Smart Electric Power Alliance

Encyclopedia of DERMS Functionalities

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Encyclopedia of DERMS Functionalities

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DERMS Glossary of Integration Terms

Table 1. Glossary of Integration Terms

Acronym	Title	Description
ADMS	Advanced Distribution Management System	A collection of applications including those typically associated with an outage management system (OMS), a distribution management system (DMS), and supervisory control and data acquisition (SCADA), designed to monitor, control, and manage operations and outages of a distribution network efficiently and reliably. ADMS functions can include automated fault location, isolation, and service restoration (FLISR); conservation voltage reduction, peak demand management; and volt/volt-ampere reactive (Volt/VAR) optimization.
AMI	Advanced Metering Infrastructure	A metering system that records customer consumption hourly or more frequently (i.e., every 15 minutes) and that provides for daily or more frequent transmission of measurements over a communication network to a central collection point.
API	Application Programming Interface	A software intermediary that allows two applications to talk to each other.
CIM	Customer Information Model	An abstract model that represents ALL major objects in an electric utility enterprise typically needed to model the operational aspects of that enterprise.
CIS	Customer Information System	A system that combines meter data management, customer care, and billing capabilities into a single, unified solution that supports modern utilities' customer care operations.
CRMS	Customer Relationship Management System	A technology for managing all of a company's relationships and interactions with customers and potential customers to improve business relationships to grow business. A CRM system helps companies stay connected to customers, streamline processes, and improve profitability.
DERMS	Distributed Energy Resource Management System	An application platform designed to manage device information, monitor and enable optimization and control of distributed energy resources (DERs) and demand response (DR). A DERMS must be able to aggregate, simplify, optimize, and translate DER and DR functionalities. The DERMS enables the implementation of system services to the grid.
DMS	Distribution Management System	A DMS is a decision support system that is intended to assist distribution system operators, engineers, technicians, managers, and other personnel in monitoring, controlling, and optimizing the performance of the electric distribution system without jeopardizing the safety of the field workforce and the general public while protecting electric distribution assets.
DNP	Distribution Network Protocol	The development of the distributed network protocol (DNP) was a comprehensive effort to achieve open, standards-based interoperability between substation computers, RTUs, IEDs, and master stations (except inter-master station communications) for the electric utility industry. DNP is based on the standards of the IEC TC 57, WG 03.
DRMS	Demand Response Management System	Management software that allows utilities to monitor, control, schedule, and manage a portfolio of DR programs and DERs, primarily load altering DERs such as hot water heaters, smart thermostats, and HVAC switches.
EMS	Energy Management System	Provides the fundamental information and computation capability to perform real-time network analyses, provide strategies for controlling system energy flows, and determine the most economical mix of power generation, power purchases, and sales.

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Table 1. Glossary of Integration Terms		
Acronym	**Title**	**Description**
FLISR	Fault Location, Isolation, and Service Restoration	Centralized FLISR systems use SCADA-enabled switches and sensors located at key points in the distribution system to detect an outage, locate the faulted area, isolate the fault, and restore service to unfaulted areas.
GIS	Graphical Information System	Integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information.
GMS	Generation Management System	An automated system employed for real-time operations to remotely monitor, dispatch, and control generation units.
GUI	Graphical User Interface	The interactive visual components, display screens, and operational functions available to the user to interact with the management software.
IEC	International Electrotechnical Commission	The IEC authors international standards for all electrical, electronic and related technologies. This standards collection addresses product development, performance, compatibility, and related topics in order to ensure product compatibility and environmental safety.
LMP	Locational Marginal Pricing	LMP is a pricing model that allows wholesale electric energy prices to reflect the value of electric energy at different locations, accounting for the patterns of load and generation and the physical limits of the transmission system.
MDMS	Meter Data Management System	A suite of software programs that receive and store meter data and support a host of revenue cycle and other functions (e.g., billing, outage management, and distribution engineering).
MultiSpeak	MultiSpeak	A key industry-wide standard for realizing the potential of enterprise application interoperability. The MultiSpeak Specification is the most widely applied de facto standard in North America pertaining to distribution utilities and all portions of vertically-integrated utilities except generation and power marketing.
OMS	Outage Management System	Computer-aided systems which are used by electrical distribution systems. They are primarily used by the grid and distributed system supervisors to return power to the grid. Outage management systems identify outages and provide instant alerts.
OpenADR	Open Automated Demand Response	A non-proprietary, open standardized DR interface that allows electricity providers to communicate DR signals directly to existing customers using a common language and existing communications such as the internet.
SCADA	Supervisory Control and Data Acquisition	A computer-based system for gathering and analyzing real-time data to monitor and control equipment that deals with critical and time-sensitive materials or events.
SunSpec Modbus	SunSpec Modbus	A serial communication protocol developed and published by Modicon® in 1979 for use with its programmable logic controllers (PLCs). In simple terms, it is a method used for transmitting information over serial lines between electronic devices.
VPP	Virtual Power Plant	A cloud-based distributed power plant that aggregates the capacities of heterogeneous DERs for the purposes of enhancing power generation and trading/selling power on the electricity markets

Source: SEPA. (2023).

Introduction

Overview

This encyclopedia is intended to be a guide for utilities, and their customer service, planning, operations, and/or energy supply departments, looking to implement a distributed energy resource management system (DERMS). This guide is organized using a use case and DERMS module format. SEPA, along with 12 utilities and 11 DERMS vendors, developed this encyclopedia to address common DERMS functionalities. While utilities and other energy providers may have different use cases for needing a DERMS, this guide consolidates the use cases into four major categories: Configure, Analyze & Optimize, Control, and Transact (Figure 1). These four use cases address the most common utility business needs for integrating and deriving value from distributed energy resources (DER) assets interconnected to the grid.

For the purposes of reading this encyclopedia, each module can be treated as an individual component of a DERMS system. In practice, different DERMS solutions may have functionalities that cross the different modules defined in this guide. For example, some vendor solutions address DER aggregation and the creation of a virtual power plant as one function.

This guide identifies discreet modules to clearly identify required functionality for the reader with an understanding that actual DERMS solutions may be constructed differently yet provide the same capabilities. Each module brief in this encyclopedia is organized as follows:

- **Overview**—Provides a description of the functionality including its adoption maturity and how the module interacts with other DERMS modules. Addresses types of DERs supported.
- **Market Availability**—Discusses how the functionality has been adopted in the marketplace and provides examples of where utilities have deployed the functionality.
- **Technical Considerations**—Provides a high-level discussion of any technical considerations specific to the module including any prerequisites required to support the module, key integrations, and data requirements.

The encyclopedia contains information on vendor support for the various DERMS modules through utility case studies and a high-level market assessment. This initiative obtained vendor information by first developing an initial list of potential DERMS vendors. This list was vetted with the Collaborative Team to arrive at a final list of vendors to research. This list included AutoGrid, Doosan GridTech, EnergyHub, GE Grid Solutions, Generac Grid Services (Enbala), Hitachi Energy, mPrest, OATI, Oracle, OSI, PXiSE, Schneider Electric, Siemens, and Smarter Grid Solutions (SGS).

Figure 1. DERMS Module Inventory by Use Case

Configure	Analyze & Optimize	Control	Transact
Registration	Monitoring/Estimating	Scheduling/Dispatch	Aggregator Data Exchange
Asset Configuration/Modeling	Optimization	Grid Management	Bidding
	Forecasting	Virtual Power Plant	Settlement
	Measurement & Verification	Renewable Smoothing	Transactive Energy
	Aggregation	Curtailment	
		Resilience/Microgrids	
		Demand Response	
		Volt/VAR Optimization	

Source: SEPA. (2023).

Additionally, this encyclopedia builds upon the functionalities identified in SEPA's "Distributed Energy Resource Management System (DERMS) Requirements Version 2.0" report. The "DERMS Requirements 2.0" document highlights key functionalities such as user interfaces, display dashboards, data processing, reporting structures, and other software requirements that utilities expect from DERMS vendors. A team of utilities, solution providers, and industry stakeholders created the "DERMS Requirements 2.0" guide, and representatives from Southern California Edison, Duke Energy, and ComEd co-led its development. Together, this encyclopedia and the requirements guide offer utilities a strong foundation for understanding their DERMS needs.

Common Architecture for DERMS Implementation

While different use cases do not require full DERMS functionality, any DERMS is likely to require integrations to legacy utility systems, market systems, and different communication channels to the individual DERs (Figure 2). DERMS can communicate with behind-the-meter (BTM) and front-of-the-meter (FTM) DERs through third-party aggregators, directly communicate to devices, or use various types of distributed controllers. However, most DERMS communication with BTM customer DERs will typically involve either a third-party aggregator or the DER device manufacturer. In contrast, a DERMS likely communicates with FTM utility DERs via a distributed controller or communicates directly to the device through a variety of communication protocols (e.g., SunSpec Modbus, DNP3, 2030.5, etc.).

DER communications are a key component for integrating DERs into a utility DERMS and should be considered from the onset of a DERMS implementation project. This encyclopedia makes multiple references to the need for utilities to establish a systems/communications architecture that aligns to DER asset capabilities as key prerequisite for realizing the value that can be created from DERMS systems. Additionally, each module brief in the encyclopedia contains information on key integrations and data needed for that module.

ADMS vs. DERMS

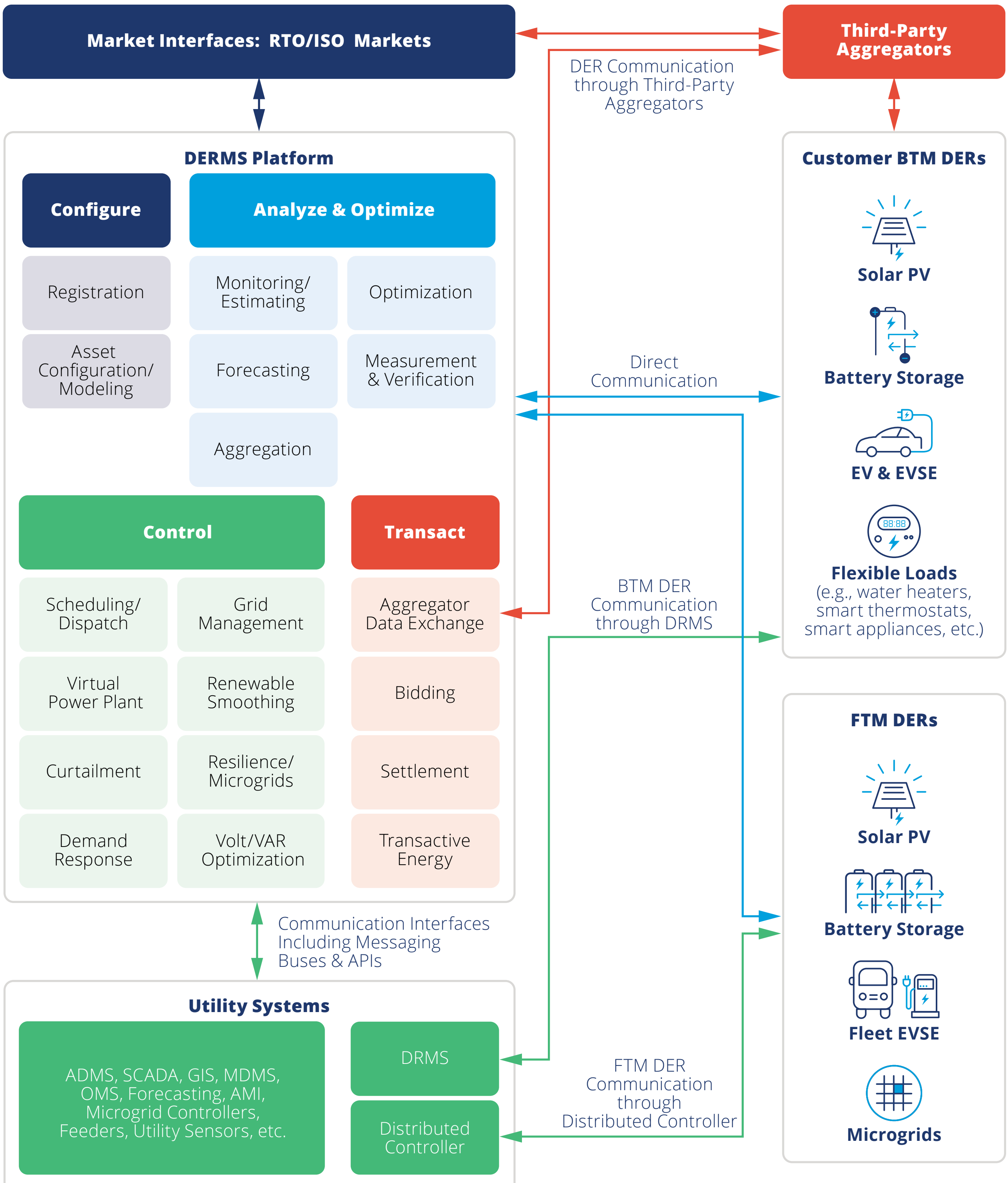
Integration to an Advanced Distribution Management System (ADMS) is one major DERMS integration identified in many of the module briefs. ADMS is linked to the discussion on DERMS given the close coupling of the two as distribution control systems. In fact, the industry has not reached consensus on the relative role of these two systems. ADMS systems are software-based platforms originally intended as next generation outage management systems (OMS) that also provide distribution situational awareness. Situational awareness refers to the ability of operators to visualize the system network through a network model of all the utility owned/controlled assets (capacitor banks, relays, fuses, fault indicators, reclosers, switches, breakers, tap changers, etc.) displayed in a topographical and/or system one-line display. Utility operators use an ADMS to run power flow on the "as -operated" network with the primary purpose of ensuring grid safety and reliability. Advanced functions can include fault location, isolation and service restoration (FLISR), conservation voltage reduction, peak demand management, and volt/volt-ampere reactive (volt-VAR) optimization.[1] ADMS systems commonly integrate with other utility systems such as GIS, DSCADA, and AMI.

A DERMS differs from an ADMS in several ways. Foremost, a DERMS is created exclusively for managing FTM or BTM DERs owned by the utility or by customers. A DERMS will also typically manage programmatic information related to DER devices and may include registration or enrollment functions that would be accessed by a customer or a third-party. A DERMS attempts to optimize those DER resources based on economic or environmental parameters to provide customer or grid services. DERMS can do this optimization for all DERs or for DERs on specific feeders as needed for different grid conditions and/or planned DER events.

The lines between ADMS and DERMS blur as utilities look to manage DERs and traditional grid assets in a holistic fashion. Doing so requires a network connectivity model that includes all the DERs on the network such that power flow can be run on all assets. This requires tight integration between ADMS and DERMS and introduces questions around which system owns the network model and runs power flow. Most vendors offering ADMS solutions now also offer DERMS solutions that are modules of their ADMS or are built to leverage power flow capabilities of an ADMS. The coupling of a DERMS to an ADMS will depend on the use case and whether the full functionality is reliant on a power flow model. Once the use case is determined, various deployment models can exist where both the ADMS and DERMS are operated in a coordinated fashion.

1 U.S. Department of Energy. (2015). Voices of Experience. Insights into Advanced Distribution Management Systems.

Figure 2. Architecture Diagram for DERMS Integration



Source: SEPA. (2023).

DRMS vs. DERMS

Another notable utility system is the demand response management system (DRMS). DRMS systems are often legacy systems designed to target a utility's day-head and bulk system needs using BTM assets that can alter load. DRMS systems typically provide an "all or nothing" impact meaning all DERs are controlled at once for a full system impact with no ability to provide locational impact. As utilities move to more real-time control and management of DERs, the functionalities of DRMS systems have become more sophisticated and similar in function to a DERMS. While both types of system can monitor, control, and dispatch DERs, DERMS systems can better integrate and utilize real-time data and perform advanced functions related to Volt/VAR optimization, renewable smoothing, ancillary services, curtailment, and transactive energy exchanges. Many DRMS suppliers have modules and/or DERMS offerings and the distinction between the two systems have become less clear. DERMS is often seen as the next step from a DRMS system.

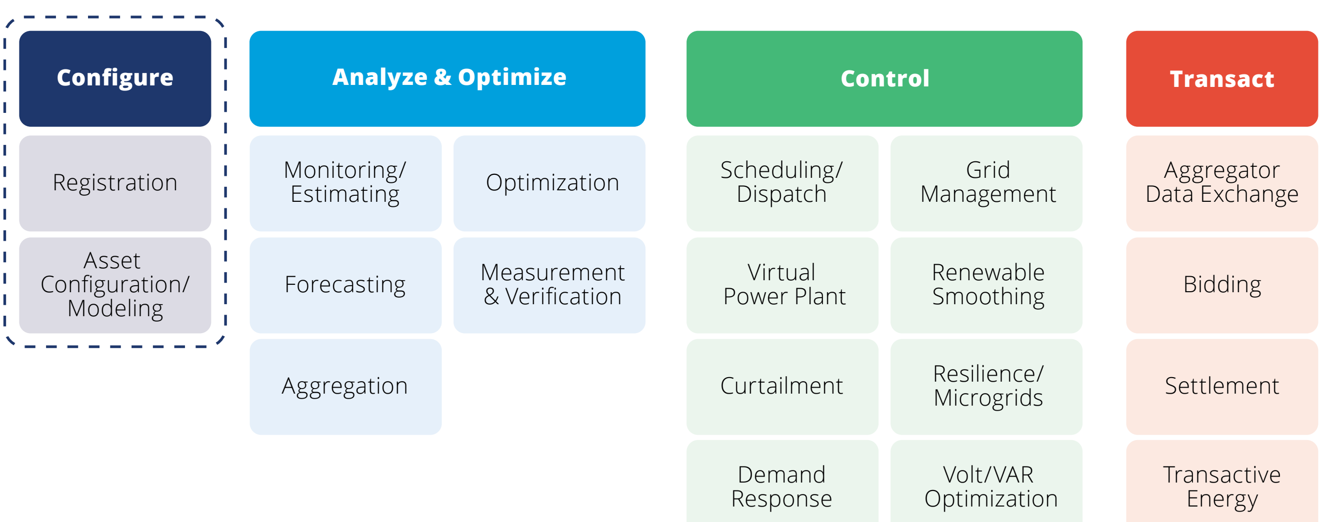
DERMS implementations heavily rely on integrations to other utility systems and the close coupling of the DERMS with ADMS and/or DRMS systems can blur the lines among the systems. The industry has not yet reached consensus on the relative role of DERMS, ADMS, and DRMS.

Configure

The Configure use case includes registration of DERs and the modeling of individual and grouped DERs to support other DERMS functions. DER configuration is the first step to integrating DERs into the grid system, viewing them on the network model, and determining their overall impact and flexibility for grid services. This use case involves obtaining registration information for the DER, which often includes nameplate capacity, operational set-points, and programmatic information such as participation in demand response (DR) or ancillary service programs. By configuring all DER data in the DERMS system, the utility and/or third-party aggregator can view the various devices in the system, especially grid-edge and behind the meter assets. Device configuration also allows for more efficient DER groupings, which improves both utility control over the assets and data exchange between the utility and third-party aggregators and between third-party aggregators and other service providers or the market. Through this use case, a utility operator can visualize the registered DER topographically within the utility's network model. Configuration consists of use cases that give insight into DERs, but do not necessarily allow for direct control.

The modules included in the configuration category are Registration and Asset Configuration.

Figure 3. DERMS Module Inventory by Use Case: Configure Capabilities



Source: SEPA. (2023).

Registration

Concept | Emerging | Deployment

Overview

A key function of any DERMS is capturing relevant asset, programmatic, and network information to provide utilities with increased visibility into DERs. This includes DERs participating in utility programs, utility owned and operated DERs, DERs participating in independent system operator (ISO)/regional transmission operator (RTO) programs, or third-party aggregated DERs including those aggregated under FERC Order 2222 tariffs. Information categories include:

- **Asset Information:** Nameplate or Technical Information (including communication and control component information).
- **Programmatic Information:** Ownership and Account Information, programs including operational constraints or requirements, aggregator ID or other third-party identifier, and program limitations that prevent DERs from being utilized in multiple programs.
- **Network Information:** Static device information including location, feeding line/circuit, load zone, access codes, encryption keys, etc.

The DERMS utilizes this registration information for the dual purposes of feeding DER information to the other DERMS use cases of Analyze & Optimize, Control, and Transact and to enroll customer DERs into utility programs.

DER registration data may be input directly into the DERMS registration module via the system graphical user interface (GUI)/common information model (CIM) or provided via interface from another system such as a customer information system (CIS)/customer relationship management system (CRMS) or standalone registration/enrollment system. Devices can also auto-register when they are installed if the device and communication network support this function. A specific example of this registration capability is the management of DERs participating in utility sponsored programs such as DR programs or utility management programs such as those supporting export limit control, flexible interconnections, and other device management services. In the case of demand reponse enrollment, DER data is available from customers either enrolling in the program through an enrollment portal or through data exchanges with device manufacturers, called original equipment manufacturers (OEMs), who enroll at the customer's request, or through third-party enrollment and outreach vendors. Utility operated DER data also may be available from interconnection applications, as seen with larger commercial and industrial (C&I) customers, or need to be entered manually based on nameplate data for the individual DERs, as typically seen with FTM utility assets. The source of registration data will likely be determined by whether the DER is owned or controlled by the utility and whether it is smaller and located BTM or larger and installed FTM.

In the case of utility sponsored programs, customers and third-parties often use an online portal to register the customer's DER(s). The portal can verify customer eligibility automatically, necessitating knowledge of the program requirements. Some device manufacturers, such as those for smart thermostats, customer battery systems, or EVSE devices, act as the customer-facing entity for both device registration and participation management. Customers register the device on the manufacturer's online portal and the manufacturer interfaces between the device and the DERMS through APIs and other communication protocols. Thus, many BTM DER are fully provisioned and operated by a third-party with their own registration portal. Device asset and location data, regardless of the source, can be used for visualizations, analysis, and market transactions.

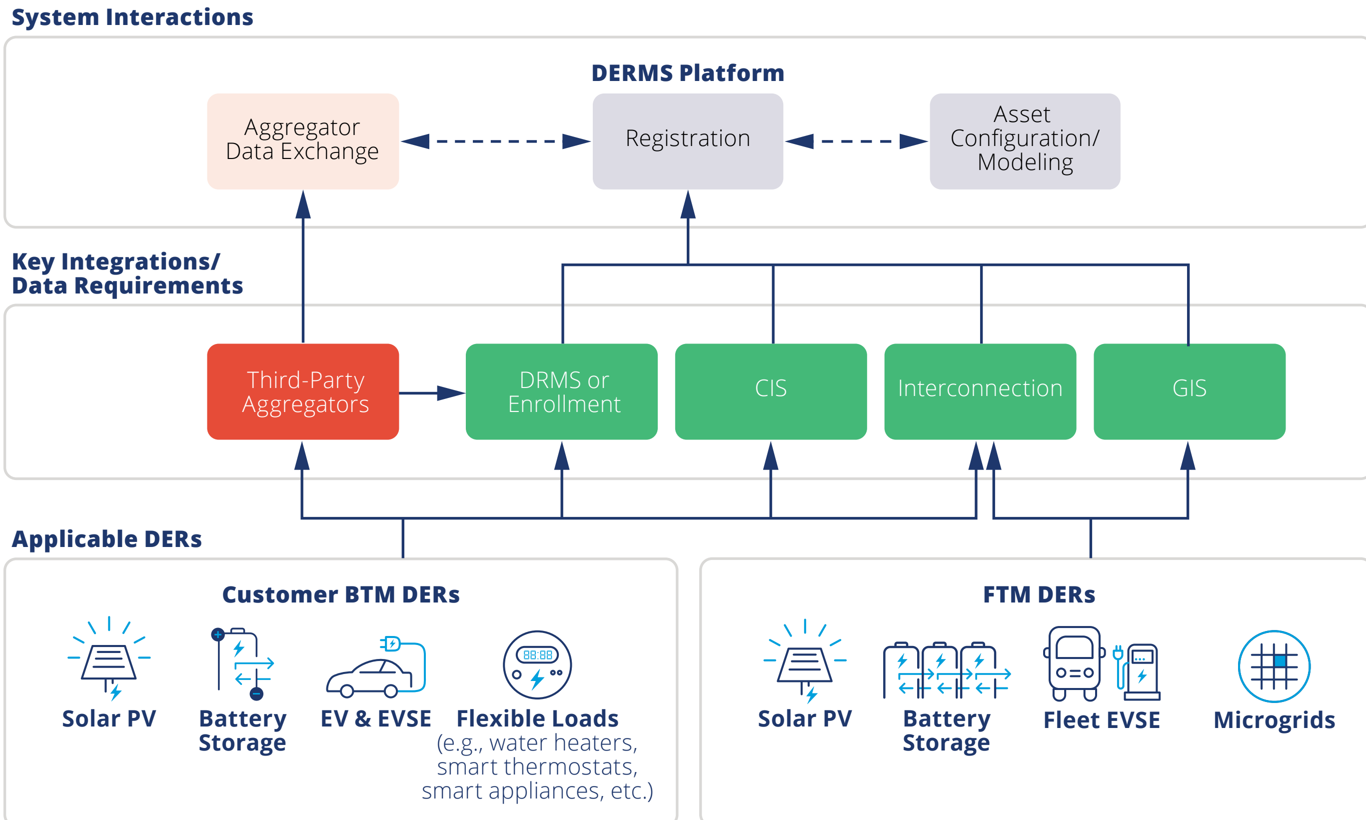
System Interaction

DER information is typically first captured in the Registration module. The DER's device information is fed into the DERMS system through an enrollment portal used by customers or a third-party aggregator, direct input by a utility operator, or via integration to a CIS, the DER's device information is fed into the DERMS system. The Registration module primarily interacts with the Asset Configuration & Modeling module where DER device and programmatic data is combined with locational information and other DER attribute data. As a solo module, the Registration module allows the utility to update its system of records with BTM and FTM assets. When coupled with Asset Configuration & Modeling, the Registration module's information on operational set points, programmatic availability, and capabilities can be used to update the utility's network model and provide higher level insights into how the DERs interact with the grid.

Supported DER Types

The registration function is intended to support all types of DERs whether located BTM or FTM.

Figure 4. Key Integrations and System Interactions with the Registration Module



Source: SEPA. (2023).

Pipeline Stage

This functionality is in the **deployment stage** as DR and DER technologies become sufficiently mature to participate in utility programs.

Market Availability

Market Adoption

Deployment is dominated by a few key players.

A handful of major players who initially provided DRMS solutions dominate the vendor landscape for this functionality. As more fully functioning DERMS systems have been developed, DER Registration functionality has been incorporated along with the existing DR enrollment capability.

Example Applications

Registration functionality has primarily been used by utilities that have implemented a DER program. The most common example of this is in DR programs where an enrollment function is required.

- **AVANGRID (NYSE&G, RG&E)** uses EnergyHub's DERMS platform to enable customer enrollment of thermostats and window air conditioning units in their Smart Savings Rewards program.[2]
- **CPS Energy** works with Resideo and EnergyHub to enroll customers into their WIFI Thermostat Rewards Program.[3]
- **El Paso Electric** uses EnergyHub's Mercury DERMS to manage customer enrollment and validate eligibility for their bring-your-own-thermostat (BYOT) program.[4]

2 EnergyHub. (Dec. 2017). EnergyHub and AVANGRID successfully complete first season of 'Smart Savings Rewards' program.
3 EnergyHub. (March 2017). CPS Energy and Nest connect with customers to increase demand response enrollment.
4 EnergyHub. (May 2017). EnergyHub launches Bring Your Own Thermostat demand response program with El Paso Electric.

- **LA Department of Water and Power** manages and validates customer enrollment in their BYOT summer program through EnergyHub's DERMS.[5]
- **New Hampshire Electric Cooperative** has implemented AutoGrid's customer enrollment portal for their residential and commercial DR program.[6]
- **National Rural Telecommunications Cooperative** has partnered with AutoGrid to use its Flex DERMS platform to enroll customer DERs into programs for grid services such as DR and load shifting, coincidental peak management, renewables integration, and other AI-based analytics and optimization capabilities.[7]
- **Southern California Edison** is piloting "Transactive Energy," as part of the DOE EASE Project, with Smarter Grid Solutions' (SGS) DERMS system which would allow customer participation in wholesale markets. The platform combines DER permitting and interconnection processes for SCE and assigns each new DER a unique digital ID with a "self-provisioning" process that connects them to SCE's centralized distribution grid control platform.[8]

Technical Considerations

Pre-Requisites

Architectural and security standards must be in place to guide integrations especially since customer data can be involved.

Key Integrations and Data Requirements

Registration can be programmed within the DERMS system or can be a standalone system integrated into a DERMS. Cybersecurity is the primary motive for keeping registration in a standalone system. This is especially true if customers and third-parties would be accessing the system to input DER registration data, as may be the case for customers participating in utility DER programs. In the case of a standalone system, the key architectural consideration is development of the interface between the two systems, including the process and/or requirements for updating data as DERs are registered. Ideally this interface would leverage established APIs supported by the vendor DERMS.

Cybersecurity, ease-of-use, and branding are the key architectural considerations when utilizing the native registration functionality of a DERMS. In this scenario, the registration module may also serve as the customer enrollment interface and be embedded within the utility website. Customers and aggregators would access the tool to register their DER assets. Some DERMS vendors offer this customer portal functionality as part of their system, with their own cybersecurity protocols for customer interfacing. Others offer completely different user interfaces for customer registration rather than combining the interface with utility owned and managed DERs.

Integration requirements depend on whether registration will be a standalone system or occur within the DERMS. In either scenario, integration with a utility or third-party enrollment/registration system or the utility customer information system (for DERs participating in utility programs) is required. Integration to the utility interconnection processing system or a geographic information system (GIS) may be required to capture non-program participating DER data. The registration information that is collected should follow IEEE Standards 2030.11-2021's recommendations including nameplate information, communication information, installation information, electrical location, device settings and interconnection rating, in/out service dates, and DER modeling information. Additional data to be collected could include aggregation/aggregator information, operational limits (export limits, ramp rate limits, time-based schedules), meter information, or customer or participating utility or ISO/RTO program, if applicable.

5 EnergyHub. (Oct. 2020). Los Angeles Department of Water and Power and EnergyHub enroll over 16,000 thermostats in BYOT program, targeting 25 MW of flexible capacity.

6 AutoGrid. (Apr. 2016). New Hampshire Electric Cooperative Goes Live with Three New Residential and Small and Medium-Sized Business Demand Response Programs Using AutoGrid DROMS.

7 National Rural Telecommunications Cooperative. (n.d.). Monitor and manage behind-the-meter distributed energy resources.

8 Renewable Energy World. (July 2020). Southern California Edison launches transactiveenergy pilot using customer-sited DER.

Asset Configuration & Modeling

Overview

A DERMS can enable utilities to digitally model, visualize, optimize, and control FTM and BTM DERs. Before a DERMS can visualize, optimize, or control DERs, it must first have data on the DERs connected to the grid. A DERMS typically does this in one or both of the following ways:

1. Registration and Configuration of individual DER assets
2. Modeling DERs in the larger distribution network connectivity model

Configuration of individual DERs involves collecting DER asset, programmatic, and network data (see Registration Module) for use in other DERMS functions. The data required for the DERMS optimization engine to initiate control schemes based on different operational objectives that leverage DER capabilities is crucial.

Modeling DER electrical characteristics and attributes in the network connectivity model allows distribution operators/dispatchers to view and control DERs alongside traditional utility assets. Electrical attributes include:

- Smart inverter set points
- Operational maximum and minimum device set points
- Current connectivity to the grid
- Programmatic information that influences how much of the device is available for a given network configuration

Distribution planners can use this consolidated network model to improve load forecasting capabilities and to conduct load flow calculations. A DERMS may include the consolidated network model or it may only maintain DER configuration data and interface with an advanced distribution management system (ADMS), GIS, or planning tool (such as CYME, etc.) that maintains the network model. The chosen deployment model impacts what grid services functions the DERMS provides and which the ADMS or other control system provides. Leveraging the existing utility assets or running a digital twin network model within a DERMS will depend on both the vendor capabilities and the individual implementation choices made by the utility.

DER configuration and modeling potentially involve organizing vast quantities of data from a wide range of assets for the DERMS to utilize. This can involve integration to other utility systems. Assets can be incorporated into the network model at the same level of granularity of the existing model. Larger assets would likely be added first, then the remaining FTM assets, followed by BTM assets as needed. The DER configuration data must be updated continually as optimization occurs and DER parameters change. This dynamic function is a core capability that supports many other functions within the system. An internal dynamic configuration loop allows the system to automatically ingest information from the DER model to determine how a particular DER should be operated (e.g., for outage control, minimizing customer billing, ancillary services, aggregation bundles, etc.) and update the DER record. These operational parameters, including relevant aggregation information, can be useful for operational and planning purposes and should be regularly updated to reflect the most up to date system.

System Interaction

The Asset Configuration & Modeling Module pulls data from the Registration module and directly from existing utility systems that maintain distribution network connectivity information such as demand management systems (DMS), ADMS, and GIS. Many downstream modules utilize information from the Asset Configuration & Modeling Module including the Aggregation, Forecasting, and Optimization modules and the Control Modules. The Aggregation module utilizes individual asset information to create new DER aggregation groups, which are often needed for the Control modules to more accurately utilize the DERs. The Forecasting and Optimization modules use the configuration settings to analyze the DER landscape and send those calculations further downstream to the other modules.

DER Types

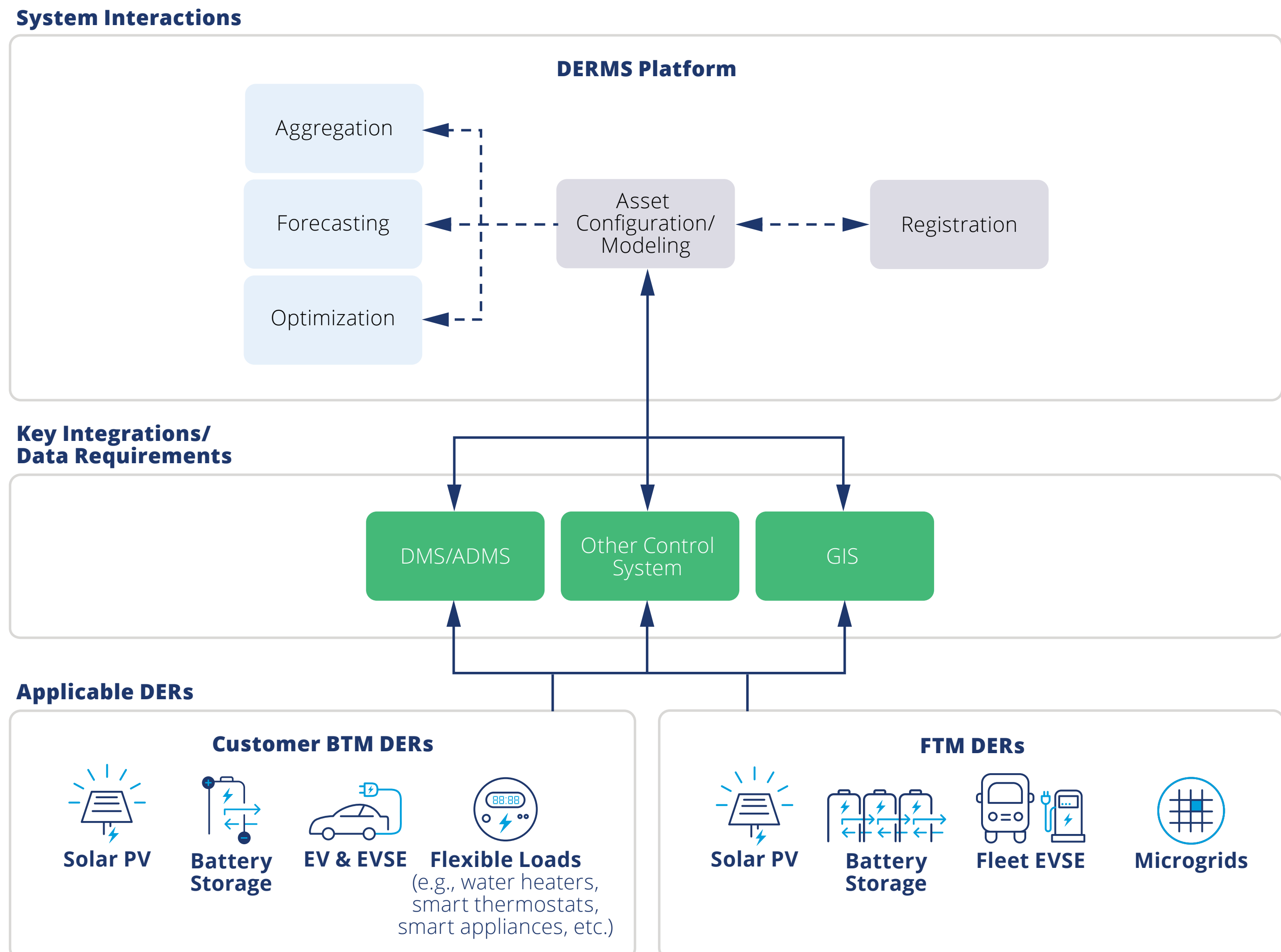
The Asset Configuration & Modeling function is intended to support all types of DERs whether located BTM or FTM.

Pipeline Stage

The modeling functionality is in the **emerging stage**.

Parts of the functionality are already established and others are still being piloted. DER asset modeling on a topological map to enable visibility into operation is an established functionality. Incorporating those models into the overall distribution network model commonly seen in the ADMS system is still considered an emerging area.

Figure 5. Key Integrations and System Interactions with the Asset Configuration & Modeling Module



Source: SEPA. (2023).

Market Availability

Market Adoption

Asset configuration & modeling functions are mature across the different vendors.

Providing DER visibility has been a priority for most of the DERMS that have been implemented to date. The market for modeling DERs used in DR such as smart thermostats is fairly mature. Modeling of DERs in the distribution connectivity model is less developed as industry reconciles how to interconnect the DERMS digital model with the ADMS network connectivity model.

Example Applications

- **LA Department of Water and Power** uses EnergyHub to build individual DER asset models to optimize control in their BYOT program.[9]
- **PG&E's** Electric Program Investment Charge (EPIC) DERMS pilot (EPIC 2.02 - Distributed Energy Resource Management System) was a field demonstration of optimized control of a portfolio of third-party aggregated BTM solar and energy storage and utility FTM energy storage resources. The project utilized a DERMS from GE Grid Solutions integrated with an ADMS, where the electrical connectivity model was maintained.[10]

9 EnergyHub. (Oct. 2020). Los Angeles Department of Water and Power and EnergyHub enroll over 16,000 thermostats in BYOT program, targeting 25 MW of flexible capacity.

10 Pacific Gas and Electric Company. (Jan. 2019). EPIC Final Report.

- **PSE&G** integrated their OSI demand management system (DMS) and DERMS with DER modeling as a key function of the latter system.[11]
- **PPL**, in their DOE funded Keystone Solar Future Project, made their GE DMS "DER aware" by capturing DER geographic, operational, and system impact information in its FLISR and volt/VAR optimization (VVO) applications. FLISR functionality was improved by accounting for masked load and VVO was improvised by including DER as part of the control scheme.[12]

Technical Considerations

Prerequisites

Individual DER asset data is required in order to be modeled in a DERMS. Absent an existing DERMS, this data may be maintained in the utility CIS or GIS or could also be accessed through interconnection requests.

A solid, validated network model is required for a DERMS providing grid services. Arriving at this point may be an evolution as network model anomalies are found and corrected. Developing a clean network model is a non-trivial task. In their EPIC project learnings, PG&E noted that the project had to install an ADMS and resolve multiple data quality and utility equipment field telemetry issues just to enable DERMS. Similarly, if the as-operated network model is shared between applications, considerations should be given to the process and technical requirements for keeping the model updated and synchronized between systems.

Key Integrations and Data Requirements

To support DER asset modeling, the DERMS needs to obtain DER nameplate information as well as ownership, status, grouping, monitoring, and dispatch of controls and autonomous settings information. This information is typically available from interconnection systems, customer information systems, or from the GIS. Some utilities may utilize the DERMS as the system of record for DER data following complete data migration of legacy DER data. Ideally, the integration between the DERMS and these systems would be electronic with automated updates, especially as DER penetrations increase. If DERMS will serve as the system of record for this data, these interfaces can be eliminated once all legacy DER data is migrated.

The distribution network model represents all the devices and equipment physically installed in the distribution system, including key electric attribute data on those various devices. The GIS is typically the official system of record for the "as-designed" or "as-built" version of this information. From there the network model is commonly integrated with a demand management system (DMS), ADMS, DERMS, or distribution planning system. ConEd in their Distributed System Implementation Plan states, "The GIS will offer one consolidated mapping and visualization system that stores the physical location and other operating characteristics of facilities and assets, including DER. It maintains the as-built model of the electric and gas distribution systems. When fully built, it will be the backbone for the connectivity model that shares information and provides feedback across the grid and will enable… advanced analytic capability when integrated with other systems."

