Pacific Gas and Electric Company®

PG&E's Grid Modernization

Progress Report

April 24, 2024

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I. Introduction

California is a leader in the growth of Distributed Energy Resources (DERs) including solar, battery storage, electric vehicles, and demand response. This progress is driven by a confluence of technology advancements, consumer preferences, and complementary legislative and regulatory actions in the state. Moreover, increasing climate-related risks have also accelerated the proliferation of resilience-focused DER solutions in California. PG&E plays a central role in enabling the safe and continued adoption of DERs. As of December 31, 2022, PG&E has interconnected over 700,000 Behind-the-Meter (BTM) Solar PV systems (~7 GW) over 50,00 BTM batteries (~500 MW) and ~400,000 electric vehicles.

While DERs may help achieve California's clean energy and resilience objectives, they may also potentially create new challenges and complexity on the grid including capacity constraints, power quality issues, and adverse impacts on protection systems due to bi-directional flow. In addition to the electrical complexities, there are programmatic and policy requirements that also need to be managed as the rules and regulations around DERs in PG&E's service territory continue to evolve.

Modern Operational and Planning tools and capabilities form an essential foundation for PG&E to achieve a secure, reliable, and affordable electric grid that enables clean energy and California's economic interests while providing maximum flexibility and value for customers. The goal of PG&E's grid modernization effort is to meet today's challenges while also positioning the grid to meet the demands of a dynamic energy future with improved situational awareness, operational efficiency, cybersecurity, and DER integration and orchestration capabilities.

II. Highlights of PG&E's Grid Modernization Activities in 2022-2023

This section shares PG&E's grid modernization activities and deployment projects done in 2022 and 2023.

A. Grid Management Systems

1. Advanced Distribution Management System (ADMS)

The ADMS is PG&E's core distribution operations software tool to enable visibility, control, forecasting, and analysis of a more dynamic grid. When fully deployed, the platform will bring the capabilities of today's Distribution Supervisory, Control and Data Acquisition (D-SCADA), Distribution Management System (DMS), and Outage Management System (OMS) applications into a single, integrated platform and enable many new capabilities.

The ADMS is a foundational tool that will bring far-reaching benefits to PG&E, its customers, and the distribution system. Some of the capabilities enabled by ADMS include:

- Reduced cybersecurity risk from replacement of PG&E's legacy RT-SCADA system

- Labor efficiencies from automated switching recommendations, automated switch log development, and consolidation of functionality into a single application and screen
- Reliability improvements from instantaneous fault location, automated switching recommendations, and enablement of more flexible, model-based Fault Location, Isolation, and Service Restoration (FLISR) schemes
- Improved safety from streamlined internal processes and automated detection and mitigation of overload conditions on non-telemetered points on the distribution grid
- Better quality of communication to customers during outages
- Energy savings, peak demand reduction, and greenhouse gas emissions reductions from future ADMS-managed automated Volt Var Optimization (VVO) schemes
- Improved management of Distributed Energy Resource (DER)-related grid issues through awareness of masked load associated with DER generation and the automated mitigation of DER-related thermal, voltage, and protection issues
- Enablement of Distributed Energy Resource Management System (DERMS) functionality such as the proactive dispatch of DER to mitigate real-time and forecasted grid constraints identified via the ADMS

PG&E has divided its ADMS implementation into three main “releases”, which are described in more detail below.

- **ADMS Release 1:** The scope of ADMS Release 1 is to replace PG&E’s legacy RT-SCADA system with an ADMS-based SCADA system that is integrated with PG&E’s network model. Scope for ADMS Release 1 also includes replacing PG&E’s legacy Yukon Feeder Automation (YFA) FLISR software with a native ADMS FLISR product, developing ADMS functionality to support PG&E wildfire risk mitigation efforts such as reclose blocking, implementing the Operator Training Simulator (OTS) in ADMS to assist with new Operator training.
- **ADMS Release 2:** The scope of ADMS Release 2 is to replace PG&E’s current outage management applications with OMS functionality in ADMS including outage planning, calculation of outage location and extent, crew dispatch, customer outage notification, switch log generation, and reliability reporting in a single vendor-supported product. ADMS will replace the highly custom-built and complex ecosystem of outage management applications PG&E uses today that is costly to maintain and challenging to integrate.
- **ADMS Release 3:** The scope of ADMS Release 3 is to enable Advanced Applications within the ADMS platform. PG&E’s initial focus for Release 3 will be enabling foundational integrations with Line Sensor data and implementing Enhanced Powerline Safety Setting (EPSS) and Fault Calculation functionality. PG&E’s focus will then shift to enabling Load Flow/State Estimation and Forecasting capability, which provide the ability to model real-time and predicted future power flows at any location on the distribution grid using a combination of SCADA telemetry, physical properties of network features stored in GIS and CYME, device settings stored in PowerBase, and the as-switched state of the grid as maintained in ADMS. These foundational capabilities enable many additional advanced applications on PG&E’s future roadmap including:
    - Identification of real-time and predicted future grid constraints
    - Automated switching recommendations for outages or constraint mitigation

