Understanding DERMS

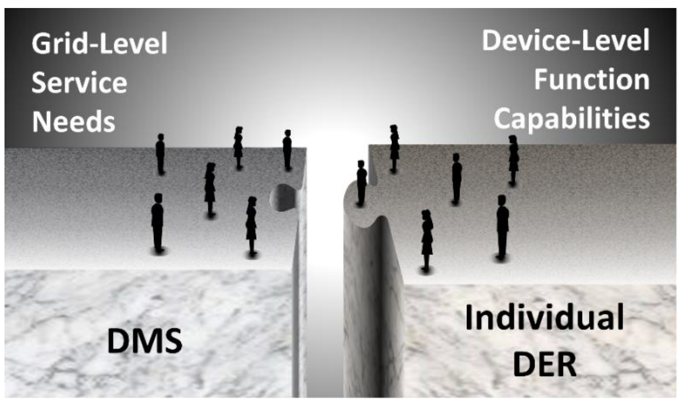
Contents

DERMS Origins

With the rapid deployment of distributed energy resources (DER), there is a high level of interest in how these devices can be integrated with utility operations at all levels for management and monitoring purposes. This integration is challenging in that the number of devices is high and that ownership is often that of a customer or third party.

Industry stakeholders first began to address DER integration by identifying and standardizing the functions that individual DER can perform autonomously, a distributed manner. Device-level functions like "voltage ride-through", "volt-var", "frequency-watt", and "dynamic reactive current" were designed and documented and are now supported by communication standards and grid codes worldwide, making grid-supportive capabilities mandatory for new interconnections.

This was a first step. A necessary step, but not sufficient to achieve end-to-end integration of DER with the grid. A substantial gap was recognized between the granular controls of individual DER and the type of organized services needed for grid support, integration with distribution management systems (DMS) and grid operations. In 2012, stakeholders began working to define a common set of grid-supportive services and means to integrate large quantities of DERs into utility systems in a way that is practical, sustainable and extensible. Because multiple parties could be involved; utilities, DMS providers, DER aggregators and facility/microgrid controller providers are working together.

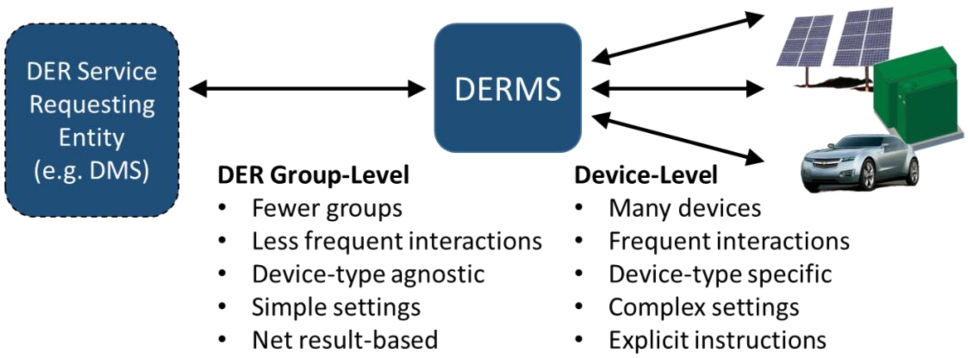


Several needs have been targeted:

- **Quantity:** To be utilized effectively in a power system, DER will have to work in harmony with other control devices: load tap changers, capacitors, voltage regulators and switches. Their capabilities will have to be aligned with the power system: by feeder, phase, circuit segment, etc. This requires a flexible means to aggregate DER into groups by which they can be viewed and managed collectively.
- **Complexity:** The many complex functions of smart inverters coupled with their continuously-variable settings results in an infinite number of potential settings and multiple ways to achieve similar outcomes. DMS algorithms are concerned with the net effect of such settings on the grid, not the specific functions or settings used to achieve the effect.
- **Sustained Nature of Service:** Power system management systems need services provided in a stable, sustained fashion. Because many DER are variable (e.g. solar), achieving this involves

intelligence, and potentially frequent adjustment of device settings to maintain targets set for DER groups.

A logical component that satisfies these needs is called a DER Management System, or DERMS. In short, a DERMS bridges the gap between DER group-managing entities and devices by taking the complex capabilities of many and presenting them as a simpler more manageable set of services.



DERMS Core Capabilities

As described later, a DERMS can be integrated at a wide range of levels and can vary broadly in scale. Regardless of the placement or scale, a DERMS provides several key functions:

Aggregation - DERMS take the services of multiple (potentially millions) individual DER and present them as a smaller, more manageable, number of aggregated virtual resources that are aligned with the grid configuration. How DER are organized into groups is in itself a research question and must be flexible.