A DMS or ADMS updates the network model to reflect the "as-operated" state of the network accounting for the actual operational status of devices, maintenance, outages, and switching operations. A DERMS needs access to this as-operated model to perform certain grid services functions such as power quality management and constraint management (see Control modules for more examples). In these cases, the network model may be shared between ADMS and DERMS, with the ADMS system often maintaining operational priority over the network model. Some utilities are considering the distribution common information model (CIM) as an approach to share the network model regardless of which system "owns" it. Regardless of which system maintains the as-operated network model, DER data from each device such as electrical impedances, fault contribution, thermal limits, and other information is required. When one system, such as an ADMS, maintains the as-operated network model, tight integration with the DERMS is required with clear business rules established for what functions should reside in each system. This will also define integration requirements and the system of record for DER data.

A platform that can manage large quantities of data over time is paramount. A large amount of operational information about each DER will be gathered, such as its switching patterns, state of charge patterns, failures, etc. The DERMS modeling capability must use this information along with other information such as the weather, economy, etc. Deployment of a DERMS should provide a means of managing the large amount of operational data that will be gathered from the Asset Configuration & Modeling module.

11 OSI. (Jan 2018). New Jersey's PSE&G Selects OSI's Distribution Management System and DERMS.

12 Smart Electric Power Alliance. (Jan. 2021). Insights from PPL's DERMS Implementation.

Analyze & Optimize

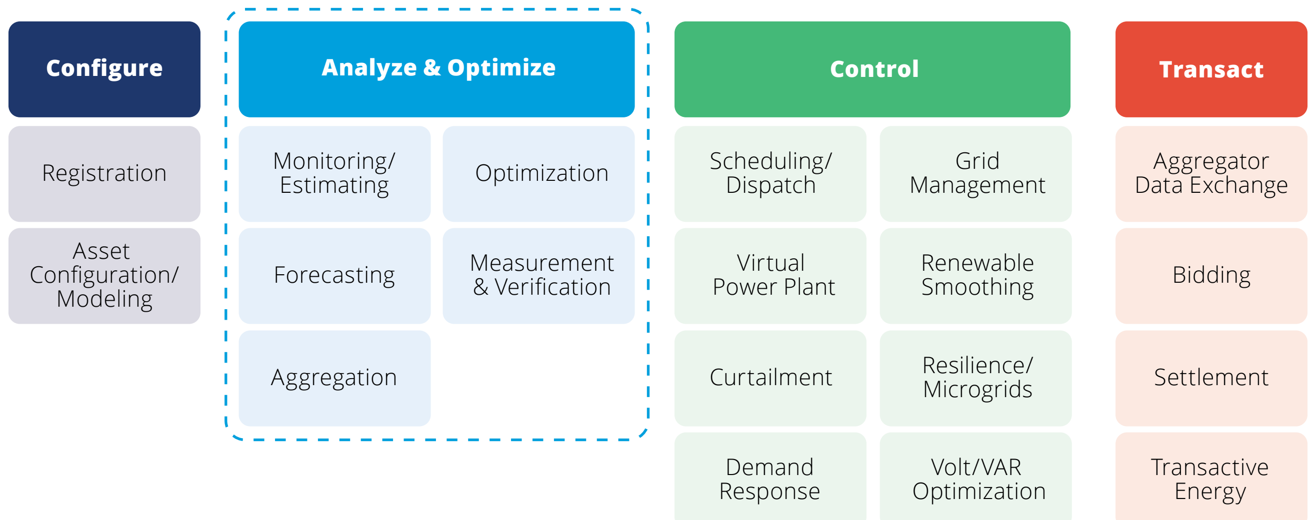
The Analyze & Optimize modules provide advanced capabilities for utilizing and integrating DERs into the grid. Analyze & Optimize modules of a DERMS involve monitoring, aggregating, forecasting, and visualizing DER asset data for real-time operations and future utility planning. This set of modules also includes the optimization engine used to instruct how all subsequent DERMS functions best utilize the capabilities of DERs. Lastly, measurement and verification functions provide after the fact analysis used for a variety of commercial/financial transactions.

All of these modules utilize the information from the Configure Modules in order to perform the DER analysis. Analyze & Optimize functions need data about the DERs in order to perform their functions, but this category of modules does not send dispatch and/or control signals to the DERs. The primary function of these modules is understanding the historical, current, and predicted capability of DERs to comprehend their grid impacts.

Collectively, these modules give utilities a clearer understanding into the expected or real-time status of customer and grid DER assets, including information such as location, operational status, and device connectivity. Better DER situational awareness and the ability to optimize DER capability allows utilities to optimize the many services DERs can provide.

The modules included in this category are Monitoring/Estimating, Forecasting, Aggregation, Optimization, and Measurement & Verification.

Figure 6. DERMS Module Inventory by Use Case: Analyze & Optimize Capabilities



Source: SEPA. (2023).

Monitoring/Estimating

Overview

DERMS can be designed to monitor, sense, and measure DER outputs and provide real-time information to utility operators and planners. One aspect of monitoring includes visualizing monitored data, which allows distribution operators to manually and/or automatically adjust DERs or alert DER aggregators as needed to assist with maintaining grid stability and energy consumption needs. Monitoring can provide functional data on the connectivity, location, real-time load/output, state of charge, and operating status of individual and grouped DERs to confirm customer compliance with DER programs, to ensure compliance with net metering capacity limits (e.g., 25kW AC system size), and to send automatic updates to detection and control systems for functions such as anomaly and constraint detection. Effective monitoring requires decision making on the granularity and frequency of the data acquisition. From an operational perspective, aggregation level monitoring is sufficient for grid control, especially for DERs that are aggregated based on location. Locational aggregation allows for DERs to be simplified into generation, flexible load resources, and storage resources. From a system planning and measurement and verification perspective, monitoring individual DER devices is required.

Ideally, monitoring involves real-time data accumulated through direct communications with the applicable DER and/or aggregated DER groups. Sometimes real time communications are not available if regulations prevent utility access to customer-owned BTM DER or for loads smaller than 250-500 kW (guidance from the National Utilities Regulatory Commission (NURC) for preventing masked loads). In these cases, monitoring can also be accomplished using engineering estimates for DER behavior. Typically, monitoring requirements are specified in utility interconnection agreements and associated tariffs, such as California's Rule 21 and Hawaii's Rule 14, and are generally driven by the size of the DER. Further data limitations may occur if the DERs are monitored through a third-party aggregator. Utilities often do not have insight into these individual DERs and must rely on monitoring estimates for the aggregated load.

Whether monitoring is done directly or through a third-party aggregator, a DERMS should include tools to display available DER device information and store information for long-term uses such as distribution planning. Monitoring data can include graphical, tabular, locational, and geographical data, all of which can be configured and sent to different utility operational end-users depending on the monitoring use case.

DERMS can be designed to directly monitor and control individual and group DERs or to coordinate with other communication-capable devices through distribution supervisory control and data acquisition (DSCADA), advanced metering infrastructure (AMI), intelligent alarm processing (IAP), and field area network (FAN) systems. Monitoring via a DERMS can enable a more complete picture of the distribution network by providing DER information alongside traditional utility assets such as capacitor banks, voltage regulators, automated line switches and reclosers, and stand-alone distribution sensors such as faulted circuit indicators and current and voltage sensors.

Monitoring via a DERMS can also provide information on masked load, where load is hidden from the upstream component by DER generation sources. Masked load is the customer gross load without DER generation and can be calculated using both the DER's direct measured output and the customer's net load from AMI data or through engineering estimates. Masked load becomes an issue when the customer DER generation is disconnected or becomes unavailable unexpectedly.

System Interaction

Monitoring & Estimating primarily feeds into the Demand Response, Measurement & Verification, Optimization, Forecasting and Bidding modules and receives data from the Asset Configuration & Modeling and Aggregation modules. The primary data type exchanged between the modules is information on device status and operations, where the Monitoring & Estimating module provides situational awareness to DERMS operators. DER aggregations and other grouping information can be obtained from the Aggregation and Asset Configuration & Modeling modules to determine the level of granularity and type of data analysis that can be displayed/visualized within the Monitoring & Estimating module. The Monitoring & Estimating module receives DER information from distributed controllers, AMI meters, and DSCADA and incorporates planning level data where telemetric/real time information is not available. Together this data provides situational awareness and visualizations of DERs on the grid and can be used to trigger alerts to operators.

Supported DER Types

The monitoring function is intended to support all types of DERs whether located BTM or FTM.

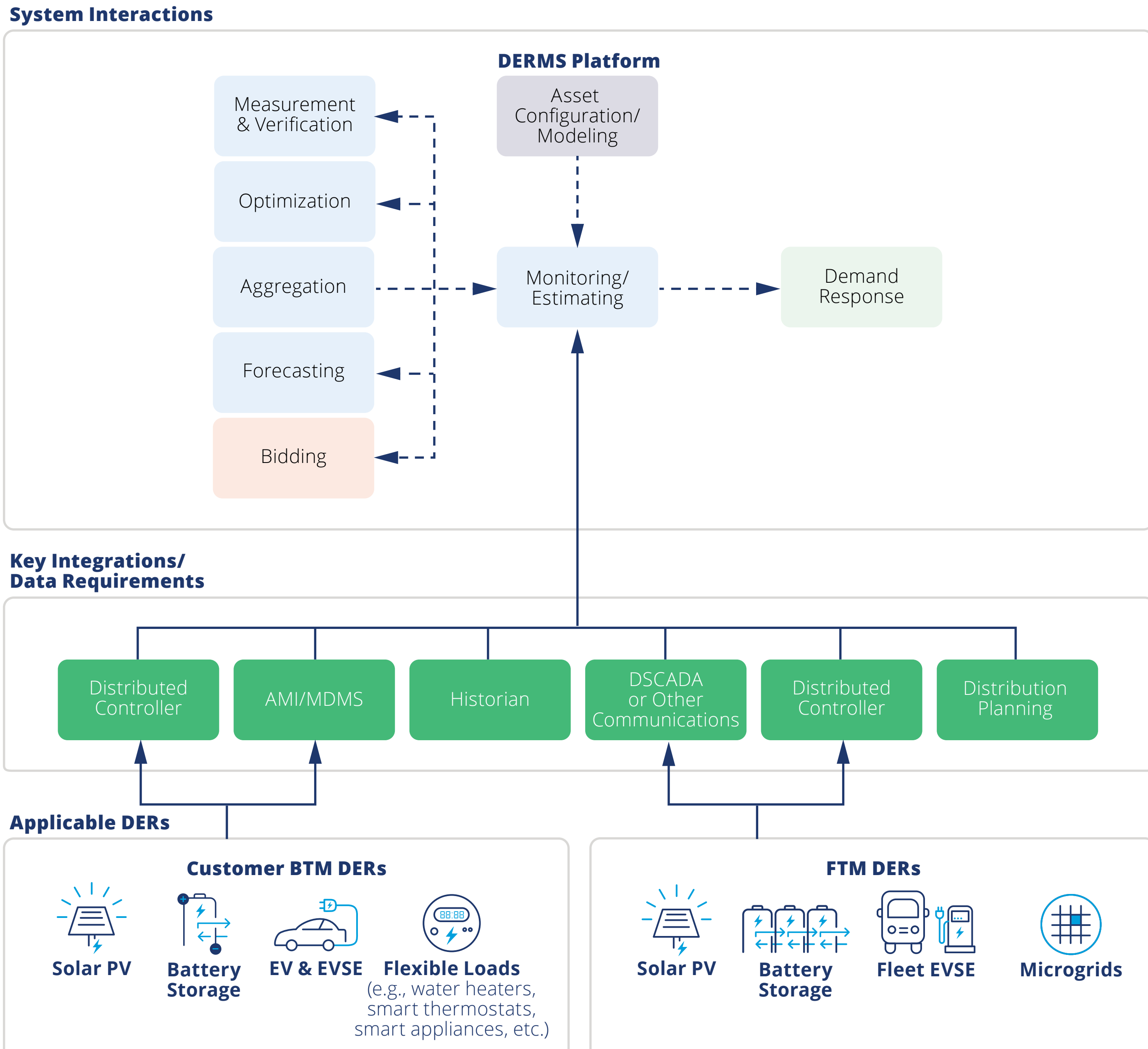
The type of monitoring performed and the availability of data can be highly dependent on the size, location, and ownership of the DER. BTM may be more difficult to monitor individually in real-time, thus requiring more performance estimation. Utility-owned DERs are likely equipped with remote monitoring capabilities making data available in real-time. Other DER monitoring information may only be accessible through a third-party aggregator.

Pipeline Stage

This functionality is in the **piloting/emerging conceptual phase** as the industry evolves and DER penetration increases.

Utilities are revising their interconnection standards to adopt evolving industry standards that specify monitoring requirements.

Figure 7. Key Integrations and System Interactions with the Monitoring & Estimating Module



Source: SEPA. (2023).

Market Availability

Market Adoption

Market adoption is mature across the different vendors.

Virtually all utilities who have implemented a DERMS utilize its monitoring functions. This includes leveraging other utility applications such as AMI, SCADA, and ADMS systems to achieve full functionality.

Example Applications

- **Baltimore Gas & Electric** is partnering with Enel X and EnergyHub to use a combination of the Mercury DERMS system and Enel's JuiceBox platform to gather and visualize customer Level 2 charging data with 15-minute granularity.[13]

13 Proctor, D. (Dec. 2020). Partnership's New Charge– Pair EVs with Utilities, Grid.

- **Pacific Gas & Electric's** EPIC DERMS pilot leverages aggregation to dispatch DERs using least-cost optimization.[14] One key takeaway from the pilot was that old methods of monitoring with SCADA are insufficient for load masking and for correct net load calculations. Utilities need to have a DER-aware ADMS with monitoring functionalities to effectively monitor loads. The pilot also used aggregator vendor portals to remotely monitor the DER assets and compare them with the aggregator interface.
- **PPL** made their GE DMS "DER aware" by capturing DER geographic, operational, and system impact information in its FLISR and volt/VAR optimization (VVO) applications in their DOE funded Keystone Solar Future Project. This allowed for real-time monitoring and communication between PPL and communication-capable DERs.[15]
- **PSE&G** integrated their OSI DMS and DERMS applications with DER Monitoring as a key function of their grid modernization efforts.[16]

Technical Considerations

Pre-Requisites

Monitoring functions require robust communications systems that allow DERs to connect to the DERMS system and that allow the DERMS system to subsequently connect and communicate with secondary devices such as DSCADA or directly with the utility control system. Alternatively, engineering estimates must be used for expected DER performance. As utilities design their system architecture, they will need to consider if the monitoring via a DERMS is to be independent of any other monitoring or control systems such as DSCADA and ADMS systems or if it is an additive module, designed to integrate with existing technologies. Monitoring via the DERMS may be duplicative if the utility already has an ADMS or if the two systems are kept independent of one another. DERMS systems may include automatic event triggers based on monitoring and constraint limits that can feed these alerts to an ADMS system, which creates a use case for including the monitoring function in both the DERMS and ADMS.

Key Integrations and Data Requirements

The communication architecture and the integrated technologies are primary considerations for monitoring DERs. The two-way communication capabilities required for elective monitoring of DERs can be supported by a range of wired and wireless solutions. Selection of the communication support technologies depends on system topology and the location and application of the DERs. Additional requirements such as communication network scalability, bandwidth, quality of service (QoS), data quantity and storage, data content, cybersecurity, and interoperability may be needed for successful implementation of monitoring capability. Additional measures can be taken within certain DERMS systems to confirm the accuracy of the data and identify if faulty data has been fed into the system.

Being able to monitor DERs directly requires the DERMS to be equipped with appropriate communications and interoperability standards that can scale to many DERs, because custom integrations to each device are not practical or scalable. Data requirements are specific to the utility's use case but likely include information about the individual or grouped DER assets, monitoring information, operational statuses and alarms, and control setpoints and commands. The IEEE's 1547-2018 guidelines include interoperability requirements such that the DER:

- Has provisions to communicate with the local DER interface.
- Supports either IEEE Standard (Std) 2030.5, IEEE Std 1815, or SunSpec Modbus communication protocols.
- Is able to exchange information on device characteristics and operating conditions.
- Maintains communication read response times of fewer than 30 seconds.

State specific interconnection rules typically build on the IEEE 1547 guidelines.

Commonly used communication protocols based on SEPA's research of DERMS pilot projects include IEC 61850-8-2, IEEE 2030.5, and OpenADR 2.0b. MultiSpeak is another protocol often favored by cooperative utilities. California's Rule 21 Smart Inverter Working Group has also developed guidance on communication with inverter based DER. Monitoring modules from vendors often support various industry standards, but often have their own vendor specific interoperability protocols.

When direct monitoring of DERs is not practical, utilities may estimate DER performance using DER nameplate data, historical load data, and other engineering estimates. This requires the DERMS to integrate to systems such as a meter data management system (MDMS), historian, or other utility database/planning tools.

14 Pacific Gas and Electric Company. (Jan. 2019). EPIC Final Report.

15 Smart Electric Power Alliance. (Jan. 2021). Insights from PPL's DERMS Implementation.

16 OSI. (Jan 2018). New Jersey's PSE&G Selects OSI's Distribution Management System and DERMS.

Forecasting

Concept Emerging Deployment

Overview

DERMS forecasting functionalities can be used to improve a utility's visibility of DERs in aggregate or at an individual level. Forecasting capabilities vary based on vendor but often include load forecasting and/or capacity forecasting. These forecasts can be constructed based on real-time data, historical data, or a combination of both. In some cases, the DERMS will also communicate with weather predictions and external pricing data, such as wholesale prices and time-of-use (TOU) rates, to better estimate future energy demand and DER behavior. When coupled with state estimation functions that can collect data on voltage and power flow, forecasting allows for greater situational awareness for system operators and aids in both long-term and short-term distribution planning processes.

The advanced forecasting capabilities DERMS employ are often conducted in real-time, requiring interaction with DER metering devices to collect data. Forecasting can be conducted for load, capacity, and power quality data such as voltage and frequency. Forecasting engines can communicate with weather sensors or externally collected weather data, especially for DERs such as solar panels that heavily depend on those parameters. The calculations used for forecasting can rely on daily and seasonal variation such as weather, temperature, solar irradiance, wind speed, and usage profiles varying from near real-time to longer periods. Forecasting modules can also utilize load profiles based on historical data and DER operational capabilities.

Price signals may factor into these capabilities, so some forecasting solutions include a market interface. System operators use forecasts to predict the ability of DERs to meet demand and schedule DER interconnection accordingly. The software should have some connection with the utility's scheduling and dispatch abilities to maximize the value of these forecasts.

There are several types of forecasts that may be required for successful DERMS operation (power flow forecasting is done in an ADMS):

- **Gross load forecast**—The actual load being served for the portion of a circuit at a given time, excluding the influence of BTM DER. Data may be pulled in through the ADMS to support this forecasting.
- **Net load forecast**—The load being served at the customer meter for their portion of the circuit and including the reduction/increase of gross load due to the effects of the BTM DER, and can be based on historical information, SCADA information, and/or weather normalized profiles. Net load forecast is especially useful as a component for under-frequency load-shedding forecasting because it shows how much actual load relief can be expected. Synchronized estimates of both load and generation forecasts may be needed to predict the local DER capacity.
- **DER generation**—includes any resource that can supply energy to the grid, but excludes energy storage and DR due their characteristics.
- **Energy storage devices**—these devices are difficult to forecast but easy to include in a schedule, especially if they are participating in an energy market.
- **DR resources**—the DR forecast is the amount of load the DERMS could interrupt if necessary.The availability of DR resources are difficult to forecast especially if they are market participating. Some load assets, such electric vehicles (EVs), present additional forecasting issues due to their mobility and ability to be both a load and a generation resource. Locational forecasting could help predict when an EV is likely to be a load (i.e., in public and workplace charging locations) and when it is likely to be a generation resource (i.e., at a residential home with vehicle-to-grid (V2G) or vehicle-to-building capabilities).

The forecast can either be a top down forecast which allocates loads across the model or bottom up forecast which is a forecast for each individual asset. The forecast can also be aggregated at various levels such as feeder segment, feeder, or substation level. The forecast should be able to estimate load under normal, abnormal, peak, and contingency conditions with the time horizon, granularity, and availability of the forecast dependent on the organization's needs.

Masked load is the load that is hidden from the upstream components by DER generation sources. It is essentially the customer load (gross load) without DER generation and is much higher than the measured net load (gross load minus DER generation). Forecasting of both DER output and native load for future potential masked load is necessary for planning purposes. The direct measurement of either the DER output or the actual measured load will also require only the forecast of the remaining unknown value.

System Interaction

Data integrations into Forecasting include the Aggregation and Aggregator Data Exchange modules, Asset Configuration & Modeling, and the Monitoring & Estimating modules. All of these modules provide the relevant DER programmatic, operation, and activity data needed to run the forecasting engine.

Data integrations from the Forecasting module include Optimization, Measurement & Verification (M&V), Bidding, and Demand Response. The Optimization, Bidding, and Demand Response modules utilize the forecasting data to optimize DER utilization through different use cases. M&V uses the forecasting data to develop baselines used in DR programs and to allow utilities to account for the effects of demand side management programs during planning processes.

Forecasting is linked with Dispatch & Scheduling functions through the Optimization engine because the forecasted predictions often feed into the optimization algorithm and influence the final dispatch schedules.

Supported DER Types

The forecasting function is intended to support all types of DERs whether located BTM or FTM.

Pipeline Stage

This functionality is in the **deployment stage**.

Both short-term and long-term utility load and generation forecasting is well established. Using DERMS for forecasting and including the impacts of DERs is a more emerging space; however, all DERMS systems offer some level of forecasting capability.

Market Availability

Market Adoption

Mature across the different vendors

Forecasting is a fairly common application in DERMS solutions, appearing in planning stages, pilots, and fully active systems.

Example Applications

- **Arizona Public Service** has load and capacity forecasting functions as part of their BYOT DR program. Forecasting for the solar assets is conducted in the ADMS and passed along to the DERMS. The DERMS system is from EnergyHub.[17]
- **Eversource Energy's** DR dispatch is directly informed by load forecasts generated by their EnergyHub system.[18]
- **LA Department of Water and Power** uses forecasting to improve situational awareness of their BYOT program.[19] The system manages thermostats for the LADWP DR program. The end goal is to use the system to achieve 25 MW of flexible power capacity.
- **Pacific Gas & Electric's** EPIC DERMS pilot provides real-time load forecasting capabilities.[20] The team conducting the pilot found that large highly variable DERs participating in wholesale frequency regulation markets are difficult to forecast and incorporate into distribution calculations.
- **PPL Electric** investigated DERMS through their Keystone Solar Future Project, which included irradiance forecasting.[21]

Technical Considerations

Prerequisites

Forecasting depends heavily on data to develop predictive models requiring utilities to have a robust data collection system. Advanced metering may improve forecasting, especially if utilities are interested in real-time or short-term forecasts. This may be a requirement for predicting the premise level load and generation forecast. Regardless, meter data from a MDMS or historian is commonly used to generate forecasts.

Key Integrations and Data Requirements

Data exchange is a key integration component of the forecasting module. Data availability and timing of data can be a factor that impacts integration design and must be considered early in the DERMS planning process. Redesigning data exchange pathways after a DERMS deployment will be costly and harder to implement. Additionally, the DERMS should be integrated with the utility ADMS, if there is one, and to other utility distribution

17 Energyhub. (Nov. 2018). Arizona Public Service chooses EnergyHub's Mercury DERMS to deliver innovative grid-edge DER management strategies.

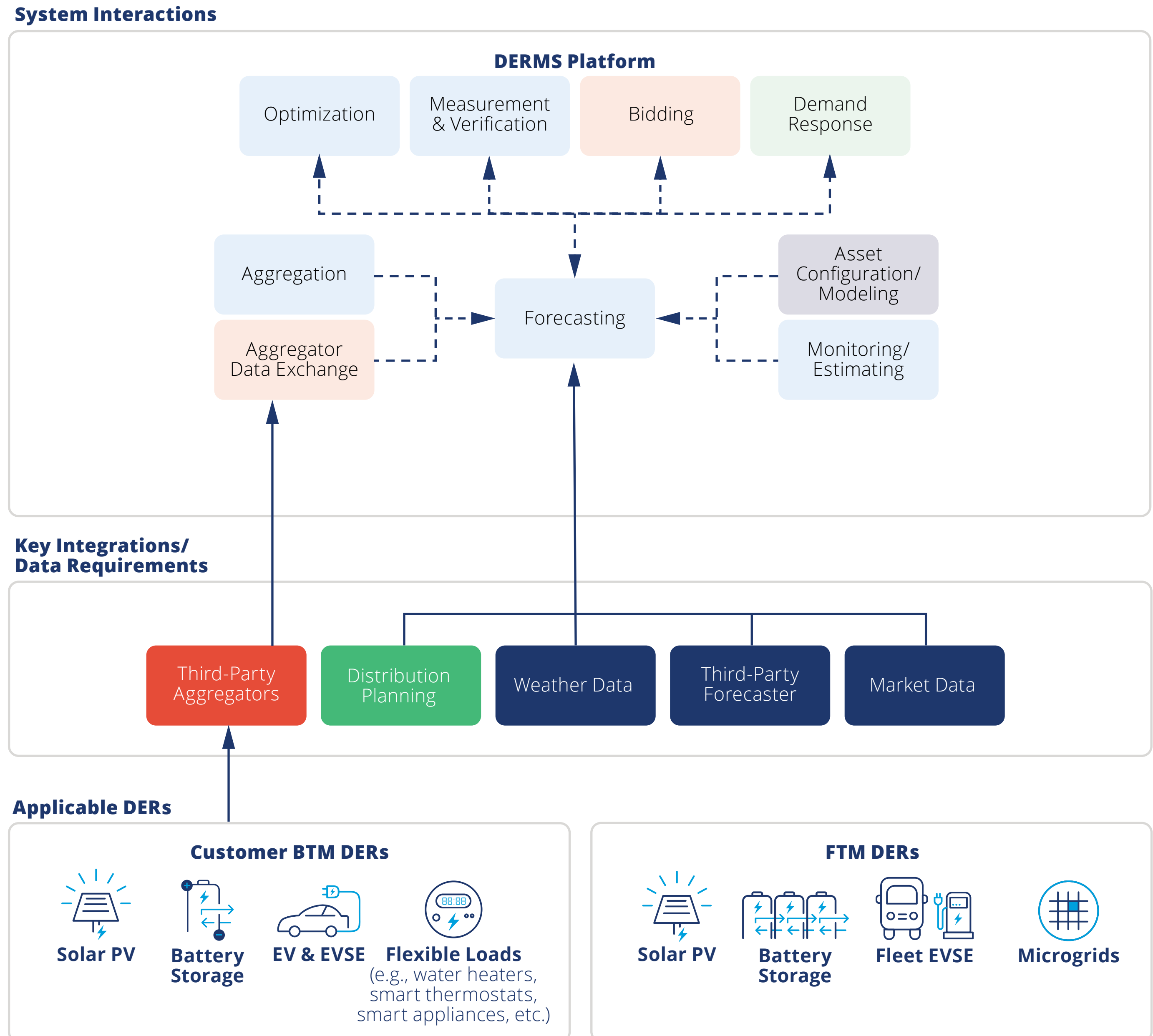
18 Eversource. (May 2019). Integrating Distributed Energy Resources onto the Utility System.

19 EnergyHub. (Oct. 2020). Los Angeles Department of Water and Power and EnergyHub enroll over 16,000 thermostats in BYOT program, targeting 25 MW of flexible capacity.

20 Pacific Gas and Electric Company. (Jan. 2019). EPIC Final Report.

21 Smart Electric Power Alliance. (Jan. 2021). Insights from PPL's DERMS Implementation.

Figure 8. Key Integrations and System Interactions with the Forecasting Module



Source: SEPA. (2023).

systems so that the network data from these systems can update the forecasts and improve their accuracy.

Likewise, utilities should consider how the DERMS will be integrated with third-parties including weather forecasting and data collection systems and other DER-specific forecasting systems to obtain aggregated DER data and weather data. DER forecasting occurs within the DERMS system; however, coordination and data exchange with an aggregator are essential to obtain the right level of device data. The forecasting module can provide macro forecasts to the aggregators and oversubscribe third-parties to ensure utility commitments to the market are being met.

Integration of utility-developed or third-party sourced weather forecasts is important for forecasting weather dependent DERs such as solar and wind. Minimum data requirements include historical usage and DER generation profiles. Data needs are dependent on forecast granularity (hourly, 15 min, etc.) and time horizon (next hour, next day, next year, etc.) and can expand to include weather related forecasts.

Aggregation

Overview

The increasing number of DERs connected to the grid presents new challenges for utilities. DERMS aggregation functions allow grid operators to view and control many different assets as simplified groups. In many cases, a third-party who then interfaces with the utility DERMS performs the actual DER aggregation. As more third-party aggregators enter the DER space and/or become more mature in their capabilities, it has become more common for utilities to work with these aggregators to obtain access to customer BTM and to form the DER aggregations.

In this case, the DERMS would need to maintain a map of third-party provided aggregations. Aggregation functionality can also allow utilities to create virtual power plants (VPPs) to streamline asset dispatch and market interaction functions. Aggregations can take many forms based on DER type or technical characteristic, location or system connectivity, ownership, communication method, third-party aggregator, etc. ISO/RTO FERC 2222 compliance tariffs may also require additional aggregation requirements.

Individual DERs may exist in multiple groupings based on DER generation type, locational status, or other manual designations. DERMS systems can track DER programmatic and activity statuses to ensure that they are not participating in multiple groupings or programs at the same time and to avoid double counting.

The DERMS system must keep the distribution and/or the transmission system operators informed of the status of the DER under its control. Aggregation helps with this by combining DERs into more manageable groups. Hierarchical grouping starts at the lowest level of the distribution network, the service transformer, and continues to group into larger portions of the system. This simplifies and helps with DER modeling and control. Programmatic grouping involves grouping assets that reside in particular utility programs. Other aggregation groupings could include:

- **Capacity grouping**—grouping according to capabilities that are dictated by the interconnection agreement.
- **Resource grouping**—grouping by asset type such as solar, wind, energy storage, etc.
- **Combination grouping**—grouping that allows the best operations.
- **Other grouping**—grouping that is not defined by location and could be for reasons based on market participation, communication method, etc.

System Interaction

The Aggregation module is utilized to aggregate BTM and FTM DERs and to centralize the aggregations made by third-party aggregators. The Aggregation module pulls in DER device data from both the Asset Configuration & Modeling and Aggregator Data Exchange modules. Aggregation functions can be performed manually by system operators or semi-automatically based on DERMS algorithms. The aggregation data is then used by the Optimization and Forecasting modules that can verify and/or modify the aggregation. Aggregated DER data is also used by the Bidding, VPP, and DR modules to update them with the newest aggregation of DERs. DER aggregation data includes DER device information, monitoring/status, operation/control setpoints, and the different groupings in which a DER device could be included.

Supported DER Types

The aggregation function is intended to support all types of DERs whether located BTM or FTM.

Pipeline Stage

This functionality is in the emerging to **deployment stage**.

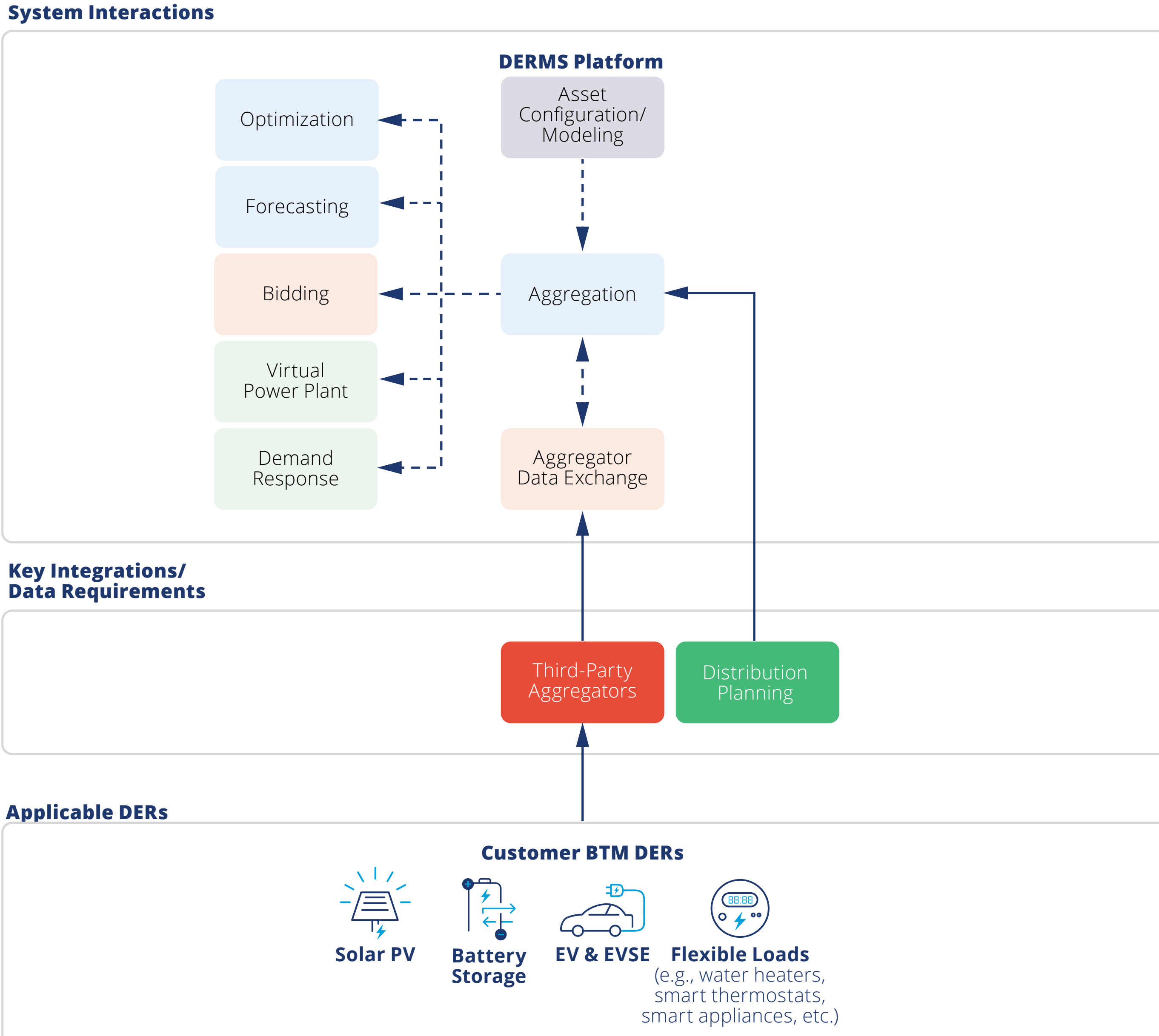
While aggregation is a basic component of all DERMS systems, its use in managing DERs and integrating third-party aggregations is still emerging but is progressing toward deployment.

Market Availability

Market Adoption

Deployment is happening on a smaller scale, primarily with the key players in the DR space.

Figure 9. Key Integrations and System Interactions with the Aggregation Module



Source: SEPA. (2023).

Example Applications

- **Austin Energy's** Austin SHINES program relies heavily on third-party aggregators, which communicate with the DERMS through OpenADR.[22] The program partnered with Doosan GridTech. Lessons learned include:
  - The current state of DER communication and integration standards poses a non-trivial risk of uncertainty to wide-scale asset deployment.
  - Building codes and permitting processes are not currently keeping pace with DER technology advancements, hindering installation in some cases and potentially creating unaccounted for impacts in others.
  - Proper system design is highly dependent on the value application and location on the grid.

22 Austin Energy. (2020). Optimal Design Methodology.

- Deployment of emerging technologies involves uncertainties regarding safety.
- Current review processes are not keeping pace with emerging technologies.

- **DTE Energy** piloted DERMS from 2014-2016 and aggregated community energy storage (CES) across their entire service territory and used utility industry protocol (DNP3).[23]
- **Hawaiian Electric** received approval in 2019 for implementation of OATI's cloud aggregation software.[24] This system will be used for DR.
- **LA Department of Water and Power** aggregates DR thermostats through EnergyHub's DERMS.[25] The end goal is to use the system to achieve 25 MW of flexible power capacity.
- **National Grid** uses EnergyHub and aggregation functionality as an integral part of their commercial and industrial DR program.[26] This project will be able to manage multiple DER classes for DR.
- **Pacific Gas & Electric's** EPIC DERMS pilot uses third-party aggregators for economic control of customer, utility, and third-party DERs.[27]
- **PECO Energy** conducted a DERMS pilot that ended in 2020 examining aggregation features in coordination with microgrid management. The project used Schneider Electric's DERMS.[28]
- **Tucson Electric Power** investigated coordinated dispatch of smart thermostats, water heaters, and EV chargers through aggregators in Project RAIN (Resource Aggregation and Integration Network).[29]

Technical Considerations

Prerequisites

Aggregation functions require robust communications systems given the coordination that must happen between the third-party aggregator and the utility. Utilities must have a customer enrollment program in the case of DR applications.

Two-way communications are needed if any DER control is required. Because of the complexities of the potential uses of the DER, further aggregation or grouping of assets may be necessary. The aggregation can be as low as the feeder section level or as wide as at the substation level.

Key Integrations and Data Requirements

A DERMS that utilizes grouped DER provided by third-party aggregators must be able to manage DER/aggregator relationships close to real-time. Real-time data includes details on the grouped capability of the DERs and their location, so that any downstream effects are quickly integrated into the network model. This may require integration to third-party systems (see Aggregator Data Exchange) or to other utility systems.

Key data requirements include:

- DER aggregator identifier
- DER status, including controllability
- DER mode of operation
- Available modes of operation
- Services in which the DER is participating
- Real-time available capability (power quality)
- Real-time output and other monitored values
- Time-based availability projections

23 DTE Energy. (2015). DTE Energy Advanced Implementation of Energy Storage Technologies.

24 Hawaiian Electric. (August 2019). Hawaiian Electric and Open Access Technology International Plan for Innovative Grid Services Wins PUC Approval.

25 EnergyHub. (Oct. 2020). Los Angeles Department of Water and Power and EnergyHub enroll over 16,000 thermostats in BYOT program, targeting 25 MW of flexible capacity.

26 EnergyHub. (Sept. 2020). National Grid expands DER portfolio with EnergyHub to manage commercial and industrial resources.

27 Pacific Gas and Electric Company. (Jan. 2019). EPIC Final Report.

28 Argonne National Laboratory. (Sept. 2020). Microgrid Energy Management System Integration with Advanced Distribution Management System.

29 Tucson Electric Power. (Oct. 2019). IRP Advisory Council Presentation. Distributed energy Resources and Customer-Site Energy Resource Alignment.

Optimization

Concept Emerging Deployment

Overview

DERMS optimization is generally defined as the best allocation of capacity, or other characteristics, among the various DER resources at a given time to address operational objectives. A core DERMS function is providing the requested grid services (such as economic dispatch, DR, VPP) in a way that uses the best combination of DER assets to save cost, reduce wear, and optimize asset value. Optimization includes determining the aggregation of DERs, prioritizing DERs to be dispatched, and determining the sequence of operation. A DERMS optimization module considers the capabilities and operating status of individual and grouped DERs under the utility's control and optimizes those assets to achieve operational objectives. Optimization modules also identify how different types of DERs (solar, EVs, solar + storage, etc.) can contribute to different grid services and which DER types best address the operational objectives.

DERMS optimization is similar to security constrained economic dispatch (SCED)[30] of large generation resources conducted in generation management systems (GMS), such as an ADMS. In the case of a DERMS, the optimization is only performed for DERs under management in the DERMS rather than for all DERs on the system. Utilities that have implemented ADMS systems may utilize the ADMS for security constrained reliability optimization and the core DERMS optimization engine for economic and grid-constrained dispatch.

Optimization modules can incorporate a utility's economic, reliability, and/or environmental goals, and many utilities require the DERMS to support multi-objective optimization functions. Economic optimization ensures DER usage achieves the lowest cost and/or best asset values. System reliability optimization can identify which DERs to hold in reserves so that if dispatched resources fail, the reserve resources can cover the shortfall. Optimization can also include the dispatch of equal resources (such as different types of EV chargers) that may be subject to different program rules or tariffs but that would support the same grid service (such as peak demand reduction). The optimization engine must take into account specific DER attributes in order to determine how they support the utility's operational goals. Some assets may not be suitable for economic dispatch but may be appropriate as a reserve resource. It is possible to achieve multiple strategies at the same time by understanding DER attributes' system interactions and grouping them correctly.

Additionally, optimization modules can group assets based on reactive power and/or voltage and frequency capabilities to promote grid stability and decreased congestion on feeder and substation levels. DERMS can interact with inverter-based DER to achieve voltage and frequency outcomes. The smart inverter can be commanded to absorb or inject reactive power and can control the active power output to maintain voltage and mitigate voltage rise caused by the DER itself.

Optimization for least-cost dispatch applications is achievable with DERMS systems. Even in areas absent of clear market signals, having a cost-based dispatch stack leads to more optimized economic outcomes. Mitigation of system issues can also be achieved simultaneously. However, the calculations required to perform optimization are complex and the software execution time is a consideration as they can impact timing of dispatch decisions.

System Interaction

The Optimization module is core DERMS functionality and the module needed to meet the requirements for a majority of the use cases. While data tends to be used in series between other modules, Optimization is constantly utilizing data from modules, optimizing it, and then updating those modules. For example, the Aggregation module can feed information on a set of DER groupings into the optimization engine and the optimization engine performs the analysis on the groupings based on market and grid conditions. The optimization engine then sends instructions back to the aggregation module on modifications needed to the DER groupings. Many of the grid service and control use cases utilize the optimization module similarly.