    - Fully automated FLISR schemes, allowing faster and more flexible service restoration than PG&E’s current “rule-based” FLISR
    - Automated adjustment of voltage and power factor regulation device settings (Volt-Var Optimization)
    - Automated adjustment of protective device settings (Adaptive Protection)

Work on ADMS Release 1 during the twelve months ending in March 2024 was highlighted by the following activities:

- Cutover 8 out of 19 PG&E operating divisions to the ADMS SCADA platform
- Cutover of rules-based FLISR capabilities on the ADMS SCADA platform
- Cutover of Load Shedding functionality to the ADMS SCADA platform
- Conducted pre-cutover field point-to-point testing of SCADA signals to ensure accuracy of signal mapping into the network model
- Successful maintenance of the ADMS Network Model by the newly established ADMS support team
- Deployed regular maintenance patches and updates to the ADMS SCADA systems containing issue fixes and additional functions

Delivered continued ADMS refresher training to Operator and Engineer end users of ADMSADMS Release 1 is scheduled to conclude later in 2024 after D-SCADA functionality is cutover to the ADMS platform for the remainder of PG&E’s operating divisions.

The team is also underway with delivery of ADMS Releases 2 & 3 which had previously kicked off in parallel to Release 1. Work on ADMS Releases 2 & 3 during the twelve months ending in March 2024 was highlighted by the following activities:

- Continued the Design and Build phases of the Release 2 & 3 Network Model, which will extend the existing ADMS Network Model to include the low voltage network, customer data, load profile data, and new device settings information
- Completed the Plan & Analyze Phase for Release 2 and finalized a detailed implementation plan for the Design, Build, Test, and Cutover Phases
- Started development of key systems integrations required for Release 2
- Completed Design activities for Release 2 Planned Outage functionality and portions of Unplanned Outage functionality
- Completed Plan & Analyze activities for Release 2 PSPS functionality
- Finished contract negotiations for the System Integrator, Business Integrator, Network Model, and Product Vendor roles for Release 2
- Completed Design activities for Release 3 Enhanced Powerline Safety Setting (EPSS) functionality to be built within ADMS
- Completed Plan & Analyze activities for Release 3 Line Sensors data integration and Load Flow/State Estimation functionality
- Supported Release 3 Microgrid Enablement functionality through the Redwood Coast Airport Microgrid (RCAM) SCADA screen build
- Supported Plan, Analyze & Design activities for the 2030.5 IEEE protocol enabled by the DERMS platform

This work has set PG&E on a course for the continued success of Design, Build, and Test activities related to ADMS Release 2 & 3 functionality in 2024-2025. The Go-Live date for ADMS Release 2 is scheduled to occur in 2026. The Go-Live date for ADMS Release 3 EPSS functionality is scheduled to occur in 2024, with additional Release 3 functionality deployments anticipated in subsequent years.

2. Distributed Energy Resource Management System (DERMS)

PG&E's Enterprise Distributed Energy Resource Management System (DERMS) will complement the foundational technology improvements and grid management tools built by the Advanced Distribution Management System (ADMS) program. The DERMS will allow PG&E to manage the added operational and programmatic complexity of ever-growing Distributed Energy Resources (DERs) and DER Programs on the PG&E grid. PG&E will build a DERMS platform to deliver the following capabilities:

- Full integration with ADMS – DERMS will seamlessly integrate with the ADMS, building on the integrated network model and grid modeling capabilities provided by the core ADMS product.
- DER advanced situational awareness for normal and abnormal conditions – DERMS will provide additional DER visibility beyond what is typically included by an ADMS such as DER status, flexibility, availability, forecasted flexibility, and program insights.
- Monitoring, dispatch, and program management of DER systems – DERMS will be a secure platform that enables the monitoring and dispatch of both front-of-the-meter (FTM), behind-the-meter (BTM), and aggregated DER assets with rules based on program types.
- DER constraint management for interconnection and abnormal conditions – DERMS will manage constraints on DERs including a limited generation profile, and other more dynamic constraints including during abnormal grid configurations due to outages or planned work. DERMS will also help manage DER impacts at the Transmission and Distribution interface including coordination of wholesale market participants on the Distribution system and enable more dynamic hosting and load serving capacity.
- Operation of DER-based deferral solutions - Examples of such solutions include projects participating in the Distribution Investment Deferral Framework (DIDF) and other alternatives to conventional infrastructure investments. As the number of these projects expand, platform-based controls and processes will increase the efficiency to manage the dispatch, mitigations, and settlements of these systems.