Translation - Individual DER may speak different languages, depending on their type and scale. DERMS handle these diverse languages, and present to the upstream calling entity (e.g. a DMS) in a cohesive way.

Simplification - DERMS provide simplified aggregate services that are useful to distribution operations. The services are power-system centric rather than DER-type centric. Complex device-level settings, such as volt-var curve points and fast iterative settings updates are abstracted away as services are achieved and sustained. The simplified services provided by DERMS are standardized supporting the ability of multiple upstream calling entities.

Optimization - A given service to be provided by a DER group may be achieved in many ways. Different smart inverter functions may be best at different locations or times. Different types of DER (e.g. storage, advanced loads, or solar) may make more sense in one circumstance than in another. DERMS provide requested grid services in the optimal way - saving cost, reducing wear, and optimizing asset value.

These functionalities are important to DER aggregators and downstream energy management system providers because these are intended to be products with intelligence, not as passive communication routers. Innovation is in these areas is beneficial to all stakeholders, improving efficiency and quality, rendering requested services from DER-groups in creative ways that optimize the service to the utility, the interests of the consumer and the lifetime economics of the DER resource.

Organizing DER into Groups

The effectiveness of the “aggregation” aspect of DERMS depends on how well groups of DER are organized. This is an ongoing area of research at EPRI - a new science in which best-practices will emerge over time. Industry stakeholders have identified many ways that one might choose to organize: by feeder, by segment, by phase, by DER type, etc. The standards that have been created (described later in this paper) make no limitation in this regard and allow that any list of DERs could be established as a group if desired.

Perhaps more interesting than “how” DER are organized is “who” organizes them. This question is often posed relative to a DMS and one or more DERMS. The technical answer is that the standard messages are structured so that either entity could create and declare the group to the other. And either could accept or reject this message. This symmetry was put in place because there were both DMS and DERMS providers participating in the standards process that wanted the ability to create groups. The more practical answer is probably that the DMS or upstream entity will create DER groups and declare them to the downstream DERMS. This is likely to create more use value of the group because the entity forming the group is the one that will be requesting its services.

The process of forming a DER group is straightforward, with standard messages that include a list of unique identifiers (mRIDs) for each member of the group and a unique group name. Other messages can query for existing groups, check group version/revisions, perform group maintenance, adding or deleting members from a group, or delete a group. In a simpler implementation, group definitions could be manually set and agreed-upon by DMS and DERMS.

Example DERMS Use Case

An example use case of DERMS is to utilize DER in the management of voltage and VARs on an electric distribution system. By aggregating the monitoring and controllability of many DER, DERMS provides additional control levers for the DMS. A DMS based voltage and VAR optimization algorithm would require control zones to be delineated by each voltage control device (load tap changer or voltage regulator) as shown in Figure 1. Here, four feeders are divided into six sections, which are further separated by phase to create 18 different control zones. The DER on this circuit could then be assigned to one of 18 groups, associated with these control zones.