Supported DER Types

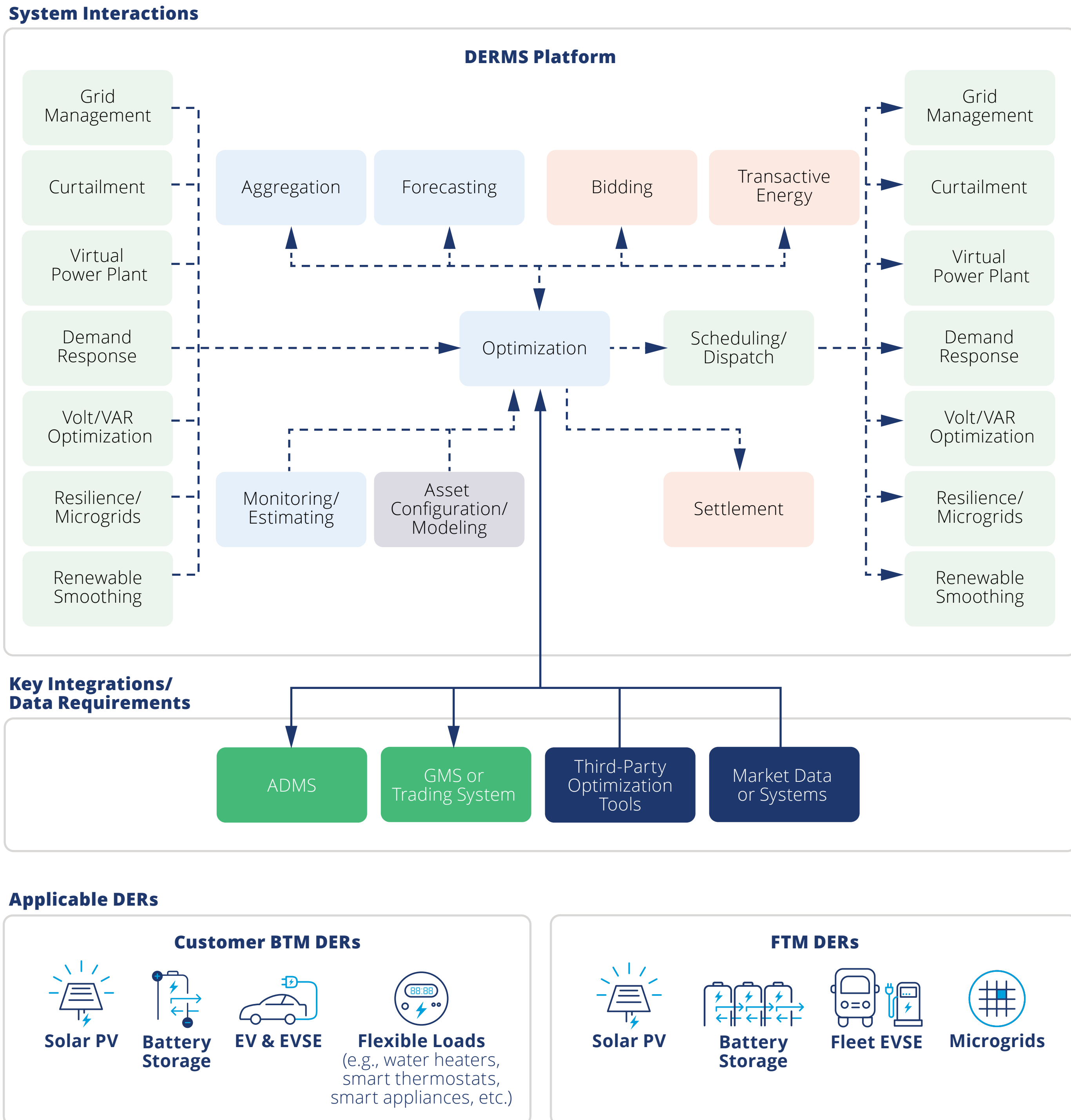
The optimization function is intended to support all dispatchable types of DERs whether located BTM or FTM.

Pipeline Stage

This functionality is in the **emerging stage**.

30 Security-constrained economic dispatch is an area-wide optimization process designed to meet electricity demand at the lowest cost, given the operational and reliability limitations of the area's generation fleet and transmission system.

Figure 10. Key Integrations and System Interactions with the Optimization Module



Source: SEPA. (2023).

Optimization is still largely in the pilot stage with few cases of optimization at scale.

Market Availability

Market Adoption

Market adoption is embedded across different vendor platforms.

Example Applications

Utilities are beginning to explore economic optimization through the use of DERMS systems. A few utilities are also using the DERMS to optimize frequency and other grid services, although at a more focused scale.

- **Austin Energy** Austin SHINES program relies on a DERMS that dispatches resources based on economic optimization.[31] The program partnered with Doosan GridTech. Some of the lessons learned include:
  - Planning should include circuit modeling for siting evaluation.
  - Engage all utility departments early in the process of implementing the DERMS.
  - Use products that meets IEEE standards.
  - Day-to-day operation of DERs will require autonomous dispatching using a circuit model.
- **DTE Energy's** DERMS pilot relied on dispatch of storage to provide frequency regulation services.[32]
- **Hawaiian Electric** received approval in 2019 for implementation of OATI's webSmartEnergy software, which provides grid reliability and balancing services.[33]
- **Holy Cross Energy** tested DERMS with frequency regulation in collaboration with NREL. The project used their DERMS integrated with a Heila microgrid coordinator.[34]
- **Pacific Gas & Electric's** EPIC DERMS pilot leverages aggregation to dispatch DERs using least-cost optimization.[35] Some of the key takeaways from the project included:
  - Comprehensive DERMS were not readily available.
  - Investing in foundational technology is crucial.
  - DERMS paired with ADMS can identify and mitigate real-time and forecasted distribution capacity and voltage issues.
  - DERs must provide sufficient locational value, volume, availability and dispatch assurance to offer grid services.
  - Significant location specific penetrations are needed to resolve distribution issues.
  - Large highly variable DERs participating in wholesale frequency regulation markets are difficult to forecast and incorporate into distribution calculations.
  - Unified standards, protocols, testing, and exchanges are needed as DERMS requirements and market structures become more defined.
  - MUA requires transparency, coordination, and rules across programs to ensure proper prioritization and equitable settlement, and to preserve distribution safety and reliability.
  - Distribution dispatch must have priority over wholesale market operations and visibility across both systems.
- **Southern California Edison** is piloting "Transactive Energy" which would allow dispatch of pricing schedules to minimize consumer costs.[36]

Technical Considerations

Prerequisites

Optimization requires configuration and modeling of DER registration data (asset, programmatic, network) as well as capturing customer program/tariff participation and interconnection information. If the asset is participating in the optimization strategy, two-way communications are required to enable control by the DERMS. If the asset is a renewable generator, a forecast of the system output also is needed. Finally, grouping the assets into categories and locations is required to support the desired optimization strategy.

Key Integrations and Data Requirements

Depending on the desired optimization strategy, the DERMS and/or ADMS may be used. The DERMS can mimic

31 Austin Energy. (2020). Optimal Design Methodology.

32 DTE Energy. (2015). DTE Energy Advanced Implementation of Energy Storage Technologies.

33 Hawaiian Electric. (August 2019). Hawaiian Electric and Open Access Technology International Plan for Innovative Grid Services Wins PUC Approval.

34 NREL. (Feb. 2020). Performance Evaluation of Distributed Energy Resources Management System via Advanced Hardware-in-the-Loop Simulation.

35 Pacific Gas and Electric Company. (Jan. 2019). EPIC Final Report.

36 Renewable Energy World. (July 2020). Southern California Edison launches transactive energy pilot using customer-sited DER.

the ADMS' full distribution network through a digital twin model, which can include a simplified hierarchy of the distribution grid organization by defining the specific feeder section, feeder circuit, and substation where each of the DERs are connected or belong. The organization hierarchy is a dynamic structure that may change with the distribution topology due to switching operations and network reconfiguration for load transferring, load balancing, planned outage services, service restoration, or periodic network reconfigurations. The approach taken will impact integration requirements between the ADMS and DERMS as well as requirements for system performance.

Market price signals, weather data, utility market and emissions data, and DER operating, cost and environmental attributes/forecasts are necessary for the DERMS to optimize DER resources for economic and environmental dispatch. Optimizations for environmental dispatch will need to include system emission rates so that the dispatch of the DER resources has the desired effect of minimizing overall emissions. Operators should take careful consideration when trying to optimize both economic and environmental dispatch and scheduling to ensure both conditions are met adequately. Resource program participation, tariff considerations, and interconnection agreement terms also factor into optimization algorithms.

The DERMS may need tight integration to the system of record for the operating network model (ADMS, etc.) if not already maintained in the DERMS. Operating limits and DER generation facility information is required from the system housing interconnection agreement information. Other key data considered by the optimization engine includes:

- DER mode of operation
- Available modes of operation
- Services in which the DER is participating
- Real-time available capability (real and reactive)
- Real-time output and other monitored values
- Time-based availability projections

Measurement & Verification

Overview

A key function of a DERMS system is to evaluate the performance of DERs in providing grid or customer services. Typically, these services are provided by the flexibility DERs can offer by adjusting load or output. DERMS Measurement and Verification (M&V) functions help utilities gain insight into the overall DER performance and into the specific performance measures needed for contract and interconnection agreements. The M&V function compiles the performance and customer meter data and sends that data to the settlement module for processing and billing.

An M&V application can quantify energy savings by comparing previous energy use with energy use during utility-initiated events and during grid interconnected conditions. A DERMS system applies its M&V functionality to evaluate performance of small DERs participating in utility programs, large individual DERs against the terms of interconnection agreements, and to third-parties utilizing DERs to provide contracted services to the utility.

DR is a common use of M&V functionality, where an M&V application can quantify energy savings by comparing previous energy use with the energy use during DR events. Utilities use M&V functionality for contracts and interconnection agreements to track the energy produced/consumed and measure the electrical interaction of the DER with the grid. For DR, M&V applications measure the energy reduction during DR events and compare that to an expected baseline.[37] This same process is applicable to energy, voltage, and frequency parameters that might be specified in a contact or interconnection agreement. In all these cases, utilities use M&V analyses to facilitate settlement where financial factors are applied to the energy adjustments.

A key aspect of M&V in a DERMS system versus a more targeted application such as DR is the need to apply M&V techniques to a wide range of DER device types, device locations (BTM or FTM), DER programs, and customer classes where customers and devices may be providing different load flexibility services. Likewise, the M&V functionality can be used to evaluate third-party compliance with contracts and provide one complete

37 Different baseline methodologies are supported such as "like day" defined as a lookup of x number of days selection of top y number of days. Calibration to event day is also typically employed via an adjustment or scaling factor prior to event time. Systems may support running multiple baseline types and selecting the best fit.

picture of DER performance to operators. M&V analyses often display forecast data, measured data, baseline data, and DER performance on one display. This can be done by program, contract, aggregator, location, or other variables.

System Interaction

Measurement & Verification is closely coupled with the Forecasting, Monitoring & Estimating, and Aggregator Data Exchange modules to obtain the DER performance data needed to confirm DER participation in utility events and to utility control signals. M&V utilizes the Asset Configuration & Modeling module to obtain the DER topographical, programmatic, and system data needed to assign performance to the devices. The Monitoring & Estimating module provides meter data that is critical for M&V calculations. The data outputs from M&V are sent to the Settlement and Transactive Energy modules so that those modules can reconcile the customer accounts for dispatched DERs.

Supported DER Types

The M&V function is intended to support all types of DERs whether located BTM or FTM.

M&V techniques can be applied to any type of DER used for shifting or shaping load, but are most commonly used with curtailable assets and those that participate in DR and load-shifting events.

Pipeline Stage

This functionality is in the **deployment stage**.

The concept of M&V is well established in the industry for energy efficiency and DR applications and is considered in deployment (although standards for M&V are still in development and will likely continue to evolve). DERMS provide real-time operational data that can be used to measure the actual flexibility provided from DERs. Applying M&V techniques in this way and expanding the M&V functionality to measure performance against contracts and interconnection agreements is a more evolving space.

Market Availability

Market Adoption

Deployment is dominated by vendors in the DR space.

Example Applications

Utilities commonly utilize a DERMS to evaluate DER performance. To date, most examples are tied specifically to DR programs.

- **LA Department of Water and Power** measures energy savings from their BYOT summer program through EnergyHub's DERMS.[38]
- **New Hampshire Electric Cooperative's** DRMS communicates with smart meters to obtain data on individual customers' responses and initiate M&V protocols.[39]
- **Tucson Electric Power** used M&V as part of Project RAIN to determine effectiveness of load control events across a variety of DERs.[40]
- **Wabash Valley Power Association** uses M&V to measure power savings from their PowerShift DR program for both residential and commercial customers across different member electric cooperatives.[41]

Technical Considerations

Pre-Requisites

M&V analyses are dependent on availability of DER performance data from meters or other monitored sources. Connection to traditional meters, smart meters, smart inverters, and other measurement devices can provide the necessary data in either real-time or after-the-fact measurements. Smart metering can provide greater visibility through more accurate and frequent data collection, although this technology is not strictly necessary for M&V. One primary purpose of M&V is to settle finances, and the data acquisition required for settlement must be utility- and market regulator-grade and standardized based on the service or program in which the DER is participating. Certification may be needed for M&V to be able to pass along the data to the Settlement module.

Key Integrations and Data Requirements

The integrations necessary to provide the required data for M&V analyses are the key architectural consideration pertaining to the M&V module. Data timing and availability needed for M&V calculations can be a factor that impacts

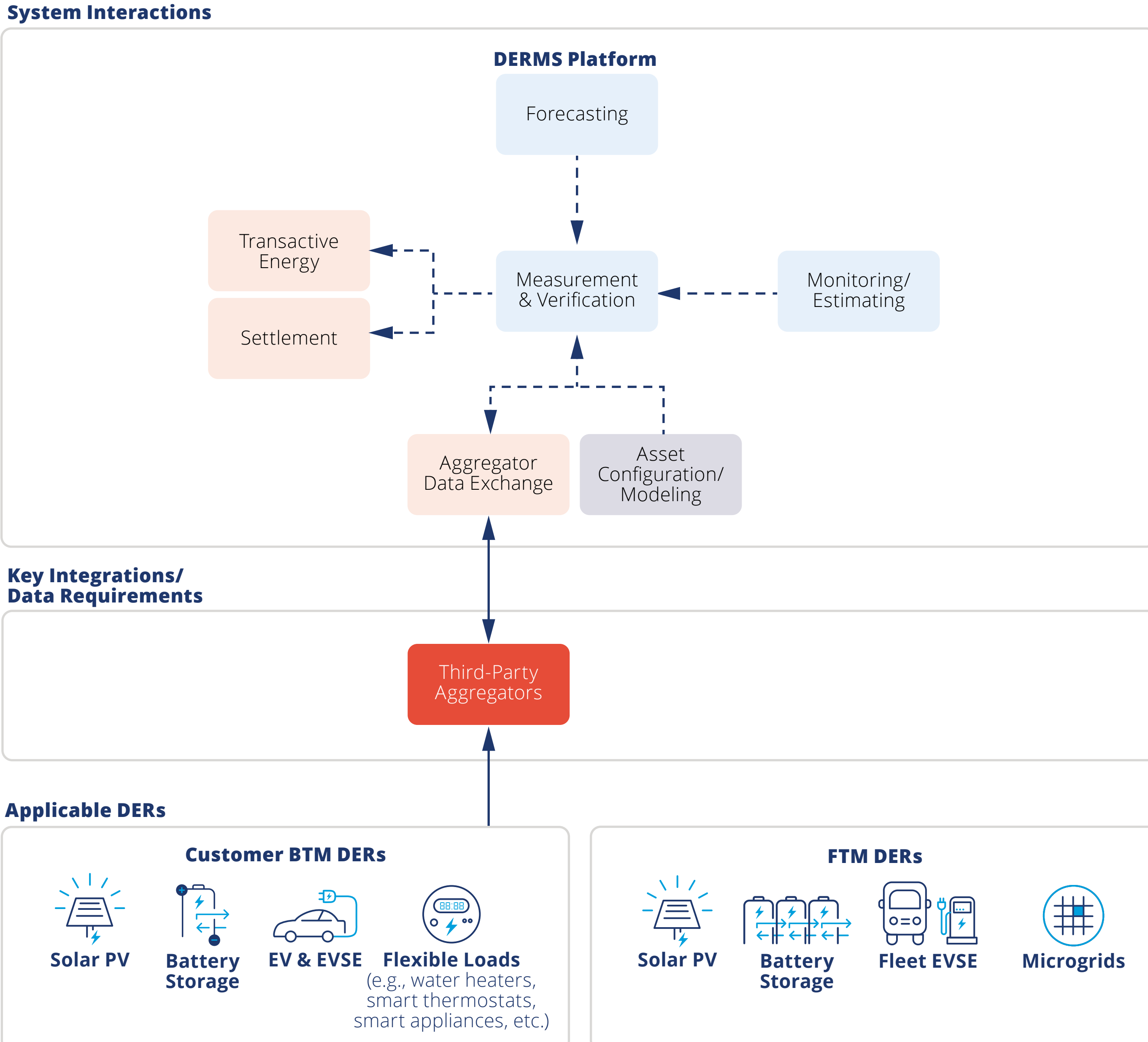
38 EnergyHub. (Oct. 2020). Los Angeles Department of Water and Power and EnergyHub enroll over 16,000 thermostats in BYOT program, targeting 25 MW of flexible capacity.

39 AutoGrid. (Apr. 2016). New Hampshire Electric Cooperative Goes Live with Three New Residential and Small and Medium-Sized Business Demand Response Programs Using AutoGrid DROMS.

40 Tucson Electric Power. (Oct. 2019). IRP Advisory Council Presentation. Distributed energy Resources and Customer-Site Energy Resource Alignment.

41 PowerShift. (n.d.). Enroll in PowerShift.

Figure 11. Key Integrations and System Interactions with the Measurement & Verification Module



Source: SEPA. (2023).

integration design. Likewise, integration to third-parties and to ISO/RTO systems may be required.

Because M&V depends so heavily on DER performance data, utilities would benefit from access to existing data analytics engines and data historians. Integration between the DERMS and a MDMS or historian may be required to provide the historical (measured) data needed for M&V. Forecast data may be provided by the DERMS or need to be integrated from another utility system. If M&V is designed to support market settlement functions, integration of the DERMS to an ISO/RTO market system may be required, especially as FERC 2222 requirements are further established.

Control

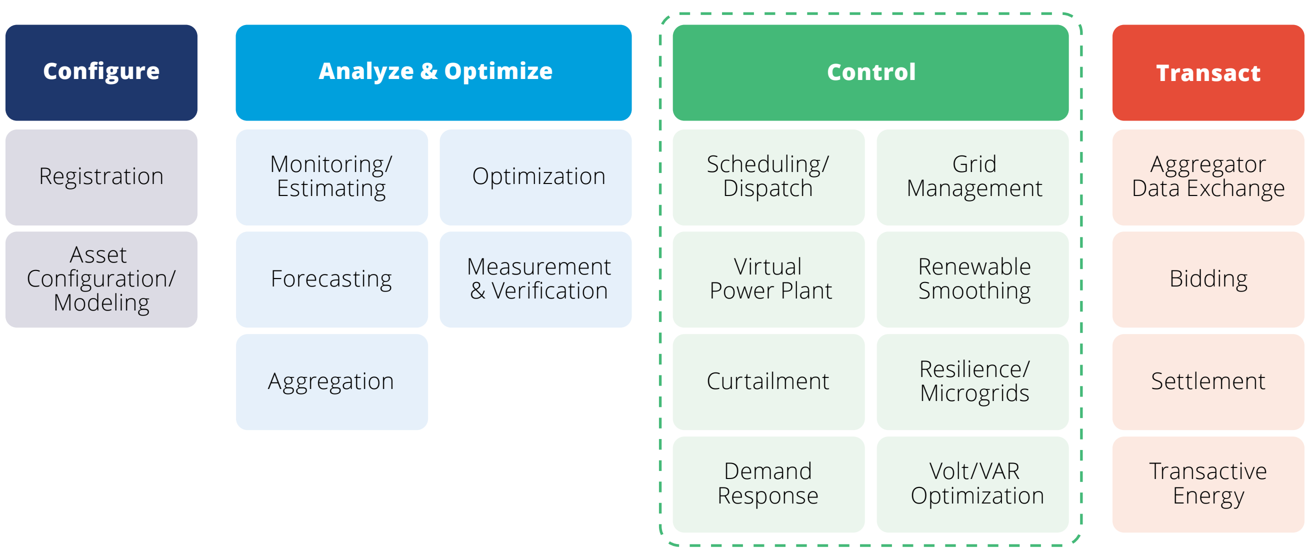
DER control is the act of automatically or manually adjusting the output of certain DERs to achieve a desired operational objective. One of the primary motives for implementing a DERMS is achieving control over both BTM and FTM DERs to manage load and provide grid and ancillary services. Control of this type may only be used on certain DER types and requires communications between the DERMS and the applicable DER assets.

Operators must have visibility into DER status, including their operational profile. The Control modules utilize the DER information from the Configure and Analyze & Optimize Modules to provide a clearer understanding of the current fleet of available capacity and how to dispatch those DERs in an optimum manner.

The Control modules are often closely coupled with the Optimization module in order to get the full economic and grid benefit from controlling the DERs. Control of DERs may include economic, resource, or environmental dispatch to maximize pricing or to meet a utility's carbon objectives. Control can also include grid optimization to reduce costs and wear, address system constraints, and optimize asset value. To enhance system resiliency, DER control also allows for stand-alone microgrid control and microgrid aggregation. DER aggregation through DER control is essential to optimize supply side resources and maximize DER assets and penetration to protect grid reliability.

The Control modules include Scheduling & Dispatch, Virtual Power Plant, Curtailment, Demand Response, Grid Management, Renewable Smoothing, Resilience/ Microgrids, and Volt-VAR Optimization.

Figure 12. DERMS Module Inventory by Use Case: Control Capabilities



Source: SEPA. (2023).

Scheduling & Dispatch

Overview

Economic Dispatch and Scheduling

Many DERMS offer utilities operational capabilities such as economic dispatch of active and reactive power in response to price signals such as locational marginal pricing (LMP), capacity, and energy price points from the local market interface. This functionality often goes hand-in-hand with scheduling so that utilities can operate assets at optimal times for maximum economic value. Depending on the software, dispatch may be automated or on-demand.

Economic optimization utilizes price signaling to support a reliability-constrained economic dispatch of the DERs. Either energy or capacity can be a price signal and these can be internally generated by the utility or be based on market price signals. The DERMS uses these price signals to communicate with and dispatch directly to individual assets or to third-party aggregators. Economic dispatch may also be integrated with scheduling functions to ensure optimal dispatch timing. While determining economic dispatch, the dispatch order of the resources should include costs to maximize value. The DERMS must simultaneously address resource constraints such as operating limits and resource program participation and tariffs.

A DERMS can enable impromptu scheduling in addition to daily, seasonal, and annual schedules. This covers emergency reserves and DR, contracted non-wire alternatives, and managing an annual 8,760 hourly load study. The DERMS can also support scheduling defined groups, including hierarchical groups, or impromptu selection of specific resources for each chosen control scheme. The DERMS system can appraise the dynamic load and generation change in addition to planned grid operations in the near future, and can derive DER dynamic export/import limits to maintain system reliability. Utility DERMS may provide dynamic export/import limits to a third-party aggregator. Using DER operation limits, the DERMS can plan and adjust DER behavior in following electric energy markets signals without causing grid constraint violations. The output of some DER, such as wind and solar, is weather sensitive, and forecasting their output is necessary. Forecasting helps utilities predict the asset commitments these types of DERs can support for daily and hourly needs. Scheduling DER resources can be done using day-ahead price signals and the dispatch can be adjusted to account for real-time versus day-ahead price differences.

Environmental Dispatch and Scheduling

DERMS can offer operational capabilities such as environmental dispatch of DERs. Environmental dispatch allows utilities to balance environmental concerns, such as decarbonization efforts or renewable generation coupling with available storage, with grid needs. The objective of this solution is to help utilities optimize DERs in support of carbon emission reduction goals while still promoting reliability.

Utilities can optimize DERs for dispatch in accordance with their low-carbon objectives. This requires coordination with higher levels of utility management, and adds an additional constraint to grid operations. Environmental dispatch can help grid operators ensure the lowest rate of emissions through optimal deployment of clean DERs and minimization of power loss.

Unlike economic dispatch, environmental dispatch relies on resource emission rates and system emissions. Although renewables are emission free, their dispatch can have effects on overall system emissions. For example, charging energy storage at a time of higher system emission rates has an adverse effect when compared to energy storage charging during lower system emission rates. Likewise, other resources can have the same effect. Like economic dispatch, resource costs should be addressed when resources have the same effect on system emissions.

Whether driven by economic or environmental goals, the DERMS immediately dispatches a control signal or develops a schedule for the DER(s) to follow. The control or schedule may:

- Change a DER's operational status (take offline or bring online)
- Change its mode of operation (battery charging vs. discharging)
- Set various operational parameters (modify voltage reference)
- Set operational VAR limits
- Modify volt-amp limits and watt limits
- Raise or lower real and reactive power
- Adjust power factor
- Control ramp rates, etc.

Individual DER or DER controller capabilities will determine which of these controls are supported.

Dispatch controls and schedules can be automated for certain devices with that capability. The DERMS monitoring capability would provide operators with verification of DER operations and responses to dispatch instructions. DERMS operators can override automated controls if needed based on system conditions.

System Interaction

The Scheduling & Dispatch function of a DERMS is the primary module that sends commands to the DERs. Scheduling & Dispatch integrate all the different DERMS decisions from the Optimization, Aggregation, and Forecasting modules to send instructions to the DERs. These instructions can be dispatched in real time or scheduled in advance. Scheduling & Dispatch sends commands directly to DERs through established communication channels such as a distributed controller, DSCADA system, ADMS, or a GMS/trading system. The module can also send commands through an intermediary module such as the Transactive Energy and the Aggregator Data Exchange modules.

Supported DER Types

The scheduling & dispatch function is intended to support all **dispatchable** types of DERs whether located BTM or FTM.

The DERMS may send a control signal to a DER controller or aggregator that then communicates directly with the DER device(s).

Pipeline Stage

This functionality is in the **emerging stage**.

Dispatch of DR resources via a DR management system (DRMS) is well established with utilities now replicating that capability in a DERMS. Economic dispatch of multiple, coordinated DER types is currently in a piloting stage. Environmental dispatch remains an emerging area.

Market Availability

Market Adoption

Adoption is occurring across the different vendors.

Economic dispatch is a common vendor offering modeled after security constrained economic dispatch functions common in generation control systems.

Example Applications

Utilities with DERMS that have environmental dispatch and scheduling are often in the pilot or planning stages of DERMS deployment.

DR resource dispatch and scheduling examples are not provided here because multiple examples exist in industry. The following highlight examples where a DERMS is used to dispatch DERs primarily for economic objectives.

- **Austin Energy** Austin SHINES program relies on a DERMS that dispatches resources based on economic optimization.[42] The program partnered with Doosan GridTech.
- **Pacific Gas & Electric's** EPIC DERMS pilot leverages aggregation to dispatch DERs using least-cost optimization.[43]
- **Southern California Edison** is piloting "Transactive Energy" which would allow dispatch of pricing schedules to minimize cost to consumers.[44]

Technical Considerations

Pre-Requisites

In cases where utilities have direct control over DERs, they must have the DERMS optimization engine algorithms tuned with appropriate data inputs and established rules to enable swift dispatch. Real-time and forecasted resource statuses along with weather forecasts are required for dispatch and scheduling of DER resources. Predefined and configured resource type groupings may be necessary to dispatch the types of assets needed to meet the specified economic or environmental goal.

Two-way communications are needed from the DERMS to the DER, DER controller, or aggregator in order to send dispatch instructions and schedules, to confirm receipt, and to verify operations. Two-way communication requires the DERMS to support multiple communication and device protocols. This could include IEC 61850, DNP3, IEEE 2030.5 (SEP 2.0), ICCP, OpenFMB, OpenADR 2.0b, SunSpec Modbus, and Wi-SUN.

Key Integrations and Data Requirements

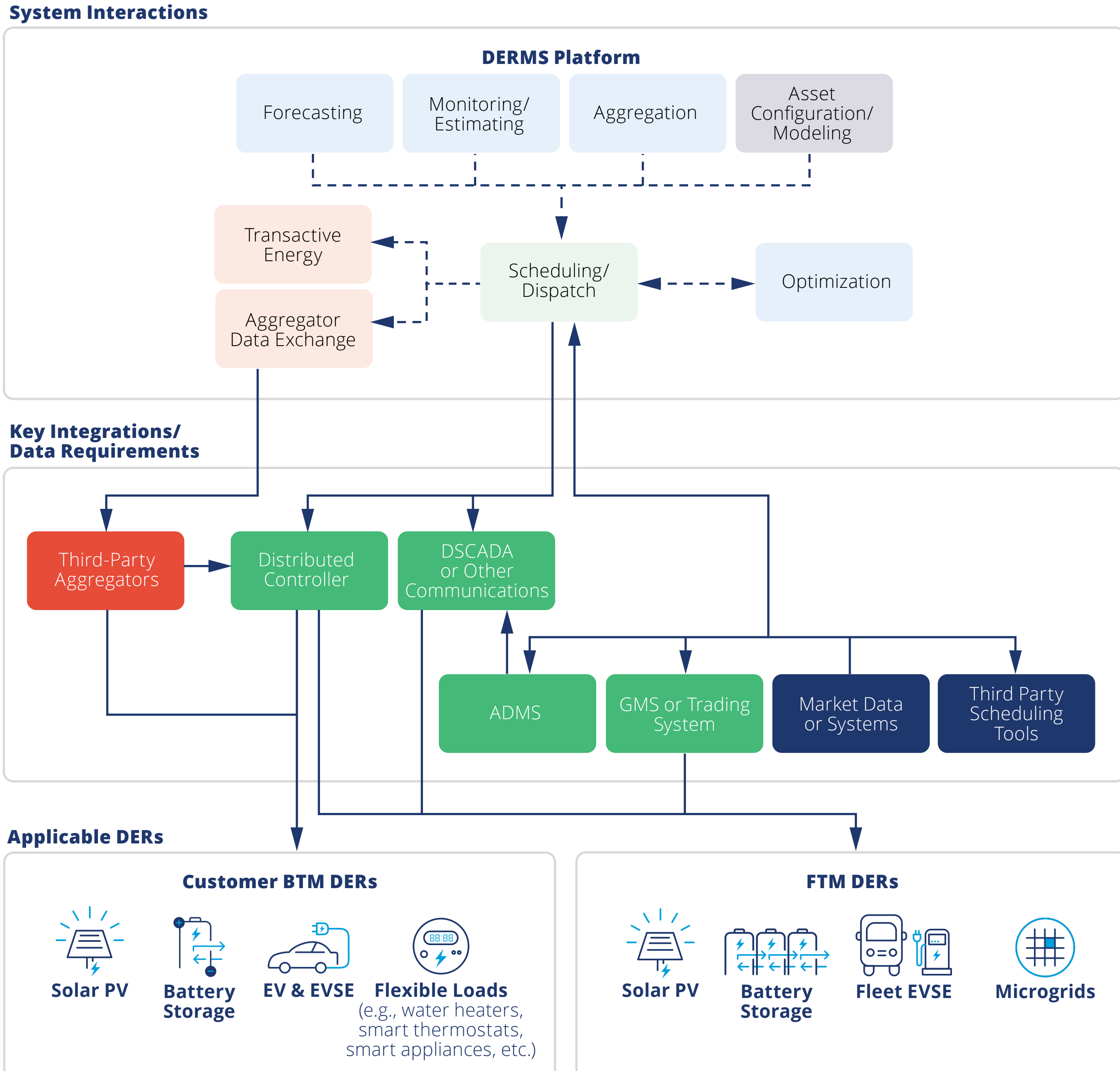
A DERMS can support scheduling and control functions through a GUI whereby the DERMS is the initiating control system or by importing a schedule or control signal through an interface to another system. In this latter case, the DERMS may simply pass along the control message from the source system, or it may utilize its optimization

42 Austin Energy. (2020). Optimal Design Methodology.

43 Pacific Gas and Electric Company. (Jan. 2019). EPIC Final Report.

44 Renewable Energy World. (July 2020). Southern California Edison launches transactive energy pilot using customer-sited DER.

Figure 13. Key Integrations and System Interactions with the Scheduling & Dispatch Module



Source: SEPA. (2023).

engine to determine which DER or grouping of DER to control. The selected architecture should support these multiple operating scenarios.

Real-time and forecasted resource statuses are required for dispatch and scheduling of DER resources. Interfaces to market systems are necessary for economic dispatch when based on LMPs and other market parameters. Alternatively, utility energy supply personnel may determine dispatch and scheduling instructions based on resource forecasts. Actual dispatch may involve manual operator action through the DERMS GUI or via integration to another system that initiates dispatch instructions. Weather condition monitoring and forecasting may also be used to inform DER dispatch and could be provided by a third-party service provider requiring a real time interface to the DERMS.

Virtual Power Plant (VPP)

Overview

Creating Virtual Power Plants (VPP) involves aggregating DERs into a single, dispatchable resource that can provide grid services such as DR, capacity for reliability or capacity markets, and reduce peak loads. VPPs can consist of one asset type, such as residential battery storage, or mixed-assets, such as combinations of electric vehicles, smart thermostats, and C&I battery assets. Both single and mixed-asset type VPPs can participate in capacity and ancillary markets. Using a DERMS to create a VPP has the additional benefits of integrating with existing enterprise systems such as ADMS, DMS, and SCADA to also provide localized grid services. A VPP was previously considered a supply-side initiative but in practice, VPPs are deployed in DR programs, where load reduction is often the VPP's purpose. However, in most cases, the VPP is utilized as a resource to address energy supply objectives.

For a DERMS to provide VPP functions, it must directly communicate with enrolled assets, whether they are FTM or BTM, to either dispatch or curtail the asset. The DERMS would leverage DER asset information along with its optimization and aggregation capabilities to create the required combinations to form the VPP based on the expected service. The DERMS dispatch and scheduling functionality would be leveraged to operate the VPP accordingly.

System Interaction

The VPP module of a DERMS, like other Grid Services Modules (Curtailment, Renewable Smoothing, Resilience/Microgrids, and VVO), utilizes data inputs from the Forecasting, Monitoring & Estimating, Aggregation, and Asset Configuration & Modeling to understand current and predicted DER states. The utility operator can initially configure a VPP in the DERMS, which is then optimized using business rules in the VPP module itself or through the Optimization module. Direct DER information from utility distributed controllers, ADMS, DSCADA, and GMS systems is provided to the VPP module via the Monitoring & Estimating module. Some integrations can also occur with third-party optimization tools, weather forecasting data, and market data to influence the creation of the VPP grouping.

VPP also exchanges data with the Grid Management module to update the DER capabilities it might utilize for the grid services it manages. Grid Management functions rely on real-time data and the most accurate assessment of the grid to make system adjustments. These adjustments feed back into VPP (or the Optimization module) to update the VPP and recast its capabilities. VPP also sends data to the M&V module to validate DER participation in a given event as part of the VPP grouping.

Supported DER Types

The VPP function is intended to support all types of DERs whether located BTM or FTM.

Pipeline Stage

This functionality is in the emerging to **deployment stage**.

The market for single asset type VPPs is a mature market whereas mixed-asset type VPPs are an emerging market. VPP software solutions are beginning to integrate more localized services including reactive power control, direct load control, locational capacity relief, power flow optimization, conservation voltage reduction (CVR), and voltage optimization. Non-DERMS, stand-alone VPP solutions are considered to be mature even though they have only been deployed in a few select markets. The use of a DERMS to provide VPP functionality is still in an emerging market moving towards deployment.

Market Availability

Market Adoption

Early adoption among vendors.

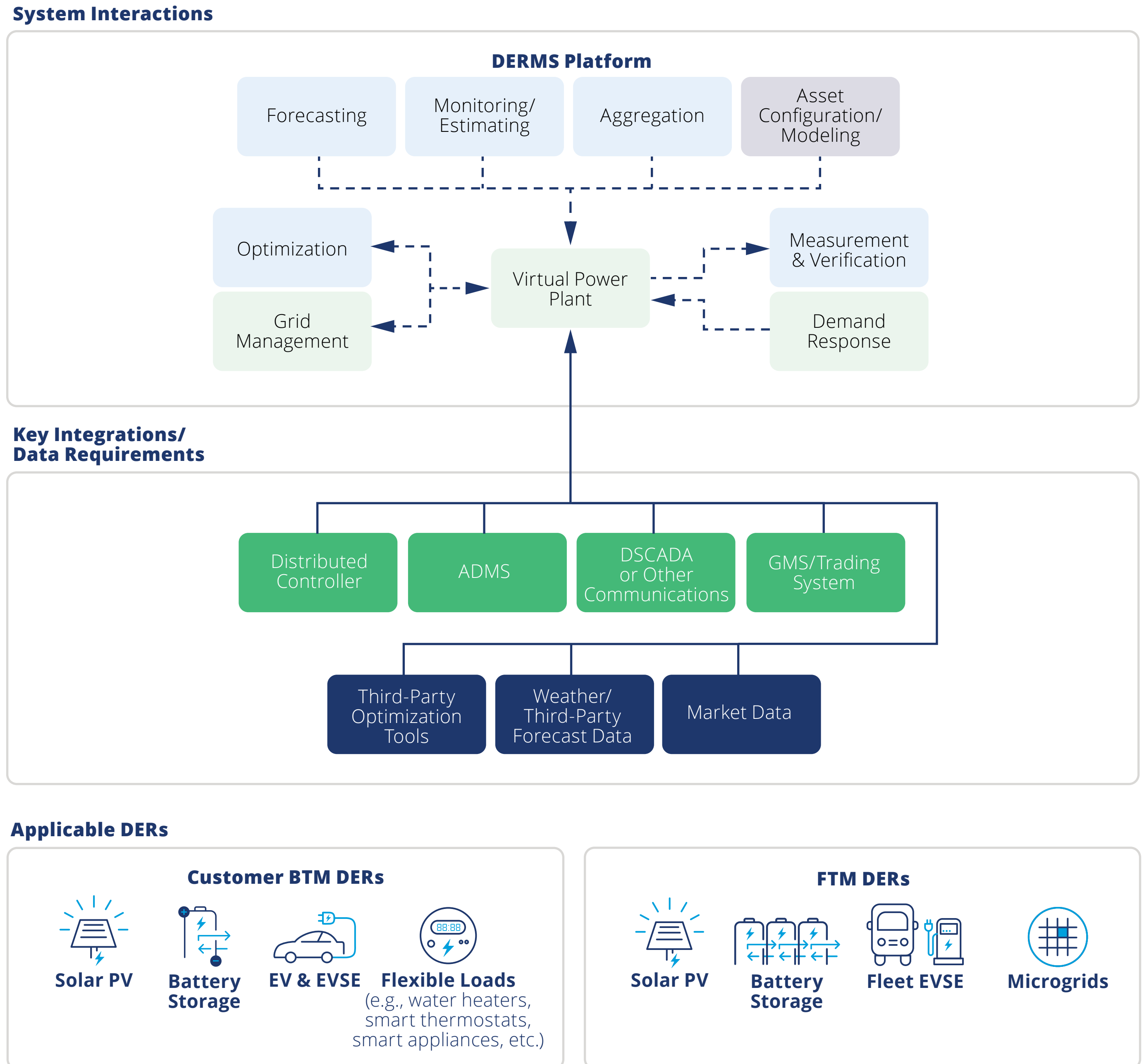
VPP DERMS applications are still primarily in the piloting/early deployment stages as more utilities adopt DERMS with this function. Aggregators have been successful bidding aggregated DER into capacity markets (e.g., Sunrun in ISO New England) but have yet to operationalize the VPP.

Example Applications

- **Alectra Utilities**, in Ontario, partnered with Enbala to launch a VPP using Alectra's EV charging facility. The VPP system balances the electricity needs and sources of the building that includes an integrated solar energy storage system and seven EV charging stations. Enbala's platform collects real-time facility data and market prices from Ontario's Independent Electricity System Operator (IESO).[45]

45 Business Insider. (Feb. 2019). Enbala's Virtual Power Plant to Power Alectra Utilities' New Workplace EV Project.

Figure 14. Key Integrations and System Interactions with the Virtual Power Plant (VPP) Module



Source: SEPA. (2023).