In 2023, PG&E deployed the first phase of an enterprise DERMS providing a foundational cloud-based platform integrated with ADMS. This DERMS platform replaced the existing DER Headend deployed through the Electric Program Investment Charge (EPIC) Project 3.03 which was based on PG&E's legacy SCADA vendor that is now being transitioned to the new ADMS platform. This function enables cybersecure communications between utility systems and third party owned DERs leveraging the Institute of Electrical and Electronics Engineers (IEEE) 2030.5 protocol and the SunSpec Common Smart Inverter Profile (CSIP), and is available for all DER interconnection customers with 1MW or greater DERs. This enables DER customers to use their own certified-interoperable devices to fulfill their interconnection telemetry requirement at a lower cost than was possible with the existing options for PG&E installed, owned, and maintained telemetry equipment.

This DERMS communication platform using IEEE 2030.5 will also be leveraged for planned automated DER control testing in 2024, with an initial focus on use cases related to managing dynamic distribution grid constraints with enhanced situational awareness of grid conditions, operational forecasts of grid conditions in the hours/days ahead, and control of participating DERs including flexible loads.

These particular use cases are driven by existing capacity constraints and the timelines required for PG&E to build infrastructure to support the full load requests of customers, for example, large EV charging stations. In 2024, PG&E will be piloting DERMS functionality to establish capacity allowances for constrained customers with flexibility based on day-ahead hourly forecasts versus the status-quo planning processes that are often limited by the worst times of the year. This is expected to allow customers to connect more quickly while unlocking significant additional capacity for them by better utilizing PG&E's existing assets based on near-term load forecasts. DERMS will provide a bridge solution for these customers until the scheduled PG&E work is completed, which can sometimes be more than a year.

Initial lab testing completed in 2023 involved the baseline modeling, forecasting, and control functionality in DERMS, however, more testing and enhancements are required and planned prior to field testing in the second half of 2024. PG&E plans to field test at a limited scale (<10 sites) in 2024 flexible service connections and to operationalize PG&E's first Distribution Investment Deferral Framework (DIDF) project. Pending the results of these tests, PG&E will use learnings to modify the system, processes, and plans to scale DERMS functionality in subsequent years.

B. Communications and Cybersecurity Infrastructure

1. Communications Networks

PG&E owns and operates a large private network to service the needs of its critical operations for the Grid, Pipeline and Generation locations and personnel. It is augmented by public networks from the carriers for redundancy, enhanced coverage, less critical applications. PG&E includes the investments of the lifecycle and enhancements to these networks in the General Rate Case.

The pertinent work that PG&E has been investing in support of the Grid Modernization Plan in 2021 and 2022 and in alignment with the GRC submittal is as follows:

- Field Area Network. PG&E is continuing the installation of the Field Area Network (FAN) mesh technology as a means of increasing the data capacity, volume of devices, cyber security and remote management of grid devices. Currently, 4000 filed nodes have been installed to support SCADA enables devices managed through ADMS.

- Satellite Communications. This 3rd party service has been and continues to be deployed in more remote areas of the service territory where private networks are not economically feasible to build and where cellular networks are not available. Aside from grid devices, this technology has been used for Weather stations in support of Wildfire Threat Area situational awareness. 1300 such connections have been procured and installed.
- Cellular Connections. With the proliferation of AT&T's FirstNet and Verizon's Frontline cellular services, PG&E is taking advantage of the higher priority cellular networks and installing more SCADA devices where this service is available.
- Fiber Optic Cable Replacement. PG&E has been investing in lifecycle replacement of existing aging fiber optic cables which service the network backbone needs with high capacity.
- Lifecycle Replacements. PG&E has engaged in replacing technically obsolete communications equipment to improve the overall health, reliability, and maintainability of our communications transmission infrastructure, migrating to IP based communications. PG&E has also continued its efforts to maintain the health of its IP based routed MPLS network at the critical core operating centers and substations.
- Monitoring Tools. Additional tools have been added to consolidate functionality that was previously disparate and difficult to integrate. This improves our situational awareness and predictive event management to effectively manage a critical private network.

2. Architectural Considerations for DER Connectivity

The communications network considerations for the DER connectivity need to take into account all the requirements for a comprehensive set of data needs at a DER location, inclusive of the following: the DER core functionality (transacting with DERMS), non-functional overhead data such as cyber protocols, device remote management, communications network performance management, access control, as well as supporting native local applications such as analytics, batch reports and distributed computing needs. Additional data requirements stem from the environmental instruments at the DER location, such as physical alarms, cameras, fuel levels, weather stations, etc.

