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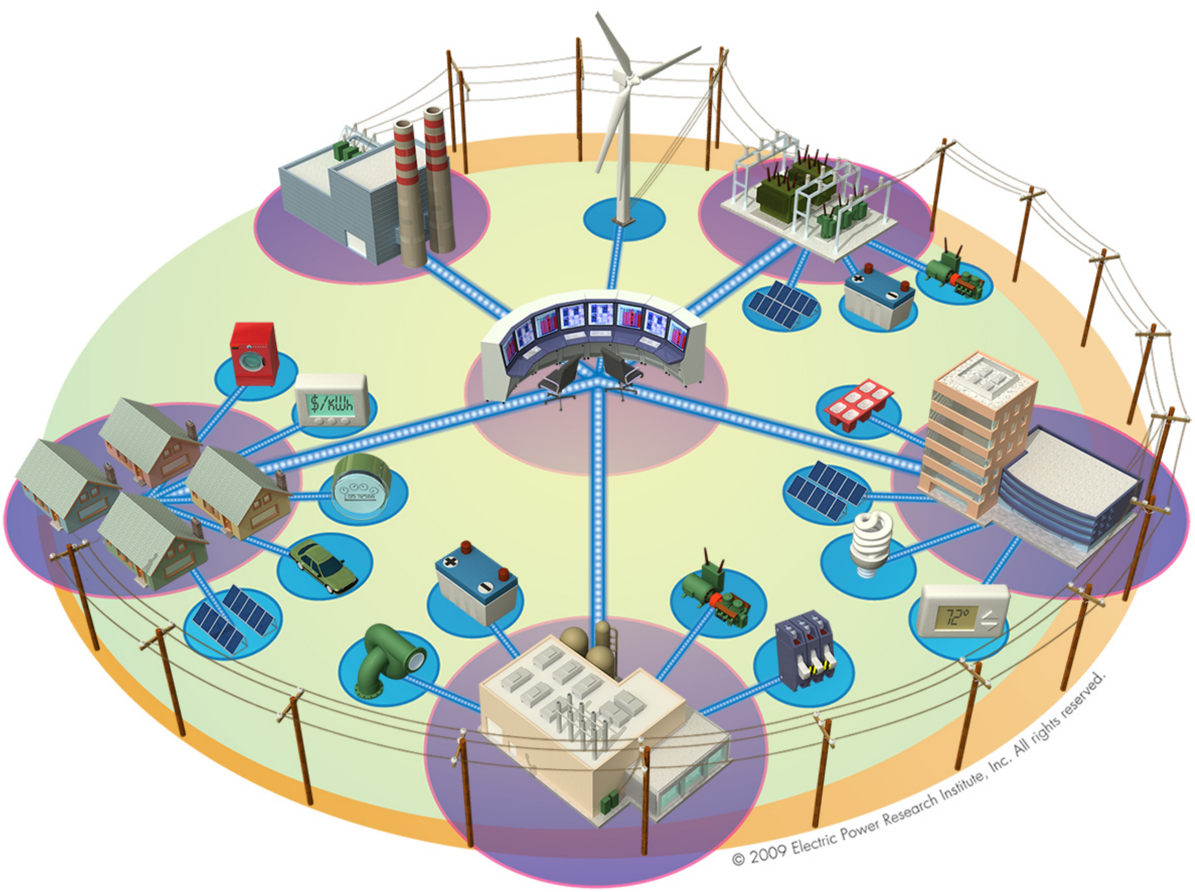
Common Functions for DER Group Management, Third Edition

3002008215



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Technical Update, November 2016

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ACKNOWLEDGMENTS

The Electric Power Research Institute (EPRI) prepared this report.

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This report describes research sponsored by EPRI.

This publication is a corporate document that should be cited in the literature in the following manner:

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

ABSTRACT

Since 2012, EPRI has facilitated a focus group of industry experts working to develop standard functions for monitoring and managing groups of distributed energy resources (DER). The activity is aimed at advancing industry efforts to integrate DER loads, storage, and generation so that they can effectively serve as interconnected grid-supportive resources. This report presents the third phase of developments by this working group, addressing DER management in aggregate groups, including group setup, status monitoring, and dispatch of real and reactive power. At the time of this publication, the Phase 3 work is finalized and will be followed by implementation and interoperability testing in 2017.

This body of work is providing the energy industry with a reference library of functions that can be used for integrating multiple levels of DER aggregation, including interfacing with other utility applications. These functions can be mapped into any communication protocol. Such mappings are in process in the International Electrotechnical Commission (IEC) Common Information Model (CIM) and National Rural Electric Cooperative Association's MultiSpeak®; alignment and mapping into the Open Field Message Bus™ (OpenFMB™) is in process. This development also tracked activity in the State of California to revise CA Rule 21, and features have been added to address those needs.

The electric power industry has taken previous steps to prepare for higher penetration of DER by developing smart inverter standards as well as field network protocols that may be used for monitoring and managing individual devices in the field. These existing standards provide very detailed and granular control as needed for directly interfacing to such complex devices. The methods presented in this document build upon this foundation, completing the architecture by supporting the management of groups of DER as they are aggregated at multiple levels and presented as virtual resources in a useful and manageable way.

The ongoing working group activity is coordinated with the Department of Energy (DOE), through the DOE SunShot Solar Energy Grid Integration Systems – Advanced Concepts (SEGIS-AC) program, and with the National Institute of Standards and Technology (NIST) through the Smart Grid Interoperability Panel's Distributed Renewables, Generators, and Storage Domain Expert Working Group. The initiative began with a face-to-face workshop held in Washington, D.C., in September 2012, and continues through a series of recurring teleconferences and workshops. These meetings bring together utility distribution management experts, distribution management system (DMS) software developers, and distributed energy storage and generation specialists to identify practical, group-level interactions for DER.

Keywords

Distributed energy resources (DER)
Distribution management system (DMS)
Distributed energy resource management systems (DERMS)
Enterprise integration
Photovoltaics
DER management

Deliverable Number: 3002008215

Product Type: Technical Update

Common Functions for DER Group Management, Third Edition

PRIMARY AUDIENCE: Technologists working in the area of use cases, functional requirements, communications, and protocols for the integration of distributed energy resources (DER), particularly those involved in system architecture, DER management systems (DERMS), and advanced distribution management systems (DMS)

SECONDARY AUDIENCE: Vendors developing products, networks, and software platforms such as DMS and DERMS

KEY RESEARCH QUESTION

This report summarizes work-in-process of an industry working group addressing DER management in aggregate groups, including group setup, status monitoring, and dispatch of real and reactive power. The report is intended to provide the energy industry with architectural guidance and a valuable point of reference for DER integration with utility applications and third party aggregators. In addition, this activity is supports the work of standards development organizations (SDOs).

RESEARCH OVERVIEW

This body of work provides the energy industry with a reference library of functions that can be used for integrating multiple levels of DER aggregations, including interfacing with third parties and other utility applications. These functions can be mapped into any communication protocol, and such mappings are currently in process.

The electric power industry has taken previous steps to prepare for higher penetration of DER by developing smart inverter standards and field network protocols that may be used for monitoring and managing individual devices in the field. These existing standards provide detailed and granular control for directly interfacing to such complex devices. The methods presented in this document build upon this foundation, completing the architecture by supporting the creation and management of groups of DER as they are aggregated at multiple levels and presented as virtual resources in a useful and manageable way.

KEY FINDINGS

- DER grouping and aggregation can occur at several levels.
- Which DER are grouped together is a key architectural decision that follows the use cases and intended utilization planning.
- Hierarchical groups could be formed (groups of groups) in which there are multiple levels of aggregation of downstream resources.
- Different types of DER can be grouped together for management as a single entity.
- DER group functions can be focused on the grid services provided and not on the nature or type of DER providing the service.

WHY THIS MATTERS

The working group that prepared the functions outlined in this report brought together utility distribution management experts, DMS software developers, and distributed energy storage and generation specialists to identify practical, group-level interactions for DER. The resulting functions present a common functionality that can shorten the path to implementation of DER group management functions by SDOs. The standards implemented by the SDOs will communicate similar information in the resulting protocols, making the various implementations similar in nature and easier to bridge from one to another and integrate into utility systems.

HOW TO APPLY RESULTS

The functions described in this document will be used by various SDOs to enable DER grouping and group management functionality in a similar manner.

LEARNING AND ENGAGEMENT OPPORTUNITIES

- Distribution system management may consider engagement in this development for a more optimized overall capability.

PROGRAMS: Information and Communication Technology for Distributed Energy Resources (161D), Information and Communication Technology for Enterprise Architecture (161E), Integration of Distributed Energy Resources – Grid Support Functions and Connectivity (174B)

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IMPLEMENTATION CATEGORY: Power Delivery and Utilization

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1 INTRODUCTION

Technology advancements in connected loads, solar photovoltaics (PV) and energy storage have driven increases in their evaluation and employment by utilities, consumers, and third parties. These Distributed Energy Resources (DER) are often connected to the grid at the distribution level where their presence in large scale or volume could be disruptive if not designed, integrated, and managed properly.

Inverters, the power converter circuits that integrate solar PV and battery resources to the grid, are highly-capable devices with fast power controls and no inherent inertia such that they can respond quickly to commands and local conditions. Even small scale inverters tend to have substantial processing and memory resources and are capable of supporting a variety of communication protocols and advanced functions. Over the last few years, industry efforts have defined a wide range of standard grid-supportive functions that inverters may provide and standard communication protocols that allow these functions to be remotely monitored and managed.[1]

If these inverter capabilities can be properly exposed and integrated into traditional utility system operations, high penetration DER can be transformed from problematic uncertainties to beneficial tools for distribution management. To achieve these potential benefits, it must be possible not just to communicate to individual DER devices using standard protocols, but also for the systems that manage DER, referred to herein as DER Management System or "DERMS", to effectively inform other software applications regarding the resources available and to exchange information that allows the DER to be managed effectively.

Traditionally, distribution systems have been operated without extensive controls or centralized management. More advanced systems may have On-Load Tap Changing transformers (LTC's) at substations, line regulators, and/or capacitor banks that operate to help optimize distribution voltage and reactive power flow. In many cases, these devices may be fixed or configured to operate autonomously. In a growing number of cases, however, a more central Distribution Management System (DMS) has been used to coordinate their behavior for a more optimized overall effect. DMS functionality may reside at the utility operations center, where a single large-scale software manages many circuits, or it may reside in a more limited fashion at the substation or other level, where smaller-scale systems act to manage individual feeders or circuits.

Regardless of the particular scenario, the present generation of DMS systems is not designed to take advantage of the capabilities that DER may offer. In many cases, DER support within a DMS is limited to monitoring the output of "utility scale" DERs (> one megawatt). In addition, existing industry standards define advanced functions for DER only at the individual device

[1] *Common Functions for Smart Inverters, Version 3.* EPRI, Palo Alto, CA: 2014. 3002002233.

level, and lack the more aggregated, feeder-level representations that are useful for enterprise integration.

Since 2012, the Electric Power Research Institute (EPRI) has been working in coordination with the DOE SunShot program and the National Institute of Standards and Technology (NIST) Distributed Renewables, Generation, and Storage-Domain Expert Working Group (DRGS-DEWG) to facilitate a focus group of industry experts working to develop appropriate enterprise-level functions for the integration of distributed energy resources. These functions are intended to work in conjunction with the common functions for smart inverters that have previously been defined. This report presents the work-in-process of the second phase of developments by this work group, addressing DER management in aggregate groups, including group setup, status monitoring, and dispatch of real and reactive power. It is intended to provide the energy industry with a valuable point of reference for DER integration with other utility applications and third party aggregators and to provide requirements to standards development organizations.

2
FRAMING THE DISCUSSION: WHAT IS DER GROUP MANAGEMENT?

The global utility industry has made significant efforts in recent years to develop methods and standards to support the integration of distributed energy resources. Much of this effort has been applied to the functions of advanced inverter-based DER (solar PV and battery storage) and communication over field networks with these systems and devices. EPRI worked with the U.S. Department of Energy (DOE), National Institute of Standards and Technology (NIST), Sandia National Laboratories, and the Solar Electric Power Association (SEPA) from 2008 to 2012 to conduct an activity that contributed to these field interfaces. The results were contributed to the International Electrotechnical Commission (IEC) Technical Committee 57, Working Group 17 which has standardized many functions for DER and developed a communication device model to support the functions. IEC Technical Report 61850-90-7 summarized these standards which were later incorporated into the IEC 61850-7-420 standard (model) and 61850-7-520 (description).

Mappings of these standard functions have also been produced, covering a range of communication protocols appropriate for various environments:

- DNP3, as might be desired for DER devices integrated into utility SCADA systems
- IEC 61850 MMS, also for SCADA systems when based on the IEC standards
- Modbus / SunSpec, as might be desired for interconnecting equipment within a DER plant or facility
- IEEE P2030.5, Smart Energy Profile 2.0 Application Protocol, as might be desired for small scale equipment integrated in residential home networks

Although they are not considered complete, these activities represent substantial progress in terms of standardizing communication interfaces at devices in the field. They leave gaps, however, in the area of upstream integration where DER may be managed in an aggregate fashion. Figure 2-1 illustrates the situation.

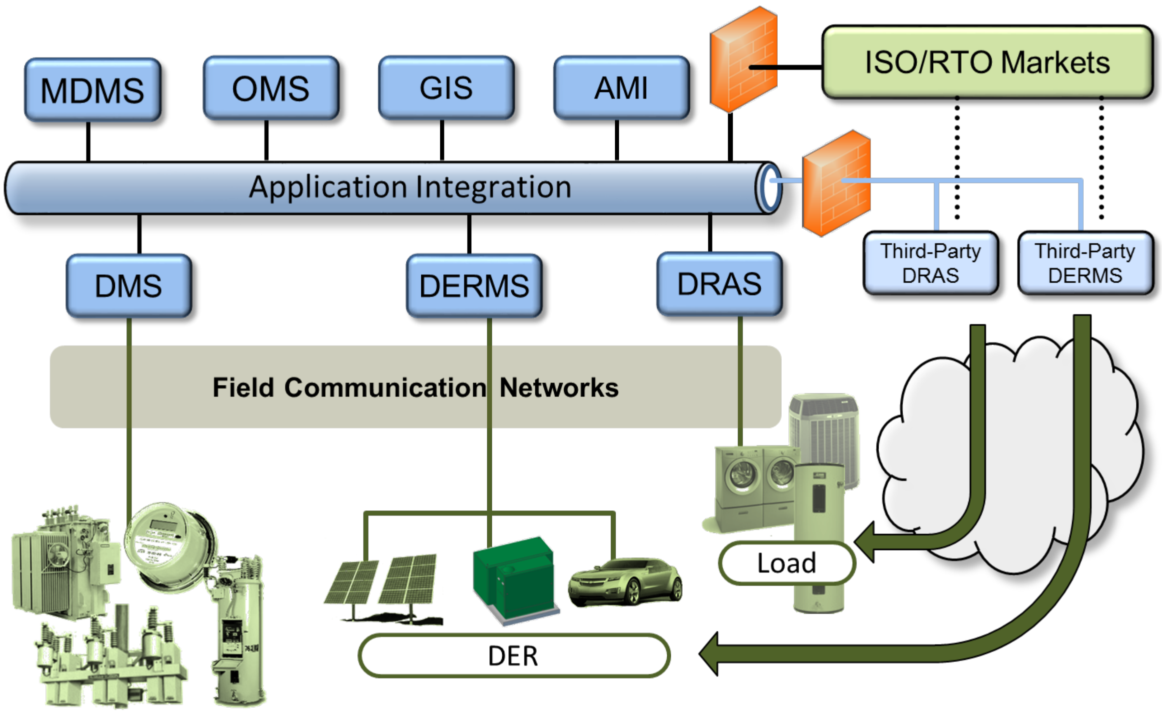


Figure 2-1
Simple Illustration, Showing Field and Application Interfaces

The elements shown in green at the bottom of Figure 2-1 represent devices in the field and communication systems that connect these devices. The elements shown in blue represent application integration environment where a variety of software applications may exchange information related to group-management of DER.

At the time of the development of this document, EPRI is engaged in a number of field demonstration projects that seek to evaluate the performance of smart inverter systems performing a range of grid-supportive functions. Some of these projects are aimed at the integration of DER with DMS, and the methods that can be used to optimize distribution systems when both traditional distribution controls (caps, regulators) and manageable DER are available.

In the course of conducting these projects, it became evident that gaps existed for integrating DER with overall system operations. Several factors were noted:

- The functions that have been defined for individual inverters are not appropriate at the DER-group level. The interactions used for communication with individual DER are too detailed and contain a range of information that is not relevant to the higher-level goals of overall distribution system management.
- Both utilities and DMS providers expressed a desire to view DER at various levels of aggregation (e.g. by substation, by feeder, by line segment). The ability to express DER capabilities as attributes of the power system, rather than attributes of individual DER, was needed. For example, in many cases it does not matter if a given service comes from one large plant or a thousand small ones, as long as the aggregate effect is the same.
- Additional communication protocols (beyond those which had been created to communicate with individual inverters in the field such as IEC 61850, DNP3, and SunSpec Modbus) are of

interest for use between software applications in business-to-business and central enterprise environments. In this domain, standards such as the IEC 61968/61970 (Common Information Model) and National Rural Electric Cooperative Association (NRECA) MultiSpeak^{TM} are often used.