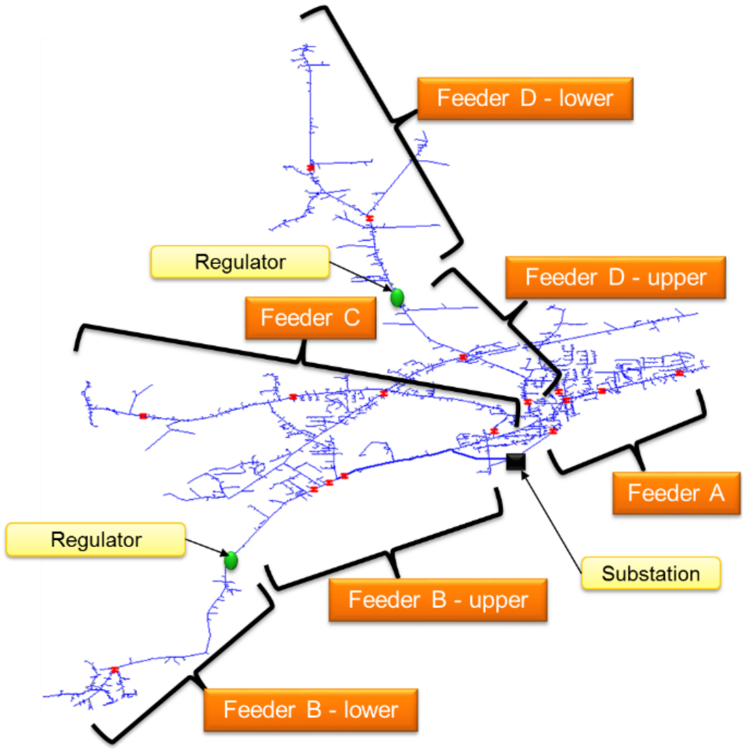


Figure 1, Circuit for DERMS Example Use Case

As system conditions or objective functions change over time, the DMS would analyze those changes and issue new instructions to the voltage and VAR controlling assets. In addition to settings or direct control of the traditional utility devices (load tap changers, line regulators, capacitors) the DMS would consider how the group-level services of the DER could be utilized and send commands to the DERMS accordingly. The DERMS would then translate these group-level commands into optimized settings changes (PF setpoints, volt-var curves, watt curtailment, etc.) or direct commands (load management, storage dispatch), to achieve the desired aggregate outcome. DERMS would then monitor and modify device settings for the duration of the service request in order to sustain it.

Standards for DERMS Interfaces

Standardization at DERMS interfaces is necessary to support natural system expansion. Due to the large number of potential actors and interfaces in the DER integration space, custom/proprietary integration is not practical other than for simple one-off demo projects. Both at the device-level (DERMS-to-DER) and at the DER-group level (DMS-to-DERMS) there will likely be multiple systems and multiple companies involved. Even in the early stages of DER integration if there is a single DERMS and single brand of DER being managed, it is advised to use standards so that the system can be sustained and expanded going forward.

In this context, “standards” refers to two primary things:

- **Standard Function/Service Definitions:** consistent behaviors to be implemented and provided by DERMS and device providers and to be expected, understood and utilized by DMS systems.

- **Standard Protocols and Information Models:** consistent communication encodings that allow system components from multiple vendors to be integrated without requiring custom mapping software for each.

Standard Functional Capability at DERMS Interfaces

From the utility perspective, it is not practical to have each DER aggregator or device vendor independently define the grid-services or protocols that they can provide. There are potentially thousands of entities that may offer such services and it is not reasonable to expect distribution control strategies that deal uniquely with each type of offered service.

Likewise, from the vendor's perspective it is not practical to have each utility or DMS provider independently define the services or protocols that they can utilize. There are many utilities, and vendors need volume and consistency in the market in order to provide quality products at feasible costs.

Standard service/function definitions and protocols for DERMS exist and are being actively improved and maintained. Utilities engaged in DERMS projects are encouraged to consider and build upon these standards, offering improvements and extensions as learnings occur. Table 1 provides a concise summary of standards and related documents that support DERMS interface functionalities.

Table 1, Standards for Functionality at DERMS Interfaces

DER-Group Level (DMS-to-DERMS) Interface	Device Level (DERMS-to-DER) Interface
Standard Group-Level Function Definitions: IEC 61968-5 (Common Information Model for DER)	**Standard Device-Level Function Definitions:** IEC 61850-7-520 and information model in IEC 61850-7-420
Public EPRI report for reference: *Common Functions for DER Group Management, Third Edition*[1]	**Public EPRI report for reference:** *Common Functions for Smart Inverters, Fourth Edition*[2]
Defined DER Group-Level Grid Services: • DER Group Creation • DER Group Version and Member Query • DER Group Deletion • DER Group Maintenance (Adding, Updating, and Deleting Members) • DER Group Capability Discovery • DER Group Status Monitoring • DER Group Forecasting • DER Group Historical Aggregate Meter Data • DER Group Maximum Real Power Limiting • DER Group Ramp Rate Limit Control • DER Group Phase Balance Limiting	**Defined DER Device-Level Functions:** • Connect/Disconnect Function • Limit DER Power Output Function • Energy Storage: Direct C/D Function • Energy Storage: Price-Based C/D Function • Energy Storage: Coordinated Charge/Discharge Management Function • Fixed Power Factor Function • Volt-Var Function • Watt-Var Function • Volt-Watt Function • Frequency-Watt Function • Watt-PowerFactor Function

[1] *Common Functions for DER Group Management, Third Edition.* EPRI, Palo Alto, CA: 2016. 3002008215

[2] *Common Functions for Smart Inverters: 4th Edition.* EPRI, Palo Alto, CA: 2016. 3002008217

• DER Group Real Power Dispatch • DER Group Reactive Power Dispatch • DER Group Voltage Regulation Function • Set DER Group Curve Functions • Provide Price to DER Group • Request Cost of Service from DER Group • Manage Power at a Point of Reference • Connect/Disconnect DER Group	• Price or Temperature Driven Functions • Low/High Voltage Ride-Through Function • Low/High Frequency Ride-Through Function • Dynamic Reactive-Current Support Function • Dynamic Real-Power Support • Dynamic Volt-Watt Function • Peak Power Limiting Function • Load and Generation Following Function • Status Monitoring Points
DER Grid Codes with Functional Requirements: DER Grid Codes are not applicable at the group level	**DER Grid Codes with Functional Requirements:** • IEEE 1547-2018 (specific set of device-level functions required, three protocol options) • CA Rule 21
Functional Testing: Not yet available. See protocol testing in the next section.	**Functional Testing:** • IEEE 1547.1 – test specification for IEEE 1547, expected Q1 2019. • UL1741SA - Supports Rule 21, to be updated to support 1547.1

