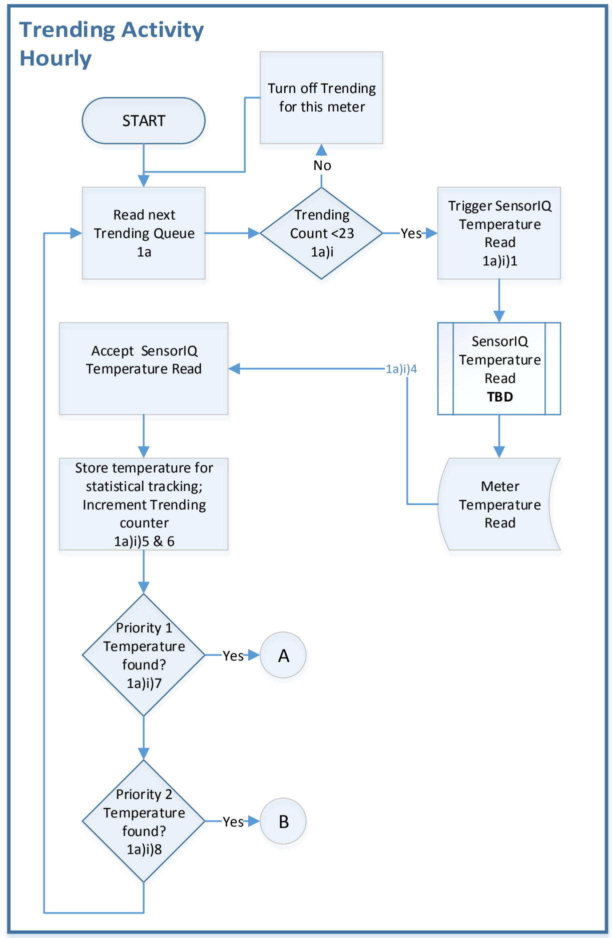


Figure 23. High Temperature Socket Use Case Flow Chart

The first part of implementing this process required identifying which meters should be hourly "trending" meter candidates, which are any meters with temperature readings over 140°F in summer or over 130°F in winter. Currently in the SMOC, this trigger comes from a weekly temperature scan taken from the entire meter population. For demonstration purposes, an hourly UIQ temperature job for each meter type (meter model 1 and meter model 2) was set up that the MoM process pulls and processes hourly. Based on these measurements, the MoM initiates its own hourly temperature discovery process for the next 24 hours specifically to the meters that have exceeded the trending threshold. Exceeding the trending temperature threshold also triggers the creation of a Minor severity alarm on the meter. The MoM process was then further configured to create a Major alarm and a Priority 2 trouble ticket when the measured temperature exceeded the Priority 2 temperature threshold. Likewise, the configuration called for a Critical alarm and a Priority 1 trouble ticket when the measured temperature exceeded the Priority 1 temperature threshold. The process was also configured to clear alarms and update open ticket statuses as the temperature decreases below the thresholds. In a production environment, this would automatically provide real-time status information to technicians in the field who may have been dispatched to resolve an issue related to meter temperature.

Testing was performed by placing several meters (both meter model 1 and meter model 2) into an environmental chamber, which could be programmed to increase and decrease the ambient temperature around the meters through the three thresholds. All meters under test alarmed, ticketed, and cleared as expected. Screenshots showing meters in Priority 2 and Priority 1 alarm are below in Figure 24.

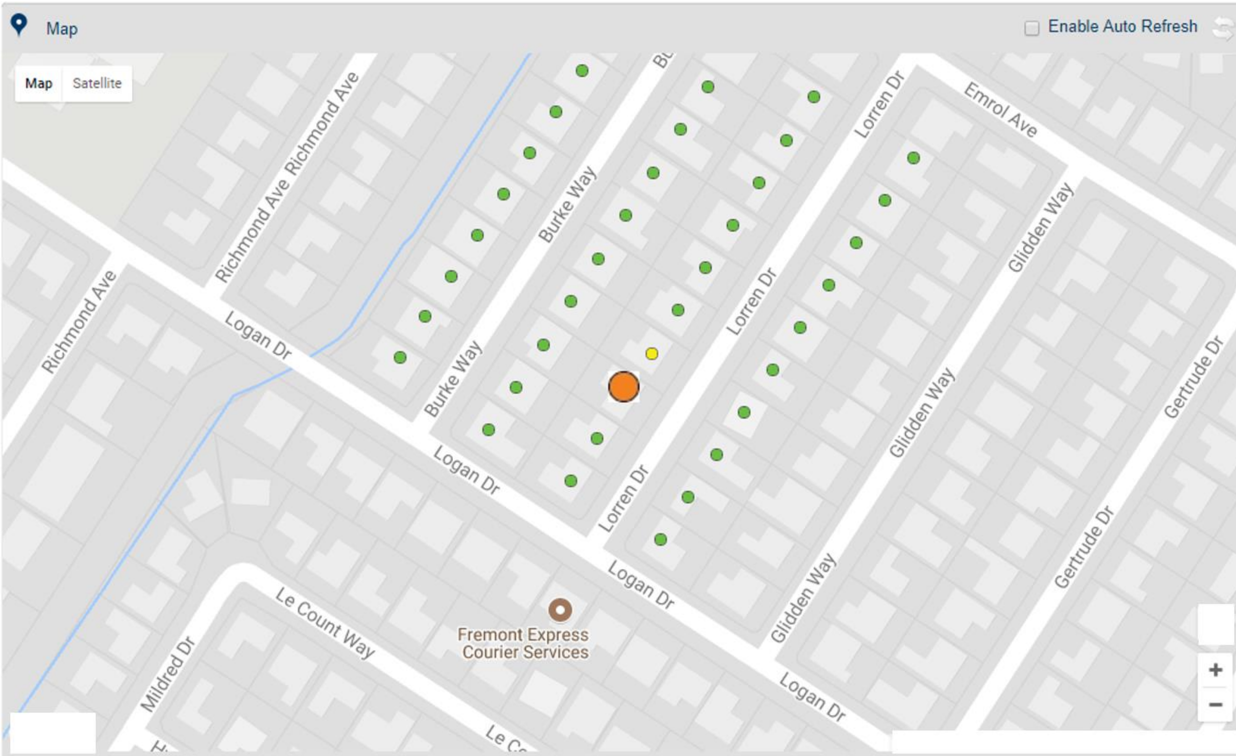
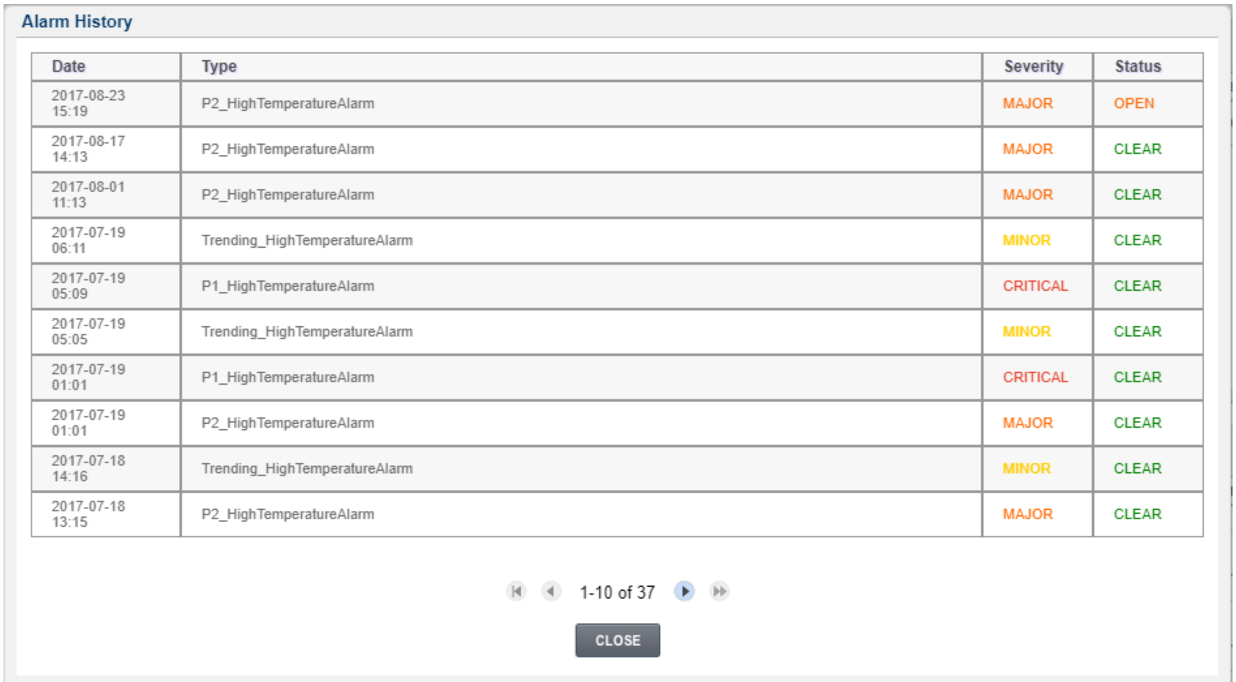