The second level of communications Network considerations is attributed to the network resiliency requirements of the DER. This would be driven by the physical location and reach, size of DER and its importance to the grid.   These types of considerations drive the network designs in terms of number of redundant network paths, mediums, constructability limitations, and availability of third-party communications service providers.

The basic premise of the communications network is IP based protocols to accommodate all the device, data and security requirements. Migrations to IP based communications enable many functions not available today such as remote software updates, increased data acquisition, and configuration updates. As these devices are converted to IP based communications and data requirements increase PG&E will need to continue to invest in new technologies to meet the growing demand. It is likely that PG&E will need to deploy emerging technologies such as private LTE, other private radio systems, and increased public carrier technologies (cellular, satellite, and leased services).

Many DERs of smaller size today are well serviced through internet connections as well as cellular services while utilizing the secure protocols described below. PG&E would only extend its private network to DER assets that it owns and operates. This private network is not considered for public DERs.

3. Cybersecurity Developments with the DER proceedings

As part of the continued work for DERs in the Rule 21 proceeding, the IOUs established a goal for the creation of the "Utility Cybersecurity Requirements Guide for Communication to DER Facilities".[1] IOU and stakeholder weekly meetings were held to discuss development of cybersecurity recommendations with final publication of the guide in the Interconnection Handbook in August 2021. In early 2022, the Smart Inverter Operationalization Working Group (SIOWG) was launched with the scope of formulating business use case prioritization. A sub-group of SIOWG was created to discuss an approach for a cybersecurity workstream. The subgroup has concluded its work and developed a working group report that includes assessment of IEEE 1547.3 and cybersecurity recommendations along with proposed regulatory guidance for the CPUC. This stakeholder effort contributed to addressing cybersecurity considerations for endpoints. This effort contributed to the development of technical standards for cybersecurity of DERs and furthers discussions for potential development of broader standards for DER stakeholders.

4. Enhanced Cybersecurity controls for ADMS

Cybersecurity controls and requirements were taken into consideration during the early design phases of Advanced Distribution Management System (ADMS) deployment. Thus, PG&E have a modern distribution grid management platform with cybersecurity embedded and not bolted-on. PG&E ADMS implementation involves extremely granular segmentations and access control both at the network and application layer. ADMS platform is implemented with multiple dedicated security directory services from Microsoft and next generation Palo Alto application aware firewalls. ADMS compute resources are subjected to continuous monitoring by the enterprise Security Information and Event Management (SIEM) platform. All remote administrative interactions with the system are brokered and monitored. Other cybersecurity capabilities extended to ADMS infrastructure includes Tenable for vulnerability management and Forescout EyeInspect for SCADA device monitoring and anomaly detection.

5. Cybersecurity for Integrated Grid Platform

[1] Rule 21, Smart Inverter Working Group Phase 2 Recommendations, Communication Requirements

Improving Operations Technology (OT) Cybersecurity will benefit PG&E, our employees, and the communities we serve. More than ever before, PG&E's Operations Technology (OT) asset landscape is being transformed considerably due to the accelerated adoption of connected smart devices with modern connected technologies. PG&E recognized the need for not to rely only on rule-based solutions but heuristic approach for early detection and alerting of anomalies in the SCADA network. This paved way for a new strategy and PG&E launched a multi-year Advanced OT (Operations Technologies) Cybersecurity program in 2019.

Key outcome - *Reinforces PG&E business values*

- Protects against an increasing, ever-evolving threat (e.g., energy sector targets on the rise, potential risk of grid control compromise, individual site takedown, or some variation)
- Addresses vital OT security needs, not just compliance (NERC CIP is a minimum baseline for limited # of assets)
- Comprehensive OT asset inventory – device properties/classification, configuration, and network context. Enable Vulnerability assessment of OT devices
- The baseline of normal communications for both IT and ICS protocols in the ICS network. Mathematical model of network life or pattern to define normalcy
- Consolidated and streamlined Alert ingestion (Integrations with asset management and SIEMs
- Multi-layer anomaly with real time alerting capability on critical and process impacting events. Ability to detect unusual engineering port, unusual time of the day, etc

The program kicked off with a pilot deployment at 10 critical Electric Transmission and Distribution sites including control centers and data centers. The program executed subsequent projects to deploy the solution at all High, Medium and low NERC sites along with critical Distribution substations.

Further, the migration from legacy SCADA to ADMS significantly enhanced the security posture by enabling centralized OT asset enumeration capabilities from Cybersecurity point of view.

6. Operational Data Network (ODN) Security Program

ODN is the industrial control system network at PG&E. ODN security program is designed to mature cybersecurity industry best practices as part of the design, build, and implementation of the new/enhance security capabilities. To enable these best practices, certain technological investments have been put in place that includes firewall upgrades, expansion and fine tuning of OT asset discovery and anomaly detection. The design and onboarding of Endpoint Detection and Response (EDR) capabilities in the OT network will significantly improve security posture of cyber assets supporting grid operations.