Standard Protocol Capability at DERMS Interfaces

Communication protocol standards have been developed to support DERMS interfaces. The encodings continue to be improved and may or may not be supported in given products. For both scalability and sustainability, communication protocol standards should be required at DERMS interfaces. Table 2 provides a concise summary of standards and related documents that support DERMS interface protocols.

Table 2, Standards for Communication Protocols at DERMS Interfaces

DER-Group Level (DMS-to-DERMS) Interfaces	Device Level (DERMS-to-DER) Interfaces
Standard information Model: IEC 61968-5 (Common Information Model for DER)	**Standard information Model:** IEC 61850-7-420
Protocol Encodings for DER Groups: • IEC 61968-100:2013 "Application Integration for 61968 Profiles" • MultiSpeak 5.0 • OpenFMB (alignment/ mapping in process) • OpenADR 2.0 (mapping being considered)	**Protocol Encodings for DER Devices:** • SunSpec Modbus • DNP3 AN2013-001, AN2018-001 • IEEE 2030.5 • IEC 61850-8-2
DER Grid Codes with Protocol Requirements: Not Applicable at the Group Level	**DER Grid Codes with Protocol Requirements:** • Multiple worldwide, unique by region • IEEE 1547-2018 (specific set of device-

	level functions required, three protocol options) • CA Rule 21
Protocol Testing: UCAI Users Group, CIM for DER compliance testing.	**Protocol Testing:** • IEEE 1547.1 – test specification for IEEE 1547, expected Q1 2019, mandates that DER support at least one of three standard protocols (DNP3, SunSpec Modbus, 2030.5) includes communication/interoperability test requirements. • UL1741SA - Supports Rule 21, to be updated to support 1547.1 • SunSpec Alliance – defines test requirements for the three 1547-specified protocols.
Protocol Certification/Listing: UCAI Users Group, CIM for DER certification and listing.	**Protocol Certification/Listing:** SunSpec Alliance provides certification listing for the three 1547-specified protocols.

DERMS is a Logical Entity

As utilities lay plans for DER integration, it is important to recognize DERMS as a logical entity, not necessarily a physical one. This means that DERMS may be a stand-alone software, or may be bundled with other functionality in combination software products.

This is normal. As an example, consider the logical definition of an Outage Management System (OMS). We know what it is, we can describe its individual purpose and capabilities, and yet vendors often bundle OMS capability with DMS, Work Management Systems, or other systems. The same is true of Geospatial Information Systems, Customer Information Systems, and others that are sometimes bundled.

"DERMS" is a function – a capability to perform a certain set of actions as will be discussed below. A given utility architecture may elect to have DERMS stand-alone or be integrated with DMS, or both. Over time the architecture is likely to evolve. In any case, the role and function of

each should be defined and specified separately. If bundled products are used, it is critical that the DMS-to-DERMS interface be exposed and accessible so that other DERMS (other managed aggregations of DERs) can be integrated into the system. Without this the system is neither scalable nor sustainable.

Starting Out Simple: Manually-Operated DERMS

A DERMS does not have to be driven automatically by a DMS, it may be used standalone - driven manually by human operators. For many utilities the needs for adjusting DER settings are infrequent. DERMS may be used, for example, to make seasonal adjustments of power factor to optimize relative to winter and summer loads or to limit DER export power on a handful of peak days per year.

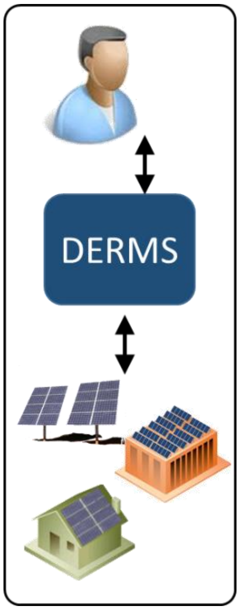


Figure 2, Manually Operated DERMS

In these cases, the operator may be provided a user interface with the same basic set of DER group-level monitoring and management services as would be available to a DMS.

Evolving: DERMS Quantity, Placement and Scale

Utilities may first focus on a single centralized DERMS – a system that will reside in the operations center alongside DMS, Outage Management Systems (OMS) and other large-scale applications. While this may be a proper place to start, the architecture should consider that DER aggregation will eventually happen at multiple levels, and that multiple parties may be involved.