Figure 24. Meter Module in Priority 2 Temperature Alarm

Figure 25 displays the alarm history for the selected meter, showing all three priorities of temperature alarms.

Figure 26 shows the currently selected meter module is in CRITICAL alarm (red).

Figure 27 shows the alarm history for the selected meter, which shows two priorities of temperature alarms.



Alarm History

Date	Type	Severity	Status
2017-08-23 15:19	P2_HighTemperatureAlarm	MAJOR	OPEN
2017-08-17 14:13	P2_HighTemperatureAlarm	MAJOR	CLEAR
2017-08-01 11:13	P2_HighTemperatureAlarm	MAJOR	CLEAR
2017-07-19 06:11	Trending_HighTemperatureAlarm	MINOR	CLEAR
2017-07-19 05:09	P1_HighTemperatureAlarm	CRITICAL	CLEAR
2017-07-19 05:05	Trending_HighTemperatureAlarm	MINOR	CLEAR
2017-07-19 01:01	P1_HighTemperatureAlarm	CRITICAL	CLEAR
2017-07-19 01:01	P2_HighTemperatureAlarm	MAJOR	CLEAR
2017-07-18 14:16	Trending_HighTemperatureAlarm	MINOR	CLEAR
2017-07-18 13:15	P2_HighTemperatureAlarm	MAJOR	CLEAR

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CLOSE

Figure 25. Alarm History for Meter Module in Priority 2 Temperature Alarm

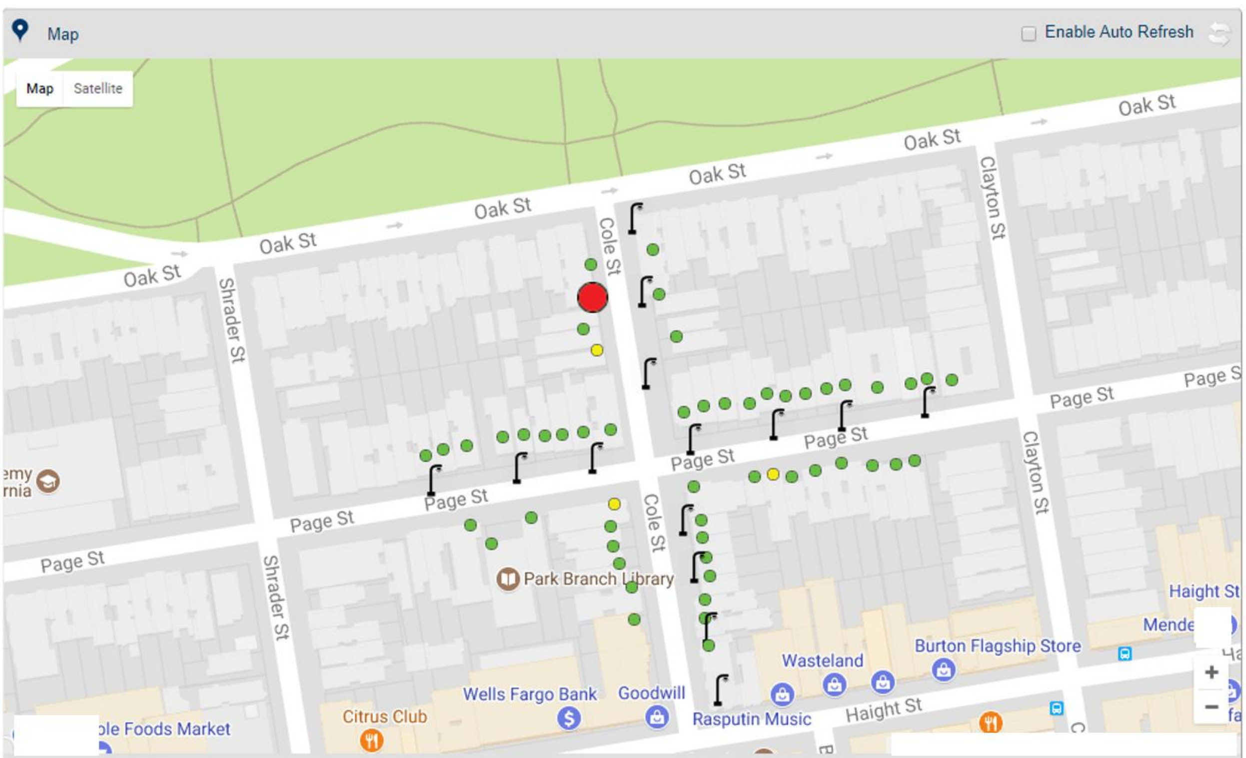
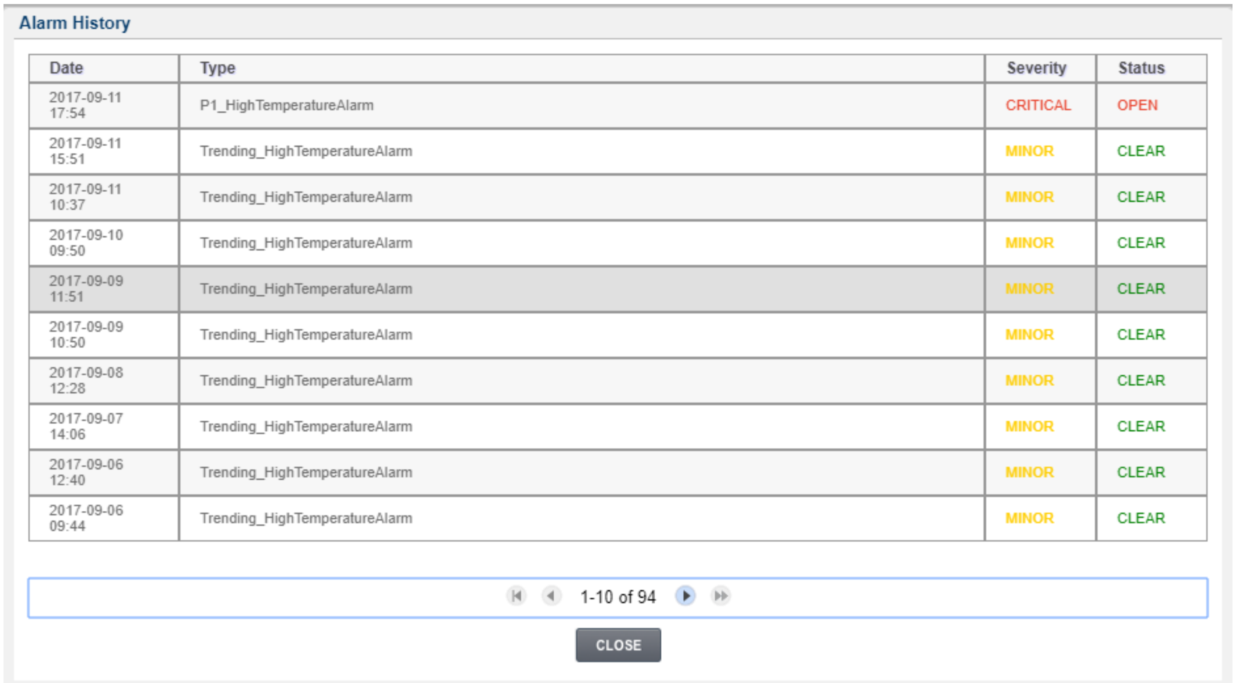