PG&E identified need for improving configuration management capabilities in ODN. Ansible platform was chosen to bridge the gap of Tripwire platform that serves as configuration management tool.

This investment track also enabled the design, development and adoption of NERC ECAMS capability for virtualized computes resources.

7. SORT – Security Intelligence Operations Center OT Monitoring and Response

To improve the Security Intelligence and Operations Center (SIOC)'s operational response capabilities, we have created the SIOC Opsec Response Team (SORT). This team's primary focus is on cyber threat detection and response capabilities within the OT networks at PG&E. The individuals on the team have received external training and certification (CISA/INL 301 and SANS ICS515/GRID) and are additionally working with the functional areas of the business to build relationships, understand their business processes, and develop our own response playbooks. The deployment of additional tools, such as ICS-tailored passive network monitoring and EDR, are being deployed and will further strengthen SORT's abilities to detect and respond to threats in PG&E's OT networks.

C. Engineering Software and Planning Tools

Modernization efforts for PG&E's engineering and software planning tools include:

- **Distribution Resources Plan (DRP) Tools:** The DRP required the creation and use of new tools, including Integration Capacity Analysis (ICA), the DRP Data Portal, and the ongoing analysis and publication of distribution data via the Grids Needs Assessment (GNA) and Distribution Deferral Opportunity Report DDOR annual reports:
  - ICA – The objective of ICA is to simulate the ability of individual distribution line sections to accommodate additional DERs without potentially causing issues that would impact customer reliability and power quality. PG&E has worked with a third-party vendor to operationalize ICA and incorporate intelligent quality control into the ICA process. The Rule 21 Interconnection Process has adopted the use of ICA. On select circuits monthly, ICA is performed, results are validated as-needed, circuit models are updated as-needed, and results are published.
  - DIDF – The annual Distribution Investment Deferral Framework (DIDF) includes the publication of the GNA and DDOR, hosting of Distribution Planning Advisory Group (DPAG) meetings, and coordination with an Independent Professional Engineer (IPE) and Independent Evaluator (IE).
    - The objective of the GNA is to provide transparency into the assumptions and results of the distribution planning process that yield the Candidate Deferral Opportunities shortlist, propose grid modernization investments, and proactive hosting capacity upgrades

proposed to accommodate forecast DER growth. PG&E's GNA presents data available regarding PG&E's projected distribution grid needs over a five-year planning horizon.

    - The objective of the DDOR is to utilize the GNA to identify PG&E's candidate distribution deferral opportunities shortlist. In addition, other objectives of the DDOR are to provide transparency into the assumptions and results of the distribution resources planning process that yield the DDOR candidate shortlist and provide the associated DER attributes required to meet these opportunities.

  - DRP Data Portal – The DRP Data Portal is an externally-facing, map-based portal that provides information about PG&E's distribution network, including ICA, GNA, and DDOR results.

- **Planning Tools Driven by DRP Compliance:** The scale of the data and analysis within the DRP requires specific and customized tools to process and ensure data quality and accuracy. GNA and DDOR requirements from the DRP require PG&E to make upgrades to existing planning tools, including the CYME application and the LoadSEER application. These items are driven by three main objectives: a) eliminating manual analysis and processes through automation, minimize manual application integration, and manage analysis complexities.
- **CYME Substation Modeling and Analysis:** This project will further model the substation within CYME, including but not limited to transmission protective devices at the interface between transmission and distribution, transformer banks, substation buses, and distribution breakers. Adding new substation components into the CYME model will allow for additional analyses to be performed within the CYME application. The current process requires engineers to do some of the substation-level analyses outside of CYME, either in separate protection analysis tools, spreadsheets, or on paper. Further incorporating the substation model into distribution planning software allows engineers to further study within CYME bank and feeder level upgrades, bank and feeder loss studies, substation elements of the distribution protection studies, and bank and feeder capability ratings.
- **Distribution Time-Series Analysis Phase 2:** This project will build upon the successful implementation of the CYME Time-Series Load Flow Analysis project and further automate the distribution planning process. This project will extend the existing time-series analysis to assist with Voltage Regulator and Capacitor optimization and Risk Prioritization. Additionally, this project will investigate the use of the Advanced Project Manager (APM), results from the time-series analysis, and the technoeconomic analysis module to generate standardized and templated project authorization documentation.
- **Distribution Planning Automation:** The Distribution Planning Automation project will develop a manage-by-exception analysis process within CYME for capacity planning study deficiencies. Circuit analyses will be initiated and reviewed at the dashboard level, allowing engineers to focus their review on circuits with forecasted deficiencies. Distribution planning tools will also be further integrated with two-way information flow.