DER Group-Level Functions, as set forth in this document, describe the grid-supportive services (categorized as monitoring, limiting, and control functions) that can potentially be provided by a DER group of any makeup and scale.

3 SUPPORTING DER AGGREGATION AT MULTIPLE LEVELS

The simplified illustration of Figure 2-1 shows only a single level of DER aggregation, with a given set of end devices being presented as a DER group. But in practice, DER aggregation at many levels is needed. For example:

- DER within a home could be aggregated by a Home Energy Management System
- DER within a building could be aggregated by a Building Management System
- DER within an islanding campus or facility could be aggregated by a microgrid controller
- DER could be aggregated by feeder or section thereof
- DER could be aggregated by substation, or power distributor
- DER of the same brand could be aggregated by the manufacturer
- DER belonging to the same owner could be aggregated as a single resource, even if scattered

In addition, hierarchical groups could be formed (groups of groups) in which there are multiple levels of aggregation of downstream resources as illustrated in Figure 3-1.

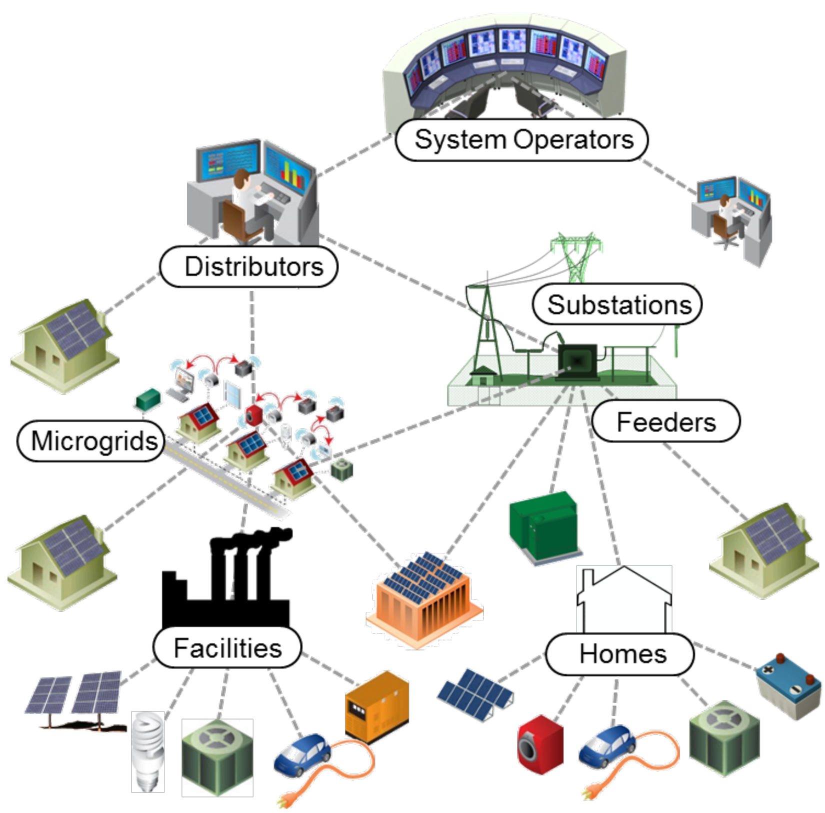


Figure 3-1
Grouping of DER at Multiple Levels

The functions and methods identified in this document have been developed so that they can be applied at any or all levels at which DER are being managed in groups. As noted in the individual function descriptions, this requires that the DER group functions focus on the grid services provided and not on the nature or type of DER that is providing the service. Such an approach is described in detail in EPRI's 2010 whitepaper "Concepts to Enable Advancement of Distributed Energy Resources"[2].

[2] *Concepts to Enable Advancement of Distributed Energy Resources: White Paper on DER*. EPRI, Palo Alto, CA: 2010. 1020432.

4

ACTIVITIES OF THIS INITIATIVE

Origin

A joint EPRI, DOE, and NIST workshop was held in September, 2012 to launch the initiative for group-based management and monitoring of DER. The workshop was held in Washington, DC. It was attended by approximately 50 industry experts, representing utilities, DMS software providers, DER management experts, inverter manufacturers, universities and researchers worldwide.

The results of the initial workshop were published in EPRI report 1026789[3] and made publically available. The participants identified a range of useful functions for group-level integration of DER and prioritized these functions in terms of value to the industry and achievability. The results of this kickoff process, which are summarized in Figure 4-1, served to establish the goals for the Phase 1 initiative, which included five priorities:

- DER Group Status Monitoring
- DER Group Capabilities Discovery
- DER Group Dispatch (Real and Active Power)
- DER Group Forecast

[3] *Collaborative Initiative to Advance Enterprise Integration of DER: Workshop Results*. EPRI, Palo Alto, CA: 2012. 1026789.

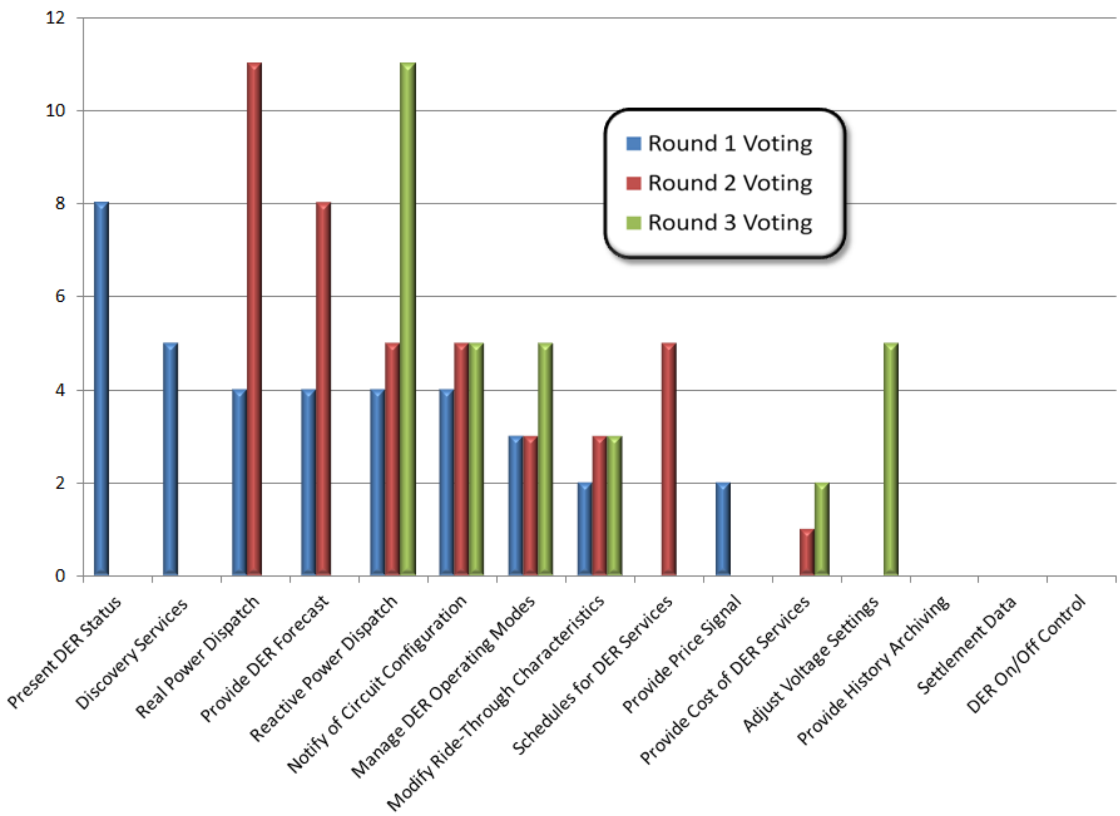


Figure 4-1
Phase 1 Priorities

Consensus methods were documented for these initial functions through a year of recurring weekly meetings. Following this, software implementations were made by interested parties and a test harness setup by EPRI to allow testing. The testing was conducted at the National Renewable Energy Laboratory's (NREL) Energy Systems Integration Facility (ESIF) in Golden Colorado in the fall of 2014. The test plan[4] and test results[5] from this event have been published and made publicly available.

The Phase 2 work began in 2015, with a review of lessons learned from the Phase 1 testing, and the brainstorming and prioritization of additional function needs. The Phase 2 topics and priorities for each are identified in Figure 4-2.

[4] *Enterprise Integration Functions Test Plan for Distributed Energy Resources, Phase 1*. EPRI, Palo Alto, CA: 2014. 3002004681.

[5] *DER Enterprise Integration, Interoperability Workshop Results*. EPRI, Palo Alto, CA: 2014. 3002003035.

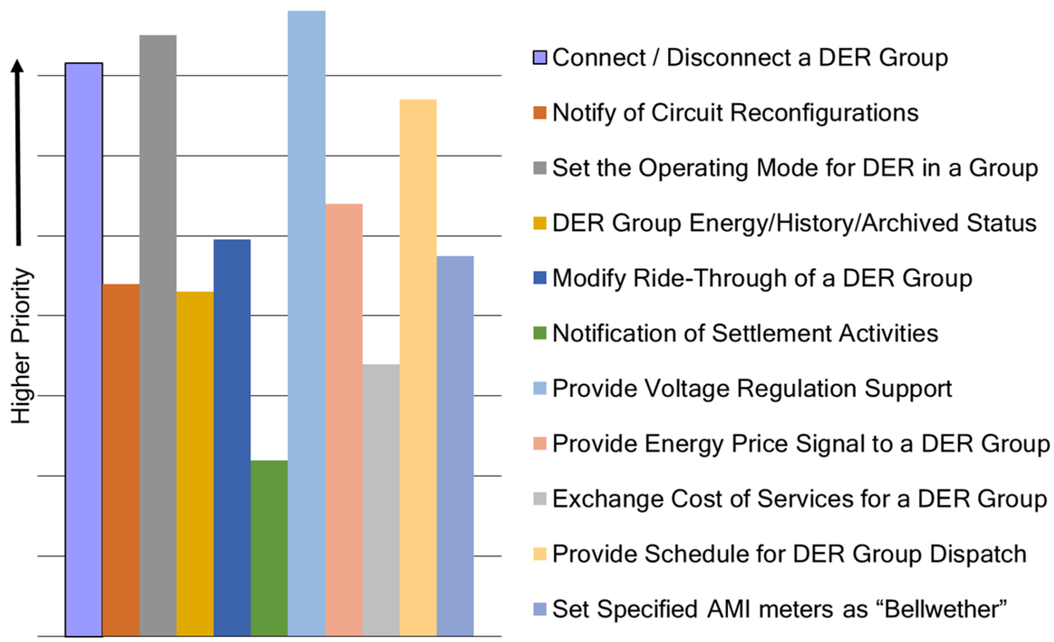


Figure 4-2
Phase 2 Priorities

Based on this guidance, the interest group met on a recurring basis during 2015 and developed additional consensus functions.

This document captures the DER group management functions to date, including both the Phase 1 and Phase 2 efforts.

Use Cases

The development of these methods was carried out with recognition that a wide range of potential use cases have been developed for grid-integration of DER. Several primary sources for these use cases have been identified and documented separately. It has also been recognized that DER integration with the grid is an emerging field, that the value of presently identified use cases may be uncertain, and that many high-value use cases may be yet unidentified. The intention of this work is to make a useful first step, maintaining flexibility, with the intention of modifying and adding new services going forward, as more understanding is gained by the energy industry.

Reference Activities and Standards

These DER group management functions have been developed in coordination with a number of related industry activities. Efforts have been made to meet the requirements and expectations of these bodies of work.

- IEEE Standard 2030-2011
- IEEE 1547 (a, -8, and other relevant parts)
- SGIP DRGS Whitepaper (Describes architecture in 5 Levels)
- California Rule 21 Changes

- IEC 61968-100 Application Integration At Electric Utilities – System Interfaces For Distribution Management
- IEC 61968-1 Interface Architecture and General Requirements
- IEC 61968-11 Common Information Model (CIM) Extensions for Distribution
- IEC 62361-100 Naming and Design Rules for CIM Profiles and XML Schema Mapping
- MultiSpeak V4.x and following

5
SCOPE OF THIS INITIATIVE: LIMITATIONS AND DEPENDENCIES

Scope Limited to Function Descriptions

This body of work is limited to the description of DER Group-Management functions.

What is included in scope:

- Clear descriptions of each function in paragraph form. Figures and examples are included where appropriate to help the reader understand the intended purpose and use of each function.
- Identification of the information that must logically be exchanged between the entities involved in order to carry out the function. Where appropriate, some information items may be identified as optional.

What is excluded in scope:

- This body of work is intended to be map-able into any number of communication protocols, so this document does not contain the protocol specifics that would be used to implement these functions. The working group is aware that other documents are being created in parallel, some by EPRI and some by other parties, to suggest how these functions will be supported in specific communication protocols. These other documents are being contributed to the relevant standards development bodies.
- Cyber security is an important aspect of any communication system, and is particularly critical for systems that will be used for managing groups of DER. Cyber security is, however, out of scope for this body of work because it is to be addressed in the communication protocol standards and systems through which these functions are supported.

"Individual DER" Representation in the System Model

This document introduces the idea of "groups" of DER, and recognizes that at a variety of levels, it is more useful to manage DER in groups (e.g. all devices on the same feeder segment, all devices with the same owner, etc.) rather than individually. However, a foundational requirement for DER enterprise integration is a way to represent individual DER plants in the system model. This is necessary so that it is possible to explore the model and discover the DER that exist and their basic characteristics so that groups can be logically formed.

The purpose of this section is to define a method by which other software applications can discover, from the system of record (e.g. a GIS) what individual DER exist, what type they are, what scale, what capabilities they have (limited for the present time to those capabilities that are enterprise-applicable and necessary to support the other functions described herein).

The sense of an “Individual DER”, from the utility/grid perspective, is determined by how the DER exists in the model and in how they are communication-integrated in the field. For example:

- If an individual solar inverter communicates with a utility control system and is represented in the system model, then it alone is the “Individual DER”.
- If a set of resources exist at an industrial facility or campus, and are managed collectively by a plant master controller (PMC), and this PMC is then connected to the utility system, then the whole site may be viewed as a DER. In this case, the collective capabilities of the site would be represented in the utility model as one DER.

A comprehensive representation of DER in a system model (e.g. in CIM or MultiSpeak) may have a wide range of parameters, each useful to certain utility departments for specific purposes. The items identified here are considered a required subset of this data, needed to support the basic monitoring and management services identified in this document. It is anticipated that this minimum set of parameters would be expanded as additional enterprise integration functions are identified.

Table 5-1
Parameters in the Power System Model to Represent Individual DER

Item	Description
DER Name	A unique identifier for each DER Plant
DER Type	Defining the type of DER plant. To include: • Photovoltaic • Battery storage • Fuel cell • Wind • Thermal • Hydro • Biogas • Biomass • Cogeneration • Compressed Air • Flywheel • Combination DER
DER Physical Address	The physical (street) address of the DER Plant
DER Geographic Location	Latitude and Longitude
DER Owner	Identification of the asset owner / operator
DER Contract / Agreement	An identifier of the contract / agreement to which this DER is related (if exists)
DER Terminal and phase(s)	The ID of the point of grid connection and Phase(s) to which the DER plant is connected
DER Watt Rating	The as-installed Watt rating of the DER (for PV plants, this may be panel-limited). In CIM, this is referred to as ActivePower • Per-phase, if applicable • Watts Delivered and Received, if applicable
DER Var Rating	The Var capability of the DER. In the CIM referred to as ReactivePower • Per-phase, if applicable
DER VA Rating	The VA capability of the DER • Per-phase, if applicable
DER Storage Watt-hours	The usable energy storage Watt-hour capability of the DER
DER Notification time	Notification time required before DER can start operation
DER Ramp time capability	The rate at which the DER real power output can ramp up/down in response to commands received
Services that the DER can provide	Enabling the identification of the capabilities of DER groups
DER Power System Connectivity	The phases and nodes in the system model at which the DER is connected.

Note: It is recognized that the methods identified herein may be limited to those DER that are known to the utility and/or represented in the system model. It remains to be seen if all or certain types of customer-side generation will be made known to the utility. A number of mechanisms are possible which would incentivize or require the customer to inform the utility about their equipment, and to allow monitoring and management to occur.

DER Grouping Dependencies and the Concept of Operations

Prior to the definition of DER group-level functions, individual DER functions were generally respective to the physical characteristics of a specific distributed resource. For example, if the real power available is queried, the response indicates what that DER is able to provide. In addition, it is possible to know how requested changes would impact the system specific to the location of the DER.

In a system where group-level functions are carried out by a group managing entity, this may not necessarily be reflective of the physical capabilities and characteristics of the group due to DER location and other loads and resources. The point where requested changes in the behavior of the group are detectable is directly related to how the group has been created. Groups need to be created commensurate with the intended utilization of the aggregated group of DER.