Figure 3 illustrates this principle through an example. In Stage 1, the utility employs a central DERMS which may work alongside or within their DMS. This DERMS connects to the DER that the utility initially intends to manage, making these devices an active part of the system operations. In Stage 2, the system is expanded with third party solar aggregators, storage fleet managers, or any other DER managing entity playing a role in the overall architecture.

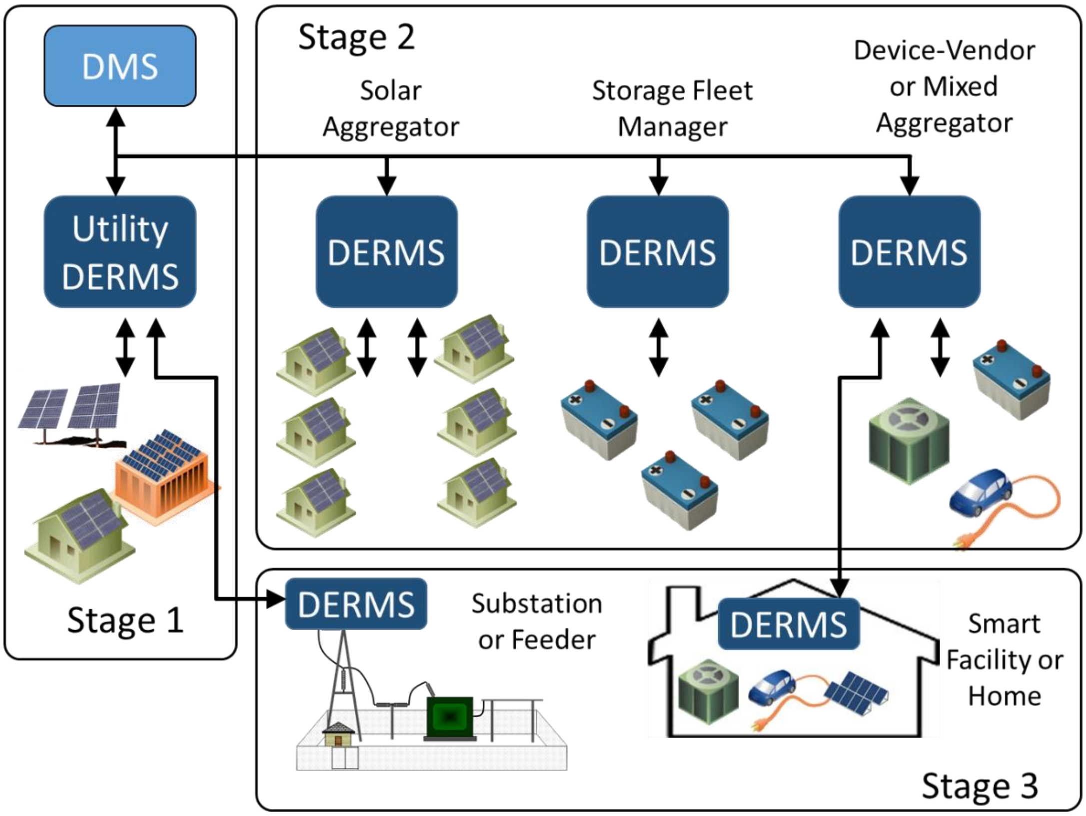


Figure 3, Central, Distributed, and Hierarchical DERMS Functionality

In Stage 3, the system is further expanded with distributed DERMS, DER aggregation and management performed downstream, such as at the feeder, community, facility or home-level. Each of these points of distributed intelligence is a DERMS in its own right, providing the same basic logical functions as the central DERMS.

The work of standards groups regarding methods for DER group-level management has been influenced by prior work in the demand response area that enabled aggregation to occur at multiple levels. Accordingly, the standards that have emerged for DERMS apply equally to large-scale central DERMS, feeder-level controllers placed at substations, microgrid controllers, advanced energy communities, or facility/home energy management systems. The methods can be nested, and the services of multiple downstream DERMS (such as third-party aggregators) can be utilized directly or rolled-up into upstream DERMS (such as a central utility application).

A key principle here is that the interface between DERMS and DMS is of critical importance architecturally. While there is no issue with having a DERMS capability included within a DMS, it is not rational to view this as the only DER aggregating system that will be involved. To ensure system scalability and sustainability, the DERMS-to-DMS interface should be accessible.

Another key principle is that DER management can begin in a simple form, such as a single central software application as described in the previous section. Later, if desired, intelligence can be distributed and the overall DER management approach made a system-of-systems as shown in Figure 3.