Figure 26. Meter Module in Priority 1 Temperature Alarm



Alarm History

Date	Type	Severity	Status
2017-09-11 17:54	P1_HighTemperatureAlarm	CRITICAL	OPEN
2017-09-11 15:51	Trending_HighTemperatureAlarm	MINOR	CLEAR
2017-09-11 10:37	Trending_HighTemperatureAlarm	MINOR	CLEAR
2017-09-10 09:50	Trending_HighTemperatureAlarm	MINOR	CLEAR
2017-09-09 11:51	Trending_HighTemperatureAlarm	MINOR	CLEAR
2017-09-09 10:50	Trending_HighTemperatureAlarm	MINOR	CLEAR
2017-09-08 12:28	Trending_HighTemperatureAlarm	MINOR	CLEAR
2017-09-07 14:06	Trending_HighTemperatureAlarm	MINOR	CLEAR
2017-09-06 12:40	Trending_HighTemperatureAlarm	MINOR	CLEAR
2017-09-06 09:44	Trending_HighTemperatureAlarm	MINOR	CLEAR

1-10 of 94

CLOSE

Figure 27. Alarm History for Meter Module in Priority 1 Temperature Alarm

Incorrectly-Wired Meter: For the incorrectly-wired meter use case, an hourly C12.19 job was configured to discover the diagnostic registers required to identify the meters with potential wiring issues. PG&E personnel were able to safely configure a meter for testing that was then detected by the MoM discovery process and a minor alarm was triggered for the meter as show in the screenshots below. This detection enabled PG&E to remotely identify the incorrectly-wired meters and take actions to correct them to prevent billing issues. This detection capability could also potentially help eliminate some of PG&E's current metering field inspection programs.

Figure 28 shows a map indicating that the currently selected meter module is in MINOR (yellow) alarm.

Figure 29 displays the alarm history for the selected meter which shows both Trending Temperature alarms and Wiring Diagnostic Fault alarms.

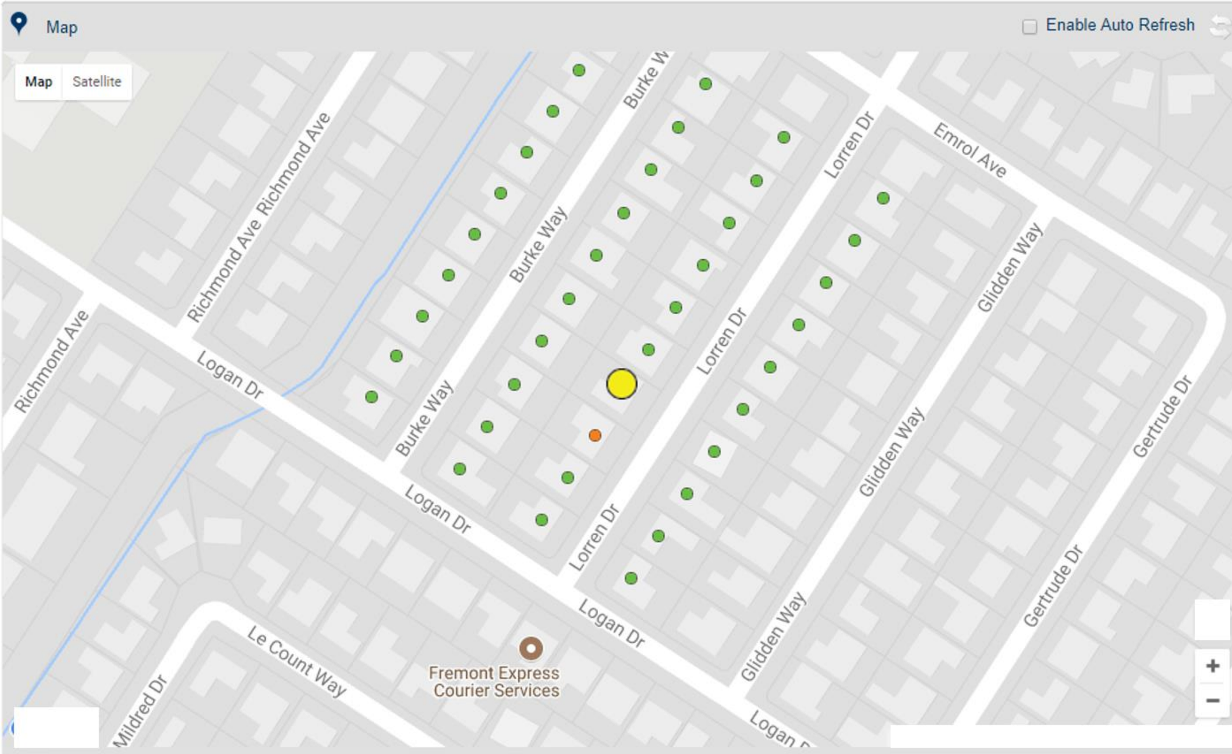


Figure 28. Meter Module in Wiring Diagnostic Fault Alarm

Alarm History

Date	Type	Severity	Status
2017-09-11 16:53	Trending_HighTemperatureAlarm	MINOR	CLEAR
2017-09-11 09:49	Trending_HighTemperatureAlarm	MINOR	CLEAR
2017-09-10 09:25	Trending_HighTemperatureAlarm	MINOR	CLEAR
2017-09-09 18:30	WiringDiagnosticFaultAlarm	MINOR	OPEN
2017-09-09 16:11	Trending_HighTemperatureAlarm	MINOR	CLEAR
2017-09-09 12:04	Trending_HighTemperatureAlarm	MINOR	CLEAR
2017-09-08 12:28	Trending_HighTemperatureAlarm	MINOR	CLEAR
2017-09-07 14:06	Trending_HighTemperatureAlarm	MINOR	CLEAR
2017-09-07 13:05	Trending_HighTemperatureAlarm	MINOR	CLEAR
2017-09-06 12:40	Trending_HighTemperatureAlarm	MINOR	CLEAR