- **Consolidated Edison** partnered with GI Energy and Smarter Grid Solutions (SGS) to implement a Commercial Battery Storage project with FTM battery storage installations at three customer sites.[46] Consolidated Edison uses SGS's ANM Strata system to operate the storage as an aggregated dispatch resource that can also be traded as a residual, "non-critical" capacity resource in the NYISO.[47]
- **Electric Power Board (EPB)** partnered with OATI to develop a virtual power plant system after receiving a VPP grant from the TVA. EPB uses OATI's webDistribute system to conduct load control and conservation

46 ConEdison. (June 2023). Distributed System Implementation Plan.

47 Smarter Grid Solutions. (n.d.). ConEdison.

voltage reduction (CVR) to respond to the TVA's system peaks.[48]

- **Green Mountain Power** partnered with Tesla and Virtual Peaker to create a VPP program that creates a 13 MW VPP from 2,600 utility-controlled Powerwall batteries. GMP discharges the batteries during hours with monthly and annual peak demands.[49]
- **Hawaiian Electric** is partnering with OATI to utilize DER-based virtual power plants as part of their grid services expansion program. The OATI system dynamically supports Fast Frequency Response and schedule load-shifting through capacity building and capacity reduction grid services.[50]
- **Portland General Electric** partnered with Enbala (Generac Grid Services) to create a technology agnostic, interoperable VPP that enables control, optimization, and demand management of an entire fleet of DERs across various customers, vendors, and programs. The VPP added 77 MW of distributed flexibility to PGE with a goal of up to 200 MW by 2025. PGE's VPP includes 100 large industrial and small and large commercial loads, over 150 commercial smart thermostats, and more than 3,000 multi-family smart water heaters. The program aims to add over 700 commercial EV charging ports and 2,500 residential EV charging points by the end of 2021.[51]
- **Southern California Edison** partnered with the developer Swell and AutoGrid to install and manage over 3,000 residential home battery systems. Swell uses the AutoGrid software platform to aggregate the battery systems for SCE.[52]
- **Tucson Electric Power** investigated coordinated dispatch of smart thermostats, water heaters, and EV chargers through aggregators using a DERMS from Smarter Grid Solutions in Project RAIN.[53] They employed OpenADR protocol for interfacing with aggregators and SunSpec Modbus and vendor APIs to interface directly to other DERs. Tucson found that standard protocols still required customization for their needs.

Technical Considerations

Pre-Requisites

To create and dispatch a VPP in the DERMS, the system must have DER registration data in order to determine which aggregations the DERs can participate in that result in the VPP. VPPs rely on the aggregation of individual and grouped assets; aggregation can be as granular as the feeder section level or as wide as at the substation level. Once formed, the DERMS may utilize its optimization engine to determine which DER or grouping of DERs to control based on the grid operator requirements. The VPP can then be controlled using the DERMS dispatch and scheduling functionality. Dispatching the VPP requires network connections with the DER assets to control their dispatch through the utility communication network.

Key Integrations and Data Requirements

VPP functionality can be configured in the DERMS directly. The DERMS may or may not require integration to other utility enterprise systems such as ADMS, DMS, GIS, and SCADA systems. This depends on whether the DERMS optimization engine requires data from those systems to inform VPP dispatch. It can also be deployed independently of utility systems.

Integration to the RTO/ISO market system or utility generation management/trading system is required in order for the VPP to participate in market-based energy, capacity, and ancillary services. The DERMS optimization engine considers the VPP in its algorithms and dispatches the VPP accordingly. DER interoperability enabled through standards and communication protocols is required to implement a VPP DERMS solution. Different protocol interactions will occur depending on the DER asset type and the specific vendor solutions interconnected to the grid. Most asset types will have different interoperability requirements; common communication protocols include IEC 61850, DNP3, IEEE 2030.5 (SEP 2.0), ICCP, OpenFMB, OpenADR 2.0b, SunSpec Modbus, and Wi-SUN.

Device registration is another important aspect of VPP deployment. Device registration information should follow IEEE Standards 2030.11-2021 and have the appropriate data per each individual and grouped DER devices. Registration information for individual DERs can include nameplate information, communication preference information, physical location, date of installation, electrical location, device settings, interconnection ratings, and servicing information.

48 OATI. (2017). EPB Takes Control with a Virtual Power Plant.

49 GreenTechMedia. (Oct. 2020). From Pilot to Permanent: Green Mountain Power's Home Battery Network is Here to Stay.

50 OATI. (Feb. 2021). Hawaiian Electric and Open Access Technology International, Inc. Expand Paradigm-Shifting Grid Services Project.

51 Enbala. (n.d.). A Virtual Power Plant for PGE: The Case Study.

52 GreenTechMedia. (Sept. 2018). Swell Energy Picks AutoGrid to Optimize Thousands of Home Batteries.

53 Tucson Electric Power. (Oct. 2019). IRP Advisory Council Presentation. Distributed energy Resources and Customer-Site Energy Resource Alignment.

Curtailment

Overview

Utilities with high numbers of distributed generation resources may look to DER curtailment to maintain voltage limits and protect power quality. Most commonly used with solar inverters, a DERMS with curtailment functions can swiftly respond to external factors or feeder conditions, granting utilities greater control and avoiding flooding the grid with excess power. Curtailment traditionally involved reducing the load of (typically) commercial or industrial customers during times of peak load. These customers were most often on interruptible rate structures and were equipped with some degree of automation to reduce load. A DERMS could be used for controlling such customers in addition to other DERs on the grid. Curtailing DERs that have no emissions, such as rooftop solar, may negatively impact utility emission goals.

A DERMS with this use case must be able to control generation resources, often through connection to smart inverters, to reduce load. The DERMS would also need to communicate with power quality data or, in the case of market-triggered curtailment, market data such as LMP. Curtailment may be necessary at local levels or at higher levels depending on whether power quality or other factors necessitate curtailment. The use of curtailment can avoid or defer the need for expensive grid upgrades to accommodate new load. Active curtailment must include some type of compensation, through a market-based curtailment services agreement, local tariffs, or local incentives. These payment functions can occur outside of the DERMS systems or through a Settlement module.

System Interaction

The Curtailment modules interacts with the DERMS system in a similar manner to the other grid service modules (Virtual Power Plant, Renewable Smoothing, Resilience/ Microgrids, and VVO) in that they utilize data inputs from the Forecasting, Monitoring & Estimating, Aggregation, and Asset Configuration & Modeling to leverage current and predicted DER states. The Monitoring & Estimating and Forecasting modules are critical to curtailment in order to more accurately assess which DERs need to be actively curtailed and which DERs may need to be curtailed in the future. Given that curtailment is often economically driven, the module requires pricing data from market systems and/or retail rates/tariffs to make its curtailment decisions.

Curtailment also exchanges data with the Grid Management module to update the DER capability data the Grid Management module might utilize for the grid services it manages. Grid Management functions rely on real-time data and the most accurate assessment of the grid to make system adjustments. These adjustments feed back into Curtailment and/or the Optimization module to update the module and recast its capabilities. Power quality driven curtailment can cause tighter coupling for the Curtailment and Grid Management modules.

Curtailment also updates the Settlement module with curtailment event details so that owners can be compensated for grid services through the utility implementor or utility billing system.

DER Types

The curtailment function is intended to support all types of DERs that can inject energy into the grid, whether located BTM or FTM.

Smart inverters can improve curtailment capability but are not strictly necessary.

Pipeline Stage

This functionality is in the **piloting/emerging conceptual stage**.

Load programs have offered the ability to curtail interruptible loads for years, and this is an established practice. The use of a DERMS to initiate these controls in combination with other DER curtailment is still emerging.

Market Availability

Market Adoption

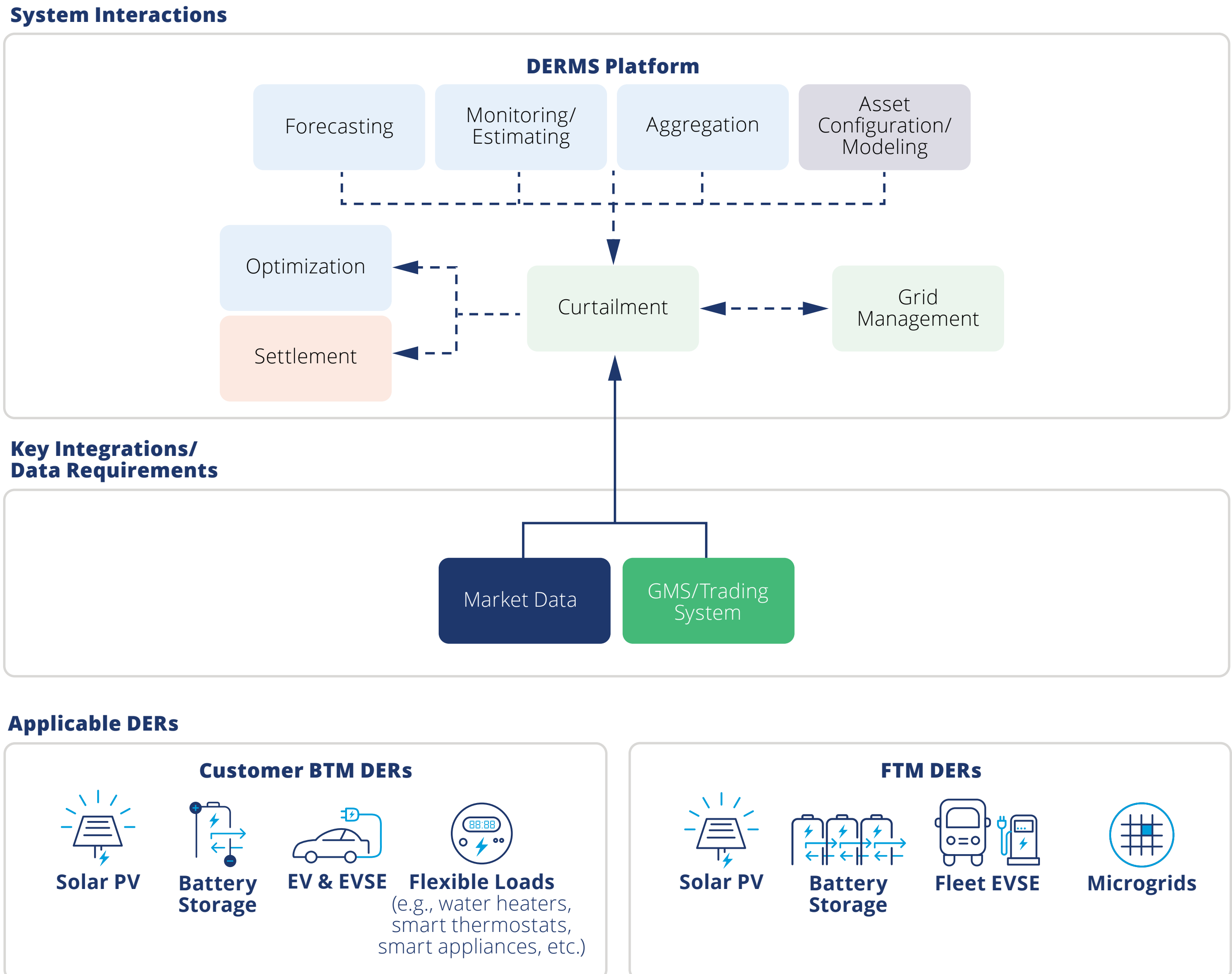
Adoption is mixed across the vendors.

Example Applications

- **Arizona Public Service** uses a DERMS to curtail commercial solar production through manual control and autonomous market-based control.[54] The DERMS system is EnergyHub.

54 Energyhub. (Nov. 2018). Arizona Public Service chooses EnergyHub's Mercury DERMS to deliver innovative grid-edge DER management strategies.

Figure 15. Key Integrations and System Interactions with the Curtailment Module



Source: SEPA. (2023).

- **Pacific Gas & Electric's** EPIC DERMS pilot allows the utility to curtail solar PV output through smart inverters.[55] One curtailment recommendation stemming from the pilot was that inverter manufacturers and DER developers should work on developing accurate and standardized methods to determine max power capabilities for solar generation under curtailed states.
- **Southern California Edison** curtails smart inverters as part of their transactive energy pilot.[56] The DERMS system is from Smarter Grid Solutions.
- **Tucson Electric Power** explored curtailment of distributed solar generation in Project RAIN.[57] The pilot project used the Smarter Grid Solutions software. Tucson Electric Power was able to validate the technical ability to control and align customer energy resources (CERs) to grid needs including the ability to curtail capacity and prevent reverse power flow.

55 Pacific Gas and Electric Company. (Jan. 2019). EPIC Final Report.

56 Renewable Energy World. (July 2020). Southern California Edison launches transactive energy pilot using customer-sited DER.

57 Tucson Electric Power. (Oct. 2019). IRP Advisory Council Presentation. Distributed energy Resources and Customer-Site Energy Resource Alignment.

Technical Considerations

Pre-Requisites

Utilities need communication infrastructure to curtail generation resources or to automatically curtail interruptible loads. Smart inverters can be used for solar curtailment and often include industry standard communication protocols such as IEEE 2030.5. However, not all inverters support this integration. A compensation mechanism such as tariffs or incentives to compensate customers for the DER curtailment also needs to be in place.

Key Integrations and Data Requirements

Two-way communications and the operational state of the DER are necessary for curtailment. Curtailing the entire DER output is easier than partial curtailment. In the partial curtailment scenario, the DER generation state is also required. If the curtailment is extended for a longer period of time, the DER output forecast is also required.

A DERMS that is being used for curtailment must be integrated with a communications network in order to communicate with the DER inverter/interruptible load and issue commands along with return communication from the inverter/load controller. DERs capable of performing curtailment services may be grouped to simplify the curtailment process, however individual DER communications are necessary. If the curtailment is tied to price signals, then the DERMS would need to be integrated directly to a market/trading system or the ISO/RTO pricing system because those price signals are also a required data input. Reliability driven curtailment requests might be initiated from an ADMS or other control system.

Demand Response

Overview

The demand response (DR) module of a DERMS includes a variety of functions required for management of a DR program including:

- Customer enrollment
- Event scheduling
- DR weather and capacity forecasting
- Dispatch signaling
- Measurement and verification of the events

Financial settlement with retail customers or with the wholesale market is also part of DR but is considered part of the Settlement module of a DERMS.

Many DERMS used only for DR are marketed as grid-edge[58] systems that allow utilities better control and insight into supply-side resources and the distribution grid, both for small- and large-scale DER assets. Complete DR DERMS packages can include all associated subfunctions stated above or are modules added to the vendor's larger DERMS platform. Supported programs include "dispatchable" behavioral DR, where only notifications are sent and customers make the load adjustments they see fit, or direct control programs, consisting of switched devices and/or smart thermostats. In either case, dispatch strategies often rely on forecasting abilities and sometimes price signals, or other market strategies, to determine when events should be called and to optimize the dispatch schedule. Called events are likely determined by the regional ISO/RTO or individually by the utility, and a signal is sent to the DERMS system to initiate the dispatch of the enrolled DERs. Typically, in the case of critical peak pricing or event-based DR, customers receive a pre-event communication alerting them of the upcoming DR event to prepare them and to give them a chance to opt-out or take other load reduction actions. When communicating with customers, the DERMS system likely interfaces with a utility-customer communication platform.

DR programs can include a variety of DER assets from small, residential smart appliances to larger commercial and industrial assets such as battery storage. DR DERMS platforms are designed to handle a diverse portfolio of assets and to communicate with different customer classes.

System interactions depend on whether the DR program is a retail program or a program offered through the ISO/RTO and if the program is based on economic (optimize for financial impact), environmental, grid management, or emergency (optimize for reliability) factors. This will impact when and how event days and duration of events are identified, how event notifications are conducted, end-user participation rules, load drop/baseline calculation

58 "Grid edge is a term used to describe technologies and business models that advance a decentralized, distributed, and transactive energy grid. This includes physical infrastructure assets, network or control software, applications, and data analytics tools." NRDC. 2018.

methodologies, snapback management, and event reconciliation/settlement.

Regardless of the type of program, the DERMS' dispatch capabilities are configured to interact with data analytics systems that monitor and predict load conditions. DR event notifications can then be dispatched to customers, either through provided contact information (such as text or email) or through devices themselves. Some programs allow voluntary participation and load reductions, whereas other programs initiate direct control of DER assets. DERMS may initiate notifications, but they utilize a communication platform specified by the utility. Retail DR programs also need to include some type of compensation, either through local tariffs or local incentives. These payment functions can occur outside of the DERMS systems or through a Settlement module.

System Interaction

The DR modules interacts with the DERMS system in a similar manner to the other grid service modules (Virtual Power Plant, Curtailment, Renewable Smoothing, Resilience/Microgrids, and VVO) in that it utilizes data inputs from the Forecasting, Monitoring & Estimating, Aggregation, and Asset Configuration & Modeling to know the current and predicted DER states. The DR module utilizes additional information directly from the Registration module to ensure verification of DER customers to the DR program, verify the operational and programmatic limits of those DERs, and provide the customer information to the Settlement module.

When used for traditional DR purposes where all DERs enrolled in a program are controlled to provide all their capacity, the DR module simply executes an all-or-nothing control command for the designated DER cohorts. By incorporating business rules via the Optimization module, the DR module can refine and optimize its control commands in different ways.

DR also exchanges data with the Grid Management module to update it on the DERs capabilities, so it can use them for grid services. Grid Management functions rely on real-time data and the most accurate assessment of the grid to make system adjustments. These adjustments feed back into DR (or the Optimization module) to update the module and recast its capabilities. Power quality driven curtailment can cause tighter coupling for the DR and Grid Management modules.

M&V exchanges data with the DR module so that as DR events run over time, those data measurements can verify the success of a program and better inform the DR module on customer habits. Often DERMS utilize machine learning to optimize the DERMS software as more data is collected on the individual utility system with its particular customer base.

Supported DER Types

The DR function is intended to support all types of **dispatchable** DERs whether located BTM or FTM.

Pipeline Stage

This functionality is in the **deployment stage** as DR and DER technologies become sufficiently mature to participate in utility programs.

DR DERMS have been fully deployed for several years with many programs initially focused on specific DER technologies. As the market matures, utilities have moved away from the piloting stages to fully deployed, expanded programs that incorporate multiple DER types.

Market Availability

Market Adoption

There is adoption across the vendors, especially those with DRMS offerings.

Example Applications

- **Arizona Public Service** has load and capacity forecasting functions as part of their BYOT DR program using the Mercury DERMS from EnergyHub.[59]
- **AVANGRID (NYSE&G, RG&E)** uses EnergyHub's DERMS platform to enroll customer thermostats and window air conditioning units in their Smart Savings Rewards DR program.[60]
- **CPS Energy** utilizes EnergyHub + Resideo for customer enrollment in their DR program called WiFi Thermostat Rewards Programs.[61]
- **El Paso Electric** uses EnergyHub's Mercury DERMS to manage its BYOT DR Program.[62]
- **Eversource** uses Generac Grid Services' Concerto DERMS platform to control a host of DR assets for its overall ConnectedSolutions DR program. Concerto acts as a dispatch platform that interacts with the residential DR program using the EnergyHub platform, a C&I DR

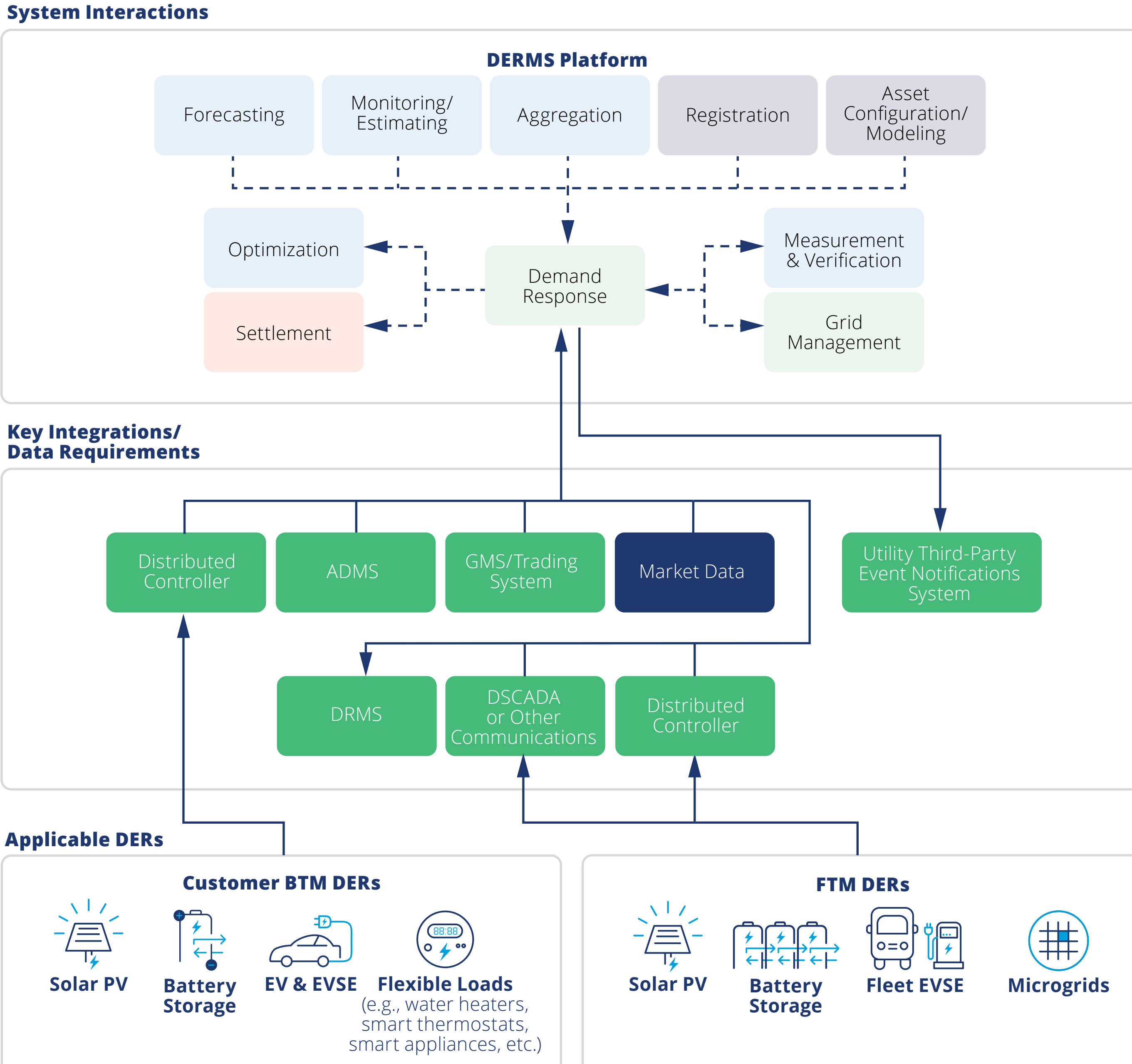
59 Energyhub. (Nov. 2018). Arizona Public Service chooses EnergyHub's Mercury DERMS to deliver innovative grid-edge DER management strategies.

60 EnergyHub. (Dec. 2017). EnergyHub and AVANGRID successfully complete first season of 'Smart Savings Rewards' program.

61 EnergyHub. (March 2017). CPS Energy and Nest connect with customers to increase demand response enrollment.

62 EnergyHub. (May 2017). EnergyHub launches Bring Your Own Thermostat demand response program with El Paso Electric.

Figure 16. Key Integrations and System Interactions with the Demand Response Module



Source: SEPA. (2023).

program, battery electric storage assets, and an EV load management program. Total enrolled dispatch across all customer classes is 150 MW as of 2021.[63]

- **Hawaiian Electric** received approval in 2019 for implementation of OATI's cloud aggregation software. This allows for utility control of customer-owned BTM DERs and to set the foundation of HECO's DR programs.[64]

63 Enbala. (n.d.). The Eversource ConnectedSolutions Program.

64 Hawaiian Electric. (August 2019). Hawaiian Electric and Open Access Technology International Plan for Innovative Grid Services Wins PUC Approval.

- **LA Department of Water and Power** uses forecasting to improve situational awareness of their BYOT program.[65] The system will manage thermostats for the LADWP DR program. The end goal is to use the system to achieve 25 MW of flexible power capacity by the end of 2021.
- **Pacific Gas & Electric's** EPIC DERMS pilot leverages aggregation to dispatch DERs using least-cost optimization.[66] The pilot found that old methods of monitoring with SCADA are insufficient for load masking and for correct net load calculations. There is a need for a DER-aware ADMS with monitoring functionality. The pilot team also used aggregator vendor portals to remotely monitor the DER assets and compare them with the aggregator interface.
- **National Grid** uses EnergyHub and aggregation functionality as an integral part of their commercial and industrial DR program.[67] This project will be able to manage multiple DER classes for DR.
- **New Hampshire Electric Cooperative** has implemented AutoGrid's DORMS offering to manage their residential and commercial DR program.[68]

Technical Considerations

Pre-Requisites

The ability to conduct M&V analysis to support settlement functionalities is often dependent on the availability of DER performance data from meters, third-party aggregators, or other monitored sources. Connection to traditional meters, smart meters, smart inverters, and other measurement devices can provide the necessary data in either real-time or after-the-fact measurements. Smart metering through utility infrastructure such as AMI can provide greater visibility through more accurate and frequent data collection, although this technology is not strictly necessary for M&V and Settlement.

Key Integrations and Data Requirements

DR enrollment is a function that can live in the DERMS system or as a standalone system that integrates to a DERMS. Standalone systems reduce cybersecurity concerns especially in cases where customers and third-parties would be accessing the system to input DER registration data. This could be the case for customers participating in utility DR programs.

In the case of stand-alone systems, the key architectural consideration is development of the interface between the two systems including the process and requirements for updating data as devices are registered. Ideally, this interface would leverage established APIs supported by the vendor DERMS. An interface with the utility CIS system may also be required for customer information not captured as part of enrollment or to record the customer's participation in DR events and to facilitate bill calculations.

As an integrated offering, the DERMS registration module may also serve as the customer enrollment interface and be embedded within the utility website. Customers, aggregators, or trade allies would access the tool to register their DR assets. Some DERMS vendors offer this customer portal functionality as part of their system, with their own cybersecurity protocols for customer interfacing. The architectural and security standards are important integrations given that customer data can be involved in the DR program. Another key architectural consideration is the need for a communication network that supports DR notifications as well as dispatch of DR assets directly from the DERMS.

Integration to a utility or third-party enrollment system may be required for DERs participating in the DR program. The registration information that is collected should follow IEEE Standards 2030.11-2021. Recommendations include:

- Nameplate information
- Communication information
- Installation information
- Electrical location
- Device settings and interconnection rating
- In/out service dates
- DER modeling information

Additional data to be collected could include aggregation/aggregator information, operational limits (export limits, ramp rate limits, time-based schedules), customer contact information, meter information, and the participating utility or ISO/RTO program.

DR programs have further integration requirements to support the M&V and settlement functions of the programs. Because M&V depends so heavily on data, utilities would benefit from access to existing data analytics engines and data historians. Integration between the

65 EnergyHub. (Oct. 2020). Los Angeles Department of Water and Power and EnergyHub enroll over 16,000 thermostats in BYOT program, targeting 25 MW of flexible capacity.

66 Pacific Gas and Electric Company. (Jan. 2019). EPIC Final Report.

67 EnergyHub. (Sept. 2020). National Grid expands DER portfolio with EnergyHub to manage commercial and industrial resources.

68 AutoGrid. (Apr. 2016). New Hampshire Electric Cooperative Goes Live with Three New Residential and Small and Medium-Sized Business Demand Response Programs Using AutoGrid DROMS.

DERMS and a MDMS or historian may be required to provide the historical (measured) data needed for M&V. Forecast data may be provided by the DERMS or need to be integrated from another utility system. If the DERMS is supporting market settlement functions, integration to an ISO/RTO market system may be required.

Grid Management

Overview

Grid management consists of controlling DERs to obtain energy, capacity, and ancillary service objectives. As DER penetrations increase, managing the energy output and/or load profile of individual and aggregated DERs becomes more important to adequately manage supply and demand on the grid. A DERMS can provide real time energy usage monitoring and visibility into DER impacts on net load, and it can allow the utility to control energy input and output to balance the grid and to provide load shedding and shifting services.

Energy Management

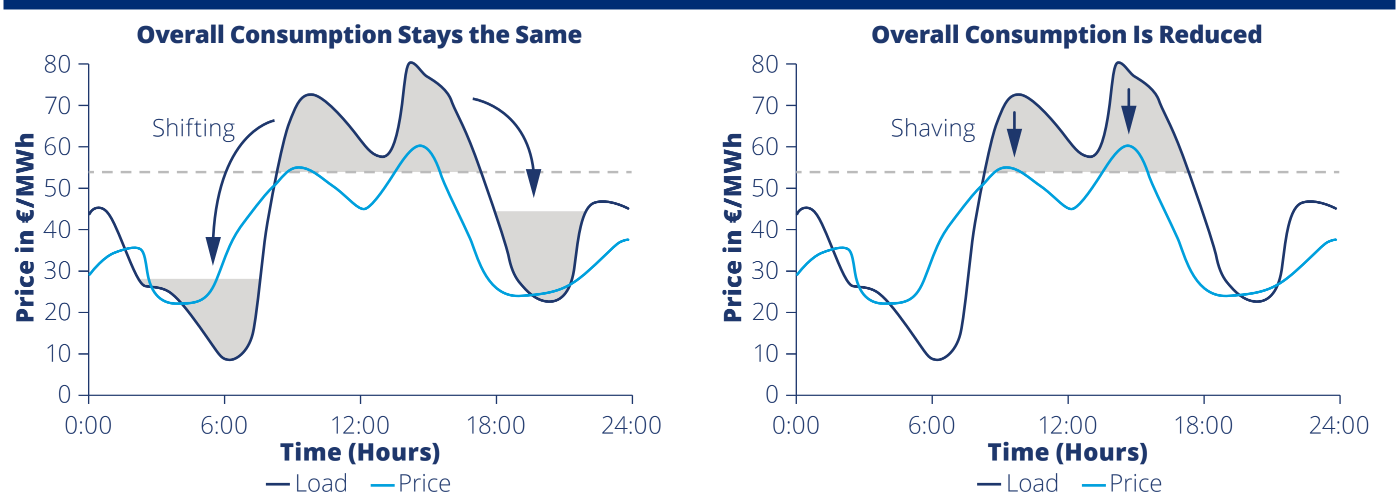
Energy arbitrage is a type of energy management that controls DER energy consumption and output. Energy arbitrage can be performed for wholesale market purposes which involves purchasing energy when the prices are low and reselling that energy when prices are high. For distribution, energy arbitrage is exercised by the utility through tariffs that depend on the time of day and encourage consumers to shift their energy use from higher priced times to lower priced times or to optimize renewable energy output to best align with load requirements. Managing the energy output from renewable DERs can also support the utility's carbon goals and can complement their grid scale generation portfolio.

A DERMS can provide energy management by using DERs to deliver a needed quantity of energy to the distribution grid. The energy provided can be positive or negative depending on grid needs. IEEE 2030.11 points out that the energy supplied can be absolute (e.g., directly metered), relative to an established production plan or forecast (e.g., curtailment of PV still results in energy delivery but less than forecasted), or relative to a calculated baseline (e.g., reduction in EV charging is still consuming energy but is lower than the baseline consumption). In all cases, a DERMS can provide real-time energy usage monitoring and provide visibility into DER impacts on gross and net load.

Capacity Management

The most basic capacity service is to allow the DER to deliver or consume power. The DERMS provides this type of flexible capacity service through control of DER ramp rates. These ramping reserves are power reserves that are associated with loads and resources used for system balancing. The DERMS can also be calibrated to employ load shifting or

Figure 17. Load Shifting vs. Peak Shaving



Source: Next Kraftwerke. (n.d.). What does Peak shaving mean? Recreated by SEPA.

peak shaving strategies to improve the distribution efficiency and mitigate problems with intermittent resources. Load shifting and peak load management is often achieved using DR or energy storage.

Using DERMS to provide load shifting allows the utility to better match supply and demand by raising load at low periods and reducing load at peak periods. It can also ensure stable power flow and customer voltage despite peaks in solar and customer demand. Load shifting can reduce infrastructure maintenance costs and protect key distribution infrastructure, such as transformers and protective equipment, from overloading and reverse power flows.

Ancillary Services

Utilities may use a DERMS to limit distribution system constraints and violations or to alleviate overloads and power quality issues. The most likely application for this is utilizing DERs to manage voltage and frequency where the DERMS controls DER output to match supply and demand on the grid. Through a DERMS, DERs can help solve the constraint issues caused by their integration into the grid system.

Frequency limits can be maintained through frequency control (device-level continuous, autonomous adjustment of DER output in response to a frequency error from scheduled frequency under normal operating conditions) and frequency response (device-level automatic adjustment of DER output in response to a frequency error from scheduled frequency for significant frequency events). Frequency control becomes difficult in relatively small balancing areas (i.e., Hawaii) where grid operators require countermeasures for variable renewable resources to reduce their power fluctuation amplitude. Voltage support is provided by controlling DERs capable of dynamically correcting excursions outside of voltage limits by absorbing/injecting reactive power as well as by controlling DER power output impact on voltage.

IEEE 2030.11 identifies cold load pick-up as a special case of constraint management. A DERMS can support cold load pick-up (reducing the instantaneous power required for restoration after an outage) by controlling the ramping requirements for individual or groups of DERs local to the outage site after restoration.

A DERMS can provide these constraint management services by dispatching DERs to address both thermal and power quality limits in an integrated manner. Dispatch may refer to a request for active/reactive power to meet a system constraint (such as feeder congestion) or the dispatch of a constraint to a specific DER (e.g., limiting export to a certain amount, or curtailment) or group of DERs. This dispatch could occur in real time based on the DERMS monitoring network conditions or via a request from a third-party operational system such as an ADMS. This dispatch could be scheduled in advance based on short-term grid-condition forecasts and then adjusted in real-time as conditions change.

The DERMS constraint management function should include both the initial dispatch of DERs to alleviate the constraint as well as dispatch instructions for returning the DER to normal operations once the constraint is alleviated.

Two specific power quality functions that can be integrated within a DERMS platform are **power factor correction** and **phase balancing**. Power factor is the ratio of working power absorbed by the load to the apparent power in the circuit. Power factor correction on a circuit is provided through injection or absorption of reactive power in an effort to arrive at utility power factor. The presence of reactive power in the circuit leads to a power factor of less than one. Traditionally in electric circuits, power factor improvement is achieved through the use of equipment on the distribution grid such as capacitor banks, synchronous banks, and phase advancers. Certain DERs can also provide reactive power either on demand or via continuous regulation of DER smart inverters capable of absorbing and outputting reactive power.

Phase balancing is a complex process undertaken by distribution operators to balance loads across the three phases of a distribution circuit in an effort to reduce voltage drop and system losses. Phase unbalance can introduce additional power losses in the distribution network. Balancing loads between the three phases of the distribution system becomes challenging with higher DER penetration. The variability of DERs also adds to the complexity of controlling phase balancing. However, inverter based DERs, especially batteries, can be used to assist with phase balancing as their phase power output can be dispatchable. This can support the balancing of some unbalanced local loads.

System Interaction

All grid management services, especially ancillary services, depend on knowing the current state of the distribution network and thus leverage data from other operational control systems such as ADMS and distribution automation systems to provide network, power quality, and device information. The Asset Configuration & Modeling module provides static DER nameplate information and modeled locational information including network connectivity which is especially important for determining DER capability to provide ancillary services to alleviate constraints in specific locations.

Operators would utilize the Monitoring & Estimating module to monitor grid conditions and DER status and use alarms and setpoints to identify constrained conditions. The Forecasting module supports the Optimization and Scheduling & Dispatch modules by identifying future potential constrained conditions and providing forecasted energy and capacity needs in real-time in response to grid conditions at specific locations. These forecasts would be generated by the DERMS or ingested from a third-party forecasting tool. The Optimization module uses this information to determine the optimal DER schedule. The Scheduling & Dispatch modules then send instructions to the DERs to deliver the requested grid service by individual or grouped DERs at specific time intervals. Commands include disconnecting from the grid, injecting energy, drawing energy, ceasing to inject, and ceasing to draw, among others.

The Grid Management module addresses voltage constraints through DER curtailment or by controlling DER reactive power. A DERMS Curtailment module may provide these voltage support strategies or a combination of the Optimization and Scheduling/Dispatch modules may accomplish this. Likewise, the VVO module could also be used to provide voltage mitigation support.

Grid operators can use a DERMS to accomplish power factor correction and phase balancing by dispatching appropriate DERs in coordination with other operational control systems such as an ADMS. The DERMS Optimization module would utilize DER capability data from the Registration module to solve for power quality corrections. The Scheduling & Dispatch module would then send the appropriate schedule or control points to the individual DER (or aggregations of DER). The DERMS could also be used to automate control using setpoints and only override those setpoints during certain operational conditions.

Supported DER Types

The Grid Management function is intended to support all types of DERs whether located BTM or FTM that can be ramped up or down for energy and capacity services and all DERs with dispatchable, inverter-based systems for ancillary services.

The inverters would need to be capable of dynamically correcting (active control) excursions outside of voltage limits.

Pipeline Stage

As a whole, this functionality is in the **emerging stage**.

Among the grid management services, energy management is the most understood. To date, DERMS have been used most widely for managing load (e.g., DR). However, monitoring DER capability and controlling their energy output (up or down) is a core feature of DERMS solutions. Utilities around the country are implementing capacity services through controlling flexible loads and DR programs. Targeted pilots are using a DERMS to control output of targeted DER, such as batteries, for load shed and load shift. To date, DERMS capacity management capabilities have mainly been deployed for DR applications and more advanced applications of capacity management are still an emerging application.

Ancillary management via a DERMS is an emerging space. The DERMS must have information on the distribution network electrical state in order for the DERs to perform constraint and power quality corrections. This requires the controlling system to receive data from, and have full-range control of, grid equipment, SCADA-connected storage and generation assets, and DERs. To date, much of the industry activity in the constraint management space has been on energy storage pilots because battery energy storage is a DER type well suited for grid management services due to its ability to respond quickly.

An ADMS system (or some other specialized control system) is typically used to provide power factor improvement through connection to capacitor switches. A DERMS can perform power quality corrections by optimizing the control levers of appropriate DERs to provide on-demand and in some cases, proactive services; however, adjusting power factor and phase balancing via a DERMS is an emerging space. There are more examples of using DERMS for power factor correction whereas the use of a DERMS for phase balancing is more the subject of academic studies.

Market Availability

Market Adoption

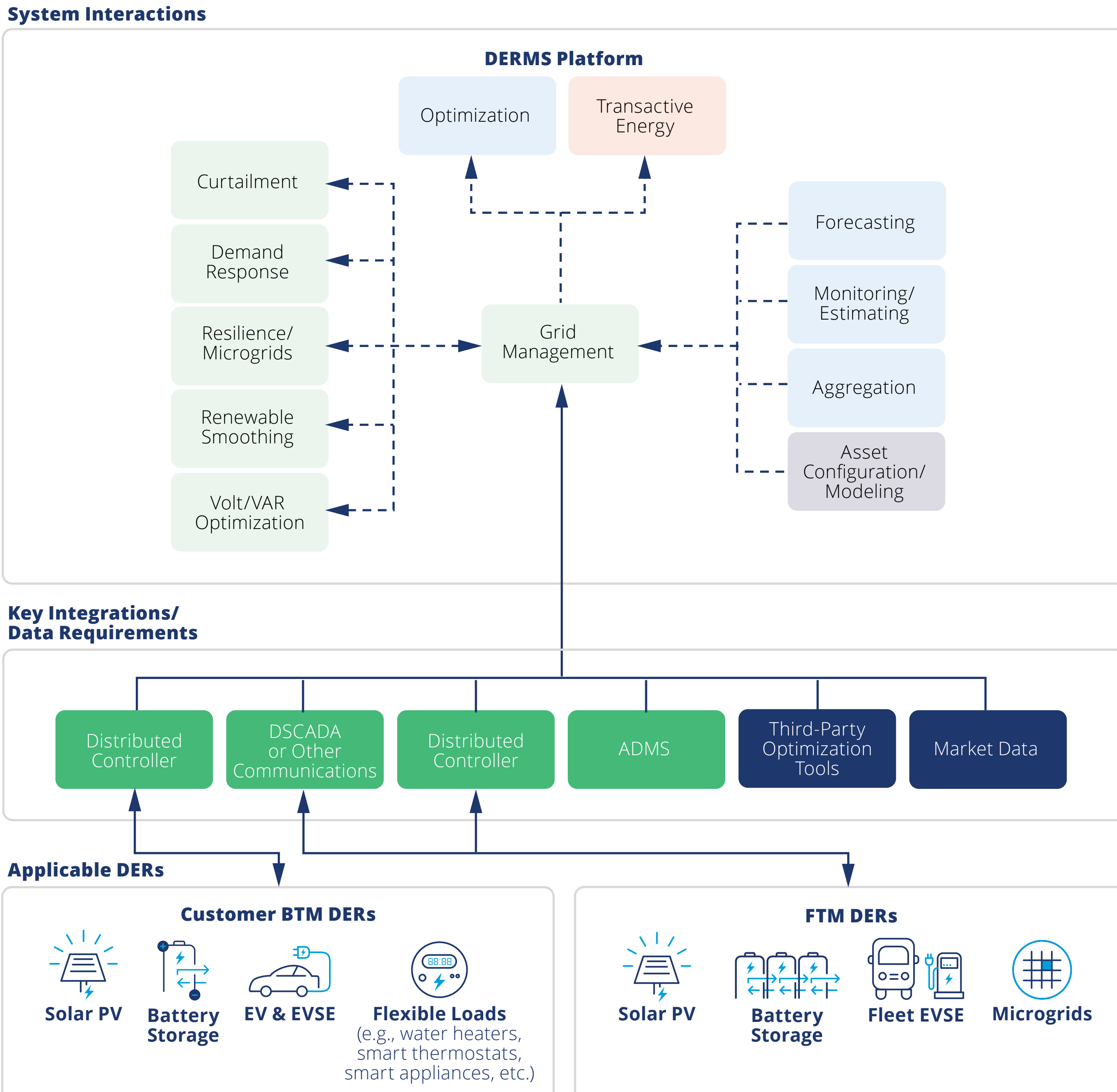
Capacity and energy management are offered across the vendors; ancillary services have mixed adoption but future capabilities are expanding.