The status of these projects are as follow.

- **DRP Tools:**
  - DIDF: PG&E has successfully published the GNA and DDOR Reports annually for the last six years. These reports contain over 1 million data points and include written assessments that provide transparency into PG&E's annual Distribution Planning Process (DPP). Through the DIDF process, PG&E has successfully procured, through third party vendors, 4 contracts for ~4.0 MW of distribution deferral services to replace or defer traditional wire-based projects in the Company's project planning pipeline.
  - ICA: The real-time use of Integration Capacity Analysis data within the interconnection application process of Rule 21 projects over 30 kW was implemented in September, 2022. Updates to the application system include:
    1. The ability for customers to use a typical solar photovoltaic (PV) profile for their interconnection application, instead of using the device nameplate capacity, which may allow for interconnection of larger PV projects, potentially increasing the proliferation of renewable power onto PG&E's grid.
    2. Consolidation of all generator interconnection applications and applications for service into one website including a refreshed dashboard with self-service abilities for customers to see project status down to the task level and any outstanding application issues.
    3. The ability for customers to check the available feeder capacity at a specific location and to see real-time Integration Capacity Analysis data within the application portal enabling a more accurate, efficient, and transparent assessment for interconnecting renewable DERs.
    4. Automated import of Integration Capacity Analysis values for Rule 21 projects over 30 kilowatts (kW).
    5. Direct link to refreshed maps to help applicants find information on potential sites for DERs. The maps show hosting capacity and other information about PG&E's electric distribution grid (Integration Capacity Analysis Maps). PG&E is working to add hosting capacity map information directly within the application portal, which will be more convenient to use and further streamline the process for customers.
- **Integration Capacity Analysis (ICA):**
  - PG&E has submitted its ICA Refinements Annual Report[2] in Q4, 2023. The load ICA refinements project is on track as scheduled and expected to be operational by the end of Q4, 2024. The progress, timelines, milestones, challenges and roadblocks, and solutions are provided in detail in the report. The ICA refinements will be built upon the features offered by the Long-Term Planning Tool (LTPT) and new version of LoadSEER described in the next sections. These include the load application database, projects database, and the ability to query 576 hours load forecast data at premise level. The future looking load information could include "DER forecast" and "load forecast". PG&E expects the Development phase to continue into Summer of 2024. This

[2] PG&E's ICA Refinements Annual Report, December 12, 2023

includes developing the software codes, web platforms, IT environments, creation of new data structures in databases, building of data and system interfaces, and identification of new procedures to support on-going maintenance. The Testing and Deployment phase will commence through Fall of 2024 and will happen at different stages of product development and deployment. The Support & Stabilization phase will take place throughout 2024 to monitor performance of the platform and ensure that the new stablished processes are stable.

- PG&E has been working on ICA methodology improvements on an ongoing basis, this includes but not limited to adjusting voltage fluctuations criteria to comply with IEEE standards, incorporation dynamic calculations of ICA limits for different voltage levels, modifications to processes and systems of record, automation of Rule 21 Screen L calculations and its publication on ICA portal, etc.
- PG&E has been identifying additional opportunities to modify the future ICA methodologies above and beyond the compliance requirements, this includes but not limited to modifications of the new study triggers, network hierarchy modelling to reduce unnecessary complexities, expedite calculations, and improve accuracy, modifications to voltage regulating devices modelling methodologies, parallel computing, exploring new database options to store historical data and reduce operational costs, etc.
- Rule 21 Limited Generation Profile (LGP) Use Case: LGP customers will be able to upload a 288-hour export profile into the PG&E application portal (12 month, 24 hours a month) in CSV format. These profiles will be treated as a separate category of generation and used as inputs for ICA calculations. Currently, the requirements have been captured and documented in the ICA refinements project but not implemented yet.
- PG&E has worked with CYME to identify a solution to reduce convergence issues associated with device status oscillations as recommended by ITE and reported in PG&E’s supplemental advice letter for data validation plan. CYME’s modified power-flow engine in CYME 9.3 Rev2 addressed voltage regulating device divergence issues identified in the previous statistical analysis, which is now used by PG&E to perform ICA calculations.
- PG&E has recently added a new interface on the public ICA map that indicates whether a desired location is expected to have capacity. This serves as an interim solution for “forward looking” functionality before Load ICA is refined to look at forecasted load and planned projects. It is intended to provide customers with better guidance for siting loads before going through the application process. For example, a customer may view whether their project location is likely to have either “Expected Load Interconnection Capacity” or require grid upgrades for interconnecting new load. This is made possible by utilizing a combination of existing Load ICA data and other available datasets such as forecast feeder capacity, forecast bank capacity, planned load applications, planned projects. This data was added to the PG&E data portal

on December 6, 2023, and will be updated on a quarterly basis. PG&E is providing three “Expected Load Interconnection Capacity” attributes at the line section level to support customers while Load ICA improvements are being implemented.