1-10 of 90

CLOSE

Figure 29. Alarm History for Meter Module in Wiring Diagnostic Fault Alarm

4.3.2 Challenges

Although not experienced on the demonstration scale, temperature monitoring can present a challenge on the production scale. On a large scale, careful monitoring of temperature trending activity will have to be performed to make sure the thresholds used for the demonstration do not increase network utilization undesirably. The amount of data associated with each request is small, but has potential to be significant when taken over thousands of meters. Discovery processes may need to be divided and scheduled into smaller population groups to distribute the additional traffic. The future EnMS platform will need to be tested in order to determine that it can handle traffic at scale. If network scalability cannot be demonstrated, it will limit the ability for the EnMS to provide end-to-end integrated solutions and use-cases that meets business needs. An EnMS and its specific use-cases will enable modernization of the grid, better management of PG&E assets, reliability, and affordability through improved monitoring and analytics.

4.3.3 Observations

All alarm types that were configured to be created based on discovered data were generated as expected and reflected in the MoM dashboard UI. Also, automatic trouble tickets were created as expected.

Additional testing was performed to show that the MoM platform could support northbound SNMP Trap forwarding of generated alarms to an EnMS platform.

By combining known operational issues with Information Technology (IT) capabilities, significant improvements in operations can be achieved.

4.4 Technical Results and Findings – Support for Future Technologies and Tenants

In addition to managing the current AMI networks and metering technologies, EPIC 2.27 also has use cases addressing the addition of new technologies onto the existing AMI networks associated with external users. This would allow PG&E to be a NaaS provider for supporting devices owned by other tenants, such as municipalities in PG&E's service territory requiring low-bandwidth backhaul of data. The primary requirements to support tenant services are being able to differentiate and separate data by technology type, and be able to create metrics and data visualizations that show core network utilization and health vs that of a "tenant" technology. The ability to grant or revoke visibility to network elements on a per user basis is also important to allow tenants to see only their portion of the network and no one else's.

For the testing purposes, the SmartPole meters were treated as "tenants" on AMI Network 1, and additional user accounts were created with limited visibility to only a portion of those elements to simulate a wireless carrier who has use of that asset.

4.4.1 Technical Development and Methods

As shown in the earlier use cases, the default user profile is that of a SMOC technician who would have visibility to all managed assets on the network. This means that all tenant elements are viewable within the Tree Navigation widget and appear as icons on maps. This is shown in Figure 30.

A second user account representing a wireless carrier user ("MoM_vzw") was created and the network element associations were made to allow this user access to only three of the tenant assets. Upon login by this new user, only the tenant assets that the user has an association to are viewable within the Tree Navigation and Map widgets. This is shown in Figure 31.