DERMS vs. DER-Ready DMS

When the term “DERMS” found its way into utility dialogue, a wide range of existing products and systems were quickly advertised as being or including DERMS. Certain providers of DMS, distribution automation, vendor/customer headends, load management software, building automation and home energy management presented their products as DERMS, whether or not they provided the core capabilities or supported the standard service definitions that are necessary for cohesive integration of multiple DER.

A common point of confusion is that of “DERMS” versus a “DMS that is DERMS-ready”. Conventional DMS control voltage regulators, capacitor banks, and circuit configuration via sectionalizing switches. They have access to meters, power system models and load models, and perform power-flow analysis on a recurring basis to determine optimal settings of the control devices based on the utility’s needs and priorities at the moment.

A DERMS-Ready DMS goes further by having the ability to include the services of DER in the math of determining of an optimal solution. Services such as dispatchable real and reactive power, ramp rate limiting and regulation provided by a DERMS can be utilized in conjunction with the conventional controls to produce overall improved responses.

The logical function of a DERMS, on the other hand, does not involve the power system model and likely does not have access to it as in the case of third-party aggregators. A DERMS may not understand why a given set of DER have been organized into a dispatchable group and likely would not know why a given service is being requested at a given time. The DMS is the part that knows why. DMS has visibility to sensors on the power system, understands it present status and limitations and knows what the operational goals and priorities are at any given time. DMS determines what service is needed, DERMS provides the service as requested.

Some utilities envision control applications that are distributed (outside the operation center) that do have access to the power system model or a section thereof and solve it as they operate the DER in that area. This is consistent with the logical definitions provided here in that it describes a decentralized DMS. In the same way that DMS and DERMS may work hand-in hand in the operations center, they can also work hand-in-hand at distributed points throughout the power system such as at a substation. **Regardless of the location, the portion that is solving the power system model is a logical part of the DMS and the portion that is aggregating, translating, simplifying and optimizing DER is DERMS.** Just as in the centralized case, a distributed software or product might do both functions, but requiring exposure of the interface between the two parts limits vendor lock-in and allows other DERMS to be involved in the solution.

DERMS Ownership and Operation

Depending on their circumstances, utilities may or may not prefer to own and operate a given DERMS. Because multiple DERMS can be involved, and at multiple (nested) levels, it is not a simple binary decision. For example, a utility may have a centralized DERMS, or substation-level DERMS that they own and operate, managing a certain set of resources. The same utility may also partner with thermostat aggregators, solar aggregators and storage fleet managing entities and may tie these into utility DERMS or DMS at multiple levels.

What ownership model makes most sense depends on several factors, including the quantity and criticality of the DER being integrated. When the grid-supportive services provided by DER are merely economic optimizers, all options are reasonable. In this case the loss of a service, or its intentional misuse, would result in a sub-optimal operating condition but the grid would remain operational and customers served without interruption. However, when the quantity of DER rises to levels that are mission critical, DERMS ownership options may be narrowed as utilities are required to ensure the power system's availability and operation.

Federated Architecture for DER

The principles of DERMS presented in this paper are supported by EPRI's holistic *Federated Architecture for DER Integration (FADER)*. This architecture is the product of a decade of DER integration research, testing and trials. The term "federated architecture" in this context refers to a system that is integrated end-to-end (e.g. from central operations to system edge) while enabling the optimal placement of intelligence throughout the system. A federated architecture is intended to "provide the highest possible autonomy in order to reduce the complexity, which at the same time shall increase what is called agility. The expected result is a high degree of flexibility — which at the end means, taking local particularities seriously and solve local problems locally whenever possible."[3]

Federated architectures are generally aimed at addressing problems with unmanageable complexity. This is fitting for the problem of DER integration with the roll-up of impacts from the device-level, to buildings, to communities, to feeders, to distribution, to transmission, to ISO. The matter is further complicated by the continuous retirement and replacement of DER over time, including connected loads, storage and generation that play roles in the operation of the grid. A management system that can effectively sustain the breadth of integration required to address this problem must be federated.

DERMS Project Examples

As noted in the introduction, utilities are finding a need for DERMS as DER levels rise and it becomes desirable to actively manage DER settings rather than leaving them fixed. DERMS active management may be manual (human operators) or automated via integration with DMS or energy markets. DERMS projects are occurring worldwide and are diverse in scale, goals, and types of DER involved. The following subsections highlight a few examples.