Some of the group-level functions defined in this document require that the DER group managing entity has access to measurements at a specific point of reference. In these cases, knowledge of the circuit model and configuration should be considered in the group-formation process and may be directly available to the DER group-managing entity for the purpose of grouping and control strategy. Likewise, there may be concerns about the impact of DER on a per-phase basis and a desire to establish and use a group of DER to affect individual phases. In this case, the phase-connectivity of DER is required in order to group the DER effectively.

Example considerations in grouping of DER:

- **Resolution of control:** The physical makeup of a group could include one or multiple types of DER (e.g. loads, generation, storage, other downstream groups). The group members could be many or few, large or small, variable or on/off. Accordingly, the resolution of control that is available from the group may vary.
- **Localization of Impact:** DER groups may be established so as to impact a specific area or location. For example, grouping may be done by feeder, circuit, section, phase, facility, or community.
- **Grouping at multiple levels:** If a command is sent to a group of DER, the general intent is to impact the sum of the results. Overall DER management architectures may involve aggregation (grouping) at many levels and may include third-party or vendor aggregators. In some third-party scenarios, the members of a DER group may be undisclosed and subject to ongoing changes or additions. In such cases, the aggregate response may be known, but the specific location of the responses on the power system are not.
- **Measurement:** In the design of an overall DER management architecture, it must be determined whether or not there is a requirement to directly measure the impact of group function calls at a specific location. For example, measurement may be determined by the DER group managing entity by communicating directly with each DER or by reading a reference meter (e.g. SCADA-connected device) that is placed at a point in the power system that captures the total for the DER group.
- **Level of Abstraction:** DER group makeup may consist of a variety of device types (such as PV, Storage, & DR). In this case, the group may be dispatched and monitored with or without consideration of the types of devices in the group. For example, a utility may establish a DER group that is made-up only of smart water heaters. This group may then be managed with that makeup in mind, tailoring the monitoring and management actions to fit water heater capabilities. Alternatively, a utility may organize many DER groups, each consisting of only one device type, but then manage the groups in an identical way, choosing to view each as a generic resource. The methods set forth in this document enable both approaches. If a DER group managing entity can effectively report the necessary information

and capabilities of a group without the need to differentiate specific DER types, scalability may be improved allowing a higher level of abstraction.

- **Intended Utilization and Program Impact:** Significant differences may exist in the way a DER group-managing entity (e.g. DMS or DERMS) implements functions which could have an impact at the calling entity. Therefore in some cases, multiple modes are included to specify a specific implementation of the function (see *Mode Number* under Technical Approach in chapter 16).
- **Cross-Utilization:** In the overall DER integration architecture, it must be determined whether a single DER, or a DER group, will receive commands from multiple upstream entities.[6] If so, and if the commands are in conflict with one another, then priorities need to be assigned to make certain the highest priority need is addressed. While assigning priorities is outside the scope of this working group, support is provided in the functional definitions in several ways:
  - Groups can be intentionally structured so as to accommodate conflicts in priorities and dispatch the appropriate group of DER.
  - A *Priority* parameter and the *Requesting Entity ID* are included which could be used to invoke a prioritization scheme carried out at the level deemed appropriate (e.g. at the application, group management, or DER level).
- **Uncontrolled Impacts:** There are often other things on the power system that are not part of a given group being controlled. This includes other (parallel) groups and independently controlled DER. These should also be considered relative to the impact on the group and approach to managing the selection of DER groups.

[6] Cross-Utilization: Managing Multiple Technologies and Applications on a Distribution System, December 2014 http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002004390.

6
PRIORITIZATION AND PRECEDENCE OF DER GROUP MANAGEMENT FUNCTIONS

The working group recognized that DER may be aggregated at multiple levels as described in Chapter 3, and that requests for DER action may originate at any level in the overall system. Communication systems may be architected so that paths are parallel or serial, as illustrated in Figure 6-1, or any combination thereof.

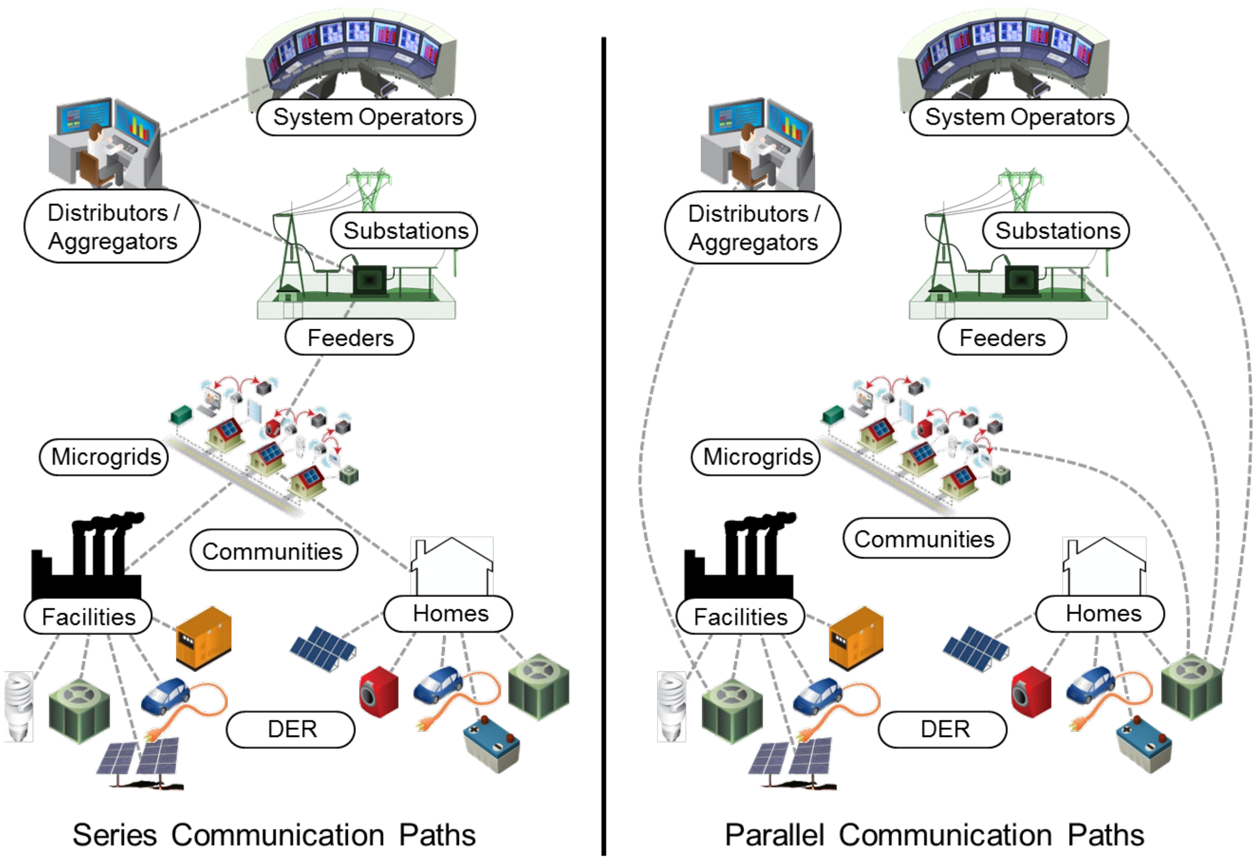


Figure 6-1
Serial vs. Parallel Communication Paths for DER Integration

Both approaches have advantages and disadvantages and it is likely that actual communication architectures will involve aspects of both.

Serial Communication Paths – This refers to scenarios in which commands flow from higher-level entities (such as system operators), through lower level entities (such as distributors), and possibly even lower levels of aggregation at facility or home management systems prior to reaching individual DER. In this kind of architecture, each entity along the path may have the opportunity to modify the incoming commands prior to passing them on downstream. For example, a transmission operator may want to have maximum reactive power (Var) support from a DER group due to a transmission system power factor issue. But the voltage profile on the feeder serving this DER group may be such that no additional Vars are possible at the present time.

Note: DER control actions can originate at any level in a multi-tiered system.

The advantage of a serial approach is that individual DER have only one immediate master and can receive control messages that do not conflict with one another. In this way, the DER do not need to know how to resolve conflicts. To achieve this, each entity in the path would employ logic to determine if or how commands should be altered or limited.

The disadvantage is that communication pathways are complex and multi-level, possibly resulting in higher latencies, lower reliability, and may result in lower utilization of the DER.

Parallel Communication Paths – This refers to scenarios in which commands flow from multiple managing entities directly to DER or DER Group controllers. For example, a commercial battery system that is distribution-connected might be connected to the distributor's SCADA system to perform substation peak load limiting and at the same time receive energy price signals from a system operator.

The advantage of this approach is that the communication pathways are direct. It also simplifies the logic required of all the managing entities because each only needs to express their own needs and need not deal with the needs of others.

The disadvantage of this approach is that the messages received by individual DER may conflict. In the example given above, at a given point in time, the system-operator's price signal may motivate the storage system to charge (low energy price) while the substation is heavily loaded and the SCADA system is instructing it to discharge.

In this case the DER must understand how to respond to multiple, potentially conflicting, commands and each requesting entity may not obtain their desired impact.

This body of work is intended to be equally suitable for use in both architectures and any combination thereof. The method and guidelines for DER Group Management prioritization and precedence identified in this section may be applied:

- By any entity/actor in a serial communication path, acting to combine upstream requests/commands with local needs and limitations to produce a resulting downstream command
- By end device DER or other upstream entities/actors that receive commands from parallel paths, acting to reconcile the multiple requests/commands into a resulting downstream command or device action.

Summary of DER Group Services and Functions

The DER group-management functions identified in this document are a subset of the unlimited range of possible functions. Many functions have been identified that may have significant utility value. The functions described herein were selected by the stakeholders in this process as first priorities because they are fundamental, of clear and near-term need, and relatively straightforward to implement.

A body of work of this type never covers all possibilities and it is recognized that future additions and revisions will be required. It is also recognized that some of the DER group functions identified herein may be found of limited use in the marketplace and will go unused.

Table 6-1 identifies those functions developed in this document as well a number of additional enterprise DER functions that were identified in the project workshop in Washington, D.C. during 2012 and during the development process that has followed. These additional functions are the starting point for the next phase of this work.

Table 6-1
Summary of DER Group Management Functions for DER

DER Group Management Function	Description	Chapter Reference
Dependencies		
Individual DER Representation in the System Model	This enables general representation in the system model and sharing of individual DER existence and capabilities among software applications and businesses. This kind of representation is a foundational need for intelligent group creation and management.	
Select Bellwether Meters	This function requests that a given list of electricity meters provide additional, or more timely data for system control purposes.	Chapter 29
DER Group Formation and Management Functions		
DER Group Creation	This function allows a software entity to define a logical group of DER and to exchange the definition of this group with other applications or businesses. The purpose of grouping is subsequent monitoring and management at the group level.	Chapter 6
DER Group Member Query	This function allows one entity to inquire from another to learn the current members of a DER Group.	Chapter 9
DER Group Deletion	This function deletes a previously created group	Chapter 10
DER Group Maintenance	This set of functions provides the ability to add, update, or delete members from a group.	Chapter 11
DER Group Capabilities and Monitoring Functions		
Status Monitoring of DER Groups	This function allows the exchange of real-time status information for DER groups. This function addresses dynamic data, including present value and the present range of adjustability (i.e. the min/max dispatchable range of manageable parameters).	Chapter 13
Capability of DER Groups	This function allows the exchange of information indicative of the installed capability of a DER group in terms of the grid-supportive services that it is capable of supporting. This data is generally static, changing only as equipment changes are made, not varying in real time.	Chapter 12
DER Group Output Forecasting	This function allows the exchange of forecast information regarding the availability of real and reactive power from DER groups. Note: This function does not relate to how forecasts are determined (e.g. weather data, sky-viewing cameras, etc.) but only to how such information might be exchanged between entities.	Chapter 14
DER Group Historical Meter Data	This function allows for exchange of interval meter data that is indicative of the aggregate production of a group of DER.	Chapter 15

Table 6-1 (continued)
Summary of DER Group Management Functions for DER

DER Group Management Function	Description	Chapter Reference
DER Group Limitation and Operational Boundary Functions		
DER Group Maximum Real Power Limiting	This function sets limits on the aggregate power generated and/or absorbed by DER groups	Chapter 16
DER Group Ramp Rate Limit Control	This function sets limits on the rate at which DER group real and reactive power levels may rise and fall	Chapter 17
DER Group Phase Balance Limiting	This function sets limits on the phase imbalance for real and reactive power of DER groups	Chapter 18
DER Group Control Functions		
Real Power Dispatch of DER Groups	This function allows the dispatch of real power to/from DER groups.	Chapter 19
Reactive Power Dispatch of DER Groups	This function allows the dispatch of reactive power of DER groups.	Chapter 20
DER Group Curve Settings	This function manages curve functions (e.g. volt-var control, watt-frequency control) for DER groups.	Chapter 22
Regulation Function	This function allows DER Groups to provide Regulation services to system operators and balancing authorities.	Chapter 24
Schedules for DER Services	As an alternative to real-time requests, this function allows the exchange of schedules for DER group services, such as the Real Power Dispatch function.	Integrated into Each Function
Ride-Through Service	This function allows event ride-through characteristics to be changed for a group of DER.	
Energy Price-Based Management	This function enables DER groups to be provided with energy price information and to be configured to provide services based on price.	Chapter 25
Service Cost-Based Management and Bidding	This function (or data-exchange addition to other functions) enables queries regarding the availability of DER services on a cost-basis and also the offer/provision of services based on a cost.	Chapter 26
Voltage Regulation Settings	This function allows for adjustment of a target voltage regulating setting of a group of DER. This could be used, for example, in coordination with a conservation voltage reduction system.	Chapter 21
Connect/Disconnect Control	This function allows for remotely turning groups of systems on or off. Potential uses include maintenance, disabling of malfunctioning equipment, and anti-islanding.	Chapter 28
Potential Additional/Future Functions		
Fast Up-Down Regulation Services	This function allows groups of DER to be rapidly dispatched (e.g. 4 seconds update rate) both up and down in real power in order to help regulate the system.	
Dynamic System Voltage Stabilization Services	This function allows groups of DER to provide real and/or reactive power in response to the rate of change (dV/dt) of the service voltage amplitude at each DER. The behaviors would resist voltage fluctuations.	
DER Group Mode Management	This function notifies groups of DER of changes to circuit configuration and other conditions that may merit a change in inverter modes.	

The contributors to this Phase 2 initiative recognized that:

a. There is an unlimited range of possible functions for DER groups, and that this body of work is not intended to be limiting.

b. That the DER group functions identified herein may or may not be of interest to individual stakeholders or the market broadly. Communication interface specifications generally seek to cover all possible needs, exceeding minimum requirements, recognizing that the market will decide which parts to utilize.

Prioritization of DER Group Limitation and Operational Boundary Functions

DER Group Limitation and Operational Boundary Functions take precedence over *DER Group Control Functions*. These are identified in Table 6-1, and include DER Group Maximum Real Power Limiting, DER Group Ramp Rate Control, and DER Group Phase Balance Limiting.

Limitation and operational boundary functions take precedence because they relate to safety, asset capabilities, and physical limitations such as breaker settings, transformer ratings, and customer voltage range.

None of the limitation and operational boundary functions are mutually-exclusive, all can be in effect simultaneously. Figure 6-2 illustrates the action of various limit and boundary settings as applied to a DER group.

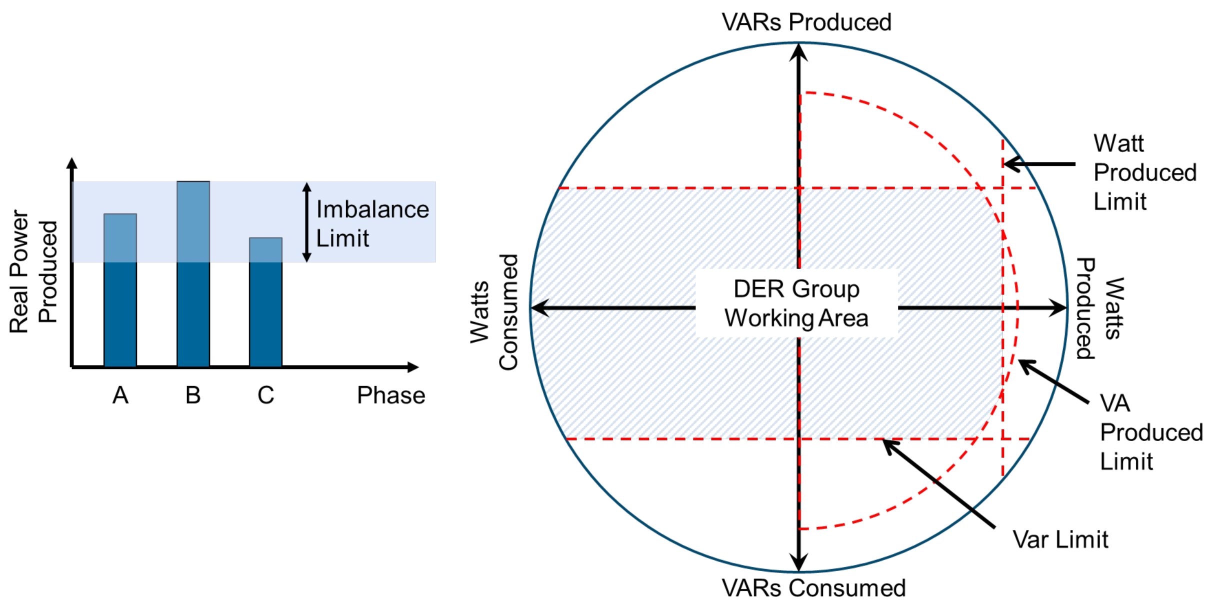


Figure 6-2
Example Limit Settings for DER Groups

In the case where multiple limit settings are simultaneously called, the effective values are those that are the most restrictive. This principle is illustrated in Figure 6-3. For example, at a given point in time, a distribution circuit may not be able to accept more than 1[MW] of generation from a DER group because of the circuit voltage. At the same time, a facility management system that oversees the same DER group may not be able to allow more than 800[kW] of generation due to the loading of a transformer within the site, so the effective limit for the DER group is 800[kW], the most restrictive of the two.