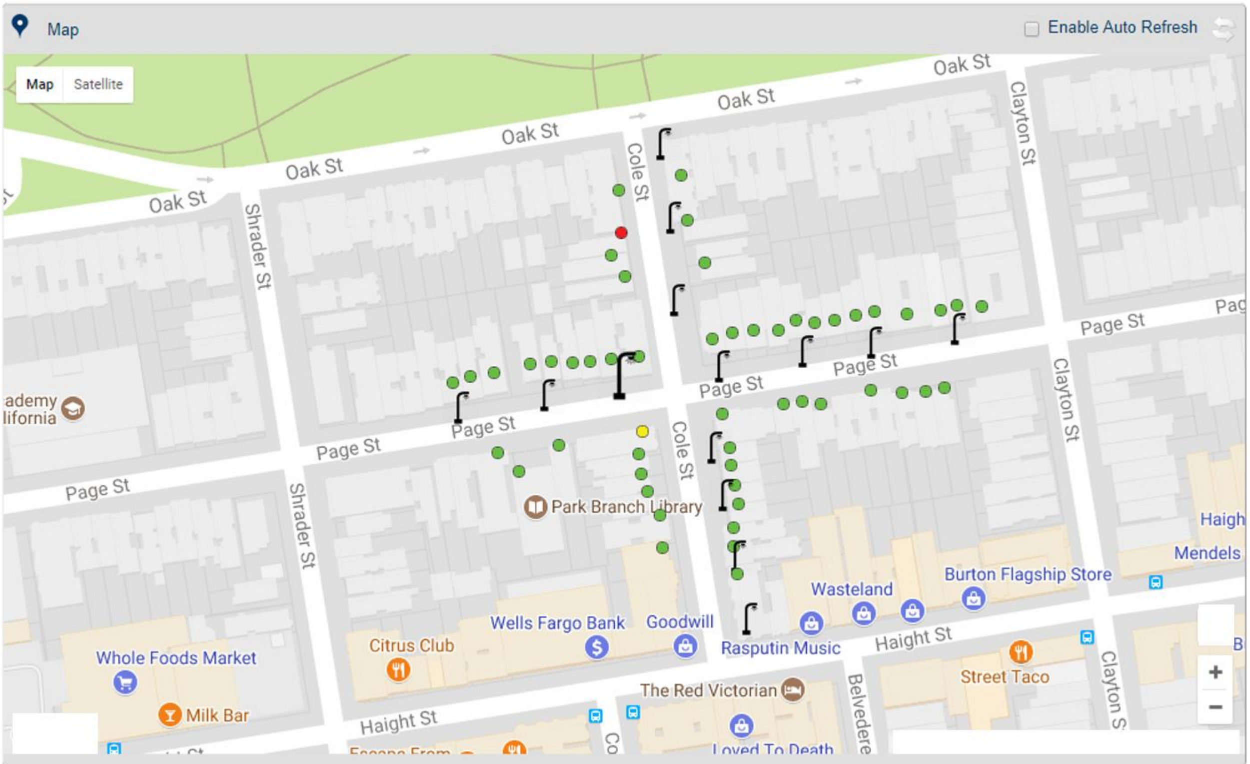


Figure 30. Map Widget Showing All Tenant (SmartPole) Elements

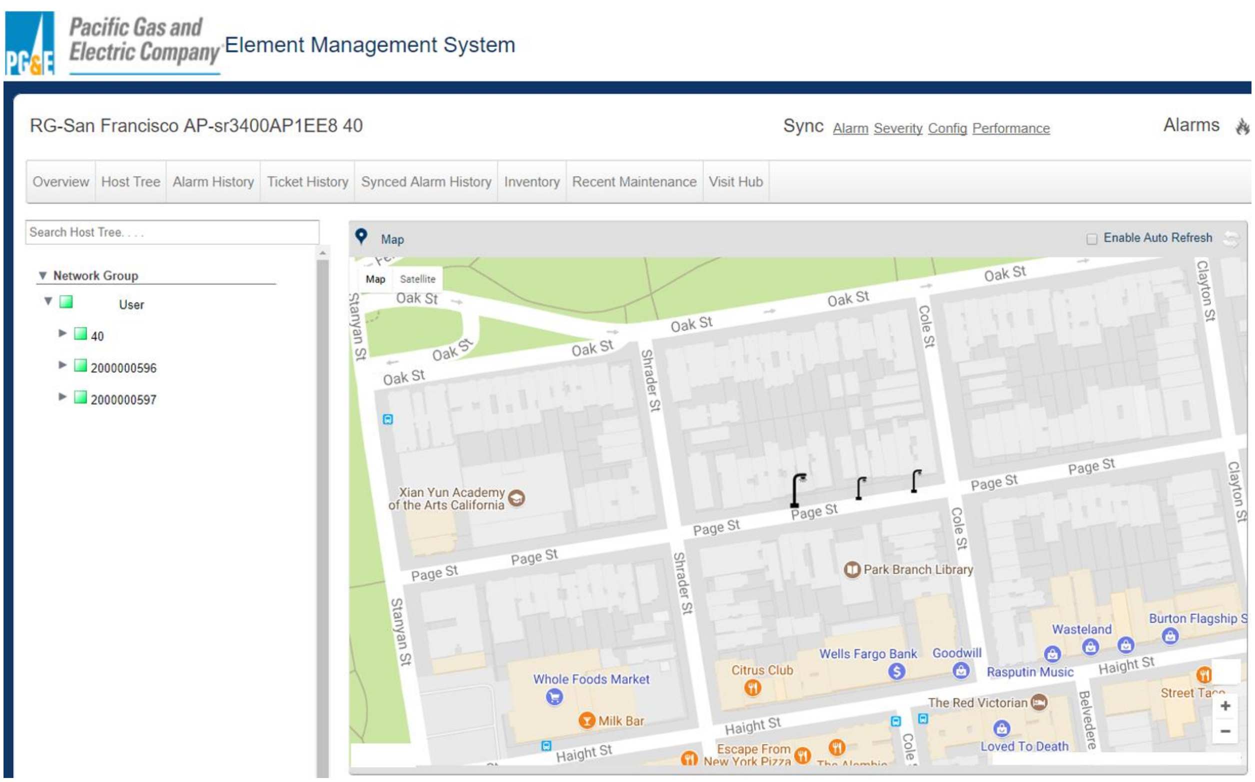


Figure 31. Tenant User Login Showing Visibility Restricted to Tenant's Assets

4.4.2 Challenges

Devices such as Smart Poles and shared-infrastructure devices have the potential to support multiple customers, such as wireless carriers or other service providers. The MoM platform supports one-to-many associations of devices to customers, but additional configuration will need to be done to customize the data made available to each customer in reports.

4.4.3 Observations

The flexibility and configurability of the MoM platform successfully supports the management of devices considered "tenants" and can grant or revoke visibility to devices and their associated network data on a per-user basis. This enables PG&E as a NaaS provider to see and manage the entire network while simultaneously giving their network customers limited visibility to their devices.

4.5 Key Learnings

This project demonstrated that the integration of multiple AMI systems into a useful operations tool is doable and effective. It demonstrated that multiple types of identified issues can be summarized at a high level for awareness, then a drill down can be quickly performed to determine the specifics. If appropriate, automatic follow-up work orders can be generated and tracked through completion. These key learnings and specific use cases can be utilized as PG&E moves forward with the EnMS project.

With an effective IT merging tool, the value of multiple data systems with real-time updates can be optimized by developing operational displays indicating the status and identifying issues. Additionally, the operational displays can begin with an overall system view which can be quickly and easily focused on specific areas and identified problems. The net result supports enhanced AMI performance, safety improvement, and cost reduction. This was demonstrated through the two use-cases developed in this project which are included in PG&Es EnMS deployment roadmap. The EnMS execution team can leverage the specifications developed for monitoring of points and operating parameters, flow logic, and functionality.

Although not a significant challenge for this demonstration, the AMI data communication requirements need to be thoroughly reviewed for similar projects to ensure the systems perform as expected. Without accurate estimates of the data requirements in comparison to the communication system capabilities, the tools are likely to not function properly.

The project learned the complexity of adding functions needed to make the MoM platform the sole dashboard. This is in addition to learnings in providing device detail views for the Network Elements (APs, Relays, DCUs). These add-on functions include:

- Additional Head-End Network Management functions
- Integration with GIS Layers, data sources like CC&B, MDMS
- Integration with various PG&E Ticketing Systems (Remedy, FAS)

5 Value Proposition

The purpose of EPIC funding is to support investments in TD&D projects that benefit the electric customers of PG&E, SDG&E, and SCE. EPIC 2.27 – Next Generation Integrated Smart Grid Management has demonstrated that centralized management of multiple diverse AMI networks into a single management platform is possible and enables increased operational efficiency and the possibility of opening up the existing AMI networks for additional Network-as-a-Service offerings.

5.1 Primary Principles

The primary principles of EPIC are to invest in technologies and approaches that provide benefits to electric ratepayers by promoting greater reliability, lower costs, and increased safety. This EPIC project contributes to these primary principles in the following ways:

- **Greater Reliability:** The aggregation of data across PG&E's three AMI networks into a single management platform contributes to overall SmartMeter network reliability by providing, on a real-time basis, a high-level view of identified problems and then allowing for a quick drill down for evaluation. And when appropriate, automatically generating and tracking follow-up work orders. Reliability of the SmartMeter network contributes to overall grid reliability by providing visibility to problems and enablement of troubleshooting in real time.
- **Lower Costs:** EPIC 2.27 contributes to overall lower costs through operational efficiencies gained from more efficient diagnosis of problems. Reduced labor costs are achieved by automating the problem identification process which quickly narrows the problem area and can provide improved information on when and what type of personnel to dispatch to resolve an issue. In addition, by quickly resolving issues such as high temperature sockets, equipment damage and replacement can be avoided.
- **Increased Safety:** The automation of processes to identify and notify technicians of potentially hazardous conditions related to meter temperature, incorrect meter-wiring, or energy diversion means that these conditions would be identified sooner and resolved faster than is possible through current manual processes.

5.1.1 Secondary Principles

EPIC also has a set of complementary secondary principles. This EPIC project contributes to the following three secondary principles: societal benefits, economic development, and efficient use of ratepayer funds.

- **Societal Benefits:** Utilizing currently underutilized bandwidth on PG&E's AMI networks for new "Smart City" devices can provide additional consumer benefits as more use cases are identified.
- **Economic Development:** Adding a management platform capable of supporting new tenant devices could enable new lines of revenue for PG&E as a Network-as-a-Service provider.
- **Efficient Use of Ratepayer Funds:** Operational efficiencies achieved through EPIC 2.27 would result in lower management and maintenance costs which would improve the efficiency of ratepayer funds used towards operations.

5.2 Accomplishments and Recommendations

5.2.1 Key Accomplishments

The following summarize some of the key accomplishments of the project over its duration:

AMI Network Data Aggregation

- Developed a management platform that successfully identified inventory, configuration, and performance data for all three AMI networks including both networking elements and metering endpoints, thereby enhancing real-time awareness of the current systems; and
- Identified processes that were demonstrated against three distinct data source types: AMI management software web services (via SOAP), direct equipment communication, and flat files.

Improved Display of Network Health and Utilization

- Established a management platform user interface that is a widget-based dashboard capable of mixing geospatial data, historical trend reports, and real-time performance data;
- Demonstrated a dashboard navigation tool that facilitates identification of issues at a high level and drilldown to a low level of analysis, which expedites identifying and resolving system issues; and
- Demonstrated that the displayed data can be raw or processed KPI data.