Arizona Public Service

April 2015 to June 2018

Arizona Public Service (APS) *Solar Partner Program* is assessing and advancing the use of smart inverters and energy storage in power distribution systems for:

- Managing distribution voltage at individual customer sites
- Improving power factor and reducing overall system losses
- Responding to interruptions and outages

[3] https://en.wikipedia.org/wiki/Federated_architecture

- Adjusting power flows
- Enabling interoperability among distributed resources and existing equipment (such as capacitor banks) and controls

In 2015-16, APS deployed, and integrated with a central control system, utility-owned residential PV arrays outfitted with smart inverters on 1,598 rooftops. To better synchronize solar output with peak system demand, APS selected participants with west- or southwest-facing rooftops. The rollout was based on customer participation, focusing on select areas of the service territory. To investigate the study's different use cases and underlying research questions, APS selected six feeders to be monitored and controlled as part of the research. The feeders are largely residential, with a limited number of small commercial customers that receive three-phase service. Currently, PV penetration varies significantly among the feeders, with the greatest exceeding 4MW of installed PV capacity. The study's smart inverters connect to a central control system (developed by APS and Siemens) that issues commands to individual photovoltaic systems and monitors their status.

In addition to 10 MW of new PV capacity, the Solar Partner Program deployed two battery storage systems, each rated at 2 MW/2MWh for use in peak shaving (flattening the net feeder demand) and distribution voltage management. EPRI and APS have collaborated extensively to address implementation challenges related to continuing technology development in inverters, energy storage, and control systems. The goal has been to equip APS (and other utilities) to make the best operational decisions for reliability, efficiency, and overall cost-effectiveness of their distribution system. Research questions are answered through combinations of laboratory testing, feeder modeling/simulation, field testing, and analytics.

Pacific Gas and Electric

2015 to 2018

As part of a California Energy Commission EPIC 2 program, PG&E built a prototype system to test technical feasibility of a DERMS to coordinate DERs for distribution grid services. This demonstration project's is aimed at informing PG&E and the industry as a whole about technology and process requirements to scale DERMS technology deployments. The project is addressing the following goals:

- Evaluating the technical ability of a DERMS to coordinate DERs (directly and through aggregators) for capacity and voltage support as distribution grid services
- Clarifying DERMS requirements and characterizing barriers to deployment at scale relative to today.

The project achieved its objectives by designing and executing a range of field tests covering seven DERMS use cases, in three distribution feeders in the San Jose, CA area. To enable the testing of the target use cases, project steps included deploying DERs for the DERMS to coordinate, field verification and modeling, developing the prototype system architecture for the DERMS optimization engine, and extending protocol standards to interact with aggregations of third party-owned DERs.

The project included the following products:

- Residential: 27 Tesla behind-the-meter homes with 124 kW of PV and 66 kW/4hr of battery storage
- C&I: 3 Green Charge/Engie behind-the-meter sites with 360 kW battery storage/2 hr

- Utility scale: 1 PG&E-owned, customer-sited front-of the-meter 4 MW battery storage/7 hr (wholesale resource)
- Communication System – applying the IEEE 2030.5 protocol with custom extensions
- DERMS system used – GE Grid IQ

And addressed the following use cases:

- Situational awareness related to DER impacts on the distribution grid – load unmasking to visualize hidden load
- Managing capacity constraints and reverse power flow
- Mitigating voltage issues – using real power
- Mitigating voltage issues – using reactive power
- Operational flexibility – optimization under abnormal switching conditions
- Economic dispatch – least-cost economic dispatch as the method for dispatching resources
- Dual use of DERs – for both distribution grid services & for wholesale energy market participation

PPL Electric Utilities

January 2017 to December 2019

PPL Electric Utilities *Keystone Solar Future* project is supported in part by an award from the DOE "ENERGISE" program to develop and demonstrate an advanced DER integration system.

The *Keystone Solar Future* project plans to pilot the central DMS/DERMS platform on select circuit in part of PPL EU's service territory to monitor and control new 3rd party assets in coordination with Company-owned devices. Through the project, PPL EU seeks to avoid uncontrollable and uncoordinated photovoltaic (PV) generation integration on the grid. The project involves:

- A centralized system fully capable of monitoring and controlling interconnected DER devices that is scalable for a sustainable high penetration solar framework
- Enhanced Distribution Management System applications for visualizing and automatically controlling DER in an intelligent way, addressing Volt/VAR Optimization (VVO), Fault Location Isolation Service Restoration (FLISR), Advanced Feeder Reconfiguration (AFR), and islanding connection / disconnection
- Automated customer connection process to reduce the request experience timeline from a multi-day to a one-day event

The project is building on the existing PPL EU smart grid foundation.

Salt River Project

SRP's *Advanced Inverter Pilot* is a demonstration of residential and commercial scale advanced inverters for the purpose of understanding their impact on the distribution system. The project consists of three components:

- Component #1 consists of ~ 2 MW of residential PV scattered throughout SRP's service territory. Component #1 sites have an advanced function set at installation with no subsequent communication.