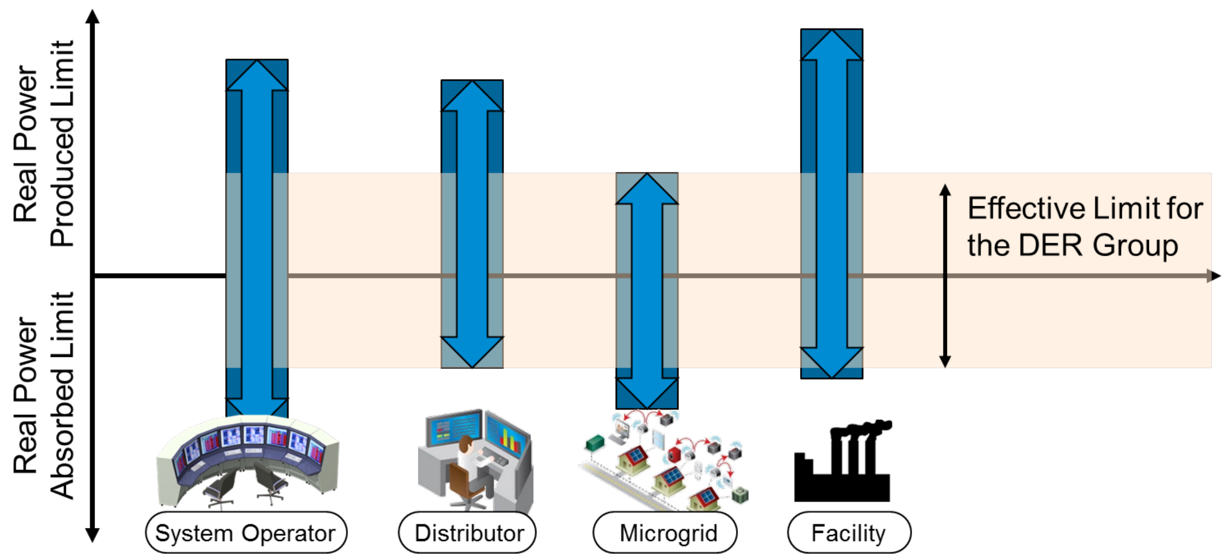


Figure 6-3
Combining Multiple Limit and Operational Boundary Settings

Prioritization of DER Group Control Functions

DER Group Control Functions differ from *Limit and Operational Boundary Functions* in that they specify an exact go-to value rather than a boundary to stay within.

All *DER Group Control Functions* other than Connect/Disconnect are lower priority than *Limit and Operational Boundary Functions* and DER groups must follow the commands only to the extent that they can do so within set boundaries. This principle is illustrated in Figure 6-2 by the hatched area that is bounded by various limit settings. Disconnecting is somewhat unique as a control function and if carried out is absolute.

Some *DER Group Control Functions* are complementary, able to work simultaneously whereas others are mutually exclusive, as summarized in Table 6-2.

Table 6-2
Summary of Control Function Compatibilities

Control Function Name	Relation to Other Control Functions
Real Power Dispatch of DER Groups	This function, which requests a particular real power level of the DER group, is in conflict with energy price-based management which implies that the DER group independently reacts based on price. Real power dispatch is also in conflict with curve functions that control real power such as Volt-Watt or Frequency-Watt.
Reactive Power Dispatch of DER Groups	This function, which requests a particular reactive power level of the DER group, is in conflict with curve settings that control reactive power such as Volt-Var and Watt-PF. It is also in conflict with the DER group voltage regulation function in which the DER managing entity independently manages the reactive power (and possibly real power) level to deliver a voltage regulating service.
DER Group Curve Settings	These curve functions, including Volt-Var, Volt-Watt, Frequency-Watt and others, are mutually exclusive to direct dispatch functions that impact the same controlled variable. For example, a DER group cannot at the same time honor a "Real Power Dispatch" to hold to a certain power level <u>and</u> follow a Volt-Watt curve to vary power according to the reference voltage(s) seen by the DER. In addition, DER Group Curve settings that impact the same controlled variable are in conflict with one another.
Ride-Through Service	Ride through functions are complementary to the other services. Whereas most *DER Group Control Functions* relate to DER behavior under normal operating conditions, *Ride-Through Services* relate to behavior during events (e.g. faults) when abnormal conditions exist.
Energy Price-Based Management	This function is not compatible with direct control functions such as *DER Group Real Power Dispatch* or *Volt-Watt Curves* because price-based management allows that the DER group managing entity will independently determine control levels based on the price signal for a given quantity.
Service Cost-Based Management and Bidding	This function involves agreements reached between DER group managing entities and upstream entities requesting various services or conducting a market for such services. In such a scenario, the DER group managing entity acts according to agreements reached for real power, reactive power, and other services, and likely cannot simultaneously serve other direct control commands.
Voltage Regulation Settings	This function allows that the DER group managing entity uses any/all methods in order to regulate voltage at the point(s) of reference. To the extent that these methods likely involve control of the real and reactive power outputs of the DER group, this function is not compatible with other direct control commands.
Connect/Disconnect Control	By its nature, the disconnect action of this function cannot be in effect at the same time as other control functions. If/when used, disconnect is considered a higher-priority function in this sense. It is recognized that in the case of islands/microgrids, a disconnect function at the microgrid-level may leave DER within the microgrid continuing to provide services in response to the microgrid controller.

7

RESPONSE SUCCESS AND FAILURE INDICATORS

Some functions identified in this specification include a response field that indicates the success and/or failure of requests. These indicators are listed and defined in Table 7-1. Many functions identified in this specification include a response field that indicates the success and/or failure of requests. Table 7-2 identifies the response fields that are associated with each DER Group function.

Table 7-1
Success/Failure Indicator Definitions

Success / Failure Indicator	Definition
Request Succeeded	Indicates that the request was successfully received and carried out. This generally implies that the parameters passed in the request were acceptable.
Unidentified/Invalid Group	Indicates that the request was not carried out because the DER group identifier was not valid.
Unidentified DER/ Group Member	Indicates that the request was not carried out, or only partially carried out, because the provided identifier of an individual DER was not valid.
Failed, Function Not Supported	Indicates that the request was not carried out because the requested function was not supported by the DER group managing entity.
Limited Due to Higher Priority	This indicator is for use in systems utilizing the optional priority parameters. When used, this indicates that the request was successfully received, but that the extent to which it can be carried out is limited due to a conflicting request of equal or higher priority.
Failed Due to Higher Priority	This indicator is for use in systems utilizing the optional priority parameters. When used, this indicates that the request cannot be carried out due to a conflicting request of equal or higher priority.
Invalid Schedule	Indicates that the request could not be carried out because some aspect of a provided schedule was invalid.
Setting Outside Present Capability	Indicates that the request was not carried out because a requested parameter was outside the range of present capability for the DER group.
Invalid Point of Reference	This indicator is for use in response to functions that involve a specified point of reference (e.g. voltage at a specified node in the power system). When used, this indicates that the specified point of reference is not valid, or not known by the DER Group managing entity.

Table 7-2
Response Success and Failure Indicators by Function

	Request Succeeded	Unidentified/Invalid Group	Unidentified DER/Group Member	Failed, Function Not Supported	Limited due to Higher Priority	Failed due to Higher Priority	Invalid Schedule	Setting Outside Present Capability	Invalid Point of Reference
DER Group Creation	X	X	X						
Group Version and Member Query	X	X							
Group Deletion	X	X							
Group Maintenance	X	X	X						
Capability Discovery	X	X							
Status Monitoring	X	X							
DER Group Forecast	X	X		X					
Read Aggregate Meter Data	X	X		X					
Maximum Real Power Limiting	X	X		X	X	X	X	X	
Ramp Rate Limiting	X	X		X			X	X	
Individual DER Phase Identification	X		X	X				X	
Phase Balance Limiting	X	X		X			X	X	
Real Power Dispatch	X	X		X	X	X	X	X	
Reactive Power Dispatch	X	X		X	X	X	X	X	
Voltage Regulation	X	X		X					X
Set DER Group Curve Functions	X	X		X	X	X	X	X	X
Regulation Function	X	X		X	X	X		X	
Provide Price	X	X		X			X		
Request Cost of Service	X	X		X					
Manage Power at Point of Reference	X	X		X	X	X	X	X	X
Connect/Disconnect	X	X		X					

8
DER GROUP CREATION

Purpose

The purpose of this function is to enable DER groups to be created. The interest group recognized that a method for identifying and organizing sets of DER was a necessary precursor to status monitoring, capabilities discovery, and dispatch functions. This is necessary so that it becomes possible to monitor and manage DER at a higher level, with a focus on the attributes, impacts, and opportunities as they relate to the group-level rather than individual DER plants or devices.

Grouping Requirements

The interest group identified the following requirements and constraints for the identification of sets of DER.

Table 8-1
DER Grouping Requirements

Requirement	Description
GR:1 Group Size	“Groups” of one or of many must be possible.
GR:2 Grouping by Power System Level	Under various circumstances and use cases, the ability to monitor and manage DER at varying levels of the power system may be needed, including: • By Substation • By Circuit/Bus • By Feeder • By Feeder Segment (contiguous conductor between switches) • By Island or micro-grid (campus, industrial facility) • By Individual Device • By Lat/Lon Rectangle
GR:3 Grouping According to Other Attributes	Under various circumstances and use cases, the ability to monitor and manage DER at varying levels of the power system may be needed, including: • By Circuit Phase - For example, a DMS could define separate groups for single phase DER that are connected to A, B, and C phases, and could request the status of these individually. • By DER Type – For example a DMS could create separate groups for PV systems, battery storage systems, EVs, or any other DER type. • By DER Owner – For example, all the DER owned by the utility, or a particular customer, could be viewed and managed collectively. • By Program enrollment or contractual arrangement. • Any combination of aggregation level or additional attributes. • By zip code • By user/customer class (residential, commercial, large C&I, agricultural) • By response characteristics (response time, directional change time delay if any, etc.)
GR:4	A mechanism must be provided for tracking the version of DER groups so that the full member list does not have to be exchanged in order to determine of it has changed.

Challenges Posed by Dynamic Distribution System Configurations

Initially, it was considered that within each monitoring request or management command, one could pass information identifying the power system level-of-aggregation, such as substation, feeder, etc., as identified in Table 8-1. This consideration was based on the notion that each DER could be associated with a certain substation, feeder, segment, etc. However, this approach was found to be impractical in many circumstances due to the potentially dynamic nature of distribution circuit configurations. The problem is illustrated in the following figures.

Figure 8-1 illustrates a simple radial feeder that emanates from a single substation and continues, through a series of switches, to an end-of-line. In such a case, it would be possible to associate, for example, DER2 with Substation 1, Feeder 100, and Line Segment 2000.

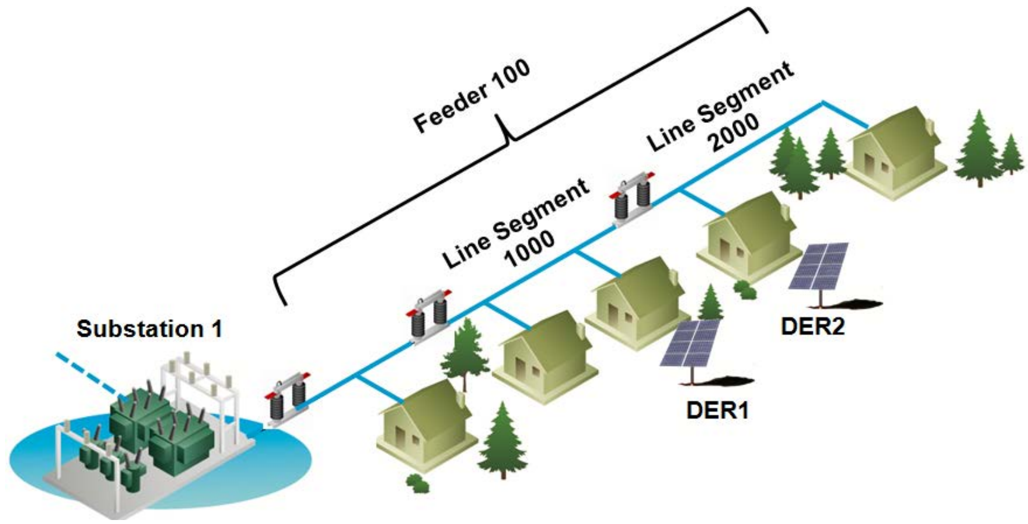


Figure 8-1
Example of Simple Radial Feeder

Figure 8-2 illustrates a more complex arrangement in which two substations are involved. As shown, an open switch is separating the system into two sections, one associated with each substation. In arrangements of this type, different switches can be opened or closed, shifting segments of line (load and DER) from one substation to another. In scenarios such as this, DER cannot be statically associated with a given substation, and the concept of a "feeder" is dynamically defined by the switch positions.

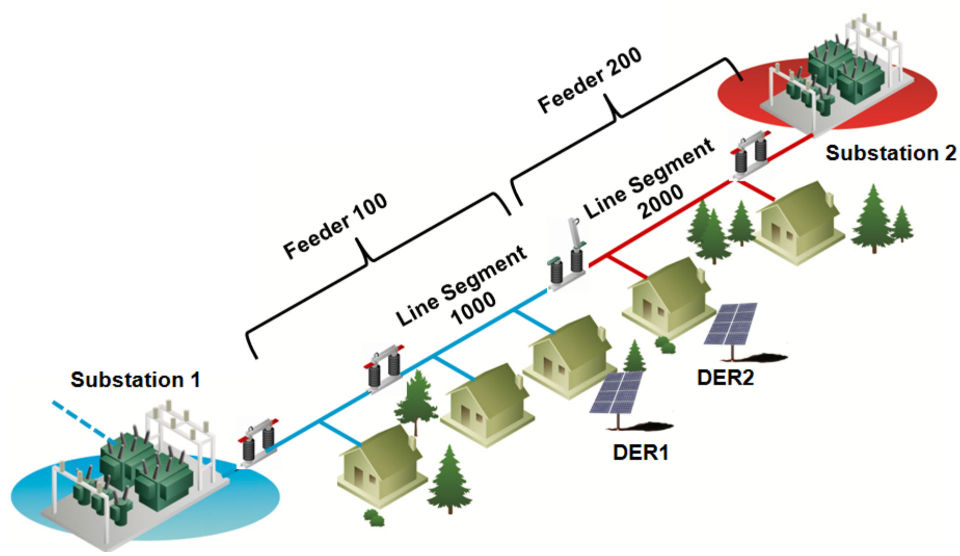


Figure 8-2
Example of Feeder with Alternate Substation

Figure 8-3 presents a further degree of complexity; a distribution network in which multiple substations are involved and the distribution grid may be fed by any one or even multiple substations. Arrangements of this type are not particularly common, but exist, particularly in urban environments, and further illustrate the difficulty faced in attempting to associate DER with a particular substation, feeder, or line segment.

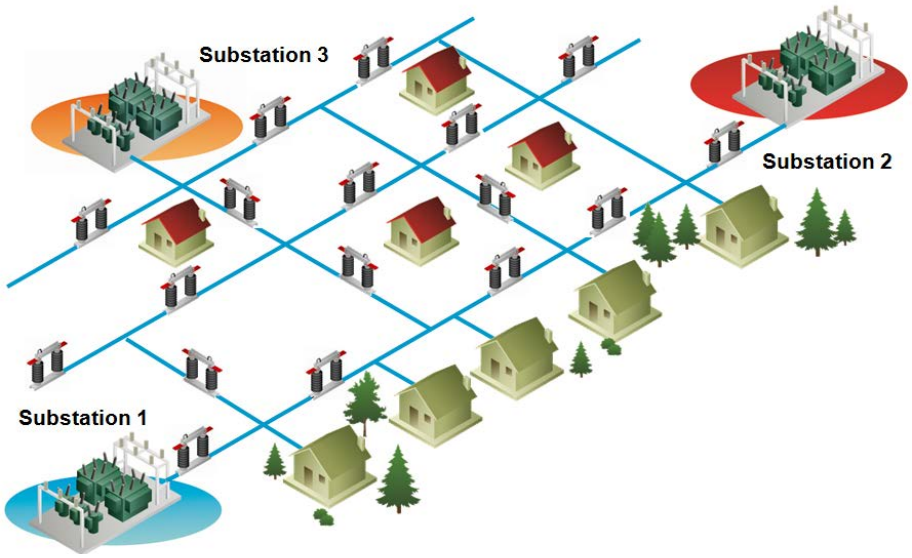


Figure 8-3
Example of an Interconnected Distribution Network

A related complication arises from non-stationary DER such as plug-in electric vehicles that may move from one charging station to another. The same vehicle may become a part of different aggregate group based on which charge point it is connected to at the time. In such cases, it is possible that group membership could be dynamically modified as vehicles move about.