Example Applications

- **Austin Energy** demonstrated the ability to realize economic value through price differentials in its SHINES Project by charging batteries when prices were low and discharging when prices were high. They tested voltage support using energy storage.[69]

69 Austin Energy. (2020). Optimal Design Methodology.

Figure 18. Key Integrations and System Interactions with the Grid Management Module



Source: SEPA. (2023).

- **Arizona Public Service** is using Energy Hub to charge batteries during peak PV production periods, thereby decreasing the impact of PV ramping in the afternoon and decreasing evening load peaks.[70] This limited peak demand by load shifting using thermal and battery energy storage. The Energy Hub platform also delivers grid services from smart inverters by managing natively supported and remotely configurable settings including active power, reactive power, and ride-through settings. Arizona Public Service also contracted with Generac

70 Energyhub. (Nov. 2018). Arizona Public Service chooses EnergyHub's Mercury DERMS to deliver innovative grid-edge DER management strategies.

to use Generac Grid Services' Concerto DERMS to manage residential battery storage systems for capacity services as well as voltage management, real power orchestration, fleet energy control, and ancillary services.[71]

- **Consolidated Edison**—Smarter Grid Solutions' ANM Strata was deployed and integrated with Con Edison systems and control room processes to deliver stacked value streams from the battery systems. ANM Strata provides automated optimization of the batteries to provide power factor correction and voltage stabilization services.[72]
- **DTE Energy** investigated voltage support in their storage pilot from 2014-2016. The homegrown DERMS pilot relied on storage dispatch to provide frequency regulation services.[73]
- **El Paso Electric** dispatches DR for their BYOT program through EnergyHub. El Paso Electric is running the BYOT pilot program to manage system peak and help meet demand-side management goals.[74]
- **Great River Energy** uses OATI's DR platform to dispatch load control events.[75]
- **Hawaiian Electric** received approval in 2019 for implementation of OATI's cloud aggregation software, which provides frequency control services.[76]
- **Holy Cross Energy** tested DERMS with frequency regulation in collaboration with NREL.[77]
- **Horizon Power** deployed the PXiSE Microgrid Controller to manage the output of a solar farm and utility scale battery in coordination with a gas-fired power station in the town of Onslow, Australia. The system simultaneously optimizes the renewable energy output and power quality.[78]
- **PECO Energy** used Volt/VAR Watt Optimization as a form of voltage support in their microgrid DERMS pilot.[79]
- **PG&E** uses solar and storage to provide voltage support functions as part of the EPIC pilot. PG&E's used their ADMS to identify grid needs and DER impacts. The DERMS determined the optimal dispatch of active and reactive power to provide voltage and capacity services. The EPIC pilot also demonstrated capabilities of using least-cost dispatch to efficiently dispatch DERs to mitigate system issues, or to provide energy arbitrage.[80]
- **Tucson Electric** used Smarter Grid Solutions in its Project RAIN initiative to shape customer energy use to better utilize solar energy during the mid-day and reduce peak demand in the evening. The DERMS controlled Solar PV and batteries to either increase load (batteries charge, solar PV curtailed) or decrease load (batteries discharge, solar at full production) as required.[81]
- **UK Power Networks** is deploying Smarter Grid Solutions's DERMS to monitor, contract, and dispatch DERs integrated into its network which will help it procure flexible capacity to defer network reinforcements and manage short-term network constraints.[82]

Technical Considerations

Pre-Requisites

Utilities must have the DERMS optimization engine algorithms tuned with appropriate data inputs and established rules to enable swift dispatch when utilities have direct control over DERs. Real-time and forecasted resource statuses along with weather forecasts and market signals such as LMP are required for dispatch and scheduling of DER capacity and energy resources.

71 PRNewswire. (Aug. 2022). Generac Grid Services to Deliver Comprehensive, End-to-End DERMS Solution for Arizona Public Service.
72 ConEdison. (June 2023). Distributed System Implementation Plan.
73 DTE Energy. (2015). DTE Energy Advanced Implementation of Energy Storage Technologies.
74 EnergyHub. (May 2017). EnergyHub launches Bring Your Own Thermostat demand response program with El Paso Electric.
75 OATI. (Mar. 2017). Great River Energy Becomes Latest Utility to Implement OATI DRMS Solution.
76 Hawaiian Electric. (August 2019). Hawaiian Electric and Open Access Technology International Plan for Innovative Grid Services Wins PUC Approval.
77 NREL. (Feb. 2020). Performance Evaluation of Distributed Energy Resources Management System via Advanced Hardware-in-the-Loop Simulation.
78 PXiSE. (n.d.). Leading the renewable energy transformation in Western Australia.
79 Argonne National Laboratory. (Sept. 2020). Microgrid Energy Management System Integration with Advanced Distribution Management System.
80 Pacific Gas and Electric Company. (Jan. 2019). EPIC Final Report.
81 Tucson Electric Power. (Oct. 2019). IRP Advisory Council Presentation. Distributed energy Resources and Customer-Site Energy Resource Alignment.
82 GreenTechMedia. (June 2020). UK Power Networks' New Platform for Flexibility Services Could Be Groundbreaking.

Predefined and configured resource type groupings may be necessary to dispatch types of assets to meet the specified capacity and/or energy management goal. To participate in grid management, the DERs have to be "dispatchable" and require necessary communications or head-end system integrations to enable the DERMS to perform direct dispatch.

In the case of ancillary services, the DERMS would have to be aware of network conditions to identify violations and develop mitigation strategies. Alternatively, another distribution operations system, such as an ADMS, could request mitigation support from the DERMS which would then optimize DER dispatch or re-dispatch to provide the necessary level of grid support.

Frequency regulation applications require connection to devices that can monitor frequency levels and trigger automatic response to changes. The use case usually requires interaction with dispatch or control capabilities to adjust DER generation output to compensate for frequency rising above or below the usual levels.

Configuration and modeling of DER registration data (asset, programmatic, network) as well as capturing customer program/tariff participation and interconnection information in the DERMS is required for power quality management as this data defines the operational constraints for the DER. If the asset is a renewable generator, a forecast of the system output is also needed. Finally grouping the assets into categories and locations is required to support the desired optimization strategy.

Key Integrations and Data Requirements

The key integration for the Grid Management module of a DERMS is to the ADMS for the network model (and updates) as well as for grid service requests (if applicable). The DERMS is not playing a central role in the assessment and response of constraint and power quality services, rather it is processing requests from upstream orchestration systems to create the necessary dispatch schedules for the DERs. Integration to a forecasting system for short-term forecasts may also be required to develop a dispatch schedule. The system housing the interconnection agreement information generally requires operating limits and DER generation facility information. Further integrations to a trading system or market interaction system will provide the wholesale, distribution, and LMP pricing data needed for energy arbitrage and ancillary services.

Ancillary service management requires the direct control of individual DERs and groups of DERs. Two-way communications are needed from the DERMS to the DER, DER controller, or aggregator to send dispatch instructions/schedules, to confirm receipt, and to verify operations. Two-way communication requires the DERMS to integrate to SCADA, DER controllers, third-party aggregators, and other communication system(s) and support multiple communication and device protocols. This could include IEC 61850, DNP3, IEEE 2030.5 (SEP 2.0), ICCP, OpenFMB, OpenADR 2.0b, SunSpec Modbus, and Wi-SUN. The individual DER, inverter, or controller would have to support setting adjustments that would change the reactive power output or power factor of the device.

In order to understand the available capabilities of DERs to correct power factor, the DERMS would need access to asset, programmatic, and network information maintained in the Registration module. Other key data considered by the optimization engine includes:

- DER mode of operation
- Available modes of operation
- Services in which the DER is participating
- Ramp rates
- Real-time available capability (real and reactive)
- Historic and predicted loads

Since batteries are commonly used for energy, capacity, and ancillary management purposes, the DERMS would need visibility into battery status and operations. This could require direct integration to battery inverters or to a separate battery energy management system. Key information includes AC voltage, current, frequency, active power, reactive power, as well as DC voltage and current, state of charge (SOC), state of health, cell voltages, cell temperatures and control modes. The DERMS takes these data points and also layers in other factors such as whether the inverter is online and available for control. Other factors include upper and lower control limits, storage level, and ramp rate. Forecasting of SOC availability should also be integrated so that battery usage for all of these services is optimized. Even if SOC is known in a particular instant, there is no guarantee that the same energy will be available for the duration of the event given the automatic, local load charging and discharging needs.

Renewable Smoothing

Overview

Renewable smoothing is a critical issue for increasing DER interconnection capacity to the power grid. As renewable generation increases, utilities are looking at multiple technology options to address the variability of these renewable resources. Smoothing the output of variable renewable resources makes the renewable generation look more like baseload generation, improving dispatchability and reliability. This is also referred to as renewable firming. Similarly, utilities want to smooth the variable nature of renewable DERs such as solar PV to mitigate voltage and frequency disturbances. These different operational needs require smoothing to occur over seconds to address power quality issues, over a day to match power purchase agreement terms, and over a year to match generation portfolio requirements.

DERs are one tool that can be used to smooth the variability of renewables. The most common approach to renewable smoothing using DERs is to charge and discharge battery energy storage to match renewable output or use flexible loads and demand-side programs to shift energy consumption to match renewable output. Renewable smoothing can be used to prevent grid constraints by utilizing information from the Forecasting module as well as to address renewable constraints closer to real-time.

System Interaction

Renewable Smoothing requires the dispatch of DERs under different system constraints to achieve different objectives such as minimizing costs, shifting energy to higher value periods, better matching of customer loads, and promoting increased renewable penetration. A DERMS accomplishes this using DER information maintained in its Asset Configuration & Modeling module. The Renewable Smoothing interacts with the DERMS system in a similar manner to the other grid service modules (Virtual Power Plant, Curtailment, DR, Resilience/Microgrids, and Volt/VAR Optimization) in that it utilizes data inputs from the Forecasting, Monitoring & Estimating, Aggregation, and Asset Configuration & Modeling to know the current and predicted states of the DERs. The Optimization module determines the best dispatch strategy based on the utility's objectives and sends that strategy to the Scheduling & Dispatch module that would then send dispatch signals to the appropriate DER(s).

Renewable Smoothing also exchanges data with the Grid Management module to update the DER capabilities it might utilize for the grid services it manages. Grid Management functions rely on real-time data and the most accurate assessment of the grid to make system adjustments. These adjustments feed back into Renewable Smoothing (or the Optimization module) to update the module and recast its capabilities. Power quality driven curtailment can cause tighter coupling for the Renewable Smoothing and Grid Management modules.

In some cases, a third-party, such as an aggregator, may provide renewable smoothing as a service to the utility. In this case, the utility DERMS would need to provide the same system interactions, except it would send dispatch instructions to the aggregator via the DERMS Aggregator Data Exchange module.

DER Types

The renewable smoothing function is intended to support all **controllable** types of DERs whether located BTM or FTM.

Pipeline Stage

This functionality is in the **emerging conceptual phase**.

To date, DERMS have largely been used for managing load (e.g.,DR). However, monitoring and controlling DER for renewable smoothing is a function that most DERMS support due to the basic component of providing energy to the grid from DERs and in controlling DERs. Direct coupling of renewable generation and dispatching loads is more of an emerging application for DERMS systems.

Market Availability

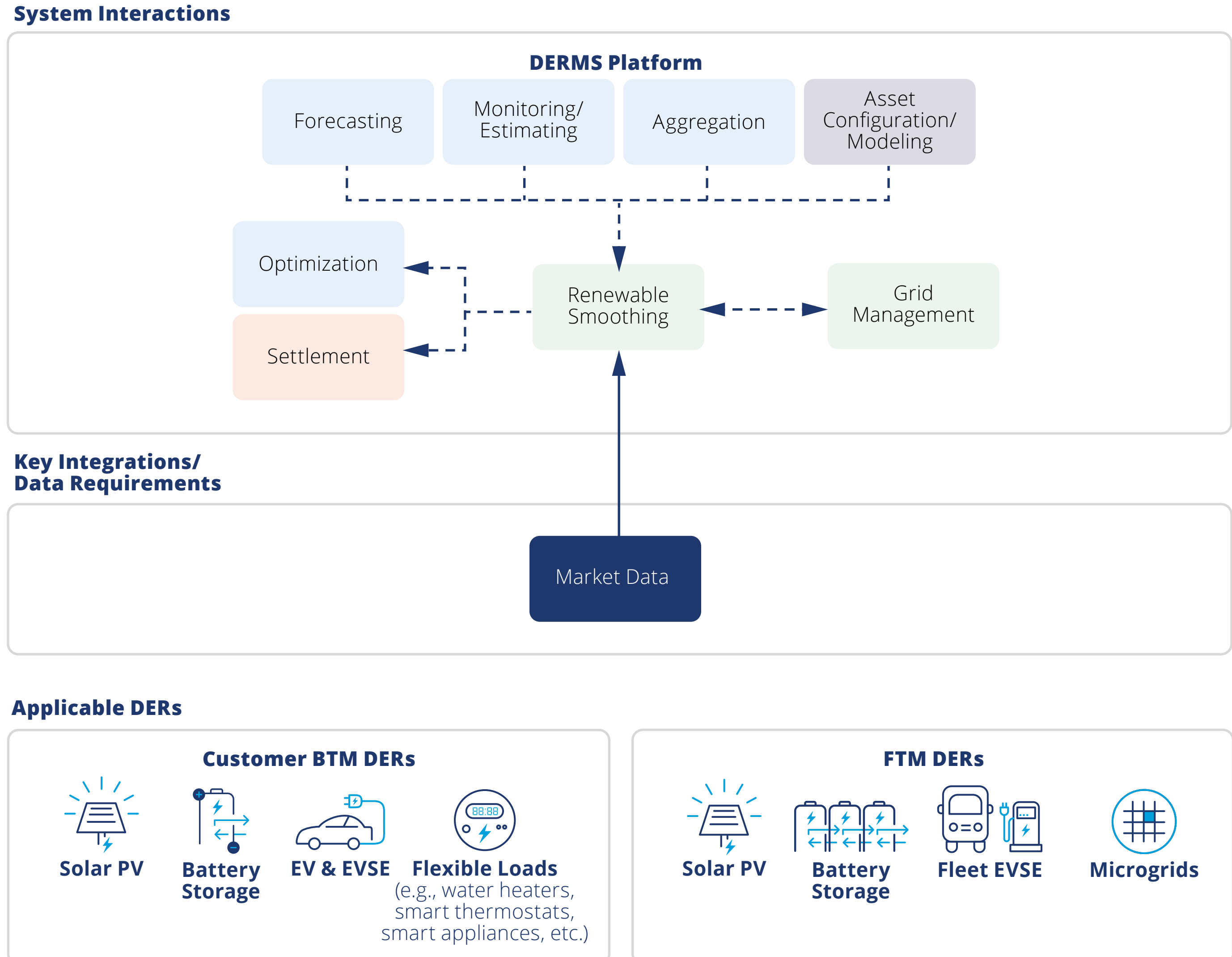
Market Adoption

Capabilities exist across vendors, however this is usually not overtly marketed.

Example Applications

Various utilities are smoothing renewables using flexible loads and DR although this is still an emerging field. Pilots using battery storage to smooth renewables including solar PV exist, but utilities are not yet incorporating such techniques into day-to-day operations.

Figure 19. Key Integrations and System Interactions with the Renewable Smoothing Module



Source: SEPA. (2023).

- **Arizona Public Service** is using EnergyHub's Mercury DERMS to dynamically manage its portfolio of grid-edge devices through peak demand reduction, load shifting and renewables matching, and solar inverter management and curtailment.[83] Arizona Public Service also contracted with Generac to use Generac Grid Services' Concerto DERMS to manage residential battery storage systems for real power orchestration and ancillary services.[84]
- **National Grid** utilizes EnergyHub's Mercury DERMS for its ConnectedSolutions DR program. The program dynamically manages a portfolio of grid-edge devices and provides peak demand reduction, load shifting, and renewables matching.[85]
- **Guam Power Authority** uses PXiSE's Active Control Technology platform to coordinate solar PV farm energy production with storage charging and discharging in an effort to minimize grid fluctuations resulting from weather variability impact on PV output.[86]

83 Energyhub. (Nov. 2018). Arizona Public Service chooses EnergyHub's Mercury DERMS to deliver innovative grid-edge DER management strategies.

84 PRNewswire. (Aug. 2022). Generac Grid Services to Deliver Comprehensive, End-to-End DERMS Solution for Arizona Public Service.

85 EnergyHub. (Sept. 2020). National Grid expands DER portfolio with EnergyHub to manage commercial and industrial resources.

86 PXiSE. (n.d.). Mitigating Power and Frequency Fluctuations from DERs.

Technical Considerations

Pre-Requisites

To enable swift dispatch when utilities have direct control over DERs, utilities must have the DERMS optimization engine algorithms tuned with appropriate data inputs and established rules. Real-time and forecasted resource status along with weather forecasts are required for the DERMS to determine the optimal dispatch strategy for DERs providing renewable smoothing functions. Predefined and configured resource type groupings may be necessary to dispatch types of assets (e.g, batteries) to meet the specified renewable smoothing goal.

Key Integrations and Data Requirements

Two-way communications are needed from the DERMS to the DER, DER controller, or aggregator to send dispatch instructions/schedules, to confirm receipt, and to verify operations. Two-way communication requires the DERMS to integrate to SCADA or some other communication system(s) and support multiple communication and device protocols. This could include IEC 61850, DNP3, IEEE 2030.5 (SEP 2.0), ICCP, OpenFMB, OpenADR 2.0b, SunSpec Modbus, and Wi-SUN.

In order to understand the available capabilities of DERs for renewable smoothing, the DERMS would need access to asset, programmatic, and network information maintained in the Registration module. Other key data required in the Optimization module for DER availability for renewable smoothing includes:

- DER mode of operation
- Available modes of operation
- Services in which the DER is participating
- Ramp rates
- Real-time available capability (real and reactive)

Since batteries are commonly used for renewable smoothing purposes, the DERMS would need visibility into battery status and operations. This could require direct integration to battery inverters or to a separate battery energy management system. Key information includes AC voltage, current, frequency, active power, reactive power, as well as DC voltage and current, state of charge, state of health, cell voltages, cell temperatures and control modes. The DERMS takes these data points and also layers in other factors such as if the inverter is online and available for control. Other factors include upper and lower control limits, storage level, and ramp rate.

Other distributed load types such as thermal and mechanical storage, heating ventilation and air conditioning (HVAC), and water pumping stations are considered “firming loads” that can be used in renewable smoothing and absorb excess renewable generation.

Resilience/Microgrids

Overview

The resilience use case for a DERMS system is centered on maintaining grid stability and access to power during widespread grid pressures resulting from events such as storms, flooding, wildfires, and other extreme weather. Primarily, the resilience use case focuses on utilizing microgrid assets during blue-sky and islanded modes. However, resilience benefits can also be gained from integrating an ADMS with a DERMS system so that the DERs can participate in FLISR operations and help manage load transfer.

Depending on their functionality, microgrid controllers may be considered a grid-edge DERMS or be separately controlled by an enterprise DERMS system during grid-connected modes. In the latter case, the DERMS can aggregate multiple microgrids, elevating them beyond individual entities into grid assets. Cases where DERMS have direct control of microgrids give utilities more control over both planned and unplanned islanding events and improve visibility to ensure microgrids are functioning as effectively as possible. Microgrids managed by DERMS can be primarily designed to operate entirely off-grid in island mode to provide a resilience benefit to loads within the microgrid, or designed to be primarily connected to the grid and only be islanded at certain times.

If the DERMS serves as the controller itself, it must be able to control dispatch of generation and storage resources and manage data based on microgrid conditions. A DERMS microgrid controller requires low-latency, intensive data, and control. Microgrids are often designed using a federated microgrid controller. In this case, a hierarchical architecture allows the utility to interconnect a centralized DERMS for the oversight of the microgrid and an ADMS for coordination with the surrounding grid system. IEEE 2030.7 has further information on the characteristics of microgrid controllers.

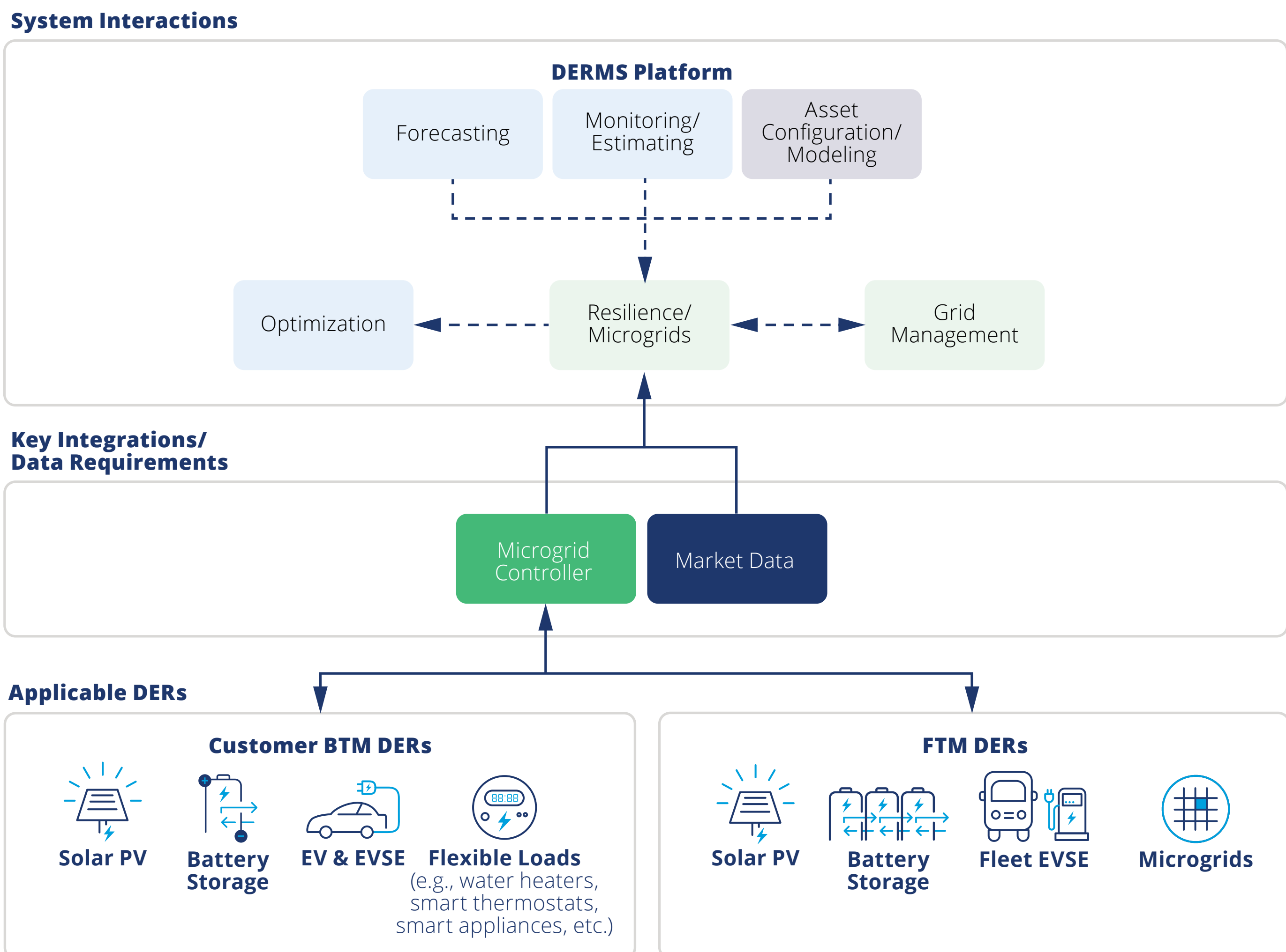
DERMS can employ other functionalities such forecasting and data analytics to inform microgrid control decisions. The DERMS may also utilize microgrids to coordinate active grid management strategies such as frequency regulation and load shifting to provide services back to the grid.

System Interaction

The Microgrids module uses the Forecasting, Monitoring & Estimating, and Asset Configuration & Modeling modules to provide insight into onsite microgrid assets and aggregations of many microgrids. Often, the DERMS interfaces with a local microgrid controller to control the microgrid in the event of islanding. The microgrid controller dispatches the signals from the DERMS to the actual generation and storage units. The DERMS system uses the Optimization engine to optimize microgrid asset scheduling during blue-sky conditions and to manage the microgrid during islanded conditions, especially for microgrids with limited generation compared to the total local demand.

Resilience/Microgrids also exchanges data with the Grid Management module to update the DER capabilities it might utilize for the grid services it manages. Grid Management functions rely on real-time data and the most accurate assessment of the grid to make system adjustments. These adjustments feed back into Resilience/ Microgrids (or the Optimization module) to update the module and recast its capabilities. Power quality driven curtailment can cause tighter coupling for the Resilience/ Microgrids and Grid Management modules.

Figure 20. Key Integrations and System Interactions with the Resilience/Microgrids Module



Source: SEPA. (2023).

Supported DER Types

The resilience/microgrids module is intended to support all types of DERs whether located BTM or FTM.

In this use case, a microgrid controller and the assets within a microgrid are all relevant to the operation of the microgrid and are of importance for interconnecting to a DERMS.

Microgrids often utilize solar PV, combined heat and power systems (CHP),[87] battery energy storage systems, and other onsite generation systems.

Pipeline Stage

This functionality is in the **piloting/emerging conceptual stage**.

Microgrid controllers themselves are in the deployment phase; however, interconnection and operation using a DERMS is still in the pilot phase.

Market Availability

Market Adoption

Adoption is widespread among vendors involved with microgrid controllers and DERMS interconnection.

Example Applications

Microgrid pilots are common; however, utilities generally have not implemented fully active DERMS-controlled microgrids.

- **Commonwealth Edison** manages their Bronzeville Community microgrid cluster using a microgrid controller that their vendor, Siemens, classifies as a type of specialized DERMS.[88]
- **DTE Energy's** DERMS pilot has occasional islanding functions to create microgrids using community energy storage systems. DTE developed the community energy storage and customer island control using in-house software for dispatch and the onboard CES units for island capability. The microgrid software uses utility DNP and SunSpec Modbus protocols.[89]
- **North Carolina Electric Membership Corporation (NCEMC)** uses a hierarchical model with a tertiary DERMS system and a secondary microgrid site controller. NCEMC uses the OATI DERMS system for visibility into the microgrid status/operations and to control the microgrid assets when they are grid connected. DERMS control of the assets allows for grid services such as voltage support and frequency response services. When islanded, the DERMS interacts with the site controller that provides visibility on the microgrid status and if it is unavailable for grid services.[90]
- **Pacific Gas & Electric** identified microgrid control as one of the key use cases in their EPIC DERMS pilot.[91]
- **PPL Electric Utilities** created the Keystone Future Solar Project in collaboration with GE Grid Solutions. The Keystone Future Solar Project is a DERMS solution that remotely controls distributed assets such as microgrids to optimize power quality.[92]
- **Snohomish County PUD** operates a DERMS with islanding functions using Doosan's DG-DERO software.[93] The DG-DERO interacts with the integrated onsite controller DG-IC that is paired with the microgrid energy storage assets and two vehicle-to-grid electric vehicle chargers.[94]

Technical Considerations

Pre-Requisites

Microgrid DERMS can be grid-edge, onsite controllers or centralized, enterprise DERMS. Grid-edge DERMS have direct control to the microgrid generation resources, while enterprise DERMS will interface with the microgrid onsite controller. Per IEEE 2030.7, microgrid control systems allow the microgrid to be a self-contained system that can manage itself, allow the microgrid to operate both autonomously and in grid-connected mode, and connect to and disconnect from the main distribution grid for the exchange of power and the supply of ancillary services. The microgrid controller should have real-time control and energy management functions to support voltage regulation, dispatch control, DER asset control/command, and DER monitoring.

87 CHP may or may not be considered a DER depending on the definition of DER referenced.
88 Microgrid Knowledge. (March 2018). ComEd Selects Siemens Microgrid Software for Bronzeville Microgrid Cluster.
89 DTE Energy. (2015). DTE Energy Advanced Implementation of Energy Storage Technologies.
90 ElectricNet. (Jan. 2020). OATI To Work With NCEMC And Local Cooperative Utility To Build A Sustainable Community.
91 Pacific Gas and Electric Company. (Jan. 2019). EPIC Final Report.
92 Galford, C. (June 2019). PPL Electric Utilities earns award for its Distributed Energy Resource Management System.
93 Snohomish County PUD. (n.d.). Energy storage.
94 Business Wire. (Oct. 2020). Doosan GridTech, a global smart grid technology provider, will examine how V2G chargers will impact grid resiliency at SnoPUD's Arlington Microgrid site.

Due to the need for islanding capabilities, the microgrid DERMS must either be integrated from the initial development of the microgrid, or the enterprise DERMS system must be separately integrated with the microgrid onsite controller after the microgrid installation. The microgrid onsite controller needs to have effective communication protocols related to the microgrid status and generation parameters to allow for the exchange of information with the enterprise DERMS system.

Microgrids can be classified as customer, community, and utility microgrids, each with different owners and/or operators. Utilities exploring microgrid management using DERMS often collaborate with local communities; a relationship with colleges, government agencies, and neighborhoods can be helpful.

Key Integrations and Data Requirements

DER assets within the microgrid are subject to the same local interconnection agreements as other DER assets and may follow IEEE 1547 rules on DER interconnections. Other state specific standards such as California's Rule 21 and Hawaii's Rule 14 have been adapted to include microgrid assets and allow islanding of those assets. Microgrid DER assets should follow the same IEEE 1547 communication protocols as those used for monitoring of DER assets. Commonly used communication protocols based on SEPA's research of DERMS pilot projects includes IEC 61850-8-2, IEEE 2030.5, and OpenADR 2.0b. MultiSpeak is another protocol often favored by cooperative utilities. Additional communication protocols such as DNP3 can connect the DERMS system to the onsite microgrid controller.

Volt/VAR Optimization (VVO)

Overview

DERMS can improve power quality through active grid management strategies. One such strategy involves voltage support through volt/VAR optimization (VVO). VVO focuses on circuit-level operations and decreases energy losses by reducing reactive power flow along the distribution circuit. VVO devices communicate with system-wide voltage measurements to minimize power losses and offer increased system efficiency. Conservation voltage reduction (CVR) is the intentional operation of the transmission or distribution system to provide customer voltages in the lower end of the acceptable range, with the goal of achieving energy and demand reductions for customers. CVR is used to flatten voltage profiles and lower overall system voltage while staying within the specified American National Standards Institute (ANSI) or International Electrotechnical Commission (IEC) voltage limits. When utilities manage and optimize voltage and reactive power simultaneously (combining the voltage management associated with CVR with reactive power management), it is referred to as volt/VAR optimization.

VVO capability is traditionally accomplished through utility control of tap changers, voltage regulators, and line capacitors through SCADA based communications. IEEE 1547-2018 requires inverter fed DERs to contribute reactive power to support grid voltage. Such inverters can be used for VAR support in case of normal power flow direction (from the substation), or to provide voltage regulation in the case of reverse flow. This is accomplished by using static inverter setpoints or through dynamic voltage control that fully utilizes the DER capacity. Incorporating DERs complicates traditional VVO functionality because increased DER penetration on a feeder can cause power flow changes. DERMS may either be designed to pass through VVO instructions from another system, such as a standalone VVO, or may be designed to optimize DER dispatch based on alerts from an ADMS or other utility system.

Utilities deploy advanced grid management functions such as VVO, integrated volt-var control (IVVC), and CVR as as pilots or as very targeted applications. Stand-alone solutions have been deployed as well as solutions enabled through an ADMS. Many academic and research initiatives focus on DER impact on VVO algorithms. While there is recognition that DERMS can facilitate the use of DERs to provide reactive power support in VVO, implementation remains limited, especially in the US. Thus, using a DERMS for VVO is not yet well adopted in the market, and trends indicate that VVO implementation will continue as a standalone, separate system. DERMS can provide additional support to any existing utility VVO system.

System Interaction

A DERMS can manage DER inverter settings (directly or through aggregators) to provide both voltage regulation and VAR support. Active, dynamic control of reactive power contribution from DERs via a DERMS system can contribute to overall system voltage control strategies and reduce the number of operations of traditional voltage regulating devices. DERMS systems coupled with ADMS and standalone VVO systems have access to power flow models that allow the DERMS to optimize the dispatch of inverter based DERs. AMI data can assist with VVO data and potentially allow for premise and circuit level Optimization.

A DERMS can provide inverter-based VVO functionality because the system knows the location of DERs on specific feeders based on data from its Asset Configuration & Modeling module. It can optimize the DER-reactive power settings to meet voltage regulation and economic objectives through its Optimization Module and send reactive power control signals to the appropriate DERs using its Scheduling & Dispatch module. VVO also uses the current grid condition data from the Forecasting, Monitoring & Estimating, Aggregation, and Grid Management modules.

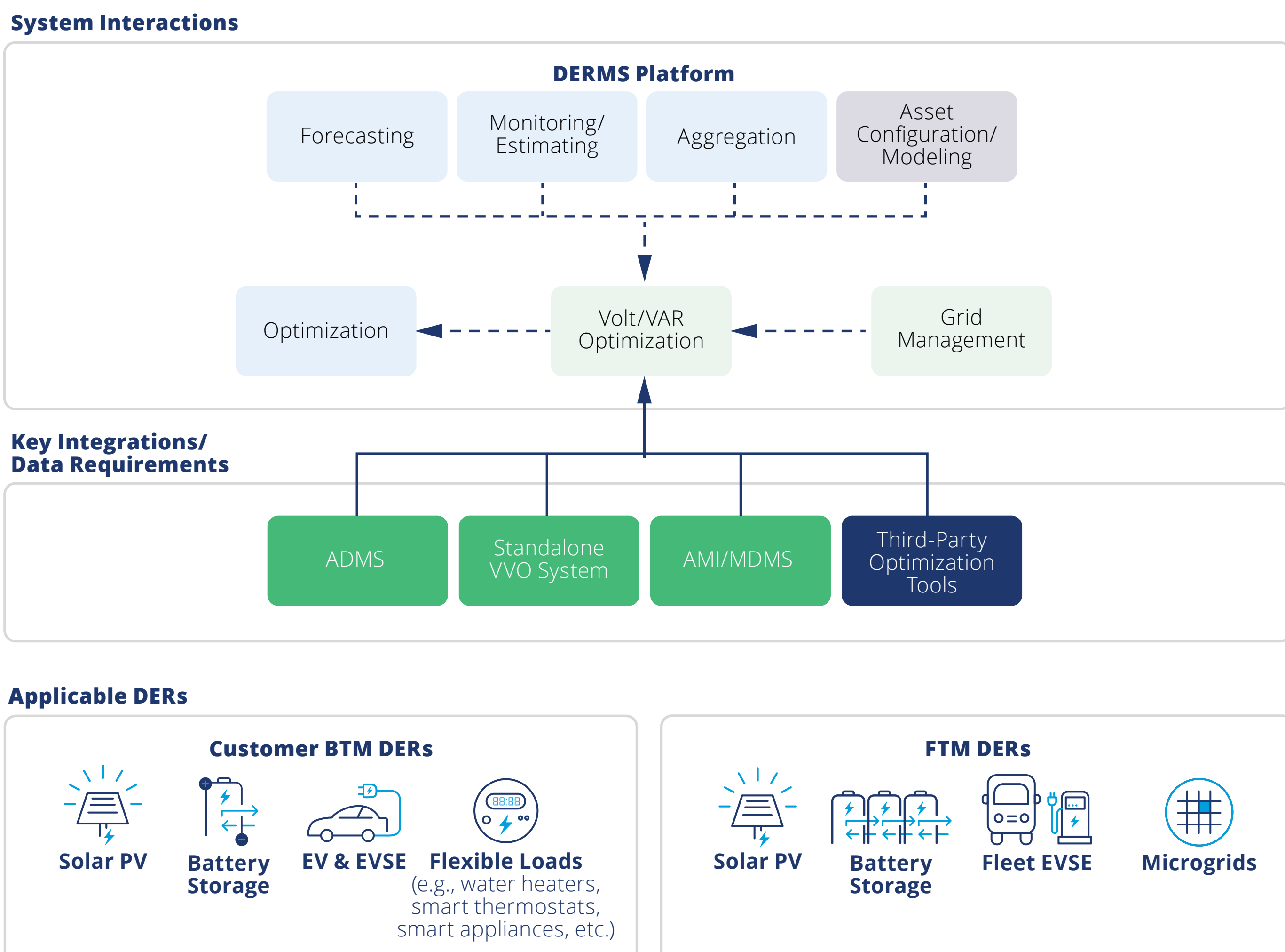
DER Types

The registration function is intended to support all **dispatchable, primarily inverter-based** DERs whether located BTM or FTM. The key component is whether the DER can provide reactive power, and the inverters must be capable of dynamically correcting (active control) excursions outside of voltage limits.

Pipeline Stage

This functionality is in the **emerging conceptual phase**.

Figure 21. Key Integrations and System Interactions with the Volt/VAR Optimization Module



Source: SEPA. (2023).

Market Availability

Market Adoption

Market adoption remains low adoption with some vendors supporting functionality.

Example Applications

- **Alectra** piloted Dynamic Volt-VAR optimization (DVVO) with GE Digital's Opus One DERMS platform.[95]
- **PECO Energy** used Volt/VAR Watt Optimization as a form of voltage support in their microgrid DERMS pilot.[96]
- **PPL** made their GE DMS "DER aware" by capturing DER geographic, operational, and system impact information in its FLISR and volt/VAR optimization (VVO) applications in their DOE funded Keystone Solar Future Project. This allowed for real-time monitoring and communication between PPL and communication-capable DERs.[97]

Technical Considerations

Pre-Requisites

Active/dynamic VVO control methods depend on bidirectional communications and optimization algorithms requiring real-time knowledge of feeder states, topology of the circuit, and DER locations. In effect, the real-time as-operated state of the network must be known. This requires the utility to have in-depth knowledge of their distribution system designs, customer-owned DER equipment interconnection locations, and two-way communications to end devices.

Key Integrations and Data Requirements

Initiating VVO controls from a software-based solution requires integration to a communication network such as SCADA to communicate with utility owned assets. Incorporating DERMS would require communications between the DERMS and DER devices providing reactive power support. The VVO application would likely be a stand-alone solution or part of an ADMS.

The key Integration for the VVO module is to the ADMS or other distribution control system for the network model (and updates) as well as for reactive power support from DERs. The ADMS or stand-alone VVO system could simply request reactive power from the DERMS.

Dispatching for VVO requires the direct control of individual/groups of DERs. Two-way communications including dispatch instructions and schedules, confirmation of receipt, and verifying operations are required between the DERMS to the DER, DER controller, or aggregators. Two-way communication requires the DERMS to support multiple communication and device protocols. This includes IEC 61850, DNP3, IEEE 2030.5 (SEP 2.0), ICCP, OpenFMB, OpenADR 2.0b, SunSpec Modbus, and Wi-SUN. The individual DER, inverter, or controller would have to support adjustment of settings to change reactive power output. In order to understand the available capabilities of DERs to provide VVO support, the DERMS would need access to asset, programmatic, and network information maintained in the Registration module. Other key data taken into consideration by the optimization engine includes:

- DER mode of operation
- Available modes of operation
- Services in which the DER is participating
- Ramp rates
- Real-time available capability (real and reactive)
- Time-based projections of availability

95 OpusOne. (n.d.). Dynamic Volt-VAR Optimization at Alectra.

96 Argonne National Laboratory. (Sept. 2020). Microgrid Energy Management System Integration with Advanced Distribution Management System.