    - PG&E’s proposed Load ICA use case: once ICA refinements are completed there is an opportunity for using load ICA data to streamline the early stages of the load energization process where capacity planners can assess all types of new business loads, including EVs. After the Intake phase is complete, Service Planning routes the application package to the Estimating (Design) team, who works with Distribution Planning to perform a review of the proposed load request and identify what equipment and/or modifications to the electric distribution system are required to safely serve the load request. If necessary, PG&E may need to study the load request further through a detailed study based upon the project size, location, and complexity for all types of customers during the Estimating phase. Projects can experience delays due to the high volume of work and the manual nature of the Distribution Planning review process. The new ICA use case is targeted to reduce processing time: to provide ready-to-use capacity information resulting in shorter processing cycle times. A pre-assessment phase can be offered for all types of service applications. PG&E is working with internal stakeholders to put together a scope and timeline of the project. The next step is to hold internal interviews and workshops to align on an implementation plan. The result of this will determine how existing processes and tools will be adapted to using the data, how the data will interface with capacity planners, and how the data will shape the customer experience.
    - PG&E’s DRP Data Portal is operational and accessible to the public, with GNA and DDOR data published annually, and ICA data published monthly.
- **The DRP Data Access Portal is undergoing a multi-year upgrade on both platform and functionality**
    - New Platform implementation to Esri ARCGIS configured by internal PG&E GIS COE to improve
        - Resource effectiveness
        - Cost efficiency
    - Updating DRP Compliance use case found in DRP DAP 1.0 with ongoing regulatory requirements
    - Adding Electric Vehicle Use Case (For Public and internal use)
    - Adding Flexibility for:
        - Added data,
        - New map layers
        - New Use Cases in the future
    - Automation of Data Flow – Facilitate data flow while lessoning business resource impact
    - Auto-failover for our clients
        - No need for Disaster Recovery or backup clients

        - Decreased downtime for our clients
    - Client Layers Flexibility to add client layers
        - Public Layer
        - Internal Layer and Redacted layer to be added as needed
    - Optimized Software & Hardware is ongoing and managed by Esri
        - No dependency on Infrastructure upgrades and purchases

- **Planning Tools Driven by DRP Compliance**
    - PG&E adopted LoadSEER 4 in 2023, which adds numerous capabilities to PG&E's forecasting process, including:
        - Transition from SCADA to AMI meter based historical load shapes
        - Weather normalization
        - 8760 load shapes
        - Scenario based analysis
        - Automated report generation
    - PG&E will use LoadSEER to create annual Capacity GNA and DDOR reports in 2024
    - The adoption of the CYME WebApp (described further in section "Distribution Planning Automation" below) enables the automated generation of the Line Section GNA report. PG&E will use this functionality for its Line Section GNA report in 2024.
- **CYME Substation Modeling and Analysis**
    - This project is in the planning stages. The focus of current development is on integrating existing systems, creating the ability to study multiple capacity planning scenarios and furthering automation of CYME analysis.
- **Distribution Time-Series Analysis Phase 2**
    - PG&E deployed CYME's Advanced Project Manager (APM) module in 2023, which has scenario-based modeling capabilities
    - PG&E is using the CYME APM, alongside CYME's Load Flow With Profiles (LWFP) feature, for the 2023-2024 distribution planning process.
    - LoadSEER 4's 8760 load shapes allow all hours to be modeled in CYME for time series analysis
    - PG&E is scoping and prioritizing further enhancements to these tools in 2024 and 2025 to support:
        - Time-series analysis of load management and non-wires solutions
        - Scenario-based technoeconomic solution identification
        - Regulator and capacitor optimization
        - Templatized and automated project proposal documents
    - PG&E's Distribution Planning team is working with the Integrated Grid Planning team to develop risk-based prioritization of capacity projects
- **Distribution Planning Automation**
    - PG&E deployed the Distribution Planning Automation project to production in 2023, including the following components:

    - CYME Webapp Forecast Integration Tool used to complete the capacity planning process that integrates multiple systems into a single application.
    - Incoming load database of new business applications for use across multiple platforms.
    - Project Database of distribution capacity projects and transfers to reduce modeling or importing into each planning study and automate reporting.
    - Portfolio Server database of distribution capacity projects and justification to reduce manual tracking.
  - The Forecast Integration Tool is being used by PG&E Distribution Engineers for the 2023-2024 Distribution Planning Process.
  - The Project Database will be used in 2024 for investment planning
  - The Webapp will be used to support automated GNA reporting in 2024
  - PG&E is scoping and prioritizing stabilization and usability enhancements for the Webapp in 2024

D. Grid Edge Computing & Applications

While the ADMS and DERMS technologies enable awareness, control, and grid coordination in a centralized system, for first party utility owned devices and third party DERs over the web, they do not scale effectively for millions of customer end points and do not have visibility to effectively manage the secondary network.