Process Automation

- Developed a fully automated process for identifying and monitoring electric meter temperature data, including automatic work order creation and update of the work order based on monitored performance changes. This automation improves safety by providing improved oversight of current system issues.
- Implemented a new automated inspection process for identifying electric meters/current transformers that have been wired incorrectly.

Support for Future Technologies and Tenants

- Implemented support for SmartPole meters and Smart streetlight photocell controllers such that the dashboard can display data distinctly from other standard electric meters; and
- Demonstrated that the dashboard can be modified on a per-user basis to grant/restrict access to specific tenant assets.

5.2.2 Key Recommendations

This project provided a worthwhile solution to aggregating and displaying multiple AMI network systems. Moving forward, results and learnings from this EPIC project will inform ongoing and future SMOC strategy for monitoring their tools and practices through the two use-cases developed. Furthermore, other PG&E stakeholders (users of MoM like platform) will be educated on this project's outcomes.

The results of this demonstration project should be integrated with the EnMS project which will have a broader scope on AMI networks integration. The project has multiple learnings that can assist EnMS to be successful. Key applicable learnings that should be considered include:

- The use cases are a good starting point as EnMS moves forward. The specification development of monitoring points and operating parameters can be leveraged.
- The analysis flow charts used for the high temperature meter sockets provide a method for automatic data flow analytics.
- The challenges and solutions in developing the MoM for AMI networks data integration.
- The identified challenges related to the volume of data that will result as these and additional use cases are spread across the entire PG&E service territory.

Specific use cases being considered for EnMS include:

AMI Communication Network Monitoring – Monitor and provide real-time data on endpoint device performance and communication functional reliability

- Network utilization
- Network health
- Endpoint device health

Meter/Transformer monitoring/initiating action for potential equipment failure

- Meter temperature threshold scan activity
- High temperature sockets
- Overload panels and current transformers
- Potential current and/or voltage transformer failure
- Miss-wired meter

5.3 Knowledge Transfer Plan

5.3.1 Invested-Owned Utilities' Knowledge Transfer Plans

A primary benefit of the EPIC program is the technology and knowledge sharing that occurs both internally within PG&E, and across the other invested-owned utilities (IOU), the CEC and the industry. In order to facilitate this knowledge sharing, PG&E will share the results of this project in industry workshops and through public reports published on the PG&E website. Specifically, below are information-sharing forums where the results and lessons learned from this EPIC project were presented or plan to be presented:

Information Sharing Forums Planned

1. DistribuTECH New Orleans, LA | February 2019.
2. Edison Electric Institute and Association of Edison Illuminating Companies Indian Wells, CA | October 2018 TBD | April 2019.
3. Bi-Annual California IOU Metering Services Managers Info Sharing Sessions – Alternates between PG&E, SCE, and SDG&E.

5.3.2 Adaptability to Other Utilities and Industry

The findings of this project are relevant and adaptable to other utilities and the industry. The tool developed in this project has great potential to enhance operations at other utilities that have or expect to have multiple AMI systems. The benefits other utilities can achieve are similar to those targeted by

PG&E by providing a consolidated view of the different AMI networks to quickly and easily identify problems and streamlining maintenance and operations through automation which results in streamlined automated process to resolve equipment failures in the field.

5.4 Data Access

Upon request, PG&E will provide access to data collected that is consistent with the CPUC's data access requirements for EPIC data and results.

6 Next Steps

PG&E's EnMS vision is a holistic network solution that includes supporting other user groups outside of SMOC (i.e., Enterprise Network Operating Center, ESM, Asset Management) to better manage the different networks. The future EnMS will include similar functionality to the MoM tool demonstrated in EPIC 2.27 beyond the AMI Network. This includes the automatic integration of network data, GIS map based device health and utilization monitoring, the ability to collect and evaluate data for dispatch of workforce and autonomous follow-up workflow management. The EnMS will provide a centralized tool to support end-to-end integrated solutions and use-cases that meets business needs for different networks, which will enable modernization of the grid, better management of PG&E assets, reliability, and affordability through improved monitoring and analytics.

EPIC 2.27 use cases and learnings are included on PG&E's EnMS deployment road map, including use-case specifications and parameters, flow logic, AMI data retrieving, archiving, and synthesizing in order to automate work processes and improve the management of the AMI networks. This allows for the execution of these applications more quickly and cost-effectively.

7 Metrics

The following metrics were identified for this project and included in PG&E's EPIC Annual Report as potential metrics to measure project benefits at full scale.[7] Given the proof of concept nature of this EPIC project, these metrics are forward looking.

Table 2. Project Metrics

D.13-11-025, Attachment 4. List of Proposed Metrics and Potential Areas of Measurement (as applicable to a specific project or investment area)	Reference
3. Economic benefits	
Maintain / Reduce operations and maintenance costs	5.1, 5.1.1
Non-energy economic benefits	5.1, 5.1.1
5. Safety, Power Quality, and Reliability (Equipment, Electricity System)	
Outage number, frequency and duration reductions	5.1
Public safety improvement and hazard exposure reduction	4.3, 5.1
Utility worker safety improvement and hazard exposure reduction	4.3, 5.1
7. Identification of barriers or issues resolved that prevented widespread deployment of technology or strategy	
Description of the issues, project(s), and the results or outcomes	5.2.2
Increased use of cost-effective digital information and control technology to improve reliability, security, and efficiency of the electric grid (PU Code § 8360)	5.2.2
Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services (PU Code § 8360)	5.2.2
8. Effectiveness of information dissemination	
Number of information sharing forums held	5.3
Stakeholders attendance at workshops	5.3
Technology transfer	5.3
9. Adoption of EPIC technology, strategy, and research data/results by others	
Technologies available for sale in the market place (when known)	4.4

7 2015 PG&E EPIC Annual Report. Feb 29, 2016. http://www.pge.com/includes/docs/pdfs/about/environment/epic/EPICAnnualReportAttachmentA.pdf.

8 Conclusion

The project proved that an integrated AMI Network MoM system is possible and provided learnings that can be applied to PG&Es EnMS project or an alternate applicable PG&E platform. An EnMS will provide a centralized tool to support different user groups and networks in end-to-end integrated solutions and use-cases that meets business needs. The EnMS and its specific use-cases will enable modernization of the grid, better management of PG&E assets, reliability, and affordability through improved monitoring and analytics.

Project successes include demonstrating the ability to:

- Aggregate AMI data from multiple networks and provide the results on displays that allow a quick drill down to determine the specific areas or sites with issues;
- Collect and evaluate AMI meter health data such as high socket temperatures to automate and identify SmartMeter maintenance health issues, dispatch work force and autonomous follow-up workflow management;
- Remotely detect if a meter was improperly wired and initiate corrective actions to mitigate incorrect customer billing and potentially eliminate some of PG&Es current metering field inspection programs;
- Determine if the communication systems are properly functioning to ensure systems perform as expected; and
- Automatically generate and monitor follow-up work orders to resolve identified issues.

The work developed through this project can be leveraged in the EnMS tool development and will inform PG&Es broader network strategy including how to further develop and execute use-cases demonstrated in this project. This will allow for the execution of these use-cases in the EnMS more quickly and cost effectively. The two use cases developed through this project are: (1) identifying electric meter/current transformers that have been wired incorrectly; and (2) developing the fully automated process of identifying meter health and work order generation.