97 Smart Electric Power Alliance. (Jan. 2021). Insights from PPL's DERMS Implementation.

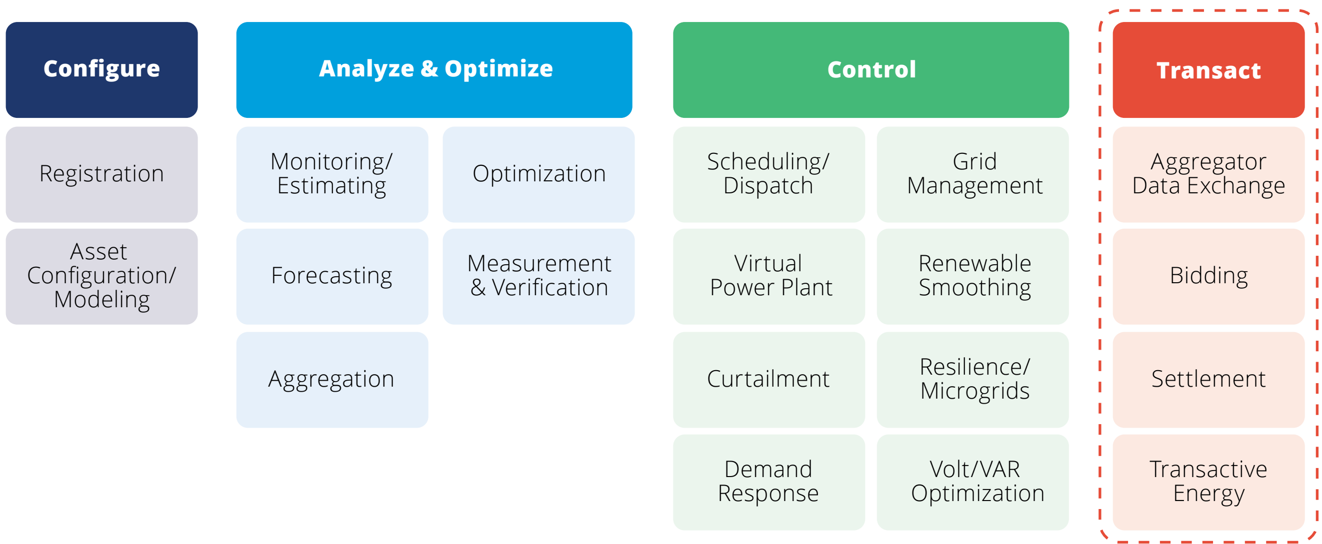
Transact

The Transact modules are a group of economic and transaction modules that aim to produce better coupling with market systems. One function of a DERMS is to facilitate DER transactions with third-parties and energy markets. The systems can monitor, predict, and present market condition information for optimized energy purchase and sales and provide utilities with a platform for coordinating with third-parties that may be managing behind-the-meter (BTM) DERs. Market-related DERMS applications require monitoring and predictions of LMPs and other parameters to inform DER trading in capacity and/or energy markets. Third-party related DERMS applications are primarily focused on the seamless exchange of DER data and controls. These functions rely on access to DER capabilities and benefit from aggregation functions to create VPPs, group DERs by aggregator, and support FERC 2222 requirements focused on connecting DERs with markets.

Many vendors are still in the developmental phases of the transact services, given the extensive communication requirements for exchanging information with market systems and with the multiple entities working in the DER space.

The Transact modules include Aggregator Data Exchange, Bidding, Settlement, and Transactive Energy.

Figure 22. DERMS Module Inventory by Use Case: Transact Capabilities



Source: SEPA. (2023).

Aggregator Data Exchange

Overview

Utilities may not have access to smaller customer-owed BTM DERs; many BTM device manufacturers for customer assets such as smart thermostats or EVSE require the utility to communicate through their channels in order to access and communicate with customer assets. In some cases, aggregators and other third-parties may manage those DERs on behalf of the customer. Whether through manufacturer or third-party channels, utilities may want to interact with these DERs or have visibility into their operation. Utilities may more effectively manage these types of DERs when they are grouped into aggregation nodes. This allows for more efficient information exchanges between the utility and third-party aggregators managing the individual devices.

Grouping DERs by third-party aggregators creates the need for interactions between the utility DERMS and the aggregator DERMS/software system. These interactions often require customized interfaces to ensure the correct, secure exchange of data. Efficient data exchange can improve operability through collaboration, but industry interfaces need further standardization. A DERMS system should include facilities to manage this third-party data exchange and support standard data formats.

Third-party aggregators often manage individual DER assets to create customer value and provide services to the utility. These aggregated assets can be bid into wholesale markets, depending on the market rules. In these cases, the utility DERMS may not connect directly to the individual DERs or to a head end system that can control the individual DERs. Instead, the utility may interface with an aggregator software to receive individual or summarized DER status information and to issue dispatch commands to individual or aggregated DERs. The aggregator is responsible for communication and dispatch of the individual DERs. When available, standards based integrations should be used, but custom extensions to these interfaces are to be expected. Utilities may also need to anticipate interfacing with multiple aggregators.

While utilities and vendors recognize aggregators' role in enabling DER value streams such as energy arbitrage, constraint management, and customer bill reductions, aggregator activity outside of California and the Northeast currently remains limited. As the industry evolves, jurisdictions and markets will likely specify more requirements for data exchange with aggregators. This has already begun occurring through FERC 2222 compliance tariffs, with various RTOs and ISOs proposing these tariffs in 2022.[98]

An important aspect of FERC 2222 aggregation requirements involves allowing for diverse DER resources. Aggregators can combine multiple DER types into an aggregation and offer it into the wholesale market. Minimum aggregation size must not exceed 100 kW and aggregation mixes can include technologies such as rooftop solar, smart thermostats, hot water heaters, EV chargers, stationary batteries, and other BTM DERs. The type of DER may not be visible to the utility when an aggregator is providing a grid service, and the utility may not have full insight into the location and status of individual DERs. When this is the case, the type of aggregated DER may be less relevant to the utility, although some utilities may still require visibility and control into all individual DERs.

Utilities will need to review the proposed aggregations to ensure they do not affect system reliability. Similarly, when the utility receives dispatch commands from the ISO/RTO, they have the ability to override some or all of the dispatches. Managing these aggregations and communication requirements in the DERMS will be crucial.

System Interaction

Aggregator Data Exchange primarily interfaces with the third-party aggregators to connect to customer BTM DERs and to allow for communication channels between the DERMS and the customer assets. DER dispatch information flows from the Bidding and Scheduling & Dispatch modules to the Aggregator Data Exchange. It then communicates with the third-party aggregators and subsequently the customer DERs.

Aggregator Data Exchange also acts as an input to the Aggregation, Forecasting, and Monitoring/Estimating systems that are then used for the other DERMS functionalities. The Registration module of a DERMS should include functionalities that can register aggregators and other third-parties, including information about the aggregated DERs associated with each party, and configure the utility-approved communication protocols used for integration with those aggregator systems.

Supported DER Types

The Aggregator Data Exchange function is intended to support all types of customer BTM assets that can participate in aggregations.

Pipeline Stage

This functionality is in the **emerging to full deployment stage**.

Integration with aggregators has been occurring with DR for several years. This is an emerging area for DERs that is moving toward deployment as standards develop and as more utilities deploy DERMS. To date, most utility to aggregator data exchange using DERMS have been conducted as pilot projects.

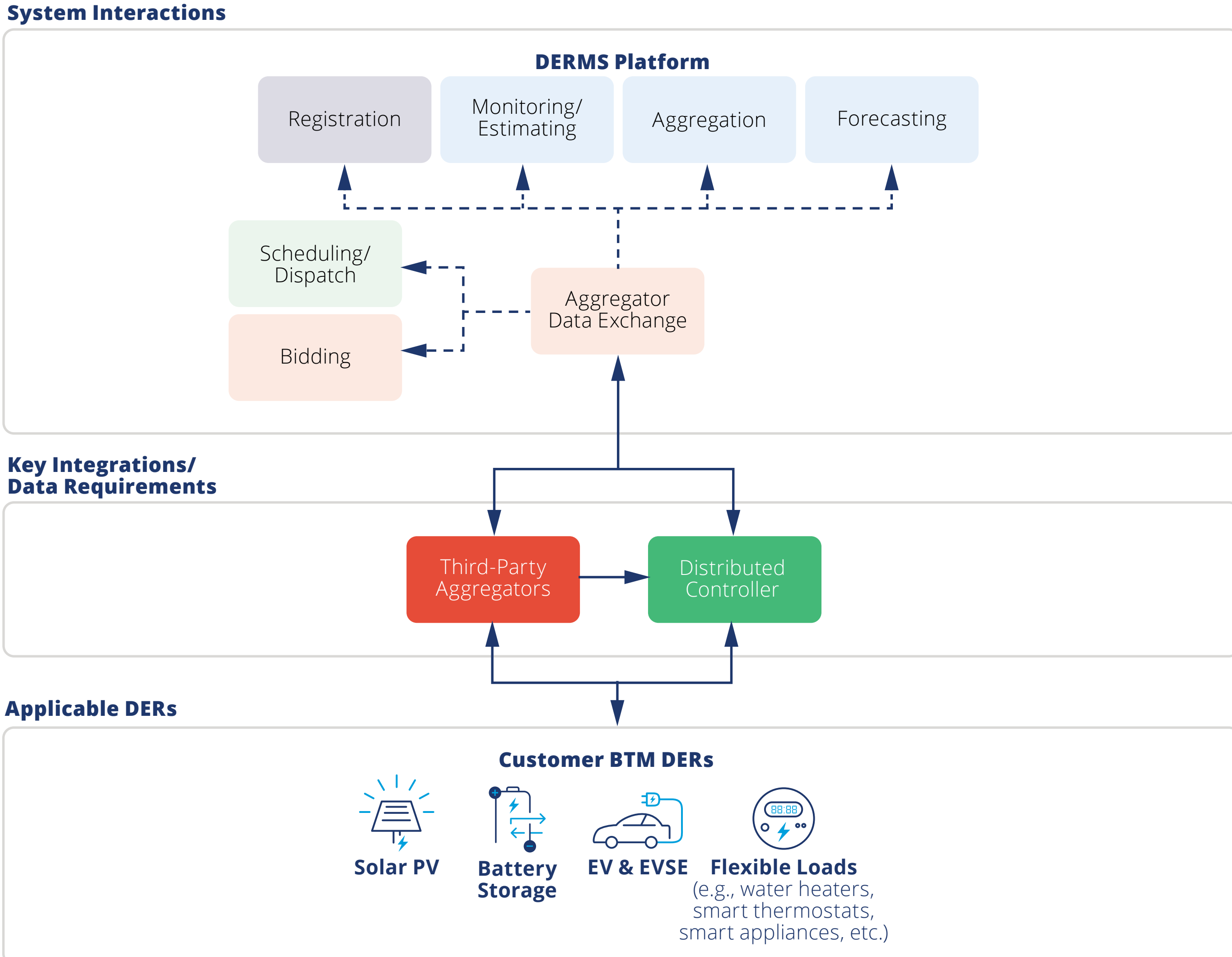
Market Availability

Market Adoption

There is mixed adoption among vendors.

98 NARUC. (March 2023). Overview of RTO/ISO Filing Status in Response to FERC Order 2222.

Figure 23. Key Integrations and System Interactions with the Aggregator Data Exchange Module



Source: SEPA. (2023).

Example Utility Applications

- **Austin Energy's** Austin Energy's SHINES program was a DOE funded pilot focused on integrating of utility scale DERs, commercial DERs, and residential DERs coordinated for different use cases by a DERMS platform. The project included a Doosan GridTech DERMS and incorporated third-party aggregators to manage DER fleets. Austin employed the OpenADR protocol to communicate with aggregators.[99] The project team found that standard protocols still require customization, and vendor support of standard protocols was inconsistent. Austin concluded that the current state of DER communication and integration standards poses a non-trivial risk of uncertainty to wide-scale asset deployment.
- **National Grid** uses a DERMS from EnergyHub to manage their commercial and industrial DR program.[100] As of Sept 2020, the system was used to interact with 13 third-party aggregators.
- **Pacific Gas & Electric's** Electric Program Investment Charge (EPIC) DERMS pilot (EPIC 2.02 - Distributed Energy Resource Management System) was a field demonstration of optimized control of a portfolio of third-party aggregated BTM solar and energy storage

99 Austin Energy. (2020). Optimal Design Methodology.

100 EnergyHub. (Sept. 2020). National Grid expands DER portfolio with EnergyHub to manage commercial and industrial resources.

and utility FTM energy storage resources.[101] The project utilized a DERMS from GE Grid Solutions and implemented a specialized IEEE 2030.5 Aggregator Interface with custom extensions for DER control between the utility and third-party aggregated DER assets. PG&E considered OpenADR 2.0b but settled on IEEE 2030.5 following a recommendation from the California Rule 21 Smart Inverter Working Group. PG&E concluded that more development is required to develop and standardize these types of aggregator communications.

- **Tucson Electric Power** investigated coordinated dispatch of smart thermostats, water heaters, and EV chargers through aggregators using a DERMS from Smarter Grid Solutions in Project RAIN.[102] The project employed OpenADR protocol for interfacing with aggregators and SunSpec Modbus and vendor APIs to interface directly to other DERs. Tucson found that standard protocols still required customization for their needs.

Technical Considerations

Prerequisites

Aggregation functions require robust communications systems and an architecture that supports public internet access given the coordination that must happen between the third-party aggregators and the utility.

An aggregator interface is likely one of only a few external integrations of a DERMS system. Cyber security should be designed into this architecture from the start. If using a standard protocol, a security framework may be specified with the protocol or utilities may specify their own security frameworks. Third-parties and aggregators would have to adhere to these standards. The integration architecture should be designed to only allow valid connections to the DERMS from approved third-parties.

Key Integrations and Data Requirements

The control architecture for aggregator data exchange requires communication channels with the aggregator, who then communicates with the individual DERs. The aggregator may pass utility commands through to the DERs without modification, or they may need to interpret them before commands can be sent to the devices. To define the communication architecture required to support this, utilities need to define what data is to be exchanged, communication response requirements (i.e., data latency, delays, prioritization, reliability, etc.), and what protocols would best meet their needs based on the specific actors, systems, and devices involved. The number of aggregator integrations in the near future is expected to remain low, but as more aggregators emerge, the integration architecture should be flexible and incorporate new standards to support increased data transactions and automated logging and exception handling. Flexible integration architectures help alleviate IT burdens and support FERC 2222 compliance tariffs as needed. This type of integration architecture usually supports atomic information transfer and control, which provides maximum flexibility, and often uses standard APIs.

Integration and interoperability standards for utility to aggregator interfaces are still evolving. Selecting a protocol or combination of protocols requires evaluation of key technical criteria, including the capabilities of the messaging protocols to meet the application requirements, and other factors including protocol maturity (level of adoption, product availability, available compliance/certification testing, security, etc.) and mandates for industry adoption.

SEPA's Catalog of Standards documents the industry standards and protocols applicable to DERMS systems.[103] Commonly used communication protocols based on SEPA's research on DERMS pilot projects includes IEC 61850-8-2, IEEE 2030.5, and OpenADR 2.0b. Cooperative utilities often favor another protocol called MultiSpeak. California's Rule 21 Smart Inverter Working Group developed a common communication profile for inverter communications that is intended to foster "plug and play" communications-level interoperability between the California utilities and third-party operated smart inverter based DERs. While it was developed for California, much of the profile is applicable to any DERMS-to-aggregator interactions.

Data requirements are specific to the use case but likely include information about the individual or grouped DER assets, monitoring information, operational statuses and alarms, and control setpoints and commands.

101 Pacific Gas and Electric Company. (Jan. 2019). EPIC Final Report.

102 Tucson Electric Power. (Oct. 2019). IRP Advisory Council Presentation. Distributed energy Resources and Customer-Site Energy Resource Alignment.

103 SEPA. (n.d.). Catalog of Standards.

Bidding

Overview

Market participants such as aggregators, competitive energy suppliers, merchant generators, and utilities submit bids and offers for buying and selling energy or providing ancillary services within energy markets. This market participation includes bidding energy provided from discrete and aggregated DER resources. Typically, market participants use a trading system which formulates the bids and offers and formats them for submission to each respective market. The trading system is configured with the market participants' bid strategy and considers all of its assets/contracts in that market. A utility can utilize its DERMS to provide DER related bid information such that the trading system can optimize their participation in these wholesale markets. Third-parties can also use the DERMS to monitor the status of DERs bid into wholesale markets by third-parties. ISO/RTO compliance tariffs for FERC Order 2222 will require additional capabilities for utilities to review and approve DER aggregations formed by third-parties prior to their submission in wholesale markets.

DER participation in wholesale markets has been the subject of several federal level regulatory actions such as FERC Order 841 and also addressed by specific organized markets. To date, DR has been the most active market for DER resources. However, DERMS system utilization to provide market interaction functions such as bidding remains an evolving area.

System Interaction

The Bidding module takes all the updated DER data and the Optimization outputs to submit bids to the connected market system and/or through a GMS/Trading system. The Forecasting, Monitoring & Estimating, and Asset Configuration & Modeling modules allow the bidding module to leverage information on the capabilities and current status of DERs. The Optimization module could optimize the DERs and aggregations based on capability of the DER (ramp rate, energy available, etc.) or to take advantage of specific market rules. The optimization may also account for grid impacts, interconnection constraints, and retail contract structures that might limit the DER's operation. This optimization would produce a schedule to be submitted to the market operator. The DERMS Bidding module would then format the schedule into the proper format for bidding/offering to the market and submit it to the market system. The Bidding module will also send dispatch signals through the Aggregator Data Exchange and Transactive Energy modules based on the outcome of the bids. Bidding interacts with the Settlement module by updating its record based on which bids were dispatched by the market system and the pricing for those dispatches.

Absent a Bidding module, the DERMS would send data on DER aggregations and their capability to a trading system, which would optimize the DERs against broader bidding strategies for all the participant's tradable assets. The trading system would then formulate the bids and offers by hour and resource and submit them to the market.

DER Types

Any DERs capable of participation in wholesale markets.

Pipeline Stage

This functionality is in the **emerging conceptual phase**.

Market Availability

Market Adoption

Vendor adoption remains limited; however, it is on the roadmap for many vendors.

Currently, most DERMS do not offer a market interaction module or bidding module. Typically, a DERMS interfaces to a GMS or trading system, which then submits bids to the market.

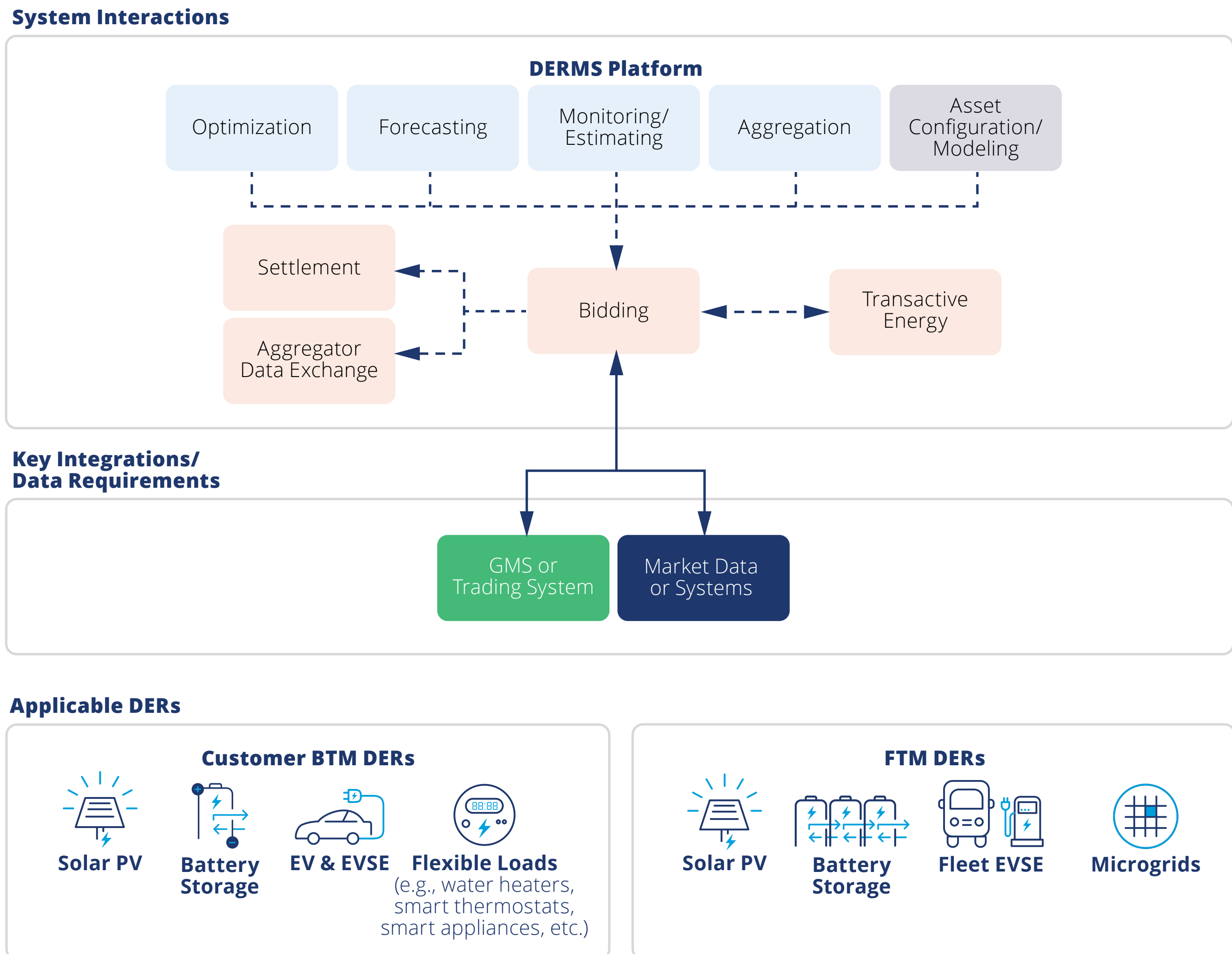
Example Applications

- **Austin Energy** allowed their fleet of DERs to bid into ancillary services markets as part of Austin SHINES.[104] The grid scale battery assets participated in day-ahead energy arbitrage and real-time price dispatch. BTM battery assets provided additional market value through utility peak load reduction.
- **Snohomish County PUD** controls battery systems using a DERMS to help the utility avoid unfavorable spot market purchases.[105]
- **PG&E** tested the interaction of DERs in wholesale markets as part of their DERMS EPIC project. Utility storage participated in the energy and frequency

104 Austin Energy. (2020). Optimal Design Methodology.

105 Snohomish County PUD. (n.d.). Energy storage.

Figure 24. Key Integrations and System Interactions with the Bidding Module



Source: SEPA. (2023).

regulation wholesale markets. To mimic wholesale market participation, PG&E aggregated third-party storage into a single DER resource and bid it into a simulated market. To further test market mechanisms for DER provided services, PG&E implemented an automated market via an IEEE 2030.5 Aggregator Interface that enabled a day-ahead ask-bid-commit and hourly ad-hoc market for distribution services.[106]

Technical Considerations

Pre-Requisites

In cases where customers will participate directly in the markets, utilities may need to develop specific programs to allow for this. Bidding also requires monitoring of market conditions such as LMPs.

Key Integrations and Data Requirements

Determining whether bid formatting and submission will occur in the DERMS system or another market interfacing tool drives interfacing requirements. Research suggests this function typically exists in a separate energy trading, GMS, or unit commitment system. A challenge with supporting this capability in a DERMS is the need to potentially support different markets with unique timing of submittals, format of submittals, market rules, etc. This is especially true for utilities attempting to deploy a

106 Pacific Gas and Electric Company. (Jan. 2019). EPIC Final Report.

centralized DERMS that interacts with multiple organized markets.

Market-related DERMS applications require monitoring and predictions of LMPs and other parameters. This data can be used to automate purchase and sale of electricity. DERMS can connect to capacity markets and/or energy markets. These functions can benefit from integration with aggregation functions, since VPPs make it easier for utilities to connect DERs with markets.

Aggregation can help utilities connect many different DERs to markets. Economic Dispatch and Scheduling often accompanies Bidding, since the two applications use similar data.

Settlement

Overview

Settlement is the process of reconciling actual operations against planned or forecasted operations and developing associated charges. Settlement has typically been conducted in a DERMS that is able to conduct the reconciliation after load control events. DERMS systems can also utilize the same information as a DRMS system in order to perform the settlement function. Using data from the customer's baseline energy usage and the energy used during the DR event, the DERMS system can calculate the delta in energy consumption.

DERMS settlement can occur at the wholesale or retail level. An example of retail settlement could include settlement between the utility and a customer after load control events. In this case, the system takes into account customer baseline energy use and energy use during the DR event. Using this data, rebates and credits for individual customers can be calculated and processed outside of the DERMS. Similarly, wholesale settlement would take place between the utility and the ISO/RTO with settlement charges generated based on the utility's planned energy consumption and that actually provided by the ISO/RTO. A DERMS settlement module could also be used to develop settlement statements between the utility and other third-parties and aggregators.

If financial settlements are involved, either due to markets or contractual agreements between a utility and aggregator or DER and DR provider, the DERMS must acquire and provide appropriate data. This may include a data exchange between a utility and an aggregator, a metering system, or other database to assemble information that will flow back to a settlement function in the DERMS or will be compiled for export to an external settlement system. The data may include:

- Applicable service rendered
- Applicable DER units
- Active and/or reactive power
- Total active and reactive energy
- Time stamps
- Other appropriate values the DERMS may have acquired or calculated

Other added functions in a Settlement module include:

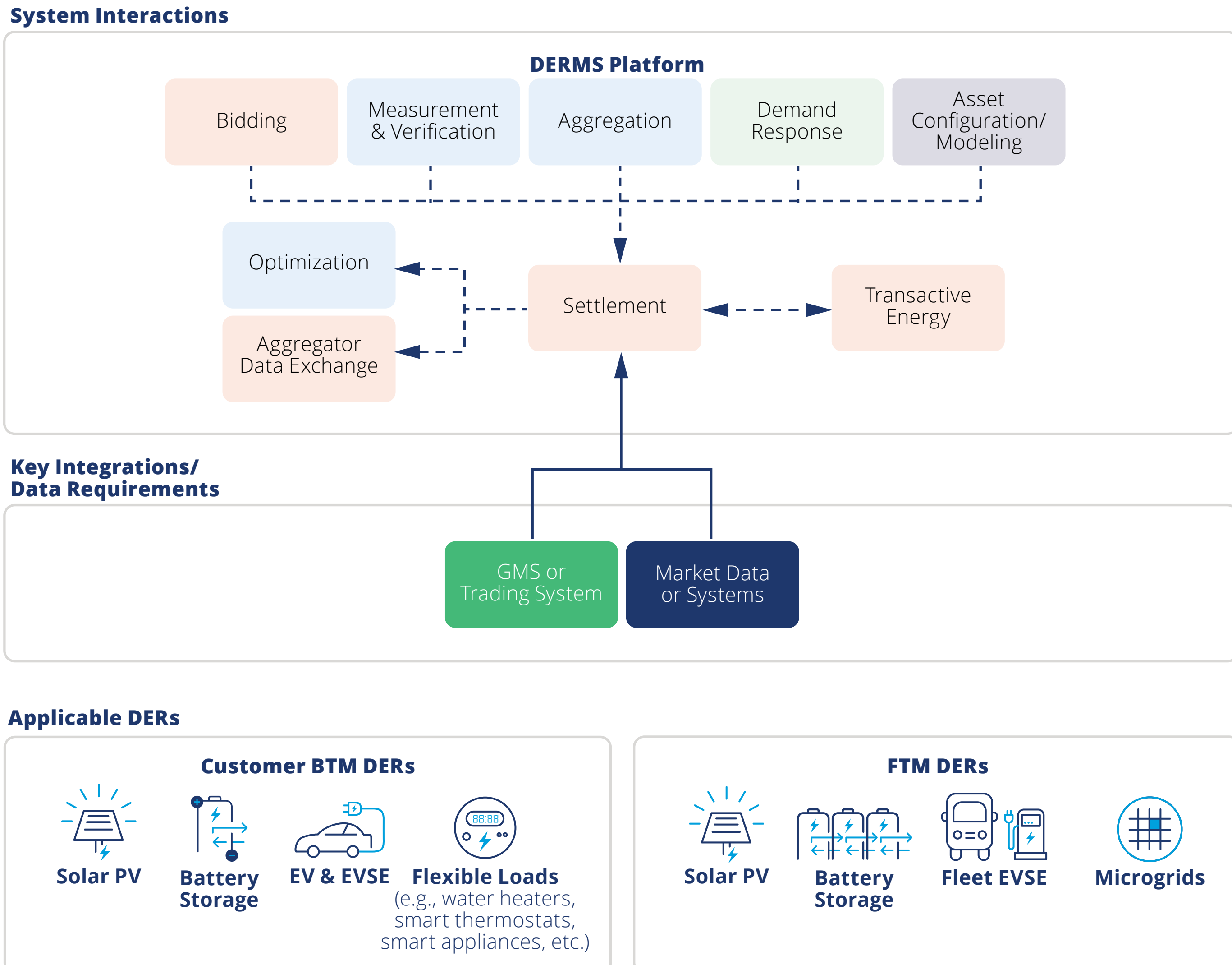
- Measurement and verification related to the ability of the resources to meet contractual obligations
- Auditing of required settings
- Analysis of the DERs' abilities to meet a requested dispatch or constraint

Data from meters, such as AMI, can be used to help utilities with the settlement process after DR events. The rebates or tariffs owed to the customer can be calculated to ensure alignment with contracts, and DERMS must be able to communicate with systems that hold customer records. This settlement process can be conducted through a third-party, or through the utility itself. Settlement is also related to market participation because it often depends on locational marginal pricing.

System Interaction

The Settlement module is the key component to extracting the compensation information from the DERMS system. The DER dispatch history and status data found in the Bidding, M&V, Aggregation, DR, Transactive Energy, and Asset Configuration & Modeling modules is all utilized in the final contract formatting and submission. Settlement will also send this information through the Aggregator Data Exchange to update the third-party aggregators on the status of the DER bids and the historical usage of those DERs. Settlement has some interaction with the Optimization module given that some of the collected data can be used in the machine learning process to improve the optimization engine.

Figure 25. Key Integrations and System Interactions with the Settlement Module



Source: SEPA. (2023).

Supported DER Types

The settlement function is intended to support all types of DERs, whether located BTM or FTM, that are associated with market prices and can be dispatched in a marketplace.

Pipeline Stage

This functionality is in the **deployment stage**.

Settlement has largely been a part of DRMS applications and has expanded into DERMS applications.

Market Availability

Market Adoption

There is mature adoption across the different vendors.

Example Applications

A few utilities have adopted settlement management as part of their DR systems, but it is not as popular as other DRMS applications.

- **Ameren** has deployed DR rebate management as part of their utility-scale microgrid in Illinois. Ameren uses Schneider Electric's Ecostruxure Software.[107]

107 Microgrid Media. (Aug. 2017). Ameren Using Schneider Electric's EcoStruxure Software to Integrate DERs into Utility-Scale Microgrid.

- **El Paso Electric** uses EnergyHub's Mercury DERMS to manage post-event settlement for their BYOT program.[108]
- **LA Department of Water and Power** processes settlement for their BYOT summer program through EnergyHub's DERMS.[109]
- **National Grid** manages settlement for their commercial and industrial DR program through DERMS.[110]

Technical Considerations

Pre-Requisites

Connection to traditional meters, smart meters, smart inverters, and other measurement devices can provide the necessary data in either real-time or after-the-fact measurements to verify results of the DERMS module(s). Smart metering through utility infrastructure such as AMI can provide greater visibility through more accurate and frequent data collection, although this technology is not strictly necessary for M&V and settlement.

Key Integrations and Data Requirements

Integration to a utility or third-party enrollment system may be required for DERs participating in the DR program. The registration information that is collected should follow IEEE Standards 2030.11-2021. IEEE recommendations include:

- Nameplate information
- Communication information
- Installation information
- Electrical location
- Device settings and interconnection rating
- In/out service dates
- DER modeling information

Additional data to be collected could include:

- Aggregation/aggregator information
- Operational limits (export limits, ramp rate limits, time-based schedules)
- Contact information of the customer
- Meter information
- Participating utility or ISO/RTO program

Integration requirements for DR programs support the M&V and settlement functions of the programs. Utilities would benefit from access to existing data analytics engines and data historians because settlement depends so heavily on data. Integration between the DERMS and a MDMS or historian may be required to provide the historical (measured) data needed. Forecast data may be provided by the DERMS or need to be integrated from another utility system. If the DERMS is supporting market settlement functions, integration to an ISO/RTO market system may be required.

Transactive Energy

Overview

DERMS are uniquely positioned to connect DERs with wholesale markets. DERMS can monitor, predict, and present information on market conditions for optimized electricity purchase and sale through energy arbitrage. These kinds of market functions can provide utilities with a platform for trading renewables and other energy.

The distinguishing characteristic of a transactive energy approach to grid management is the use of value signals, such as demand prices, to incentivize customer behaviors. DERMS systems can promote transactive energy by allowing customers, either as individuals or in aggregate, to actively engage in energy markets by responding to value signals based on demand, price, time-of-day and other considerations. This active engagement occurs through the DERMS sending value signals to the customer DER devices, which have preset and/or automated features that allow them to respond desirably to the market signal. The automated features reflect both the set points of the DER device and the customer's personal flexibility and needs. A DERMS enables scalable aggregation and near real-time management of utility-scale and small-scale DERs. Through

108 EnergyHub. (May 2017). EnergyHub launches Bring Your Own Thermostat demand response program with El Paso Electric.

109 EnergyHub. (Oct. 2020). Los Angeles Department of Water and Power and EnergyHub enroll over 16,000 thermostats in BYOT program, targeting 25 MW of flexible capacity.

110 EnergyHub. (Sept. 2020). National Grid expands DER portfolio with EnergyHub to manage commercial and industrial resources.

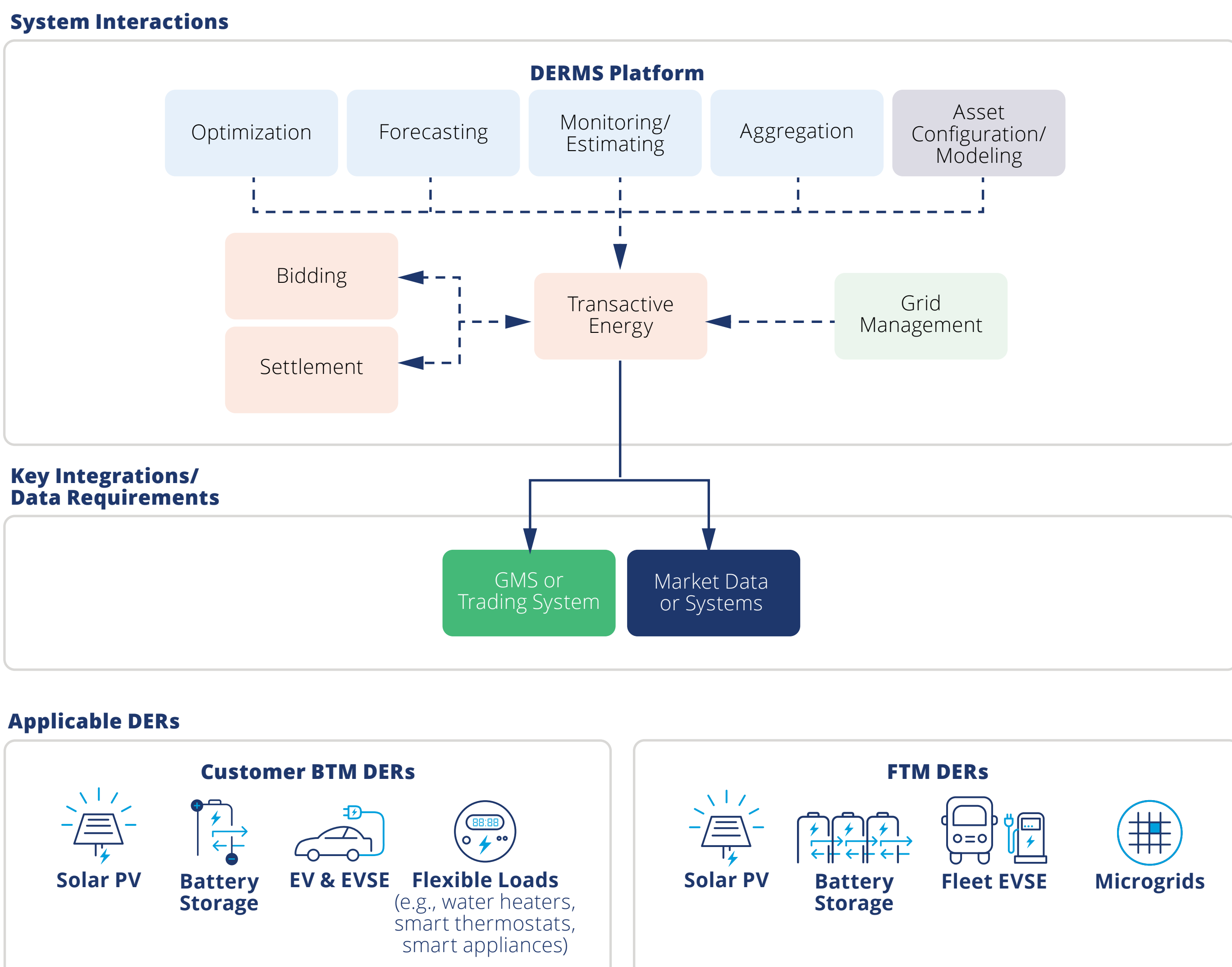
value signaling, the DERMS is a core component required for transactive control and market-based coordination of BTM DERs. To support transactive energy concepts, a DERMS leverages its DER models, scheduling, and control functionality to optimize DER participation in bulk grid services.

System Interaction

Transactive Energy use cases rely heavily on monitoring and market predictions such as LMPs. The DERMS should be integrated with the capacity and/or energy markets that give this market data and that would receive the data from the energy transactions. This data can be used to automate electricity purchase and sale. The Transactive Energy module will also interact with the Bidding and Settlement functions to provide some of the market interactions and to record the customer information needed for final settlement and compensation.

These functions can benefit from integration with aggregation functions, since VPPs make it easier for utilities to connect DERs with markets. System updates from the Grid Management, Monitoring & Estimating, Forecasting, and Asset Configuration & Modeling are also needed to ensure that the energy transactions are occurring with the most up-to-date information. The Optimization module also ensures energy transactions occur more effectively within the economic, environmental, and grid constraints set by the utility operator.

Figure 26. Key Integrations and System Interactions with the Transactive Energy Module



Source: SEPA. (2023).

Supported DER Types

The registration function is intended to support all types of DERs whether located BTM or FTM.

Pipeline Stage

This functionality is in the **emerging conceptual phase**.

Transactive energy use cases remain predominantly in the conceptual phase with some targeted deployments emerging.

Market Availability

Market Adoption

Deployment is currently dominated by a few key players.

Example Applications

- **Avista** developed a microgrid that allows for transactive energy exchanges.[111]
- **Austin Energy** allowed their fleet of DERs to bid into ancillary services markets as part of Austin SHINES.[112]
- **Southern California Edison** is piloting "Transactive Energy" with Opus One's GridOS TEMS which combines a market management system with a participant interface to engage customers and establish operating schedules for DER dispatch.[113]
- **Snohomish County PUD** controls battery systems using a DERMS that optimizes best market purchases and allows for energy arbitrage.[114]

Technical Considerations

Pre-Requisites

In cases where customers will participate directly in the markets, utilities likely need to develop specific programs, with regulatory approval, to engage and incentivize customers. Distribution Operations and Planning stakeholders should be involved in program design. Any transactive energy scheme likely also requires monitoring of grid and market conditions such that the necessary incentive signals can be sent to encourage customer participation.

Key Integrations and Data Requirements

DER device registration is an important aspect of conducting market interactions. Device registration information should follow IEEE Standards 2030.11-2021 with the appropriate data per each individual and grouped DER devices. Registration information for individual DERs can include:

- Nameplate information
- Communication preference information
- Physical location
- Date of installation
- Electrical location
- Device settings
- Interconnection ratings
- Servicing information

Capturing programmatic information for DERs is of particular importance.

Aggregation is a key component of transactive energy exchanges and different protocol interactions will occur depending on the DER asset type and the specific vendor solutions interconnected to the grid. Most asset types will have different interoperability requirements. Common interoperability types include REST, OpenADR, SunSpec Modbus, 2030.5, and OCCP.

111 UtilityDive. (July 2020). Microgrid of the future emerges in Washington as Avista preps transactive DER project.
112 Austin Energy. (2020). Optimal Design Methodology.
113 GreenTechMedia. (July 2020). Opus One Tests 'Transactive Energy' for California Rooftop Solar, Behind-the-Meter Batteries.
114 Snohomish County PUD. (n.d.). Energy storage.

Appendix: Using This Encyclopedia

As part of this encyclopedia, the project team developed four business use case examples illustrating how DERMS influence grid integrations and the utility's overall system architecture. While there are a variety of drivers for utility interest in managing DERs, this appendix illustrates the following use cases:

- DER Visibility, Device Configuration, and Program Management
- Optimizing DERs for Peak Management
- Optimizing DERs for Grid Services
- Market Animation

All of these use cases can be accomplished using a DERMS or through alternative solutions. Each use case will also include illustrations of DERMS alternatives. For the purposes of this discussion, DERMS alternatives are software-based solutions that a utility can implement to achieve DERMS-like functionalities. The DERMS alternatives discussed here include descriptions of how utilities can utilize their existing systems and technologies, such as DRMS, ADMS, etc, to implement similar functions to those included in a DERMS system. DERMS alternatives are varied and highly dependent on the specific circumstance of each utility.

This document addresses potential alternatives based on three utility scenarios including:

- A Base case, where the utility has no/few DER control systems.
- A DRMS case, where the utility has some DER control and visibility through a DRMS system.
- An ADMS case, where the utility has implemented an ADMS system that has the ability to incorporate some DERs.

DERMS alternatives are an important aspect to the DERMS implementation discussion due to the short- and long-term flexibility they may provide as utilities determine their DERMS needs. In the short-term, DERMS alternatives can support DER visualization and management while a utility determines its business needs and use cases prior to procuring a DERMS. In the long-term, DERMS alternatives may support some DER functionalities not yet fully developed in DERMS systems and/or allow the utility to better utilize existing assets and to optimize existing investments. Thus, the DERMS alternatives discussed illustrate potential approaches utilities can take to use different technologies to achieve similar functions to those in a DERMS system.