- Component #2 consists of 1.2 MW of residential PV also scattered throughout SRP's service territory. Component #2 sites have their settings seasonally changed via a cellular network. Settings changes are determined by EPRI and SRP based on measured data.
- Component #3 consists of 600 kW of residential and commercial PV systems connected on a single SRP feeder. Component #3 advanced settings are evaluated and potentially changed every 15 minutes via a cellular network. Settings changes are determined by a "mini-DMS" which runs a power flow analysis.

Component #1 and component #2 will reveal the realities of installing, monitoring, and communicating with large scale DER. Analytics for component #1 and #2 focus on the accuracy of inverters' reactive power functionality – i.e. do the inverters follow the command given.

Component #3 will focus on the coordination of the mini-DMS with traditional assets (capacitor banks and LTCs) and DER. The component #3 testing schedule includes times when the DMS is controlling traditional assets alone, DER alone, as well as combinations of both to understand the impact of DER compared with more well-understood distribution equipment.

Tucson Electric Power

January 2018 to July 2019

Tucson Electric Power's *Project RAIN* is exploring new technologies for coordinating DER for maximum benefit. This project investigates:

- the state of the industry with respect to DER aggregation
- the real-world capabilities of individual DER as well as groups
- potential for customer engagement in supporting the grid
- practical challenges of communication and coordination
- future strategies for applying DER management to TEP grid operations

Expanding on recent demonstrations of individual technologies, such as smart inverters and battery storage, Project RAIN is one of the first globally to explore how generation might be combined with flexible loads (such as electric vehicle chargers or smart thermostats) to create optimal responses to system needs. Open standards and protocols (such as SunSpec Modbus and OpenADR) will be featured in an effort to improve future system performance and reduce integration costs.

TEP and EPRI have created a set of research questions to guide the project, which will require a combination of laboratory and field evaluation to fully investigate. Several controller vendors (both established and new entrants) will be engaged as part of the process, culminating in a field evaluation of a single control system coordinating DER from multiple suppliers.

Understanding and implementing these capabilities will involve a multi-disciplinary team at TEP, bringing together staff from renewable generation, customer programs, distribution planning and operations, information technology, and cyber security.

Research Needs and Next Steps

Distribution resources, including control devices, small generators and dispatchable loads, have been connected and managed by utilities for many years, but the scale of integration and the central role that is now envisioned with DERMS is new. Available DERMS products are typically recent creations or otherwise have undergone substantial changes to position them to support smart solar inverters.

Going forward, research and evaluations are needed on a wide range of DERMS fronts:

Full Realization of what DER Can Do. Furthering the discovery, documentation, and demonstration of new and improved ways that DER can be managed to benefit the grid and the asset owner.

Improving Group-Command Execution. Finding through consensus, modeling and field experimentation high performing methods for disseminating group commands across the members of the group.

Better Use of DER Group Services. Development and sharing of DMS control algorithms that make maximum use of the services that DER can provide.

Migrate-ability of DER Control Algorithms. For both DMS and DERMS, finding open app mechanisms that enable distribution control strategies to be stored and migrated from system-to-system.

Optimal Grouping of DER. Discovering methods for DER grouping and organization that finds the best balance between cost, complexity and performance.

Learning Algorithms. Achieving control techniques that automatically learn from past data to refine control approaches going forward.

Loss of Communication and Fallback Behaviors. As DER penetration levels rise, the functions carried out by DERMS are increasingly critical to operations. With this, it is important to define the behavior of DERMS and individual DER when network connectivity is lost.

Matching DERMS Strategies to Communication Network Performance. Figuring out the latency and throughput requirements for communication systems to support given control plans. Or approached in the opposite way: figuring out what control plans are possible for a given communication system.

Addressing DER Monitoring Challenges. Even with AMI, DER may be behind the meter and mingled with local load. In addition, a certain percentage of DER may be offline or not reachable by

Gaining Value from DER Data Analytics. Just as AMI systems brought volumes of data and a wide range of new analytics value, the connectivity of DER brings a new range of information that can provide value both in realtime and after-the-fact. Documentation and sharing of these analytic methods and values is needed.

DERMS Integration with Other Applications. Beyond DMS, DERMS may interface with geospatial information systems (GIS), outage management systems (OMS), work management systems (WMS) and other utility software applications for improved value across the enterprise. How this is done, the information exchanged and the uses are not yet discovered.

DER Forecasting. DERMS may have a role in providing more granular and more frequent forecasts of DER service capability, aiding in system optimization. How this is best handled, relative to DMS and other utility systems is unknown.