This project demonstrated that the integration of multiple AMI systems into a useful operations tool is doable and effective. It demonstrated that multiple types of identified issues can be summarized at a high level for awareness, then a drill down can be quickly performed to determine the specifics. This project demonstrated that the platform is capable of auto-updating data from three different AMI sources, monitor configurable performance parameters, an ability to prioritize data traffic to manage flow of data over the AMI, and automatically initiate actions such as raising alarms or creating work orders. The net result supports enhanced AMI performance, safety improvement, and potential cost reduction for utility operations.

Appendix A: Additional Displays Options

A.1 Performance and Config Widgets

Figure 32 shows widgets that display the most recent performance (measured) and configuration (set) parameters as page loads, but can be refreshed using the reload button in the top right corner of the widget window. Where supported, this refresh will occur directly against the managed device giving real-time data. Each performance parameter can highlight the value if it exceeds the assigned threshold. While outside the scope of the EPIC 2.27 use cases, the Config widget does support the ability to change editable device parameters within the dashboard widget. This eliminates the need for an operator to switch to a separate management platform. All device configuration changes made through the Config widget are recorded with information for the date and time the change was made, user's login, and previous and new values for the change made.

For the Vendor 1 APs, shown in Figure 33, the performance parameters include data for a real-time ping directly to the AP to provide immediate information regarding network quality to that specific device.

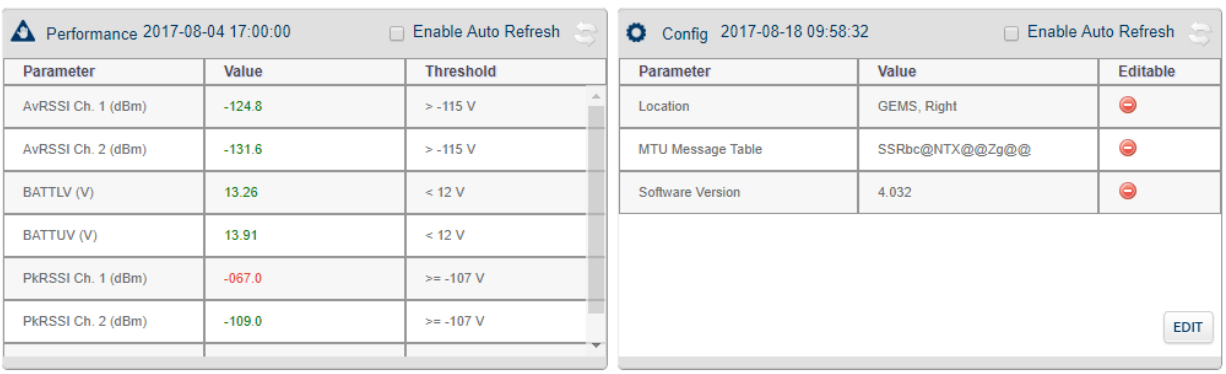


Figure 32. Vendor 2 Data Collector Performance and Config Widget Parameters

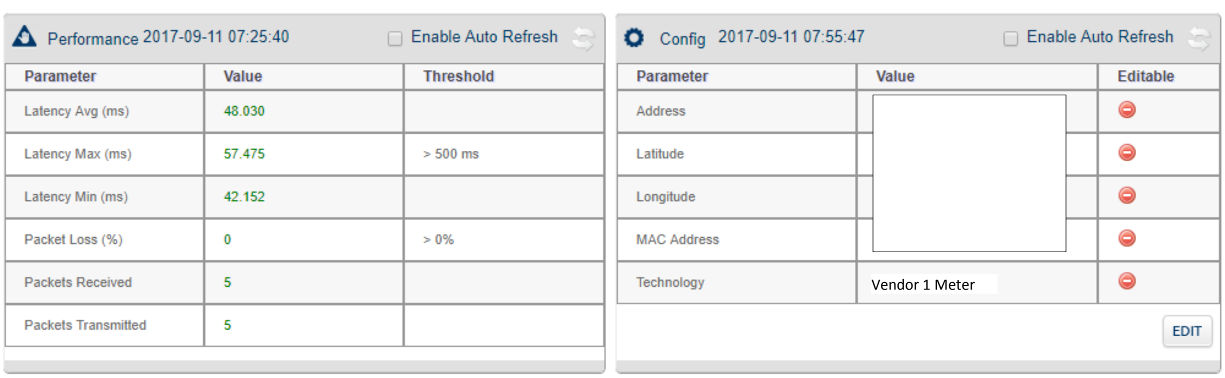


Figure 33. Vendor 1 AP Performance and Config Widget Parameters

A.2 Performance Metric Trend Widgets

The six performance trend charts in both Figure 34 and Figure 35 were added at this level to show the performance of the AMI networking elements over time. By default, they show data for the previous seven days but can also show data for the past 30 days by clicking on a link within the widget. Chart content is configurable at runtime and adapts based on element type so that APs and DCUs display distinct metrics.

Figure 34. Vendor 1 AP Health Metric Trend Reports

Figure 35. Vendor 2 Data Collector Health Metric Trend Reports

A.3 Performance and Config Widgets

Similar to the AP and DCU Performance and Config widgets, the meter devices also display performance and configuration parameters and can be updated directly form the managed device in real-time. This is shown in Figure 36 and Figure 37. For electric meters, most real-time data is retrieved by C12.19 table read and the discovery process adapts to each meter type.

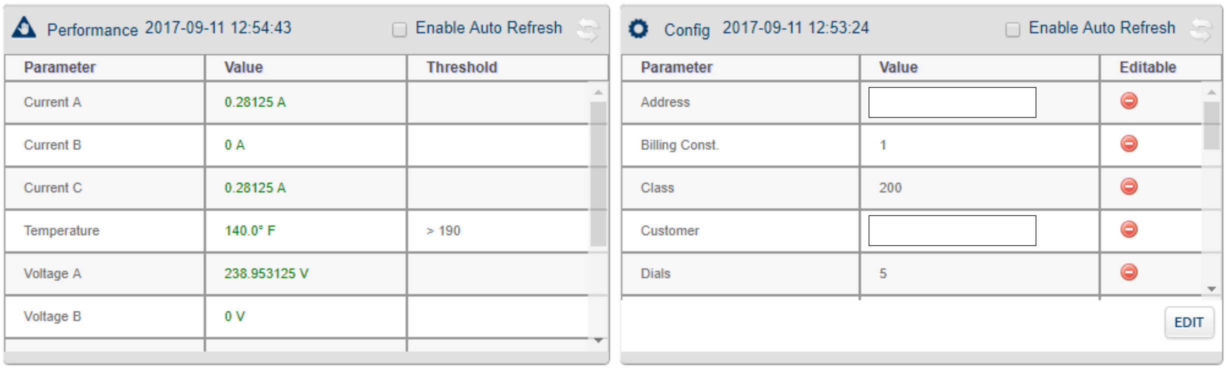


Figure 36. Vendor 1 Electric Meter Module Performance and Config Widget Parameters