Enterprise Information Models

An inspection of the IEC Common Information Model (CIM) indicated that the dynamic nature of distribution circuit configurations has been recognized previously and that devices, whether DER or other, are normally identified only with the immediate terminal to which they connect. Figure 8-4 illustrates some of the model concepts.

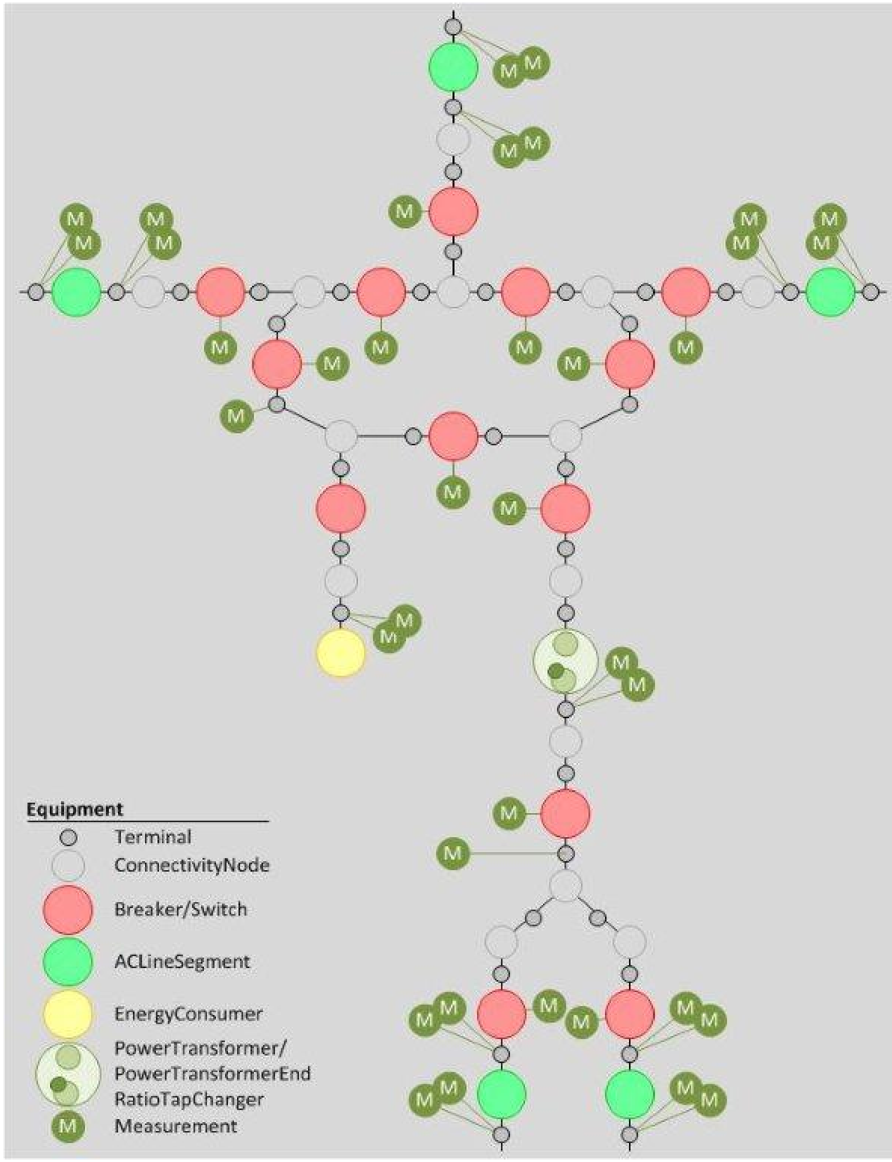


Figure 8-4
Common Information Model Illustration

Although DER are not shown in this diagram, they may be thought-of similarly to the yellow circle which represents an energy consumer. As shown in the diagram legend, the electrical connections to an element of the model are called "Terminals" and terminals are connected together by "Connectivity Nodes".

The CIM defines an "AC line segment", but this is not the same as what was discussed as line segments in Figure 8-1. In CIM, an "AC Line Segment" is a length of conductor carrying the same current throughout its length, with no load or generation along the way. In other words, at each point where a load or generation device is connected, a "Connectivity Node" exists in the model, with separate AC Line Segments before and after the node. This level of detail allows the model to include impedances and to be used for power flow analysis.

In this way, the terminals of individual elements are constant attributes, and the sense of being part of a “feeder” or “substation” is computed only dynamically, by processing the model from one connectivity node to another.

Technical Approach: Supporting Arbitrarily-Defined Groups for DER Aggregation

In view of the challenges identified in the previous section, an approach using arbitrarily-definable groups was developed. The basic idea is to precede DER monitoring or management messages with a process to define a grouping of DER. This will make it possible for any application to define groupings of DER according to whatever rationale is of interest to that application. It also makes it possible for the entity providing the DER service (e.g. a DERMS) to not be required to read-in and process the real-time connectivity model.

The approach involves an interaction in which a DERGroup is defined by one entity (e.g. the Group Forming entity such as a DMS) and provided to one or more Group Acknowledging entities (e.g. one or more DERMS). This interaction could occur immediately before another transaction, such as a DER Status request and reply, or any time prior. The diagram also shows that optionally, the DER Group creation function may not be a request/reply to another application, but might be created within a single application.

This interaction would provide a unique group name and a list of the DER that are included in the group. The DER would be identified by their unique names or unique terminals, as appropriate for the enterprise data integration model being utilized (e.g. MultiSpeak, CIM). One DER could be a member of any number of groups.

In this way, groups could be defined that relate to any level of aggregation desired, including by substation, feeder, line segment, or other, as required in Table 5-3. This approach is not prescriptive of a particular integration approach, allowing, for example:

- A DERMS could process the system model and define its own groupings, but does not require it to do so.
- A DMS could define the specific groups that are of interest to its processes. This could include different groupings that would be associated with various power system configurations. For example, in the circuit arrangement illustrated in Figure 8-2, a DMS could define one group for all the DER connected to Substation 1 (along the blue line) and another for all the DER connected to Substation 2 (along the red line). If the open switch along this line is then closed and a different switch opened, then two different groups could be defined to represent that alternative circuit configuration.

Information Exchanged for DER Group Creation

Table 8-2
Information Exchanged for DER Group Creation Requests

Information Name	Information Description
Action Identifier	Defining what is being requested: • Requesting the creation of a new group
Group ID	A unique identifier for a new group being created or acknowledged
Group Name (optional)	A reference name (string) for the group
Group Member IDs	A list of the unique identifiers of the DER to be included in the group
Description	An optional way of describing this group, e.g. all P.V. in region XYZ
Group Version	A version number that is initialized when a DER Group is created

Table 8-3
Information Exchanged for DER Group Creation Responses

Information Name	Information Description

Action Identifier	Create request response:
	• Acknowledging a new group successfully created
	• Rejecting a request for a new group (with reason why)
	  o Invalid or used Group ID
	  o Unrecognized DER IDs

Group ID	The unique identifier of the new group being acknowledged

Manual Group Creation

The approach set forth allows for manual group creation. In the case where there is no ability to automatically create groups and inform other entities of their existence, an alternative manual/human approach is possible. A "group" definition could be made using something as simple as a spreadsheet or database, and provided to each of two entities, such as a DMS and a DERMS. This, of course, assumes that these applications support the ability to have groups entered in this way. Once created, the group could be monitored or managed using other functions defined in this document.

9
DER GROUP VERSION AND MEMBER QUERY

Purpose

The purpose of this function is to allow multiple entities to remain aligned in their understanding of the DER members that make up DER groups. To support this, DER groups are to have a version that is updated each time that the group makeup changes.

This function allows one entity to query the other to determine the present version and/or list of DER that make up a specified group. This does not relate to whether or not a given DER is presently generating or not, charging or not, online or offline, but only whether or not they are presently a logical member of the group.

Example Uses

There are several reasons that this function may be useful. For example, the membership of a DER group may be established and maintained by the entity that directly communicates to the individual DERs (e.g. a DERMS or aggregator). In such a case, the membership could change as new DER are constructed and/or enrolled in grid programs and the calling entity may wish to learn of such changes.

The entity that calls upon this group may or may not be concerned with the exact membership because other functions allow monitoring of the present status and capabilities of the group from a power perspective. On the other hand, the group membership may be of interest so that distribution management systems can determine the location(s) and levels at which the group is generating or consuming energy.

Implementation

Table 9-1
Information Exchanged for DER Group Version and Member Query

Information Name	Information Description
Action Identifier	Defining what is being requested: • Requesting the current version of a DER Group • Requesting the membership of a DER group
Group ID	A unique identifier of the group for which membership is being requested
Group Name (optional)	A reference name (string) for the group

Table 9-2
Information Exchanged for DER Group Version and Member Query Responses

Information Name	Information Description
Action Identifier	Response to a "DER Group Member Query" • Response to a request for the current version of a DER Group • Response to a request for the membership of a DER group
Group ID	The unique identifier of the group for which the version or member list was requested
Success / Failure Indicator(s)	Indication of whether or not, or to what extent, the command could be accommodated. Chapter 7 describes the Success/Failure indicators and Table 7-2 identifies those that are applicable to this response.
Group Member IDs	A list of the unique identifiers of the DER included in the group
Group Version	A version number that is incremented when the membership of a DER Group changes

Once a group has been created, then any system could query to get information about group members.

10

DER GROUP DELETION

Purpose

The purpose of this function is to delete a DER group, terminating its existence as an organized virtual resource. This is largely viewed as a housekeeping function because it is always possible to just stop utilizing a defined group.

Just as groups can be created, there may be a need to delete a group.

Implementation

Table 10-1
Information Exchanged for DER Group Deletion Requests

Information Name	Information Description
Action Identifier	Defining what is being requested: • Deleting a DER group
Group ID	A unique identifier of the group that is to be deleted
Group Name (optional)	A reference name (string) for the group

Table 10-2
Information Exchanged for DER Group Deletion Responses

Information Name	Information Description
Action Identifier	Response to a “DER Group Deletion”
Group ID	The unique identifier of the DER Group that was deleted (or attempted)
Success / Failure Indicator(s)	Indication of whether or not, or to what extent, the command could be accommodated. Chapter 7 describes the Success/Failure indicators and Table 7-2 identifies those that are applicable to this response.

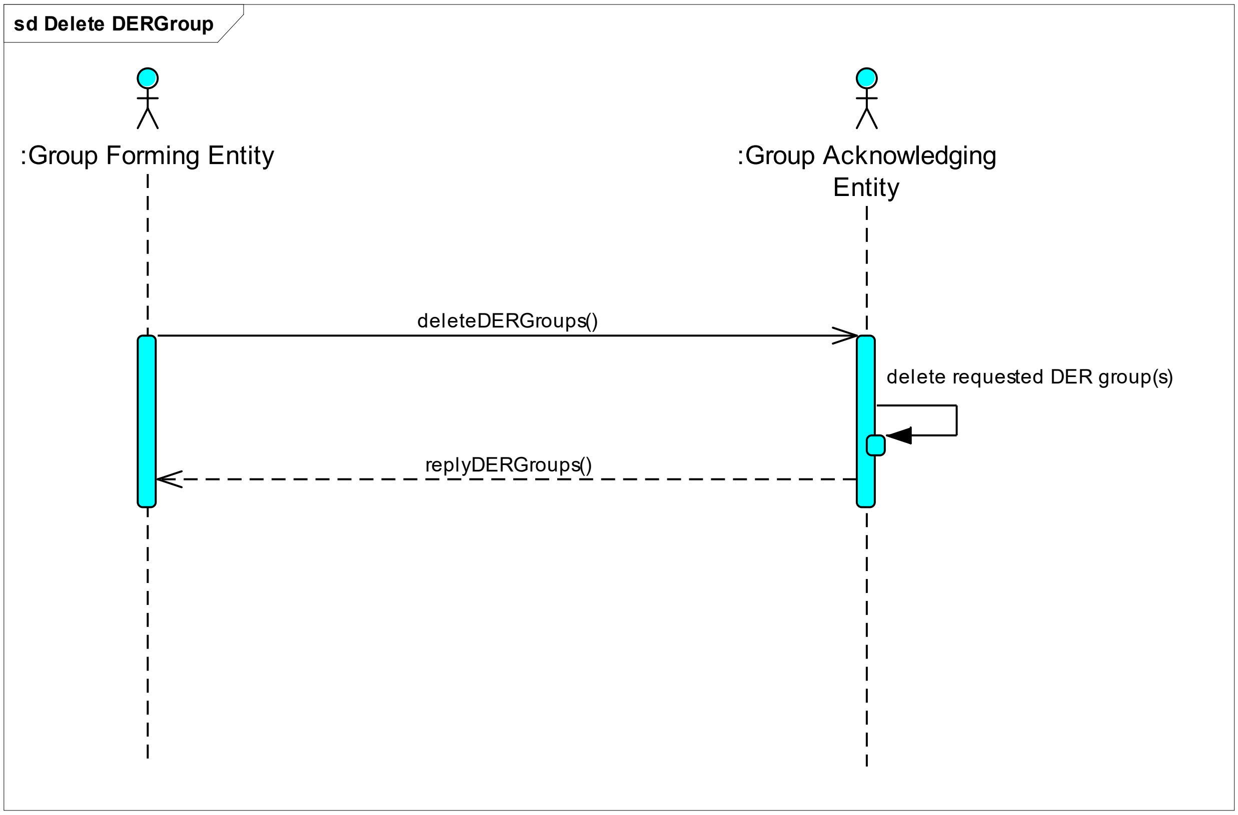


Figure 10-1
CIM Example Sequence Diagram for an Exchange wherein a DERGroup is Deleted

11

DER GROUP MAINTENANCE (ADDING, UPDATING, AND DELETING MEMBERS)

Purpose

The purpose of this function is to support maintenance—the adding and deleting of members to/from an existing group. The entity initiating this function may or may not have originally created the group.

Example Uses

Scenario: An advanced DMS organizes the DER on a given feeder into a group, then declares this group definition to a DERMS application that handles the communication to individual DER. When new DER are constructed and connected to this feeder, the model used by the DMS is updated. The DMS recognizes the addition of the new DER, and uses the "DER Group Maintenance" function to request that the DERMS add this new DER to the appropriate group. The DERMS then responds to the DMS with a "success" or "failure" response accordingly.

Table 11-1
Information Exchanged for DER Group Management

Information Name	Information Description
Action Identifier	Defining what is being requested or acknowledged: • Adding a member, or members, to a group • Deleting a member, or members, from a group • Accepting the addition or deletion of a member, or members, to/from a group • Rejecting the addition or deletion of a member, or members, to/from a group
Group ID	A unique identifier for the group whose membership is being modified
Group Name (optional)	A reference name (string) for the group
Requested Group Member IDs	• (Requests) A list of the unique identifiers of the DER requested to be added, updated, or deleted
Success / Failure Indicator(s)	A response, including the success/failure of the activity (see Chapter 7), including a list of the unique identifiers of DER successfully added/deleted (if any) and those not added/deleted (if any)

In some implementations, there may be subscription and/or notification services that can use this function to notify multiple when changes have been made to DER groups for interested end points. More information about the Publication and Notification server implementation has been provided in the related EPRI report that identifies the test script supporting this body of work[7].

[7] *Program on Technology Innovation: Test Script for International Electrotechnical Commission 61968-5:CD Messages*, Product ID 3002009276.

12
DER GROUP CAPABILITY DISCOVERY

Purpose

The purpose of this function is to read/report the capabilities of DER groups. This function is specifically focused on as-built or installed capability (e.g. static, nameplate, non-variable quantities), not real-time status data which are time-variable in nature. Knowledge of time-variable status data (capability at the moment) is addressed in the "Status Monitoring" function.

This proposal is not intended to be architecturally-prescriptive in terms of what software applications exist, what functionality is grouped in any one software application, or what interactions are employed between applications. It is intended to identify a range of common enterprise interactions, flexible such that any architecture might be supported. This "DER Capabilities" function may or may not be found useful in all cases.