Use Case 1: DER Visibility, Device Configuration, and Program Management

Use Case Summary

This use case emphasizes giving the utility insight into both BTM and FTM DERs that exist on the system including inventorying all devices, maintaining customer-device-aggregator-program relationships, maintaining program and contractual rules/constraints, and tracking basic device locational information. This use case utilizes functions that inventory and organize DER information, provides visibility into DER locations, provides the operational status of DERs, and provides the programmatic information assigned to each DER. The key DERMS modules for this use case are Registration, Asset Configuration & Modeling, Monitoring/Estimating, Aggregation, Curtailment, and Demand Response. These modules contain all the DER device information necessary to visualize the DERs on the network, understand the programmatic and customer parameters of the device's usage, and monitor how the device interacts with and impacts the grid.

Architecture Considerations

This case mainly requires consolidating available DER device, programmatic, and locational information in one common database and monitoring DER operational status. Utility systems such as Customer Information Systems (CIS), DER Interconnection Portals, and/or other customer program enrollment portals can provide customer, contract, and device level data for any registered DER. Utilities commonly interface to these systems to provide DER information to the DERMS. Given the expansion of DER aggregators in the DER space, DER aggregator head end systems are another interface needed to provide both DER device and customer information to the DERMS and to provide device data from the DERMS back to the Aggregator.

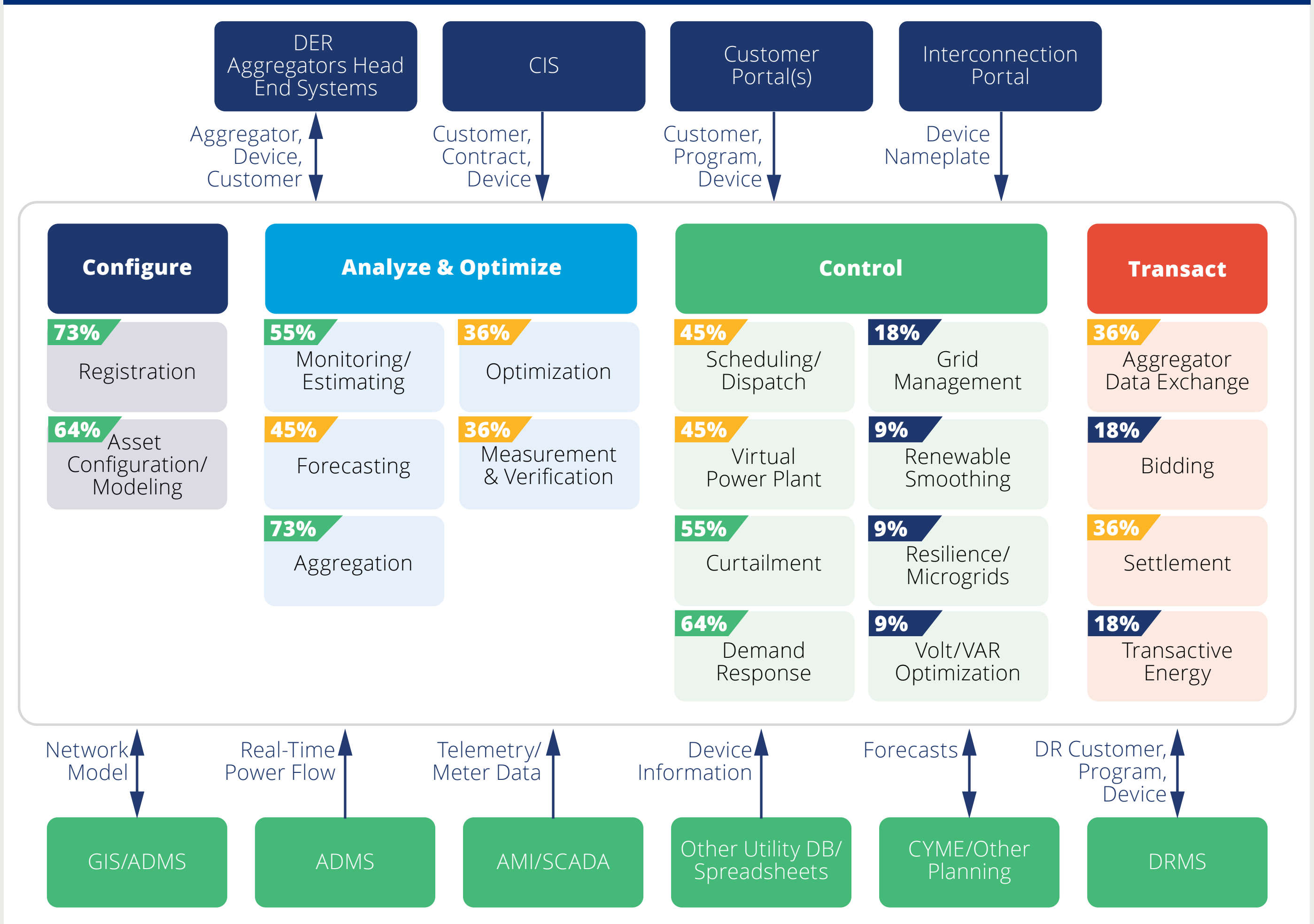
An existing DRMS can also be integrated with the centralized DERMS to provide customer DR programmatic and device information. Utilities may also import DER and load forecast information from CYME and/or other planning systems as well as specialized DER analysis conducted in other utility databases and spreadsheets. Depending on the DERMS system, some of these data exchanges may be manual and others will allow for automatic uploading of the data through point-to-point integrations via vendor APIs and custom interfaces or through a middleware-based message bus architecture.

DER device locational information can be provided from an interconnection portal, GIS, or a separate utility database used to manage that information. While a full operational network model is not required for the DER Visibility use case, utilities with an ADMS may pursue this level of modeling in preparation for more advanced capabilities. Advanced capabilities such as monitoring power flow and grid impacts rely heavily on ADMS functionality.

A key consideration with respect to ADMS integration is the process and technical approach to keep network models synchronized between systems. The GIS is typically the system of record for the as-built network model, whereas the ADMS is the system of record for the as-operated network model. Planners and other groups within the utility may have their own versions of a network model tailored to their specific needs. A DERMS may maintain its own version of a network model, but ideally it would be synchronized with the ADMS and reflect the as-operated state with the addition of DERs. To accomplish this synchronization, network models maintained in the ADMS and/or GIS should have bidirectional data exchanges with the DERMS to keep all models in sync.

After-the-fact meter data from AMI and meter data management systems (MDMS) can provide historical data used for DER estimates and predicting future performance. SCADA networks can produce telemetry data to monitor DER performance in real-time.

Figure 27. Key Implementations for the DER Visibility Use Case



Source: SEPA. (2023). Note: Utilities in the Taskforce were surveyed to rate the importance of each functionality in supporting this specific use case. Actual implementations may have different reliances on each functionality.

Alternatives

Alternative Using "Base" Systems

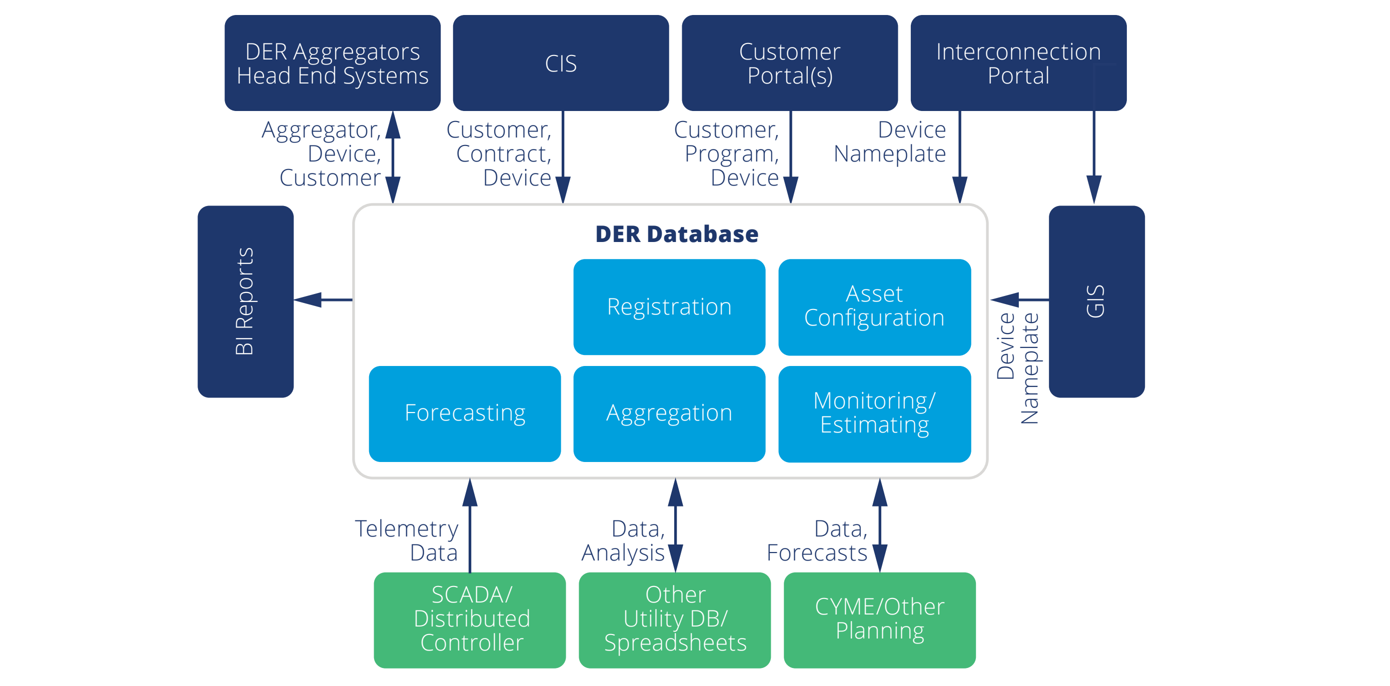
Configure

- Build automation/workflow into **interconnection tool** and capture BTM Customer, BTM Utility, and FTM DER information.
- Configure **CIS** to capture BTM Customer and BTM Utility DER relationship information.
- Buy/build **DER database** to capture BTM Utility, BTM Customer, and FTM DER device, program, and location information.
- Deploy **customer portal** or web tool to capture BTM Utility DER information.
- Integrate customer portal with interconnection tool, CIS, and new DER database.
- **Integrate with aggregators** via CIS or customer portal.

Analyze & Optimize

- Integrate FTM DER information captured in the **interconnection tool** and integrate with GIS and new DER database.
- **Monitor in real-time (RT)** based on telemetry stipulated in interconnection requirements.
- Monitor FTM DER via distributed controller or DSCADA. Monitor **BTM DER via aggregators, web platforms from device manufacturers** such as Nest, Ecobee, Tesla, etc., or other **distributed controllers**. Integrate telemetry data with DER DB.
- Provide **basic DER visibility** (tabular, static graphics) of telemetered data and estimates to users via **BI reports** written from new DER database.
- Develop basic aggregation/grouping functionality in new DER database or Spreadsheets.
- Leverage existing **forecasting tools** or build/buy new forecasting capabilities that use data from DER database.

Figure 28. DER Visibility Architecture for "Base" Systems



Source: SEPA. (2023). Note: Utilities in the Taskforce were surveyed to rate the importance of each functionality in supporting this specific use case. Actual implementations may have different reliances on each functionality.

Alternative Using "Base" Systems + DRMS

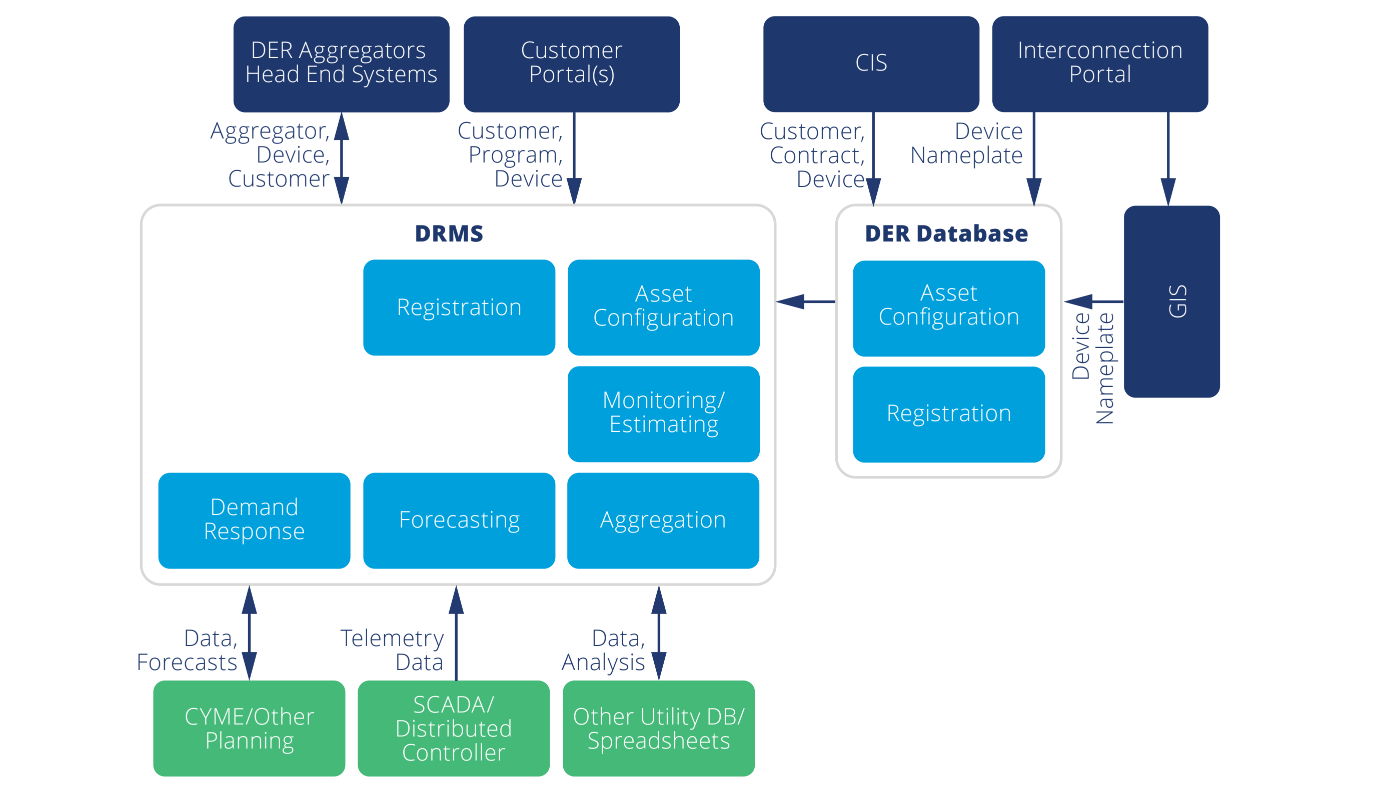
Configure

- Build automation/workflow into **interconnection tool** and capture BTM Customer, BTM Utility, and FTM DER information.
- **Configure BTM customer and BTM utility DER and customer relationship information in existing DRMS.**
- Buy/build DER database to capture FTM DER device, program, and location information. **Integrate BTM DER information from DRMS.**
- Deploy customer portal or web tool to capture BTM Utility DER information.
- Integrate customer portal with interconnection tool, CIS, and new DER database.
- Integrate with **aggregators** via CIS or customer portal.

Analyze

- Integrate FTM DER information captured in the interconnection tool and integrate with GIS and new **DER database.**
- **Monitor in RT** based on telemetry stipulated in interconnection requirements. Integration telemetry data **with DRMS** and DER database.
- Provide **basic DER visibility** (tabular, static graphics) of telemetered data and estimates to users via BI reports written from new DER database.
- **Leverage DRMS aggregation/grouping functionality and capture associations in new DER database.**
- **Leverage existing forecasting tools from DRMS for BTM DERs** or build/buy new forecasting capabilities that use data from DER database.

Figure 29. DER Visibility Architecture for "Base" Systems + DRMS



Source: SEPA. (2023). Note: Utilities in the Taskforce were surveyed to rate the importance of each functionality in supporting this specific use case. Actual implementations may have different reliances on each functionality.

Alternative Using "Base" Systems + ADMS

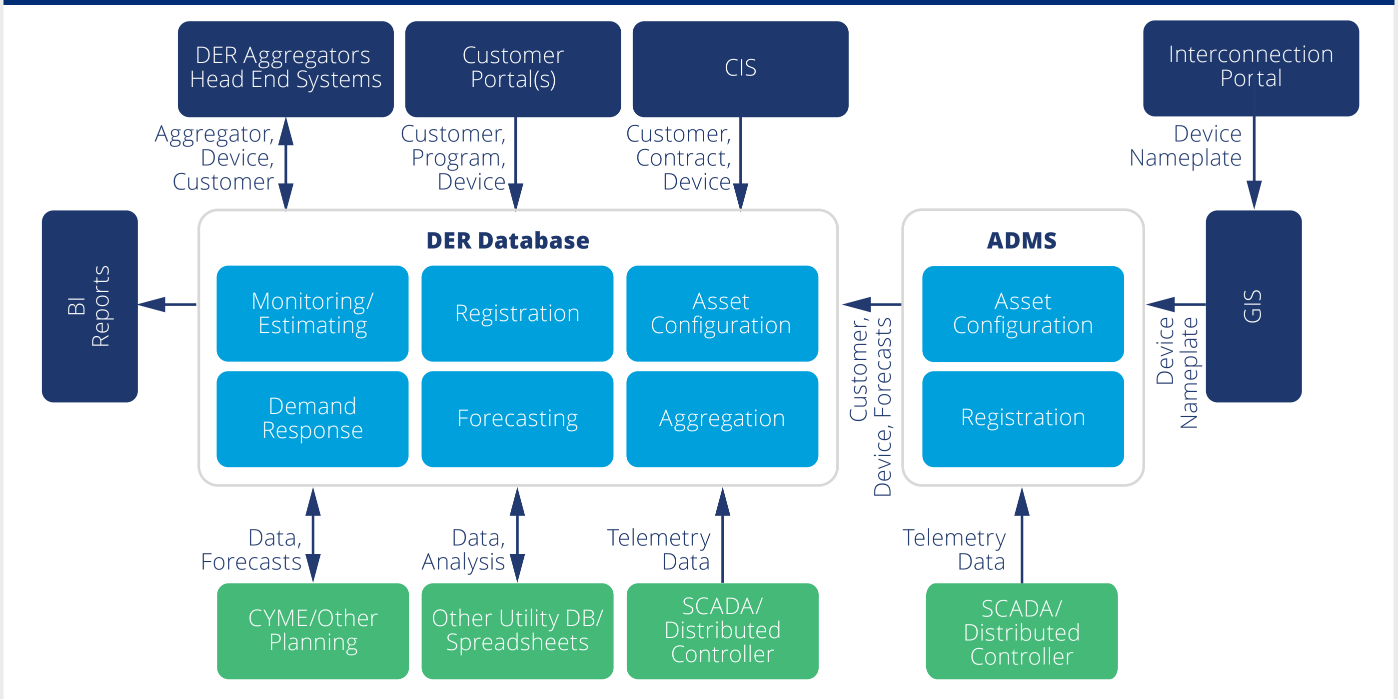
Configure

- Build automation/workflow into **interconnection tool** and capture BTM Customer, BTM Utility, and FTM DER information.
- Configure **CIS** to capture BTM Customer and BTM Utility DER relationship information as well as aggregator relationships.
- Buy/build **DER database** to capture BTM Utility, BTM Customer, & FTM DER device, program, aggregator, and location information.
- **Add all DER device information to the ADMS network model. Configure FTM DER communication path (DSCADA/distributed controller) and confirm ADMS visibility.**
- Deploy **customer portal** or web tool to capture BTM Utility DER information.
- Integrate customer portal with interconnection tool, CIS, and new DER database.
- **Integrate with aggregators** via CIS or customer portal.

Analyze & Optimize

- Integrate FTM DER information captured in the **interconnection tool** and integrate with GIS and new **DER database.**
- **Monitor in RT** based on telemetry stipulated in interconnection requirements. Integrate telemetry data **with ADMS** and DER database.
- Provide basic **BTM DER visibility** (tabular, static graphics) to non-Operations users via BI reports written from new DER database. **Provide FTM and aggregated BTM DER visibility to Operations via ADMS topographical and tabular displays and reports.**
- Develop basic aggregation/grouping functionality in new DER database. **Leverage ADMS aggregation/ grouping if available.**
- Leverage existing **forecasting tools in ADMS** or build/ buy new forecasting capabilities that use data from DER database.

Figure 30. DER Visibility Architecture for "Base" Systems + ADMS



Source: SEPA. (2023). Note: Utilities in the Taskforce were surveyed to rate the importance of each functionality in supporting this specific use case. Actual implementations may have different reliances on each functionality.

Use Case 2: Optimizing DERs for Peak Management

Use Case Summary

This use case emphasizes controlling DERs specifically for reducing or shifting system peaks. Peak Management includes all the necessary systems to forecast peaks, understand the impact of the DERs on the system, and send control systems to these DERs. The key DERMS modules for this use case are Monitoring/Estimating, Forecasting, Aggregation, Optimization, Scheduling & Dispatch, VPP, Curtailment, Demand Response, and Grid Management. These modules provide all of the DER device information necessary to visualize the DERs on the network, to understand the programmatic and customer parameters of the device's usage that would impact their control, to monitor how the device interacts with and impacts the grid, and to provide the necessary control parameters and communication protocols that allows the utility to execute DER control in support of system needs.

Architecture Considerations

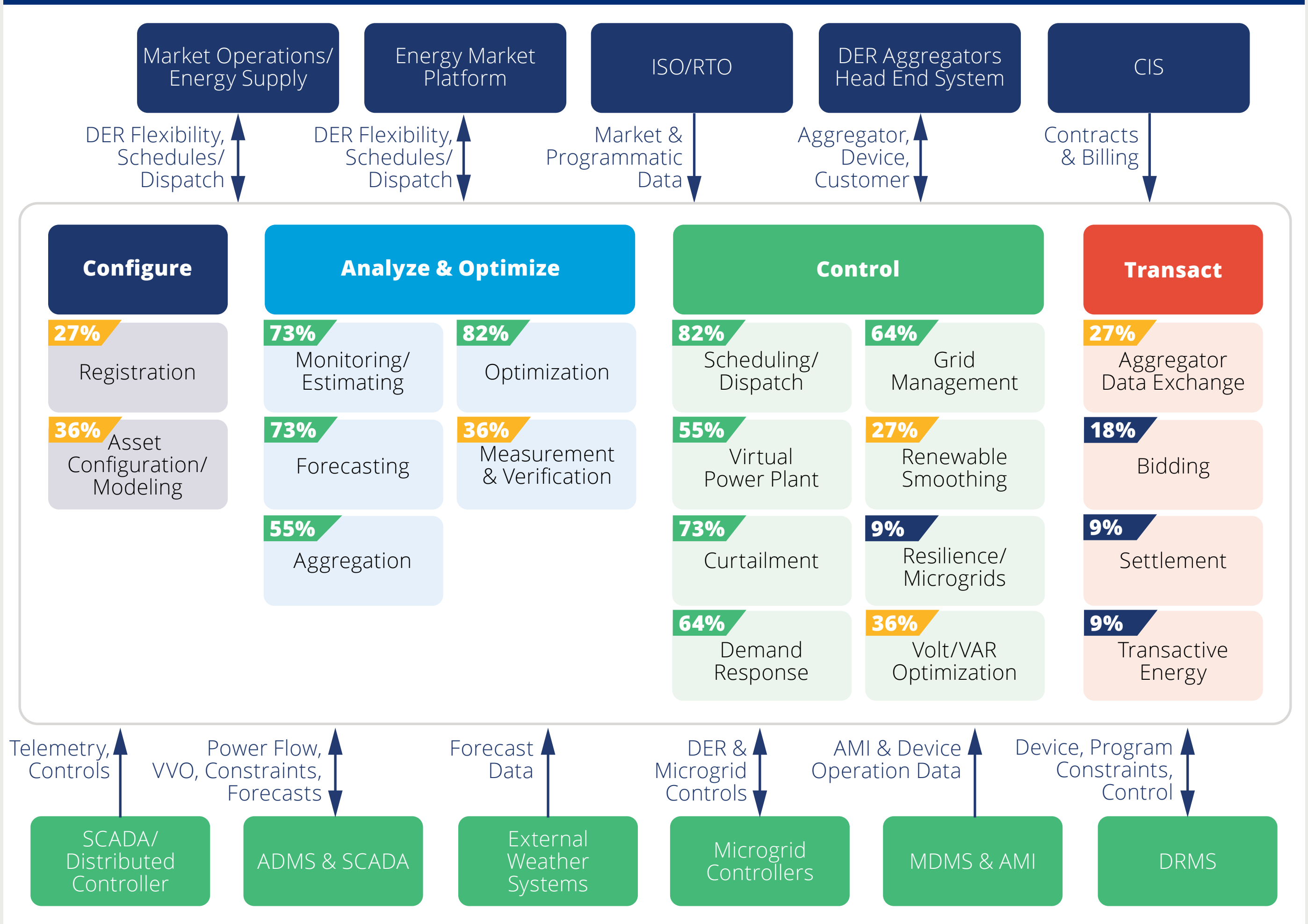
This use case requires knowledge of system level needs provided from external market systems such as Energy Market Platforms, the ISO/RTO, and other market operations systems. Energy market platforms provide information on system level energy and capacity needs or even direct dispatch instructions used by the DERMS to determine the scheduling and dispatching of DER assets. Interfacing to the ISO/RTO market platform provides further information on the market (e.g., prices) and programmatic information used by the DERMS to optimize the scheduling and dispatching of DERs.

Given the expansion of DER aggregators in the DER space, integrating to DER Aggregator head end systems may also be needed to provide both DER device and customer information to the DERMS but also to provide the Aggregator with data and dispatch instructions from the DERMS. Existing DRMS can also be integrated so that the customer DR programmatic and device information can be exchanged between the two systems. This use case also utilizes the CIS to gather the contract and billing data needed to reconcile accounts after a DER has been dispatched per the market and/or utility peak event.

Peak Management can heavily rely on the DERMS Optimization module in order to have an accurate and clear picture of the grid's state. Network data from the ADMS and/or SCADA systems provide information to the DERMS Optimization module. SCADA, MDMS, and AMI operational data is provided to the Monitoring and Forecasting modules to update the DERMS on the historical and near real-time DER operations. External forecasting systems, including weather systems, can also improve insights into DER availability and capacity to inform optimizations.

Control signals can be sent through multiple channels: through the aggregator head end, through the DRMS system, through the ADMS, through microgrid and other distributed controllers or directly to the DER devices. The communication pathway will depend on available systems, supported communication protocols, and individual DER capabilities.

Figure 31. Key Implementations for the Optimizing DERs for Peak Management Use Case



Source: SEPA. (2023). Note: Utilities in the Taskforce were surveyed to rate the importance of each functionality in supporting this specific use case. Actual implementations may have different reliances on each functionality.

Alternatives

Alternative Using "Base" Systems

Configure

Same as Visibility & Management Use Case plus the following:

- Configure FTM DERs in **DSCADA or distributed controller.**

Analyze & Optimize

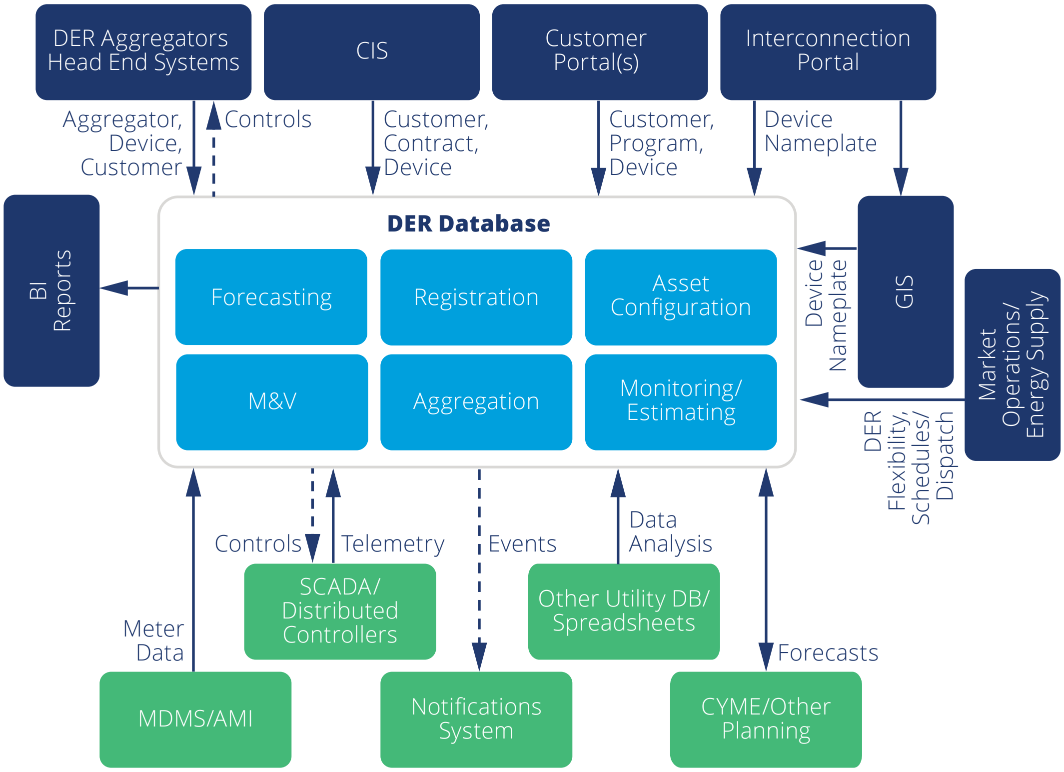
Same as Visibility & Management Use Case plus the following:

- Leverage existing **forecasting tools** or build/buy new forecasting capabilities that use data from DER database. Ensure ability to forecast aggregate DER flexibility at system level and by feeder.
- Build **analytics/optimization tools on DER database** to allow Operators and Planners to determine DER groups that can best reduce or shift peaks. Consider use of third-party optimization tools depending on need.
- Build M&V, including calculation of baselines, in spreadsheets, in DER database, or separate reporting database.

Control

- Utilize existing utility tools or buy/build a system to send **event notifications** to customers enrolled in demand response programs.
- Conduct analysis via analytics/optimization tools to determine dispatch schedules for DER assets.
- Manually dispatch and curtail FTM DERs via **SCADA, or distributed controller software.**
- Manually dispatch and curtail aggregations of BTM Customer DER and BTM Utility DER through **aggregators, web platforms from device manufacturers** such as Nest, Ecobee, Tesla, etc., or other **distributed controllers.**
- Build **BI reports/analytics** from data managed in the DER database.

Figure 32. Optimizing DERs for Peak Management Architecture for "Base" Systems



Source: SEPA. (2023). Note: Utilities in the Taskforce were surveyed to rate the importance of each functionality in supporting this specific use case. Actual implementations may have different reliances on each functionality.

Alternative Using "Base" Systems + DRMS

Configure

Same as Visibility & Management Use Case plus the following:

- Configure FTM assets in DRMS. Build integration between interconnection portal and/or GIS (source system for FTM asset information).

Analyze & Optimize

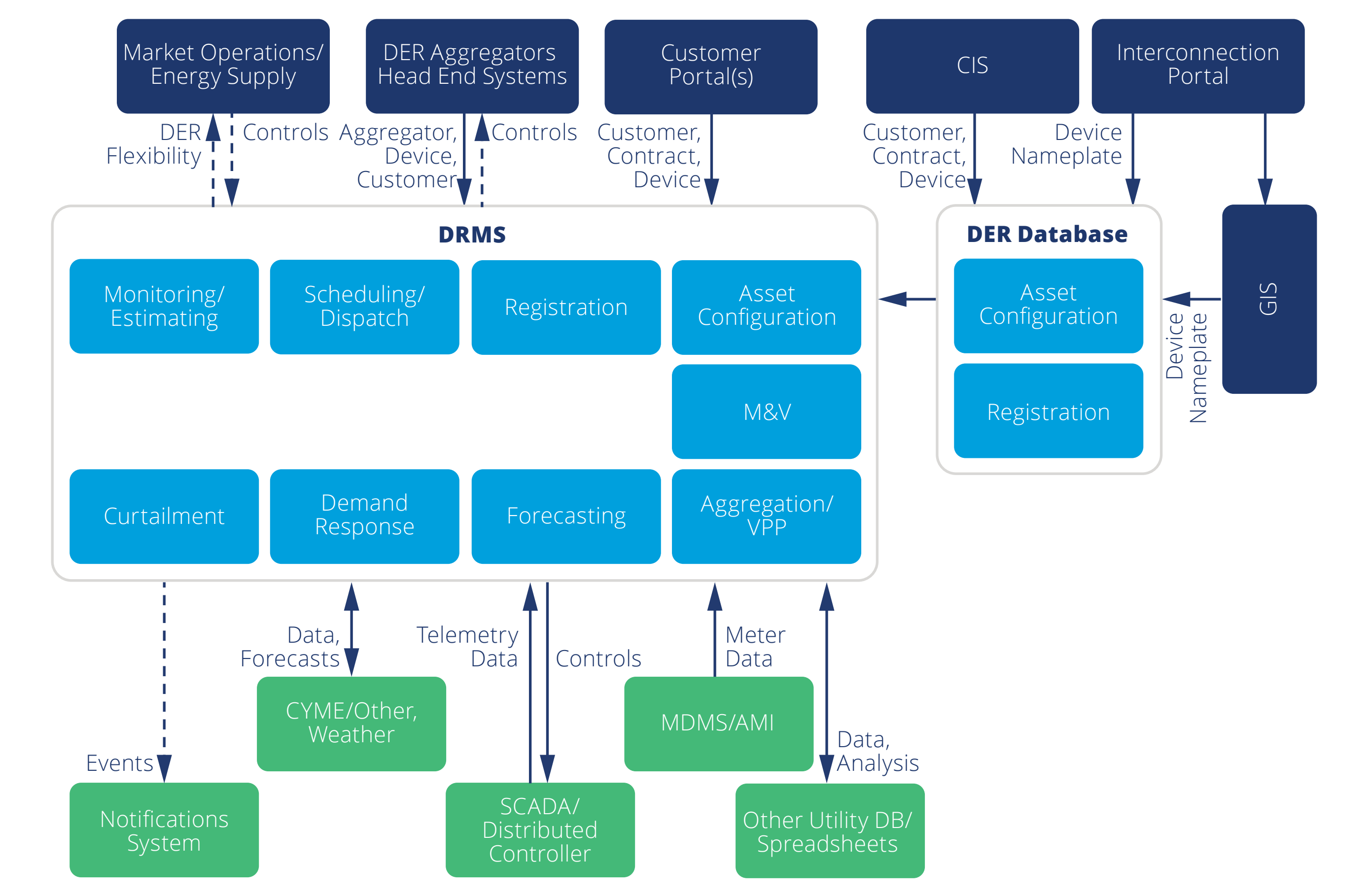
Same as Visibility & Management Use Case plus the following:

- Leverage existing **DRMS forecasting tools** or build/buy new forecasting capabilities that use data from **DRMS** and the DER database. Ensure ability to forecast aggregate DER flexibility at system level and by feeder.
- Build analytics/optimization tools on DER database to allow Operators and Planners to determine DER groups that can best reduce or shift peaks. Consider use of third-party optimization tools depending on need.
- Build M&V, including calculation of baselines, in spreadsheets, in DER database, or separate reporting database.

Control

- Utilize existing utility tools or buy/build a system to send event notifications to customers enrolled in demand response programs.
- Conduct analysis via analytics/optimization tools to determine dispatch schedules for DER assets.
- Manually dispatch and curtail FTM DERs via **SCADA, or distributed controller software.**
- Manually dispatch and curtail aggregations of BTM Customer DER and BTM Utility DER through **aggregators, web platforms from device manufacturers** such as Nest, Ecobee, Tesla, etc., or other **distributed controllers.**
- Build **BI reports analytics** from data managed in the DER database.

Figure 33. Optimizing DERs for Peak Management Architecture for "Base" Systems + DRMS



Source: SEPA. (2023). Note: Utilities in the Taskforce were surveyed to rate the importance of each functionality in supporting this specific use case. Actual implementations may have different reliances on each functionality.

Alternative Using "Base" Systems + ADMS

Configure

Same as Visibility & Management Use Case plus the following:

- Add all DER device information to the ADMS network model. Configure FTM DER communication path (DSCADA/distributed controller) and confirm ADMS control.
- Integrate ADMS with aggregators to **dispatch BTM DERs from ADMS.**

Analyze & Optimize

Same as Visibility & Management Use Case plus the following:

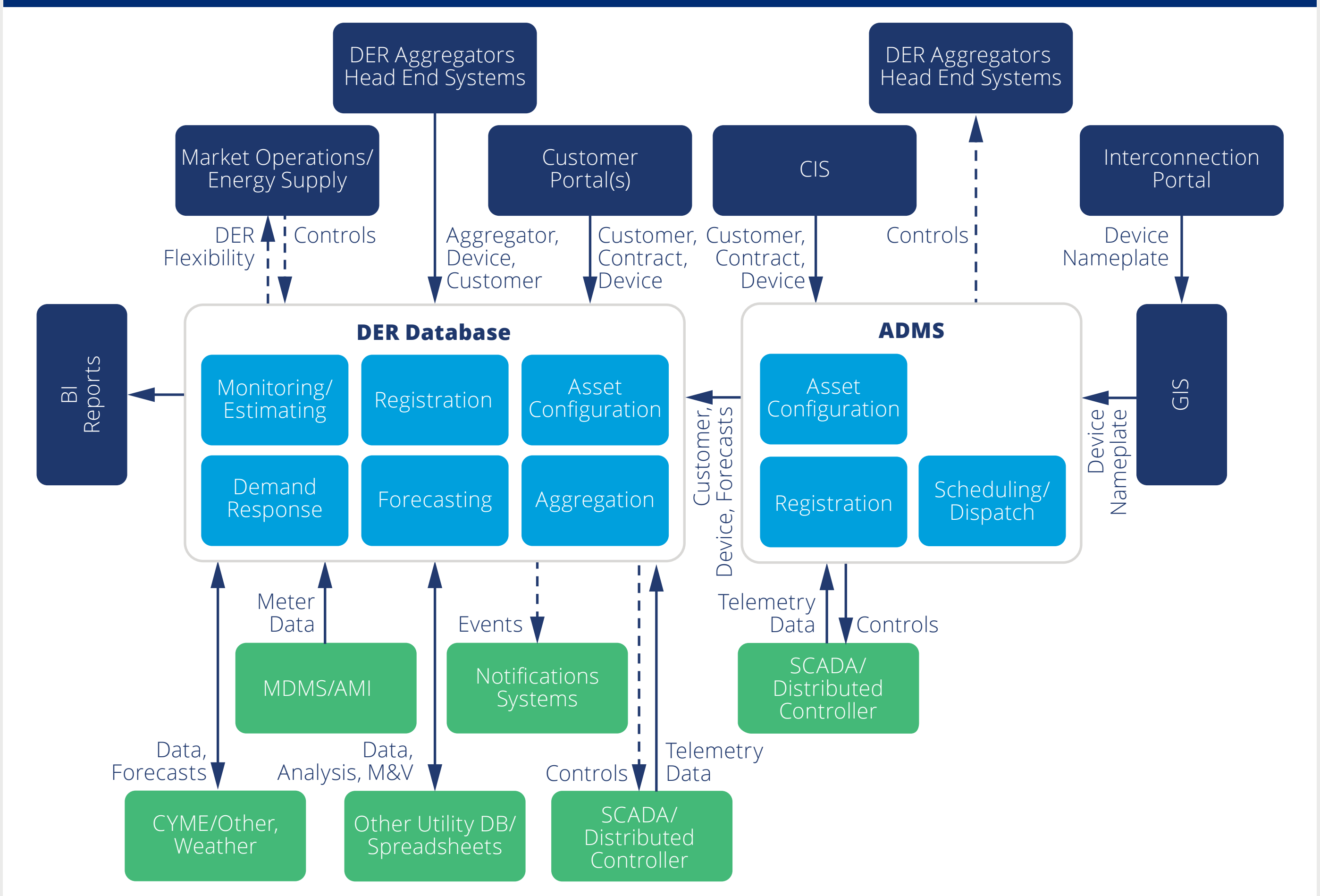
- Leverage existing **ADMS forecasting tools** or build/buy new forecasting capabilities that use data from DER database. Ensure ability to forecast aggregate DER flexibility at system level and by feeder.
- Build **analytics/optimization tools on DER database** to allow Operators and Planners to determine DER groups that can best reduce or shift peaks. Consider use of third-party optimization tools depending on need.
- Build M&V, including calculation of baselines, in spreadsheets, in DER database, or separate reporting database.

Control

Same as Visibility & Management Use Case plus the following:

- Utilize existing utility tools or buy/build a system to send **event notifications** to customers enrolled in demand response programs.
- Conduct analysis via analytics/optimization tools to determine dispatch schedules for DER assets.
- Manually dispatch and curtail DERs via **ADMS.**

Figure 34. Optimizing DERs for Peak Management Architecture for "Base" Systems + ADMS



Source: SEPA. (2023). Note: Utilities in the Taskforce were surveyed to rate the importance of each functionality in supporting this specific use case. Actual implementations may have different reliances on each functionality.