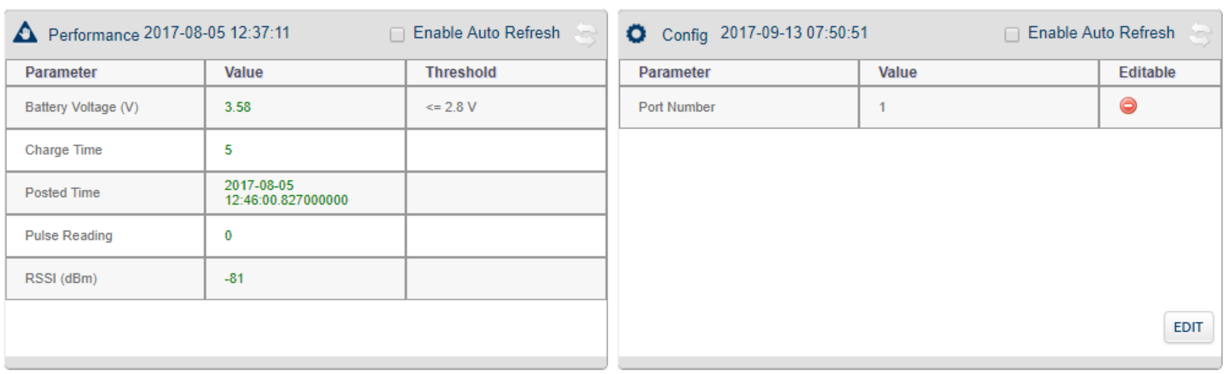


Figure 37. Vendor-2 Module Meter Transpoding Unit (MTU) Performance and Config Widget Parameters

A.4 Performance Metric Trend Widgets

For electric and gas meters, there are three base performance trend reports, as provided in Figure 38, Figure 39 and Figure 40. For electric meters, there are three additional trend reports that support the energy diversion use case which show the % voltage deviation from the average of other meters on the same transformer over time, as well as voltage and current curves compared to the five closest neighbor meters.

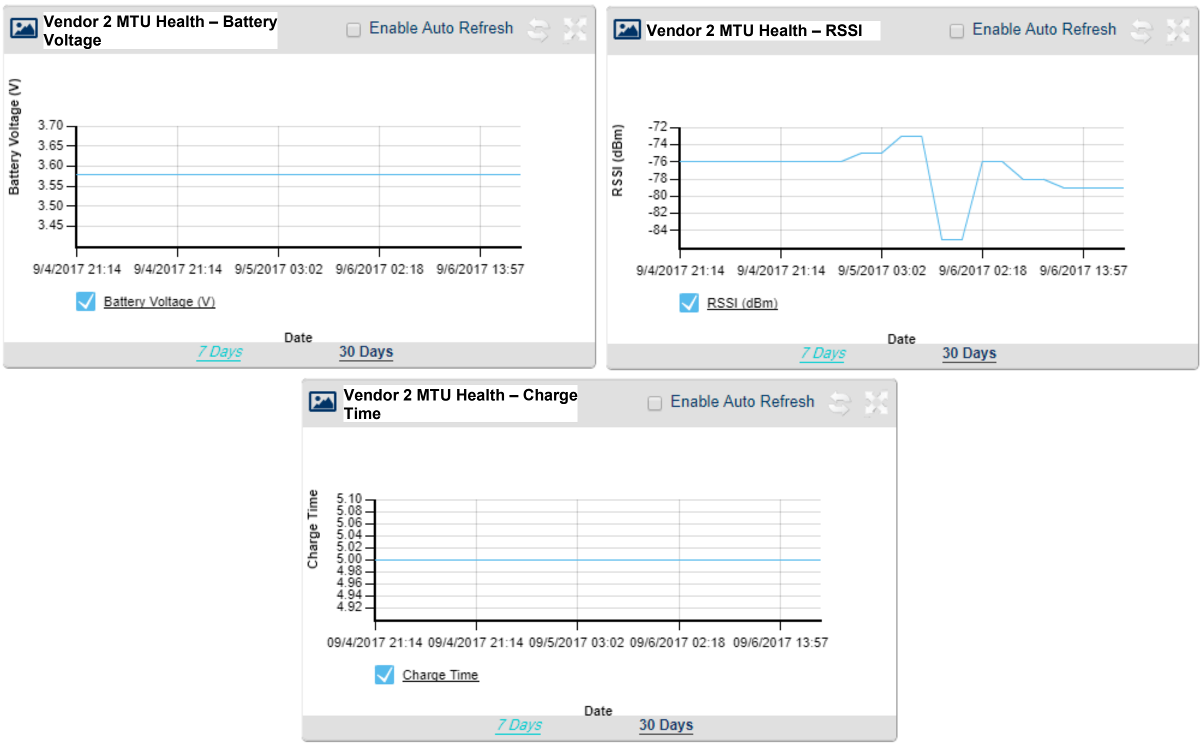


Figure 38. Vendor 2 MTU Health Trend Widgets

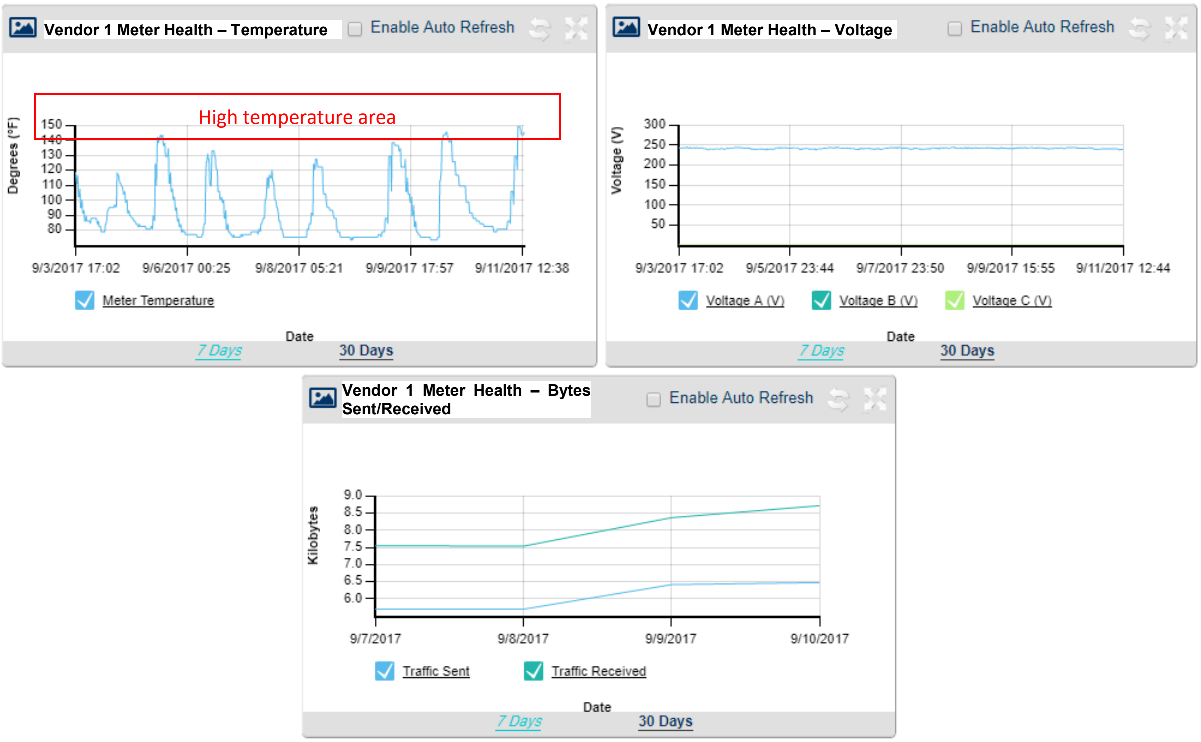


Figure 39. Vendor 1 Endpoint Health Trend Widgets

Figure 40. Vendor 1 Endpoint Health Energy Diversion Widgets