"Installed Capabilities" vs. "Initial Entry or Discovery"

This "Installed Capabilities" function is intended as a mechanism for the exchange of information between business or software applications dealing with aggregate groups of DER. This function is not intended to relate directly to communication with individual DER in the field, nor to provide a mechanism by which individual DER capabilities might be automatically registered into the group-managing entity (plug-n-play DER). Figure 12-1, illustrates the difference. An initial data-entry or discovery process (Step 1) is assumed to have taken place. This initial process could occur in a number of ways, all of which are out of scope for this body of work:

- A human process by which DER capabilities data is manually entered into a system model
- An automated process by which newly connected individual DER are discovered and described in a plug-n-play fashion
- Any number of other methods

Once the capabilities are known to some aggregator or enterprise application, a subsequent process (Step 2) may occur in which these capabilities are shared between software applications. It is this subsequent process that this function is intended to address.

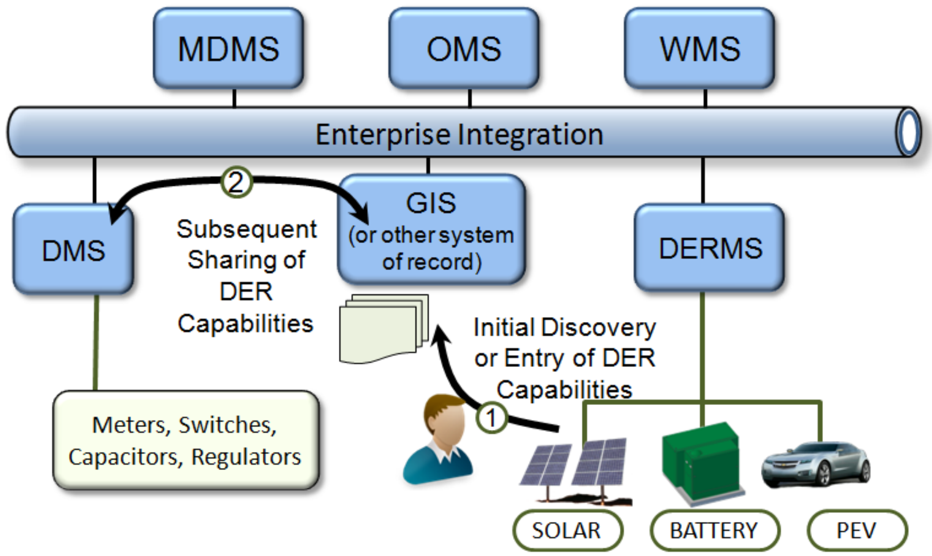


Figure 12-1
Exchange of DER Group Capabilities

Requesting DER Group Capabilities

This function envisions an environment in which one entity knows the present installed capabilities of the DER group and another entity seeks to understand this capability. As an example, consider a scenario in which an application called a DERMS is the manager of a group of installed DER. This system has information regarding the installed capabilities of individual DER, and the intelligence to translate this into the capabilities of the group. At some point in time, a separate application, such as a Distribution Management System seeks to understand the installed capabilities of a particular group of DER, and this function is utilized.

Like the "Status Monitoring" function described in a separate section, this function has a range of requirements for how capabilities might be requested, including various levels of aggregation. To satisfy these needs, the groups-based approach is used for this function.

This function assumes that the referenced DERGroup is known to both the requesting and responding entities, having previously been created. Group creation could occur immediately before this interaction or any time prior. The group definitions used for capabilities may be the same as those used for status monitoring or other dispatch calls.

DER Group Capabilities Information

The difference between capabilities information and status information has been described in the status monitoring section, and illustrated in Figure 13-1.

Table 12-1 identifies the DER Group functions for which capabilities may be discovered using this function.

Table 12-1
Enumeration of DER Group Functions

DER Group Service/Function Number	DER Group Service/ Function Name	Parameters Describing Capability for this Service or Function
1	DER Group Status Monitoring	List of monitorable parameters
2	DER Group Forecasting	List of parameters for which forecasting is available
3	DER Group Historical Interval Meter Data	List of metered parameters for which interval data is available
4	Real Power Dispatch	Max Real Power (W), Min Real Power (W)
5	Reactive Power Dispatch	Max Reactive Power (W), Min Reactive Power (W)
6	DER Group Maximum Real Power Limiting	Range over which real power can be limited.
7	DER Group Ramp Rate Control	Range of ramp rate adjustability
8	DER Group Voltage Regulation	Range of voltage regulation
9	DER Group Curve Functions	List of curve types
10	Receive/Respond Based on Price Signals	List of services for which responses to price are supported
11	Provide Bids/Cost of Services	List of services for which bids/costs can be provided
12	Connect/Disconnect DER Group	Identifying whether or not this service is provided.
13	DER Group Regulation Service	Identifier of which regulation services are available and the scale (Watts) of each.

Summary of DER Group Capability Information Items

The following information is passed in a request for DER Group Capabilities:

Table 12-2
Information Exchanged for Group Capability Request

Information Name	Information Description
Action Identifier	Defining what is being requested: • DER Group Capabilities Request
DER Group ID	The unique identifier for the DER group for which capability information is being requested
Capability Requested	This is a service identifier (or optionally a list of services) for which capability discovery is being requested, based on the enumeration of Table 12-1. This provides a way to request based on specific DER Group functions. For example, the downstream DER Group managing entity may be asked if it can dispatchable real power, dispatchable reactive power, or some other service, and to what extent.
Other Capabilities	A way to extend the object for new capabilities that had not been imagined; attributes of this class are capabilityType, capabilitySubType, capabilityValue, and capabilityUnits. This allows a flexible way for the systems to exchange a capability type that may not currently be used on envisioned for power exchange, e.g. heat, water, or some other capability.

Table 12-3
Information Exchanged for Group Capability Response

Information Name	Information Description
Action Identifier	Defining what information is being passed: • DER Group Capabilities Response
DER Group ID	The unique identifier for the DER group for which this capability information applies
Function 1 Capabilities – Status Monitoring	List of monitorable status parameters that this DER Group Managing entity can support. The elements for this list are defined in Table 13-2 and Table 13-3. A null list or other indicator must be identified in the protocol mapping to indicate if no Status Monitoring is supported.
Function 2 Capabilities – DER Group Forecasting	List of forecastable parameters that this DER Group Managing entity can support. This list is defined in Table 14-1. List of valid forecast interval times (See Chapter 14). Maximum forecast distance (look-ahead time) (See Chapter 14). A null list or other indicator must be identified in the protocol mapping to indicate if no Group Forecasting is supported.
Function 3 – Historical Interval Data	List of parameters for which this DER Group Managing entity can provide interval data. The elements for this list are identified in Table 15-1. A null list or other indicator must be identified in the protocol mapping to indicate if no Historical Interval Data is supported.
Function 4 – Real Power Dispatch	A Boolean indicator of whether or not this function is supported. The modes that are supported (see Chapter 19) The maximum and minimum real power dispatchable ranges that can possibly occur for this DER Group
Function 5 – Reactive Power Dispatch	A Boolean indicator of whether or not this function is supported. The modes that are supported (see Chapter 20) The installed maximum and minimum reactive power dispatchable ranges that can possibly occur for this DER Group
Function 6 – DER Group Maximum Real Power Limiting	A Boolean indicator of whether or not this function is supported. The modes that are supported (see Table 16-1) The installed maximum and minimum real power dispatchable ranges.
Function 7 – DER Group Ramp Rate Control	A Boolean indicator of whether or not this function is supported. The maximum and minimum range of supported adjustability for the following parameters defined in Table 17-1: • Normal Ramp-Up Rates • Normal Ramp-Down Rates • Emergency Ramp-Up Rate • Emergency Ramp-Down Rate • Soft-Connect Ramp Rate • Soft-Disconnect Ramp Rate
Function 8 – DER Group Voltage Regulation	A Boolean indicator of whether or not this function is supported. The maximum and minimum range of adjustability of the regulation
Function 9 – DER Group Volt-Var Curve Function	A Boolean indicator of whether or not this function is supported. The modes that are supported (see modes identified in Chapter 22) The maximum number of Volt-Var curve points supported The options for the dependent (Y-axis) variable: • Vars as a % of Var, max (Var priority) • Vars as a % of available Var (Watt priority)
Function 9 – DER Group Volt-Watt Curve Function	A Boolean indicator of whether or not this function is supported. The modes that are supported (see modes identified in Chapter 22) The maximum number of Volt-Watt curve points supported

Table 12-3 (continued)
Information Exchanged for Group Capability Response

Information Name	Information Description
Function 9 – DER Group Frequency-Watt Curve Function	A Boolean indicator of whether or not this function is supported. The modes that are supported (see modes identified in Chapter 22) The maximum number of Frequency-Watt curve points supported
Function 10 – Receive/Respond Based on Price Signals	To be developed
Function 11 – Provide Bids/Cost of Services	To be developed
Function 12 – Connect/Disconnect DER Group	A Boolean indicator of whether or not this function is supported.
Function 13 – Regulation Service	Identifier of the specific regulation services supported: • High Filter, Bi-Directional Regulation • Low Filter, Bi-Directional Regulation • High Filter, Up Regulation • Low Filter, Up Regulation • High Filter, Down Regulation • Low Filter, Down Regulation Identifier of the scale/quantity of the supported regulation services, in Watts.

In the CIM implementation, this message profile contains the same classes and attributes as the DERGroupStatuses profile, the only difference being the intent. DERGroupStatuses conveys what the DER group is doing at a moment in time, while as noted earlier in this section; the DERGroupCapability reflects the installed/nameplate characteristics of the group of DER. The designed flexibility of the DERGroupStatuses profile allows for a range of capabilities to be passed between systems. The other difference being that a DERGroupStatuses request might be for a single capability, e.g. RealPower, while a DERGroupCapabilities request could be asking for everything that the DER was capable of. However, since the DERGroupStatuses profile provides the option to pass 1-to-many capabilities, plus additional capabilities that are not envisioned at this time, no new profile needs to be created to support the response to this request.

13
DER GROUP STATUS MONITORING

Purpose

The purpose of this function is to read/report the present status of a DER group. In this context, “status” refers foremost to the present value and range of adjustability of real and reactive power levels. Depending on devices and the specific protocol mapping, a wide range of additional group-status related parameters may also be exchanged using this function.

Prerequisites

This function requires that the referenced DER group definition exists in both the status-requesting and status-providing entities. As described in the Group Creation Function, the makeup of the group could have been defined by the requestor, the provider, or any other entity, and could have been a manual or automated process.

As with all functions described in this document, the protocol may support push and/or pull methods for status monitoring. For example, if a publish/subscribe protocol is used, a group managing entity could subscribe to the status of a DER group. Each time thereafter that an updated status is available, the DER group-managing entity would publish to the subscribers.

Status Request Timing Types

The requesting entity may specify that the status is one of two types:

- **Latest Available:** A request for the latest status available for the DER group. This would notionally be based on information that the providing entity already collected from individual DER. The response to this kind of status request could typically be provided immediately.
- **Refreshed Status:** A request that instructs the providing entity to go out and get updated status information from the DER group before responding. The response to this kind of request would be delayed until the refreshed status could be collected from the DER in the field.

Clarifying the Difference between Capabilities and Status

During the project kickoff workshop, “Status Monitoring” and “Capabilities Discovery” were identified and defined as separate services. Based on discussion from the workshop, the distinction between these two was:

- “Status” represents the present state and can be time-variant, in the sense of the potential for moment-to-moment changes during operation
- “Capabilities” are name-plate oriented. Capabilities change when infrastructure is added or deleted and the associated new installed capabilities are entered into GIS (or other system of record)

For some parameters, the present status may be represented by three quantities: the present value, the maximum value to which it can presently be adjusted, and the minimum value to which it can presently be adjusted. All are included as part of the status information. Figure 13-1 illustrates the concept.

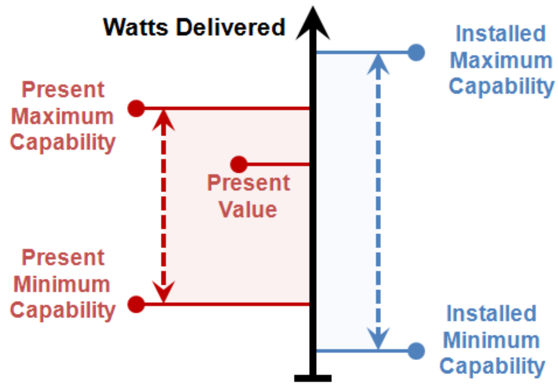


Figure 13-1
Installed (Blue) and Present (Red) Capabilities

The quantities shown in red will be part of the "status" information and those shown in blue will be part of the "capabilities" information. Defined in this way, the present values will always fall inside (or equal to) the installed capabilities range. For example, the "Present Maximum Capability" of a PV group could be less than the "Installed Maximum Capability" on a cloudy day, or if some of the DER in the group are presently offline or impaired in some way.

Likewise, the "Present Value" will always fall inside (or equal to) the present capabilities range. For example, the present Watts Delivered output from a PV group could be equal to the "Present Maximum Capability" if the group is not curtailed in any way. Alternatively, the present Watt output of the same group could be less than the "Present Maximum Capability" if some units are operating in a curtailed mode.

All three "present" quantities can be time-varying, based on a variety of factors, such as battery systems being fully charged or fully discharged, solar irradiance being high or low, equipment being online/offline, contracts, or local voltage limits.

The objective in this approach is that a requesting entity (DMS for example) could request the Watt status (for a group of DER), and get three numbers: a present value, a capability to deliver and a capability to receive. The requesting entity could then make a request for a Watt value within the red range and get the expected response, more or less.

Summary of DER Group Status Information Items

The information in Table 13-1 is passed in a request for DER Group Status.

Table 13-1
Information Exchanged for Group Status Requests

Information Name	Information Description
Action Identifier	Defining what is being requested: • DER Group status request
Timing of Status Request	Defining whether the request is for: • Latest Available • Refreshed Status
DER Group ID	The unique identifier for the DER group for which status is being requested
Quantity	What quantity is being asked for, e.g. ActivePower, RealPower, ApparentPower

Table 13-2 and Table 13-3 identify a range of information that may be returned in response to a request for DER group status, depending on what information is requested. Each item relates to status information for a group of DER. As such, additional status information that might be relevant for individual DER may not represented.

Table 13-2 identifies the present state information quantities, indicators of what the DER group is actually doing at the present time. Table 13-3 identifies the range of adjustability of each quantity. Together, these make up the “status” information shown in red in Figure 13-1.

Table 13-2
Information Related to Present State that May Be Exchanged in Group Status Responses

Information Name	Units	Information Description
Group ID	N/A	The unique identifier of the **group** for which status was requested
Group Name (optional)	N/A	A reference name (string) for the group
Watts Total	W	Present AC active power imported or exported from the DER group (signed quantity)
Watts, Per Phase	W	Same as above but for Phase A, B, and C.
VA	VA	Present apparent power imported or exported from the DER group
VA Per Phase	VA	Same as above but for Phase A, B, and C.
VAR Total	VAR	Present reactive power, capacitive or inductive, produced by the DER group
VAR Per Phase	VAR	Same as above but for Phase A, B, and C.
PF	%	Aggregate Power Factor for the DER group
PF, Per Phase	%	Same as above but for Phase A, B, and C.
Cumulative Watt-hours Exported	Wh	Aggregate energy exported from the DER group (arbitrary starting point value)
Cumulative Watt-hours Exported, Per Phase	Wh	Same as above but for Phase A, B, and C.
Cumulative Watt-hours Imported	Wh	Aggregate energy imported to the DER group (arbitrary starting point value)
Cumulative Watt-hours Imported, Per Phase	Wh	Same as above but for Phase A, B, and C.
Cumulative VA-hours Exported	VAh	Cumulative apparent energy exported from the DER group
Cumulative VA-hours Exported, Per Phase	VAh	Same as above but for Phase A, B, and C.
Cumulative VA-hours Imported	VAh	Cumulative apparent energy imported to the DER group
Cumulative VA-hours Imported, Per Phase	VAh	Same as above but for Phase A, B, and C.
Cumulative VAr-hours Imported Q1	VARh	Cumulative Reactive Energy imported to the DER group, Quadrant 1
Cumulative VAr-hours imported, Q1, Per Phase	VARh	Same as above but for Phase A, B, and C.
Cumulative VAr-hours imported Q2	VARh	Cumulative Reactive Power imported to the DER group, Quadrant 2
Cumulative VAr-hours Imported, Q2, Per Phase	VARh	Same as above but for Phase A, B, and C.