As an example:

1. For an electrified customer with a heat pump, electric vehicle, electric hot water heater, and a home battery; all four of these devices would have to coordinate across multiple centralized aggregators to perform even the most basic customer premise energy management. This incurs cost and complexities which can be difficult if not impossible to overcome utilizing centralized solutions.
2. For a grid constraint at a secondary transformer, there is no way to communicate a limit to a customer device with ADMS or DERMS, without deploying costly remote monitoring devices with associated telemetry. This would result in a need for 100's of thousands of transformer montiors to be able to gain basic visibility into the secondary network.

As a solution to these challenges, PG&E has begun exploring capability development for Grid Edge Computing which leverages the existing communications of the Advanced Meter Infrastructure (AMI) network with incremental upgrades to enable AMI 2.0 functionality.

Due to the nascent nature of AMI 2.0 technology, our approach is to first explore the capability utilizing EPIC funds before incorporating into the General Rate Case (GRC) or other funding sources. Our first meter application focuses on a high value challenge: Panel and service upgrades driven by vehicle electrification:

- **EPIC 4.02 – Socket of the Future & Residential EV Charging [Scoping phase, set to begin deployment in 2024 Q2]**

- Deployment of a cloud server which enables the AMI 2.0 platform capability, connected to our existing AMI network. This system allows for the provisioning of applications to AMI 2.0 meters, fleet management of applications, and associated functions of computing on the meters.
- Testing and configuration of our first AMI 2.0 application which seeks to enable a customer to avoid a panel, service wire, and service transformer upgrade by sending an active site limit in near real time.
    - Customer's Electric Vehicle Service Equipment (EVSE) connects wirelessly to an AMI 2.0 meter via local Wi-Fi connection using the Open Charge Point Protocol (OCPP) for signaling.
    - EVSE responds dynamically to the limit and defaults to a safe operating limit in the case of loss of communications.
    - Begun work with three EVSE partners, with plans to publish specifications more broadly for other EVSEs that meet the communication and program requirements to participate as well.
- Minimum Viable Product (MVP) approach which will support and fund up to 1,000 meters/chargers.
    - Deployment, testing, evaluation and improvement of the experience.
    - At conclusion of the project the AMI 2.0 platform remains useable for future AMI 2.0 application development/support, it becomes a permanent business system.
    - Support for the 1,000 customers after completion of the EPIC project, and any scale beyond, would need to be funded via the General Rate Case or other appropriate long term funding mechanisms (outside of EPIC).
- Out of scope at this time, but under consideration for further development either within this project or through other EPIC projects:
    - Offering EV submetered rates to the customer by leveraging the connection established between the smart meter and the EVSE.
    - "Add-on" electrification sub panels which manage smart breakers and coordinate with the smart meter to avoid panel and service upgrades using the same logic developed for the EVSE.

In parallel to the EPIC 4.02 deployment, PG&E will develop an AMI 2.0 roadmap which will include a capability scaling and application development/deployment strategy. This strategy would:

1. Develop our perspective on Grid Edge Computing, including when, where, and how the capability interacts with the other Grid Modernization technologies.
2. Leverage EPIC and other funding sources to develop, deploy, test, and scale individual applications that provide positive value to the system. Explore other types of applications beyond those listed in EPIC 4.02, such as:
    a. Wildfire mitigation
    b. Fault location, incipient fault detection, and asset health

    c. Network model improvements such as detection of transformer phasing and/or service conductor sizing identification
    d. Customer load disaggregation, energy management, and insights
    e. DER enablement
    f. Panel and service upgrade avoidance for other use cases beyond vehicle charging (e.g. solar and energy storage, V2G, etc.)
3. Coordinate with the 2027 General Rate Case (GRC), and will take an incremental scaling approach, rather than a full "rip and replace" of the electric AMI system.

III. Other relevant activities

In addition to the highlighted activities above, PG&E has been proactively making investments to modernize the grid in the face of climate change and has continued to develop customer programs to foster the adoption of DERS and electrify traditionally fossil fuel-based energy consumption such in transportation. Below are references more information about these initiatives:

- PG&E's Wildfire Mitigation Plan
- Demand Response
- Electric Vehicle Programs
- Community Microgrid Enablement Program (CMEP)
- PG&E's Electric Program Investment Charge (EPIC) Program for applied research & development and technology demonstration.