Use Case 3: Optimizing DERs for Grid Services

Use Case Summary

This use case emphasizes controlling DERs and integrating the utility's network and power flow models to inform those controls. Grid Services includes all the necessary data to understand the system's current state, to forecast the impact of the DERs on the system, and to send control systems to the DERs. The key DERMS modules for this use case are Optimization, Scheduling & Dispatch, VPP, Curtailment, Demand Response, Grid Management, Renewable Smoothing, and VVO. These modules contain all of the necessary DER device information to assign a dispatch schedule to DERs and to optimize that dispatch to correspond to grid needs to maintain power factor, voltage, and frequency within required operating bands.

Architecture Considerations

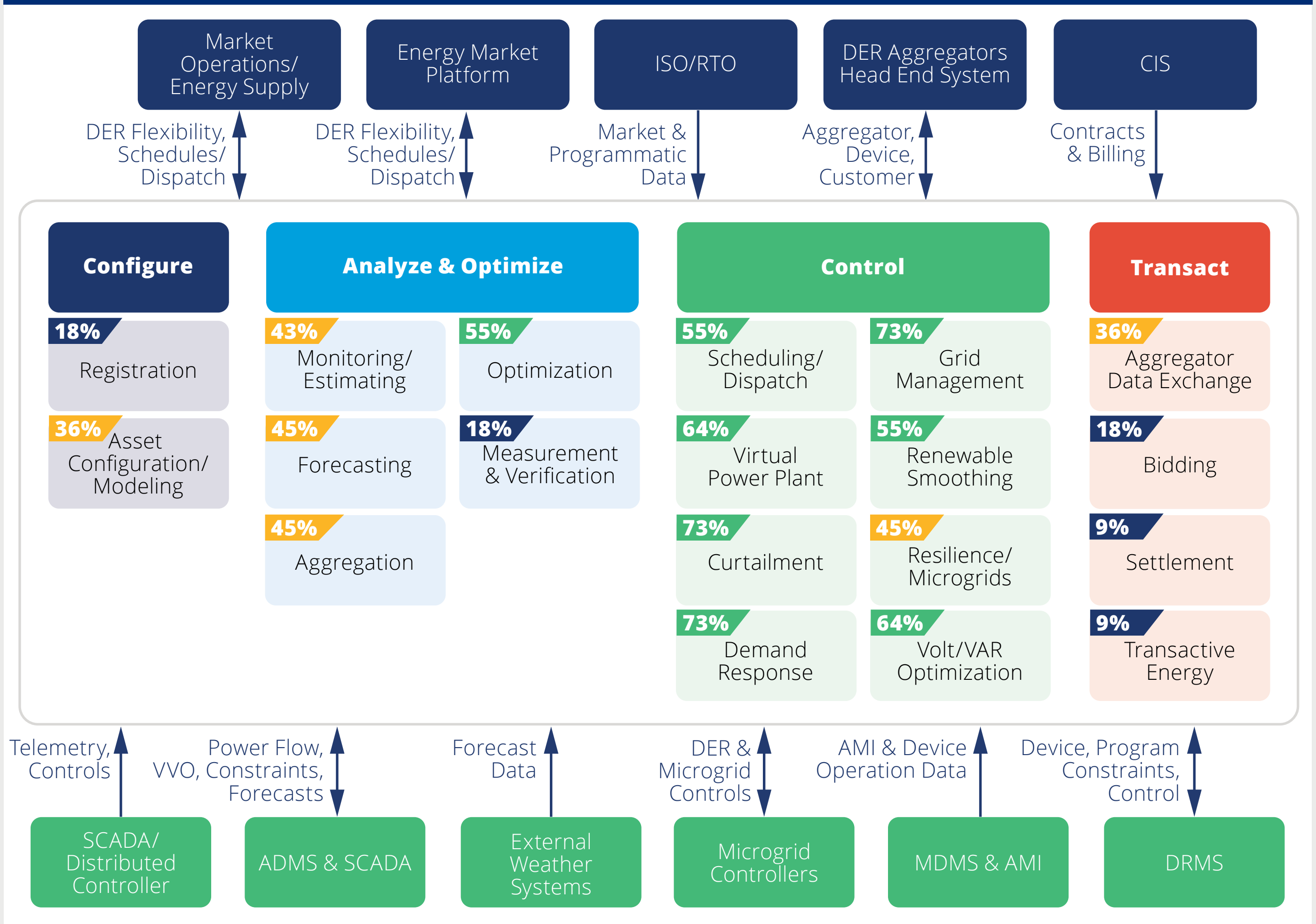
The Optimizing DERs for Grid Services ideally coordinates market level data from systems such as Energy Market Platforms, the ISO/RTO, and other market operations systems with distribution grid level data from systems such as ADMS. DERMS uses this information along with DER flexibility available through direct monitoring or DER estimates to determine the scheduling and dispatching of DER assets. The ability to conduct a real-time power flow or ingest power flow results from an external system such as ADMS is essential for this use case. This allows the DERMS optimization to determine DER controls to solve specific grid needs at specific grid locations.

Given the expansion of DER aggregators in the DER space, DER Aggregator head end systems are another necessary interface that is needed to provide both DER device and customer information to the DERMS and provide the Aggregator with data and dispatch instructions from the DERMS system.

Grid Services relies heavily on the DERMS Optimization and related Control modules in order to optimize the scheduling and dispatch of the DERs to solve different grid needs. This can involve dispatching for Virtual Power Plants, Demand Response Programs, Volt-VAR Optimization, Grid Management, Generation Curtailment, and Renewable Smoothing. Power flow and network data from the ADMS and SCADA systems provide information to the DERMS Optimization module so that the DERMS can optimize DER dispatch based on local and system-wide grid needs. SCADA, MDMS, and AMI operational data is provided to the Monitoring and Forecasting modules to update the DERMS on the historical and near real-time DER operations. External forecasting systems, including weather systems, can also improve insights into DER availability and capacity.

Control signals can be sent through multiple channels: through the aggregator head end, through the DRMS system, through the ADMS, through microgrid and other distributed controllers or directly to the DER devices. The communication pathway will depend on available systems, communication protocols supported, and capabilities of the individual DERs.

Figure 35. Key Implementations for the Optimizing DERs for Grid Services Use Case



Source: SEPA. (2023). Note: Utilities in the Taskforce were surveyed to rate the importance of each functionality in supporting this specific use case. Actual implementations may have different reliances on each functionality.

Alternatives

Alternative using "Base" Systems

Configure

Same as Peak/Demand Management Use Case plus the following:

- Configure FTM DERs in **DSCADA or distributed controller.**

Analyze & Optimize

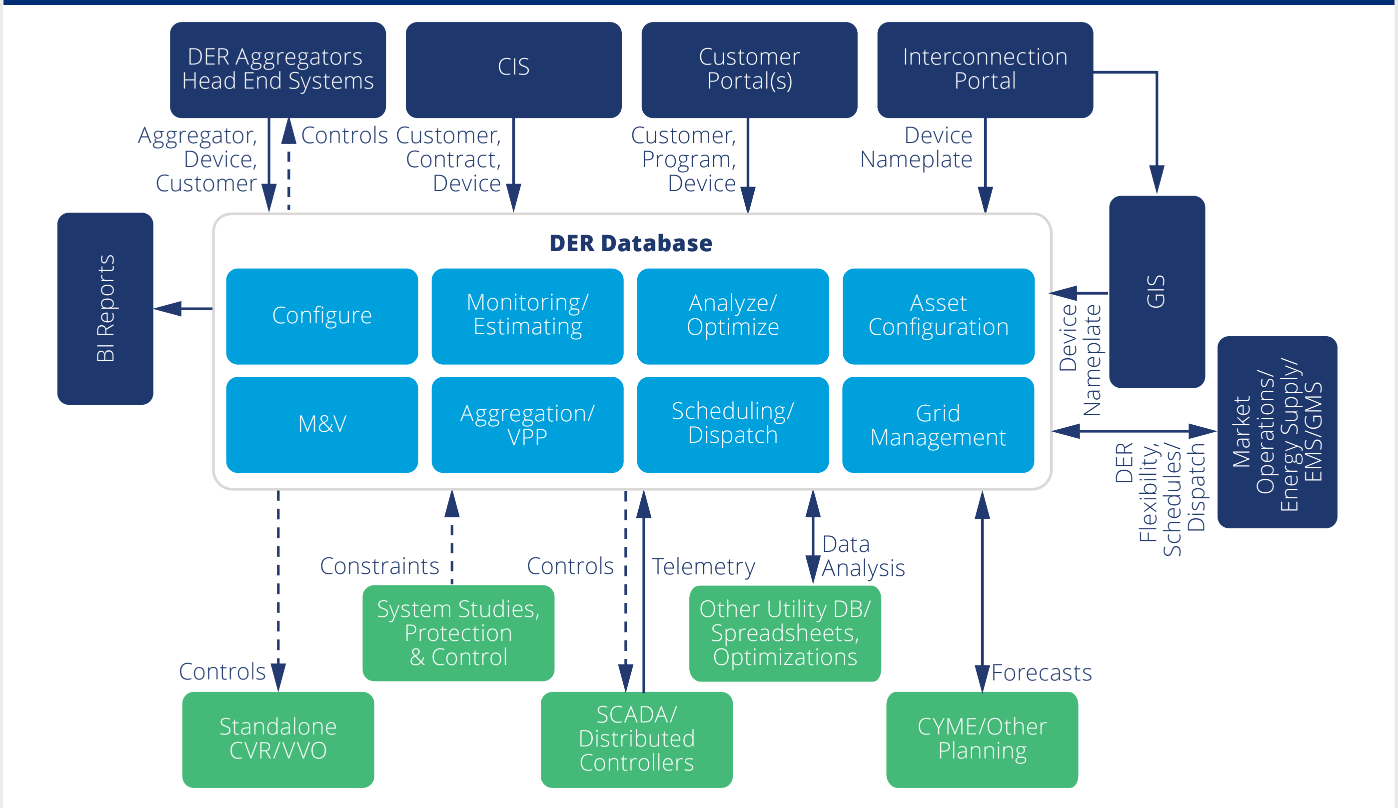
Same as Peak/Demand Management Use Case plus the following:

- Leverage existing **forecasting tools** or build/buy new forecasting capabilities that use data from DER database. Ensure ability to forecast aggregate DER flexibility at system level and by feeder.
- Leverage existing **system studies, coordinated protection and control at the substation level (such as UF relays, Automatic Voltage Regulator Control), and operational procedures.**
- Consider increasing DSCADA measurement points and combine with feeder alarm limits on an **operational dashboard** to help with decision-making.
- Build additional DER **analytics capabilities** to modify the above tools as DER penetrations increase.

Control

- Conduct analysis via analytics/optimization tools to determine dispatch schedules for DER assets.
- Manually dispatch and curtail FTM DERs via **SCADA, or distributed controller software.**
- Manually dispatch and curtail aggregations of BTM Customer DER and BTM Utility DER through **aggregators, web platforms from device manufacturers** such as Nest, Ecobee, Tesla, etc., or other **distributed controllers.**
- Build **BI reports/analytics** from data managed in the DER database.

Figure 36. Optimizing DERs for Grid Services Architecture for "Base" Systems



Source: SEPA. (2023). Note: Utilities in the Taskforce were surveyed to rate the importance of each functionality in supporting this specific use case. Actual implementations may have different reliances on each functionality.

Alternative Using "Base" Systems + DRMS

Configure

Same as Peak/Demand Management Use Case plus the following:

- Configure FTM assets in DRMS. Build integration between interconnection portal and/or GIS (source system for FTM asset information).

Analyze & Optimize

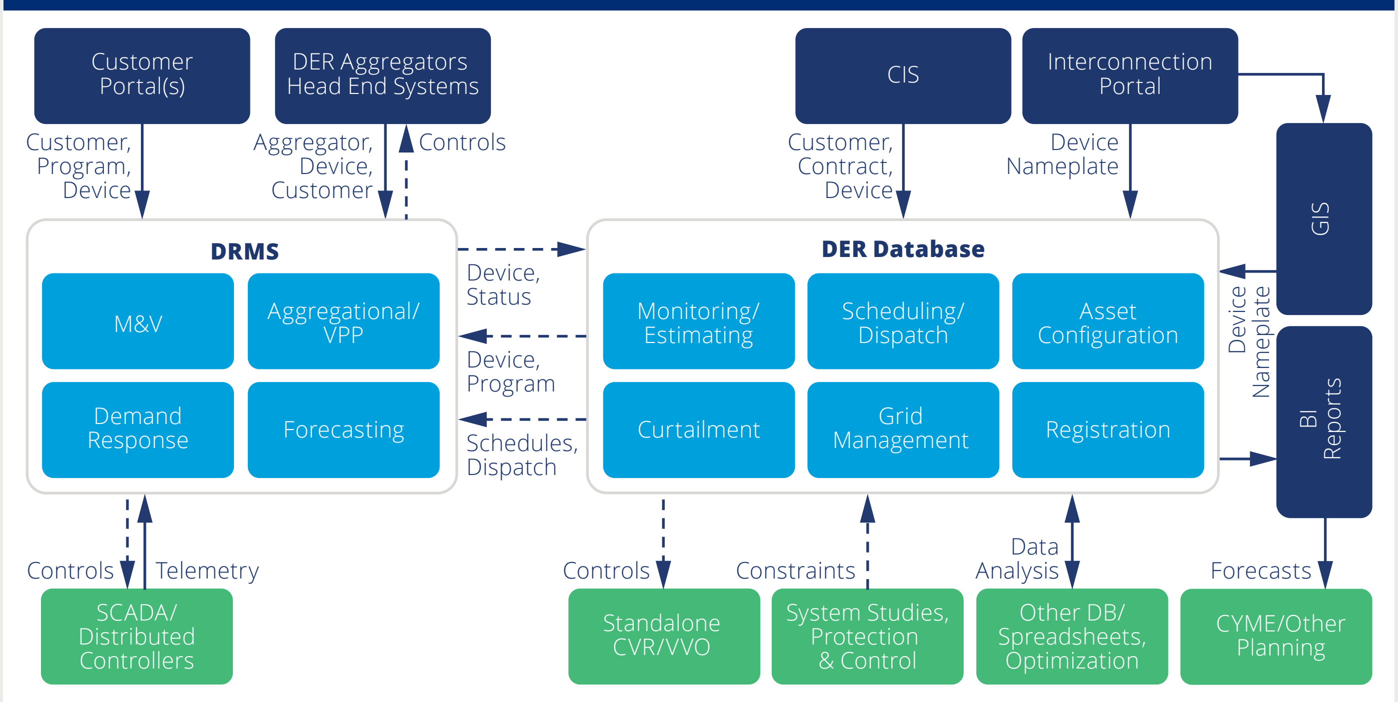
Same as Peak/Demand Management Use Case plus the following:

- Leverage existing **DRMS forecasting tools** or build/buy new forecasting capabilities that use data from **DRMS** and the DER database. Ensure ability to forecast aggregate DER flexibility at system level and by feeder.
- Build **analytics/optimization tools** on DER database to allow Operators and Planners to determine DER groups that could contribute grid services. Consider use of third-party optimization tools depending on need.

Control

- Utilize existing utility tools or buy/build a system to send **event notifications** to customers enrolled in demand response programs.
- Conduct analysis via analytics/optimization tools to determine dispatch schedules for DER assets.
- Manually dispatch and curtail DERs via **ADMS**.

Figure 37. Optimizing DERs for Grid Services Architecture for "Base" Systems + DRMS



Source: SEPA. (2023). Note: Utilities in the Taskforce were surveyed to rate the importance of each functionality in supporting this specific use case. Actual implementations may have different reliances on each functionality.

Alternative Using "Base" Systems + ADMS

Configure

Same as Visibility & Management Use Case plus the following:

- **Add all DER device information to the ADMS network model. Configure FTM DER communication path (DSCADA/distributed controller) and confirm ADMS control.**
- Integrate ADMS with aggregators to **dispatch BTM DERs from ADMS.**

Analyze & Optimize

Same as Visibility & Management Use Case plus the following:

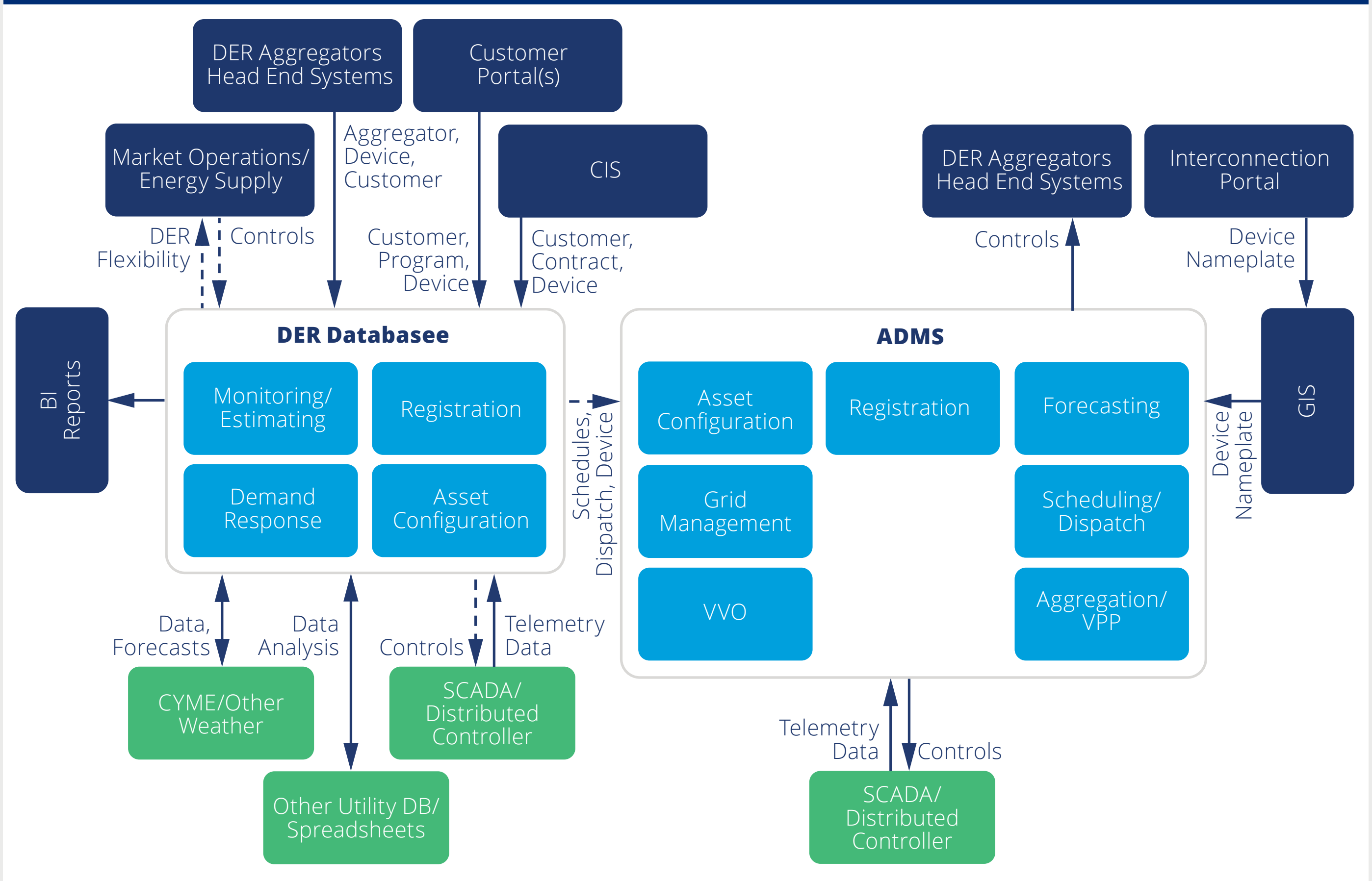
- Leverage existing **ADMS forecasting tools** or build/buy new forecasting capabilities that use data from DER database. Ensure ability to forecast aggregate DER flexibility at system level and by feeder.
- Build **analytics/optimization tools on DER database** to allow Operators and Planners to determine DER groups that can best reduce or shift peaks. Consider use of third-party optimization tools depending on need.
- Build M&V, including calculation of baselines, in spreadsheets, in DER database, or separate reporting database.

Control

Same as Visibility & Management Use Case plus the following:

- Utilize existing utility tools or buy/build a system to send **event notifications** to customers enrolled in demand response programs.
- Conduct analysis via analytics/optimization tools to determine dispatch schedules for DER assets
- Manually dispatch and curtail DERs via **ADMS.**

Figure 38. Optimizing DERs for Grid Services Architecture for "Base" Systems + ADMS



Source: SEPA. (2023). Note: Utilities in the Taskforce were surveyed to rate the importance of each functionality in supporting this specific use case. Actual implementations may have different reliances on each functionality.

Use Case 4: Market Animation

Use Case Summary

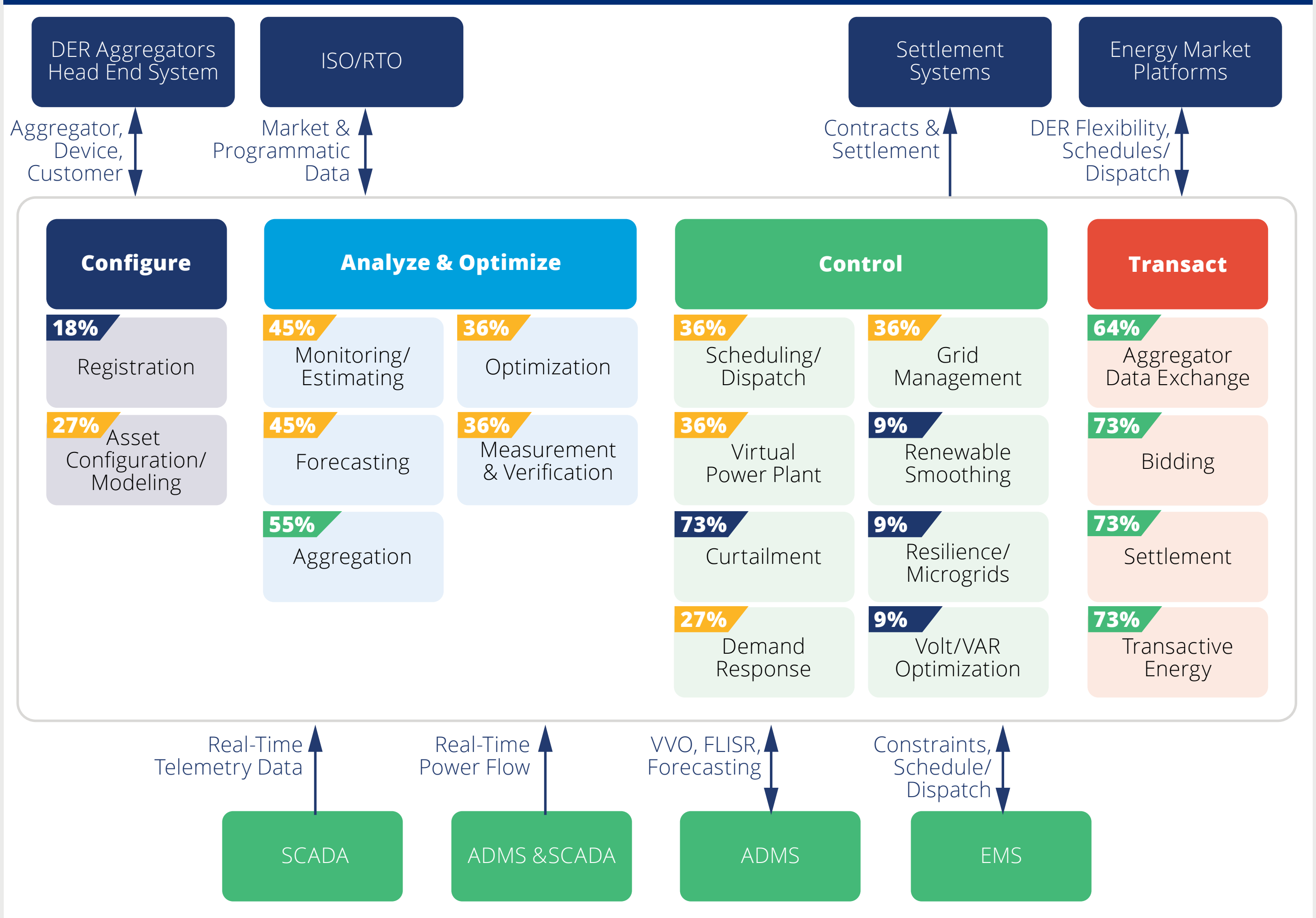
This use case emphasizes interactions with market systems in order to obtain economic value from controlling DER assets and to comply with FERC Order 2222 requirements to facilitate DER participation in wholesale market opportunities. The key DERMS modules for this use case are Aggregation, Aggregator Data Exchange, Bidding, Settlement, and Transactive Energy. These modules contain the necessary DER information for utilities to participate in market systems and then reconcile accounts.

Architecture Considerations

The Market Animation use case heavily relies on integration to external market systems such as Energy Market Platforms, the ISO/RTO, and other market operations systems. The DERMS would provide energy market platforms with information on the planned DER operations (bids) and then receive settlement statements from those systems. In this way, the DERMS facilitates DER participation in the market through the Bidding and Transactive Energy modules but supports reconciliation through the Settlement function. Interfacing with the ISO/RTO market platform provides further information on the market (prices) and programmatic information needed for these modules. Given the expanded role of DER aggregators resulting from FERC Order 2222, DERMS integration with DER Aggregator head end systems provides both DER device and customer information to the DERMS but also provides the Aggregator with data and dispatch instructions from the DERMS system.

Market Animation is focused on operational data exchange and the facilitation of control schedules to optimize DER market participation. The telemetry and other power flow data from the SCADA and ADMS systems is used to support the Bidding, Transactive Energy, and Settlement modules and to validate that dispatch of aggregated DER does not cause system reliability issues.

Figure 39. Key Implementations for the Market Animation Use Case



Source: SEPA. (2023). Note: Utilities in the Taskforce were surveyed to rate the importance of each functionality in supporting this specific use case. Actual implementations may have different reliances on each functionality.

Alternatives

Alternative Using "Base" Systems

Configure

Same as Visibility & Management Use Case plus the following:

- Capture Market–Aggregator–Device–Contract/Program attributes in new DER database.

Analyze & Optimize

Same as Visibility & Management Use Case plus the following:

- Build capability to group DERs into multiple groups/ aggregations simultaneously.
- Build analysis/optimization tools to evaluate aggregations to understand grid impacts of DER operation.
- Build or buy tools to forecast DER availability to support bidding.
- Capture Market prices and program information from RTO/ISO in DER database.

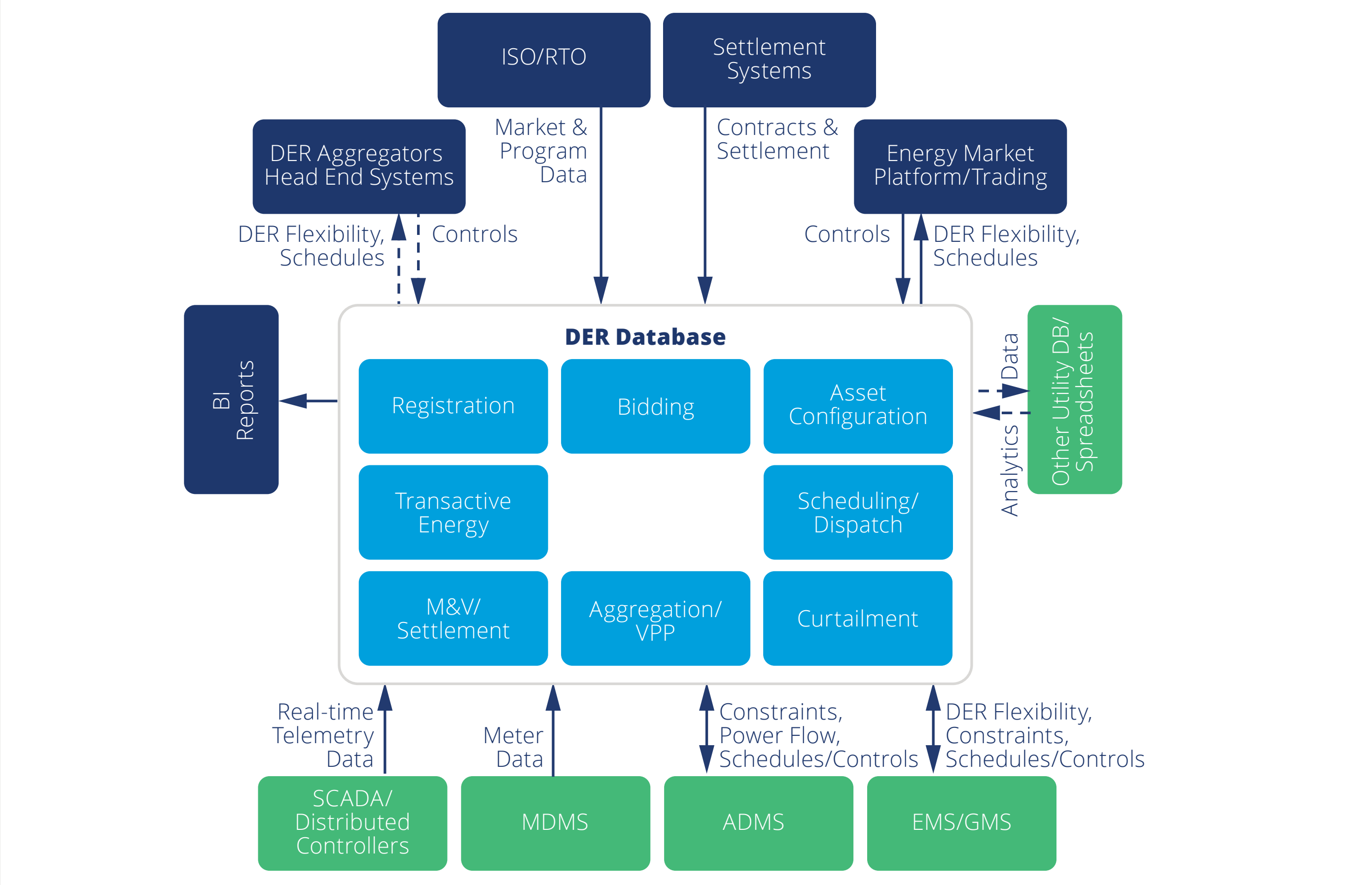
Control

- Build DER schedule from forecast and populate in trading or market management system manually or through integration.
- Submit dispatch schedules, DER flexibility, and controls manually into Aggregator systems.

Transact

- Build DER bids (schedules) in DER database and manually submit to energy market platform.
- Capture market settlement reports from ISO or Settlement system in DER database. Validate settlement via analysis in DER database or spreadsheets.

Figure 40. Market Animation Architecture for "Base" Systems



Source: SEPA. (2023). Note: Utilities in the Taskforce were surveyed to rate the importance of each functionality in supporting this specific use case. Actual implementations may have different reliances on each functionality.

Alternative Using “Base” Systems + DRMS

Configure

Same as Visibility & Management Use Case plus the following:

- **Configure BTM customer and BTM utility DER and customer relationship information in existing DRMS.**
- Buy/build **DER database** to capture FTM DER device, program, and location information. **Integrate FTM DER information to DRMS.**
- **Integrate with aggregators via DRMS.**

Analyze & Optimize

Same as Visibility & Management Use Case plus the following:

- Use **DRMS** capability to group DERs into multiple groups/aggregations simultaneously.
- Build analysis/optimization tools to evaluate aggregations to understand grid impacts of DER operation.
- Build or buy tools to forecast DER availability to support bidding.
- Capture Market prices and program information from RTO/ISO in DER database.

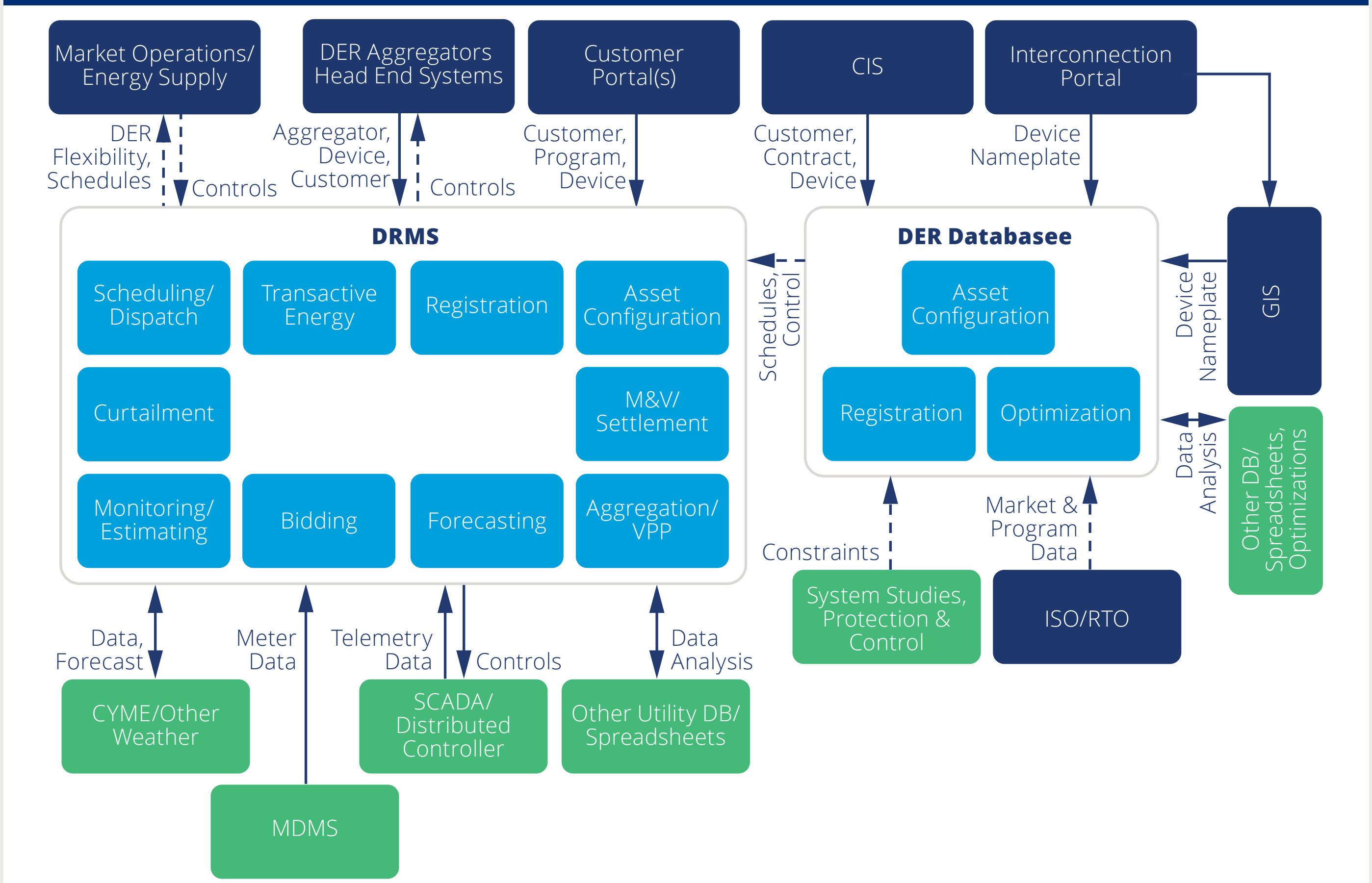
Control

- Build DER schedule from forecast and populate in trading or market management system manually or through integration.
- Submit dispatch schedules, DER flexibility, and controls manually into Aggregator systems.

Transact

- Build DER bids (schedules) in DER database and manually submit to energy market platform.
- Capture market settlement reports from ISO or Settlement system in DER database. Validate settlement via analysis in DER database or spreadsheets.

Figure 41. Market Animation Architecture for “Base” Systems + DRMS



Source: SEPA. (2023). Note: Utilities in the Taskforce were surveyed to rate the importance of each functionality in supporting this specific use case. Actual implementations may have different reliances on each functionality.

Alternative Using "Base" Systems + ADMS

Configure

Same as Visibility & Management Use Case plus the following:

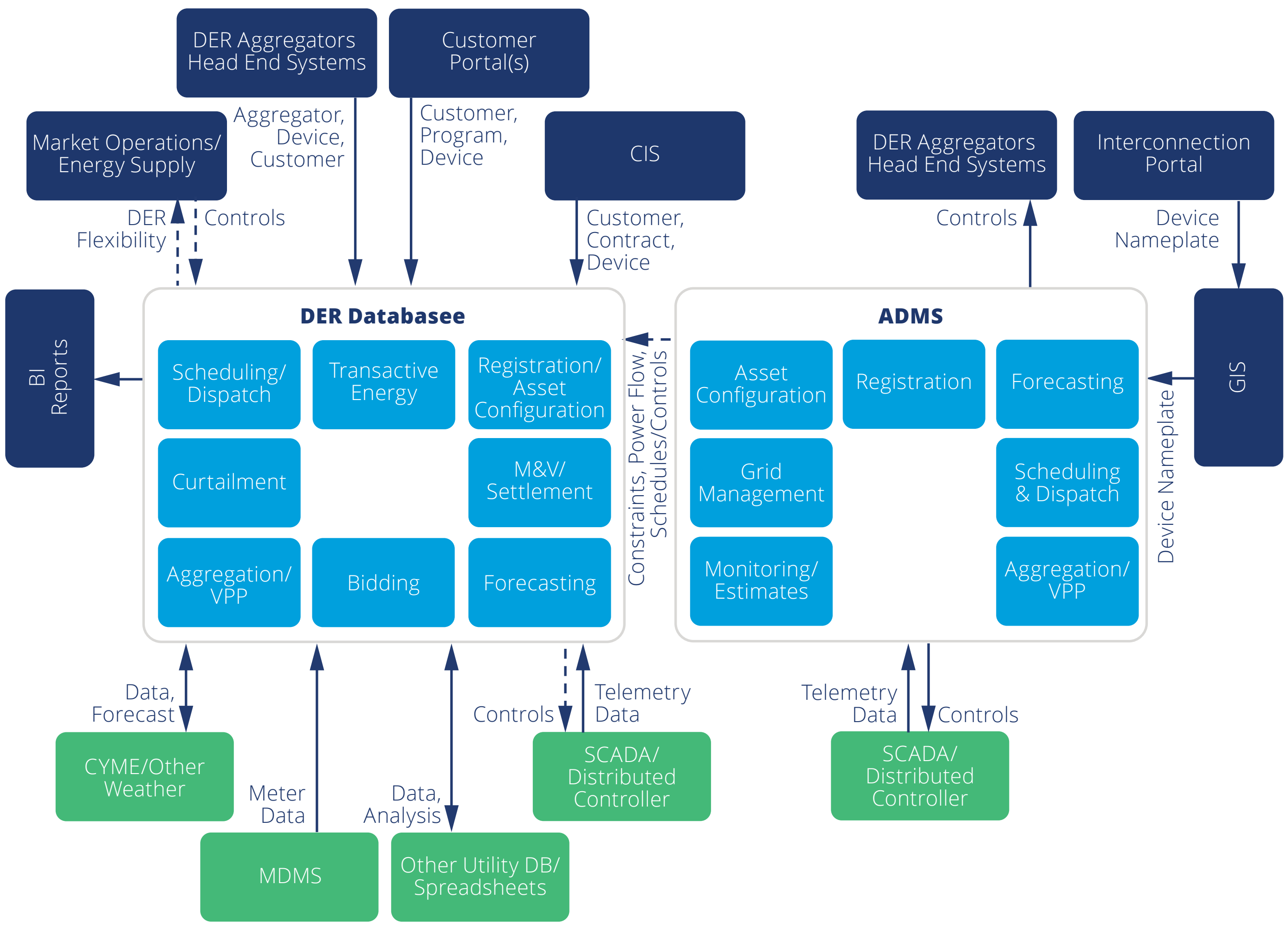
- **Configure BTM customer and BTM utility DER and customer relationship information in existing DRMS.**
- Buy/build **DER database** to capture FTM DER device, program, and location information. **Integrate FTM DER information to DRMS.**
- Integrate with **aggregators via DRMS.**

Analyze & Optimize

Same as Visibility & Management Use Case plus the following:

- Build capability to group DERs into multiple groups/ aggregations simultaneously.
- **Leverage ADMS analysis/optimization tools** to evaluate aggregations to understand grid impacts of DER operation.
- Build or buy tools to forecast DER availability to support bidding.
- Capture Market prices and program information from RTO/ISO in DER database.

Figure 42. Market Animation Architecture for "Base" Systems + ADMS



Source: SEPA. (2023). Note: Utilities in the Taskforce were surveyed to rate the importance of each functionality in supporting this specific use case. Actual implementations may have different reliances on each functionality.

Control

- Build DER schedule from forecast and populate in trading or market management system manually or through integration.
- Submit dispatch schedules, DER flexibility, and controls manually into Aggregator systems **or through direct integration from ADMS.**

Transact

- Build DER bids (schedules) in DER database and manually submit to energy market platform.
- Capture market settlement reports from ISO or Settlement system in DER database. Validate settlement via analysis in DER database or spreadsheets.

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