Table 13-2 (continued)
Information Related to Present State that May Be Exchanged in Group Status Responses

Information Name	Units	Information Description
Cumulative VAr-hours Exported Q3	VARh	Cumulative Reactive Power Exported from the DER group, Quadrant 3
Cumulative VAr-hours Exported, Q3, Per Phase	VARh	Same as above but for Phase A, B, and C.
CumulativeVAr-hours, Exported Q4	VARh	Cumulative Reactive Power Exported from the DER group, Quadrant 4
Cumulative VAr-hours Exported Q4, Per Phase	VARh	Same as above but for Phase A, B, and C.
Phase Voltage AB	V p.u.	Average per unit phase voltage AB for the DER group
Phase Voltage BC	V p.u.	Average per unit phase voltage BC for the DER group
Phase Voltage CA	V p.u.	Average per unit phase voltage CA for the DER group
Phase Voltage AN	V p.u.	Average per unit phase voltage AN for the DER group
Phase Voltage BN	V p.u.	Average per unit phase voltage BN for the DER group
Phase Voltage CN	V p.u.	Average per unit phase voltage CN for the DER group
Hz	Hz	Average line frequency of the DER group
Present Energy Stored	Wh	Present stored energy by the DER group

Table 13-3
Information Related to Present Range of Adjustability that May Be Exchanged in Group Status Responses

Information Name	Units	Information Description
Present Range of Adjustability Maximum, Watts Delivered, Total	W	Maximum present rate at which real power can be generated by the DER group. (Real power generated cannot presently be dispatched to a level greater than this)
Present Range of Adjustability Maximum, Watts Delivered, Per Phase	W	Same as above but for Phase A, B, and C.
Present Range of Adjustability Minimum, Watts Delivered, Total	W	Minimum present rate at which real power can be generated by the DER group. (Real power generated cannot presently be dispatched to a level less than this)
Present Range of Adjustability Minimum, Watts Delivered, Per Phase	W	Same as above but for Phase A, B, and C.
Present Range of Adjustability Maximum, Watts Received, Total	W	Maximum present rate at which real power can be absorbed by the DER group. (Real power absorbed cannot presently be dispatched to a level greater than this)
Present Range of Adjustability Maximum, Watts Received, Per Phase	W	Same as above but for Phase A, B, and C.
Present Range of Adjustability Minimum, Watts Received, Total	W	Minimum present rate at which real power can be absorbed by the DER group. (Real power absorbed cannot presently be dispatched to a level less than this)
Present Range of Adjustability Minimum, Watts Received, Per Phase	W	Same as above but for Phase A, B, and C.
Max Increasing Ramp Rate, Watts	W/sec	Maximum present rate at which the Watt output for this DER group can increase in response to dispatch command.
Max Decreasing Ramp Rate, Watts	W/sec	Maximum present rate at which the Watt output for this DER group can decrease in response to dispatch command.
Present Maximum Capacitive Var available, Total	VAR	Present maximum available capacitive var level for the DER group.
Present Maximum Capacitive Var available, Per Phase	VAR	Same as above but for Phase A, B, and C.
Maximum Increasing Ramp Rate, Capacitive Var	VAR/sec	Maximum present rate at which the Capacitive VAR output for this DER group can increase in response to dispatch command.

Table 13-3 (continued)
Information Related to Present Range of Adjustability that May Be Exchanged in Group Status Responses

Information Name	Units	Information Description
Maximum Decreasing Ramp Rate, Capacitive Var	VAR/sec	Maximum present rate at which the Capacitive VAR output for this DER group can decrease in response to dispatch command.
Present Maximum Inductive Var available, Total	VAR	Present maximum available inductive var level for the DER group
Present Maximum Inductive Var available, Per Phase	VAR	Same as above but for Phase A, B, and C.
Max Increasing Ramp Rate, Inductive Vars	VAR/s	Maximum present rate at which the Inductive VAR output for this DER group can increase in response to dispatch command.
Max Decreasing Ramp Rate, Inductive Vars	VAR/s	Maximum present rate at which the Inductive VAR output for this DER group can decrease in response to dispatch command.
Maximum Present Energy Storage Capability	Wh	Maximum energy that can presently be stored by the DER group
Minimum Present Energy Storage Capability	Wh	Minimum energy that can presently be stored by the DER group

14
DER GROUP FORECASTING

Purpose

The purpose of this function is to support the exchange of forecasts of DER group availability. Specifically, this method addresses forecasts for the availability of real and reactive power from a DER group. In future additions, forecasts could be made available in similar fashion for any service that the DER group can provide.

This function only defines how DER forecast data is exchanged and does not relate to how forecasts are determined. Some DER forecast-providing entities could, for example, have access to detailed weather forecast information, including satellite or sky-viewing capabilities to enable prediction of solar variability. Others could monitor DER health or analyze historical data in order to determine forecasts with greater accuracy. Regardless of the forecasting methods that may be used, this function only addresses the exchange of the forecast of the DER availability (real and reactive power) and does not address the exchange of weather or other related data.

Technical Approach

As described in a previous section, the present status for real and reactive power includes three parts: a present value, a maximum, and a minimum range of adjustability. Forecasting is relevant for the maximum and minimum values. Forecasting is not relevant for the present value because it is dispatchable and bounded only by the maximum and minimum.

Forecasts may involve varying degrees of uncertainty. To represent this, the forecast for a given parameter can be described as an envelope, a range of uncertainty, possibly widening further into the future as the forecast becomes less certain. The concept is illustrated in Figure 14-1. The present maximum and minimum values are labeled at the left hand side. Because they reflect the present state, they are specific, known values. But looking into the future, the forecasts for these quantities may be represented through a widening envelope, as illustrated by the red shaded areas.

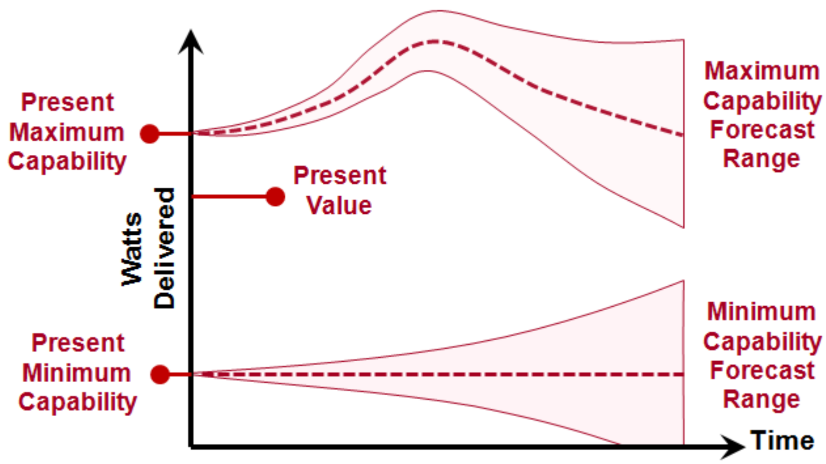


Figure 14-1
Concept of Forecasts Viewed as Envelopes

The enterprise information exchange for DER forecast data will support the exchange of this information through arrays of data as illustrated in Figure 14-2.

The forecast-requesting entity will pass to the forecast-providing entity:

- The quantity to be forecasted (shown as Maximum Watts Capability in this example)
- A forecast start time
- Interval time
- End time

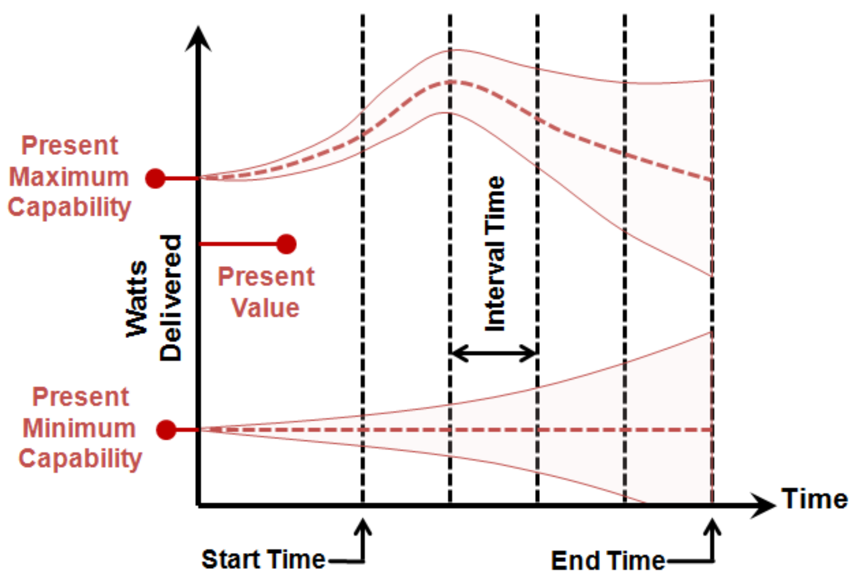


Figure 14-2
Arrays of Data to Represent Forecast Data

The data that is returned for each interval of time may take on several forms, according to the design of the forecasting entity. The form will be identified by an enumeration, also included in the returned data, and allowing, at a minimum, for the following options:

- Best guess, midpoint only
- Best guess, plus 90% confidence high/low points
- Normal (Gaussian) distribution. Providing mean and standard deviation.
- Central Chi-square distribution. Providing midpoint and degrees of freedom K.

Figure 14-3 through Figure 14-5 illustrate the data provided for three example forecast types.

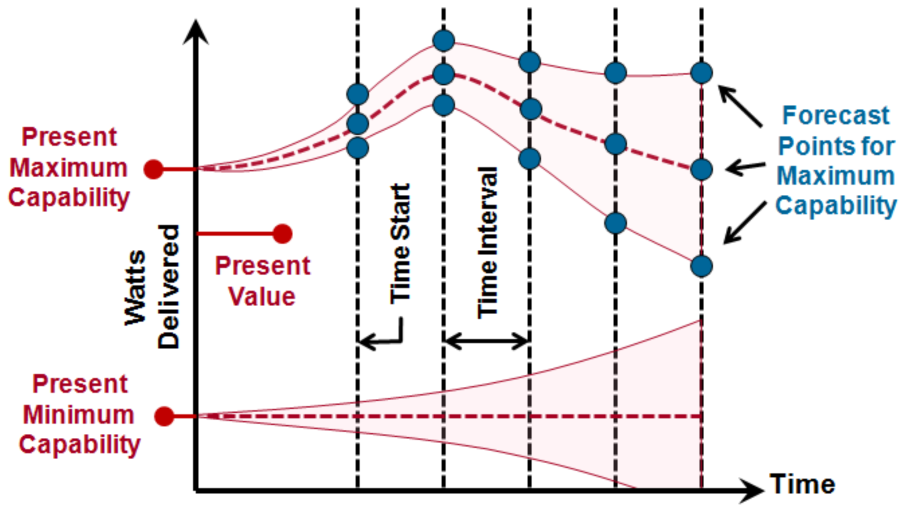


Figure 14-3
Forecast Data for Best Guess Plus 90% Confidence Points

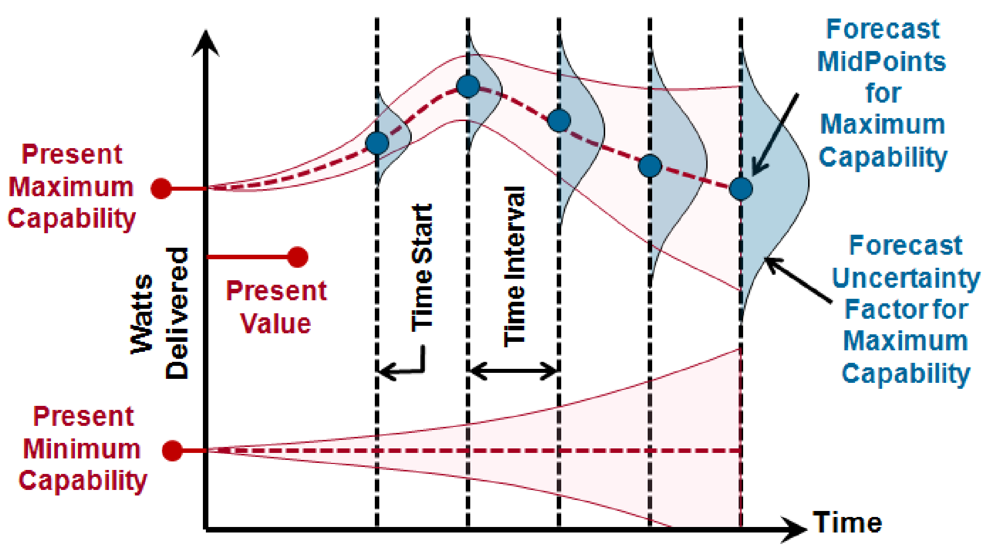


Figure 14-4
Forecast Data for Normal Gaussian Distribution

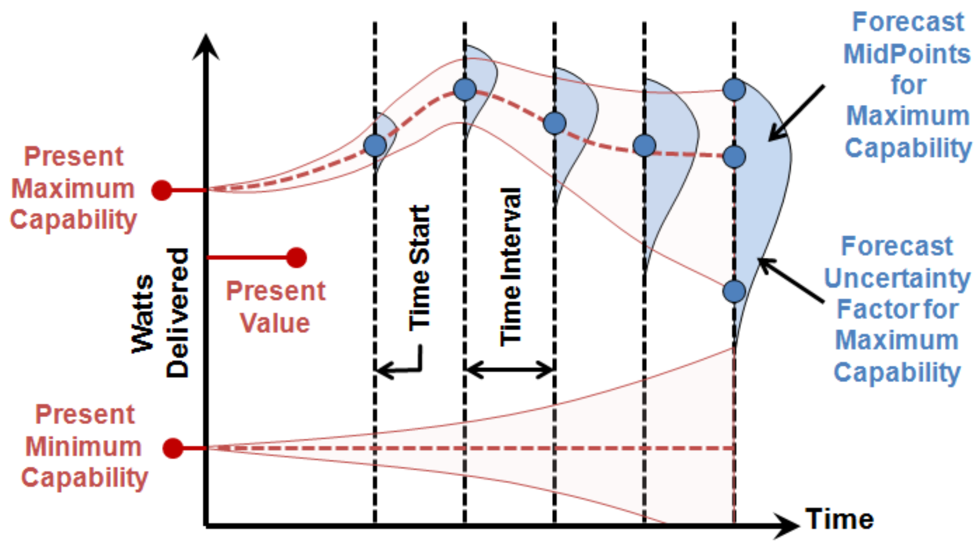


Figure 14-5
Forecast Data for Central Chi-Square Distribution

Forecast Consideration of Storage Systems

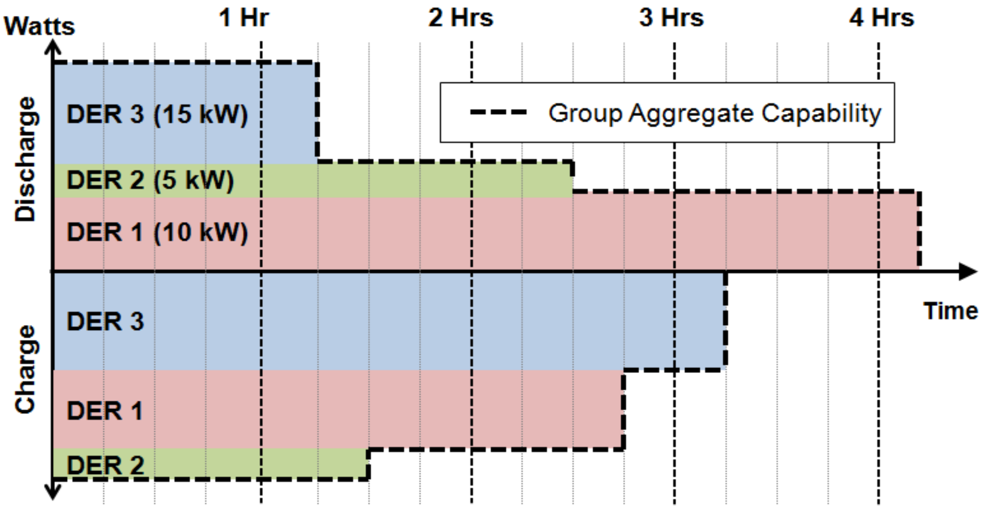
Forecasts for the availability of groups of battery storage DER may also be represented by the approach described above. The forecasted availability of these groups, however, may have a different appearance and would naturally be dependent on the level of dispatch.

As an example, consider a group comprised of three battery storage devices:

- DER1 10kW 70kWh
- DER2 5kW 20kWh
- DER3 15kW 65kWh

For simplification, this example assumes that each device can charge at the same rate at which it discharges.

Figure 14-6 illustrates how the individual charge availability and discharge availability of these three devices might appear when viewed as a group. The aggregate capability of the group to either charge or discharge is shown to drop in steps as each device's storage capacity is filled or depleted.



Power Available		
Duration	Discharge	Charge
1 Hour	30 kW	30 kW
2 Hours	15 kW	25 kW
3 Hours	10 kW	15 kW
4 Hours	10 kW	0 kW

Figure 14-6
Battery DER Group Availability Example

Figure 14-7 shows an example of a forecast using the ***Best Guess plus 90% Confidence High/Low Points*** method for the real power availability from a battery storage group. In this example, the forecast is shown to have some uncertainty in both the real power value and in the times at which the step changes occur in the group availability. Finer interval time step resolution may be desired when step-changes in forecast are anticipated.

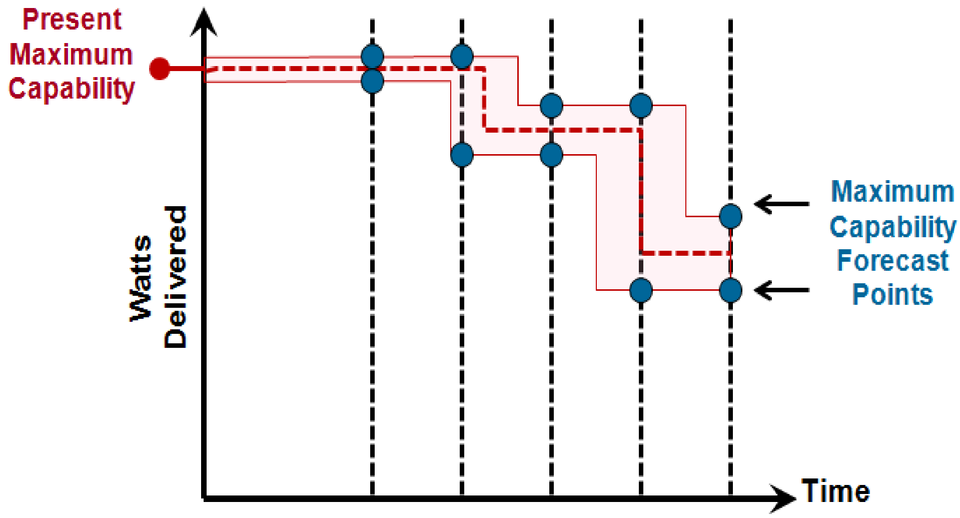


Figure 14-7
Example of Points to Represent Battery Storage Group Forecast

For battery storage groups, the forecast is inherently a function of the level of dispatch. In view of this, the entity making the request for a DER forecast will be able to do so based on a hypothetical level of dispatch that is passed in the request.

Summary of DER Group Forecast Information Items

Table 14-1
Information Exchanged for DER Group Forecast Requests

Information Name	Information Description
Action Identifier	Defining what is being requested: • DER Group Forecast Request
DER Group ID	The unique identifier for the DER group for which a forecast is being requested
Quantity ID for which the Forecast is Requested	Identifier of the parameter for which the forecast is being requested: • Real Power Delivered, Total, Maximum Capability or Minimum Capability • Real Power Received, Total, Maximum Capability or Minimum Capability • Real Power Delivered, Phase A,B,C, Maximum Capability or Minimum Capability • Real Power Received, Phase A,B,C, Maximum Capability or Minimum Capability • Capacitive Vars, Total, Maximum Capability or Minimum Capability • Inductive Vars, Total, Maximum Capability or Minimum Capability • Capacitive Vars, Phase A,B,C, Maximum Capability or Minimum Capability • Inductive Vars, Phase A,B,C, Maximum Capability or Minimum Capability
Forecast Start Time	The requested start time of returned forecast data.
Forecast Array Interval Time	The requested time interval between points in the array of returned forecast data.
Forecast End Time	The requested end time of returned forecast data.
Hypothetical Dispatch Level (optional)	A basis for the forecast, particularly useful for battery storage systems: "If the indicated DER quantity is dispatched at this level, what will the forecast be?" Note: In the case that the quantity ID is <u>not</u> under the control of the requesting entity (e.g. a fleet of storage systems that operate on their own objectives), this parameter is not applicable.

Table 14-2
Information Exchanged for DER Group Forecast Responses

Information Name	Information Description
Action Identifier	Defining what is being passed: • DER Group Forecast Response
DER Group ID	The unique identifier for the DER group for which the forecast applies
Success / Failure Indicator(s)	Indication of whether or not, or to what extent, the command could be accommodated. Chapter 7 describes the Success/Failure indicators and Table 7-2 identifies those that are applicable to this response.
Quantity ID	Identifier of the parameter for which the forecast applies. (see list in the request)
DERForecastDate	The date/time at which this forecast was made.
DERGroup ForecastType	An enumeration that identifies the format of the forecast array, supporting, at a minimum, these types: • Best guess, midpoint only • Best guess, plus 90% confidence high/low points • Normal (Gaussian) distribution. Providing mean and standard deviation. • Central Chi-square distribution. Providing midpoint and degrees of freedom K.
DERGroupPrediction	The array of points representing the forecast for the requested capability quantity, group, and timeframe. Each array entry depends on the DERGroupForecastType
Sequence	Any given instance of the forecast. (This allows the values passed in the XML to be placed in the correct order)
PredictionStartDate	The number of intervals will indicate the duration of any given forecast; this attribute indicates the DateTime the prediction period begins.

15
DER GROUP HISTORICAL AGGREGATE METER DATA

Purpose

This function provides the aggregate metered/historical record for a DER group. (Note: the "Status Monitoring" function defined in this body of work provides only the present power values for a DER group.) This new "Historical Aggregate Meter Data" function may include historical real and reactive energy production for the group, energy stored, and any status or error codes that are representative of a group of DER rather than an individual DER. The time-resolution of historical data (e.g. second, minute, hour) may be limited by the entity providing this service (e.g. an AMI headend, MDMS, or DERMS). Example benefits may include ability to perform a statistical reliability study on this DER group to include in planning and forecasting.

The entities that may request and/or provide this function are not specified and the data provided may be derived from internal metering in DER devices, separate smart meters, or any other means. This function does not dictate how the DER aggregator gained the aggregate metering information, but only how that aggregate information is exchanged between entities.

Example Use Cases

<u>AMI to DMS</u>

Precondition: A utility AMI system is informed of a DER group makeup using the group creation function and has the ability to support DER group aggregate meter data.

An advanced DMS has the ability to analyze past performance of DER groups to determine optimal control strategies going forward. The DMS uses the methods set forth in this section, acting as the requesting entity, to query the AMI system for certain aggregate historical data for the DER group.

<u>Third-Party to Utility Billing System</u>

Precondition: A utility is in a business relationship with a third-party DER aggregator. In this relationship, the utility makes payments for services rendered at the group-level, without concern for how the service was distributed among the members of the group. Settlement between the two parties is based on data that the aggregator directly collects from their fleet of smart inverters and meters.

The utility CIS, acting as the requesting entity, uses the methods set forth in this section, acting as the requesting entity, to query the third-party's system for certain aggregate historical data for the DER group.

Technical Approach

This function requires ability to exchange the data identified in Table 15-1 at the DER Group level.

Table 15-1
ER Group Historical Metered Data Quantities

Interval Quantity	Cumulative Quantity	Description
Interval Wh Delivered	Wh Produced	Interval data (e.g. 5 minute intervals) and the cumulative total of the real power produced by the DER group
Interval Wh Received	Wh Absorbed	Interval data (e.g. 5 minute intervals) and the cumulative total of the real power absorbed by the DER group
N/A	Peak Interval Watt Produced Demand	The maximum demand value (Watts) of real power produced by the DER group. Maximum demand is typically based on a given interval length (e.g. 5 minutes) and over a given time period (e.g. a billing month).
N/A	Peak Interval Watt Absorbed Demand	The maximum demand value (Watts) of real power absorbed by the DER group. Maximum demand is typically based on a given interval length (e.g. 5 minutes) and over a given time period (e.g. a billing month).
Interval Capacitive Varh	Capacitive Varh	Interval data (e.g. 5 minute intervals) and the cumulative total of the capacitive reactive power produced by the DER group
Interval Inductive Varh	Inductive Varh	Interval data (e.g. 5 minute intervals) and the cumulative total of the inductive reactive power produced by the DER group
Interval Q1 Varh	Q1 Varh	Interval data (e.g. 5 minute intervals) and the cumulative total of the Q1 reactive power produced by the DER group
Interval Q2 Varh	Q2 Varh	Interval data (e.g. 5 minute intervals) and the cumulative total of the Q2 reactive power produced by the DER group
Interval Q3 Varh	Q3 Varh	Interval data (e.g. 5 minute intervals) and the cumulative total of the Q3 reactive power produced by the DER group
Interval Q4 Varh	Q4 Varh	Interval data (e.g. 5 minute intervals) and the cumulative total of the Q4 reactive power produced by the DER group
Interval Average Voltages at Point of Reference	N/A	Interval data (e.g. 5 minute intervals) for the average voltages (Phase A, B, C) at a specified point of reference that is significant for the DER group. For example, the point could be specified as a control point of reference for DER Group Volt-Watt curve control.
Interval Max Voltage at Point of Reference	N/A	Interval data (e.g. 5 minute intervals) for the 1 second maximum voltages (Phase A, B, C) at a specified point of reference that is significant for the DER group.
Interval Min Voltage at Point of Reference	N/A	Interval data (e.g. 5 minute intervals) for the 1 second minimum voltages (Phase A, B, C) at a specified point of reference that is significant for the DER group.
Interval Energy Stored	N/A	Interval data (e.g. 5 minute intervals) for the usable energy (Wh) stored in the DER Group. For example, battery DER groups.

This function requires the ability to exchange the metering configuration parameters identified in Table 15-2.

Table 15-2
DER Group Historical Metered Data Setup

Quantity	Description
Interval Resolution	The time interval (e.g. in seconds) for the interval resolution.
Start Date/Time	For use with demand calculations, the start date/time of the analysis window.
End Date/Time	For use with demand calculations, the end date/time of the analysis window.
Demand Reset	Reset maximum demand values to zero.

DER Group Metering Setup Request Message

This message is exchanged between systems to establish what metering data is required by the requesting entity and to verify that the providing entity is capable of providing the service.

Field	Description
Action Identifier	Metering Setup Request
Required Interval Meter Quantities	An array of references to the metered quantities in Table 15-1 that are required. The array length may be 1 or greater.
Required Interval Resolution	The required interval resolution for this array of quantities. Note: this message could be exchanged multiple times, each with different quantities and interval resolutions.
Required Cumulative Meter Quantities	An array of references to the metered quantities in Table 15-1 that are required. The array length may be 1 or greater.
Billing Period	Timing establishing the periodicity of the billing process

DER Group Metering Setup Response Message

Field	Description
Action Identifier	Metering Setup Response
Interval Quantities Success/Fail	Indication of whether the requested parameters can be supported
Supported Interval Meter Quantities	If fail, an array of references to the requested quantities in Table 15-1 that are supported.
Intervals Success/Fail	Indication of whether the requested interval resolution can be supported.
Cumulative Quantities Success/Fail	Indication of whether the requested parameters can be supported
Supported Cumulative Meter Quantities	If fail, an array of references to the requested quantities in Table 15-1 that are supported.

DER Group Metering Request Message

This message is used to exchange meter data between systems. The setup messages may have previously been exchanged to instruct the providing entities and to establish expectations.

Field	Description
Action Identifier	Metering Data Request
Meter Quantities	An array of references to the metered quantities in Table 15-1 that are being read. The array length may be 1 or greater.
Interval Resolution	The resolution to be returned for this request

DER Group Metering Response Message

Field	Description
Action Identifier	Metering Data Response
Meter Quantities	Single quantity (for cumulative) or Arrays (interval data) of: • Start time • Quantity

16
DER GROUP MAXIMUM REAL POWER LIMITING

Purpose

The purpose of this function is to request that the maximum real power (generated or absorbed) be limited to the specified level.

Figure 16-1 illustrates how this function relates to the “DER Group Status” and the “Real Power Dispatch” function. In this illustration, the DER group is presently operating at +2000 and is capable of operating as high as 5000 and as low as -2000 (implying that the group includes some storage for example). The red shaded area identifies the present capability range in which real power dispatch commands may be successful according to the “DER Group Status” function.

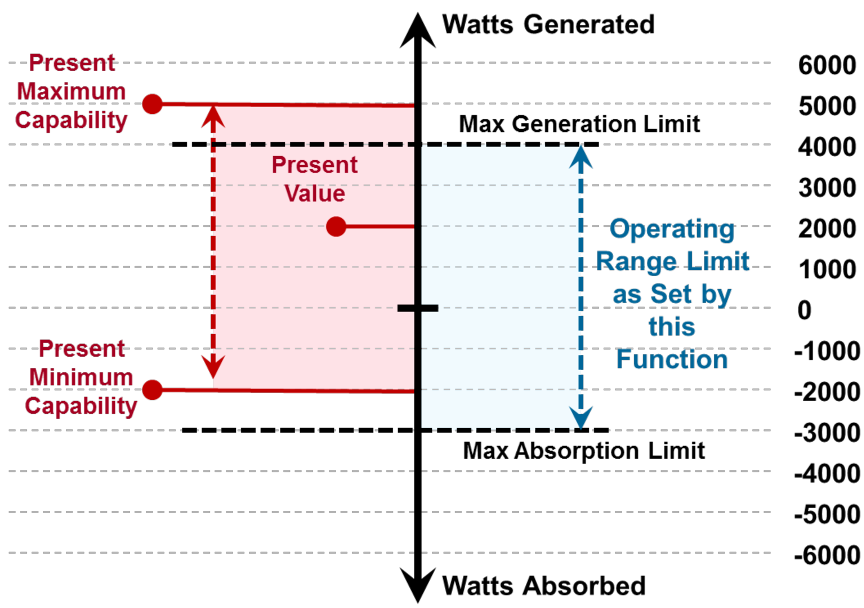


Figure 16-1
DER Group Maximum Real Power Limiting

This function adds operating limits that are not to be exceeded. As illustrated, a maximum generation limit is set to 4000 for the group and a max absorption limit of -3000. In practice either one or both of these could be used. In this example, the maximum generation setting of 4000 is below the group’s present capability of 5000, creating an upper operating limit. The maximum absorption limit of -3000 is below the present capability of -2000, so is not the limiting factor at the moment represented.

This function does not instruct the DER group to go to the values provided, but rather dictates operating limits that the DER group must remain within. It is the responsibility of the DER group managing entity to maintain operation of the group within the specified limits using whatever strategies it prefers. No specific control strategy or distribution across the DER group members is implied by this function.

Technical Approach

The DER Group Maximum Real Power Limiting function will support the modes of operation specified in Table 16-1 and described in the following sections.

Table 16-1
Maximum Real Power Limiting Function - Modes of Operation

Mode Number	Description
1	Unspecified Distribution, Percent or Power Value Setting
2	Even Distribution, Percent or Power Value Setting

Mode 1: Unspecified Distribution, Percent or Power Value Setting

In this mode, the aggregate real power generation or absorption by the DER group is to be limited to a provided real power value (Watts). The DER group managing entity may achieve the limit by any means and distribution. For example:

- The real power output of one large member of the group may be limited enough to satisfy the group limit
- The real power limit of each member of the group may be limited, but to different levels based on any rationale
- A battery storage unit may be used, absorbing real power, to limit total real power produced by the group
- Any other means

Mode 2: Even Distribution, Percentage Value Setting

In this mode, the real power generation or absorption by each member of the DER group is to be limited to a provided real power percentage of nameplate real power capacity. In this mode, the DER group managing entity is required to limit each member of the group using the provided percentage value.

Summary of DER Group Maximum Real Power Limit Information Items

The following information is passed in a DER Group Maximum Real Power Limit Request:

Table 16-2
Information Exchanged for Group Real Power Limit Requests

Information Name	Information Description

Action Identifier	Defining what is being requested:
	• Identifier of the type of dispatch being requested
	  ○ Max DER Group Generation Limit
	  ○ Max DER Group Absorption Limit

Priority	A parameter to identify the priority-level associated with this control message. Protocol mappings will identify (a) if a priority is/isn't defined and (b) a range of at least 10 priority levels. Determination of whether and how priority levels are assigned is up to power system operator/designers.
DER Group ID	The unique identifier for the DER group for which a real power level is being limited
Effectivity Schedule	The time/date window for which this request is effective. This includes the start time/date and end time/date or duration. The method also supports starting immediately and indefinite durations. Note: The specific handling of schedules is dependent on the protocol used to support these methods. This document seeks to utilize existing scheduling mechanisms to the extent possible. Some protocols may allow for a comprehensive schedule of many time intervals be transmitted in a single exchange, others may involve a series of single interval definitions.
Meter reference	
Real Power Limiting Mode	An identifier of which mode is requested: 1. Unspecified Distribution, Percent or Power Value Setting 2. Even Distribution, Percent Value Setting
Power Quantity ID	Identifier of which real power parameter is being limited: • Real Power Total (Delivered or Received) • Real Power Phase A (Delivered or Received) • Real Power Phase B (Delivered or Received) • Real Power Phase C (Delivered or Received)
Real Power Limit Value	For use in association with Mode 1, the real power limit value (Watts)
Real Power Limit Percent	For use in association with Mode 2, the real power limit percentage (% of nameplate real power capability)

Table 16-3
Information Exchanged for Group Real Power Limit Responses

Information Name	Information Description
Action Identifier	Defining what this message represents: • Real Power Generated Limit • Real Power Absorbed Limit
DER Group ID	The unique identifier for the DER group for which a Real Power Limit was requested
Success / Failure Indicator(s)	Indication of whether or not, or to what extent, the command could be accommodated. Chapter 7 describes the Success/Failure indicators and Table 7-2 identifies those that are applicable to this response.

17
DER GROUP RAMP RATE LIMIT CONTROL

Purpose

The purpose of this function is to manage the maximum ramp rates at the DER Group Level. This type of control at the group level is consistent with individual DER capabilities that are identified in the IEC 61850-7-420 and 61850-7-520 standards. DER group managing entities may use those settings in the process of providing the services called-out here.

Technical Approach

In general, when DER are organized into groups and managed as such, the entity managing the group may use any preferred method to achieve the group-level goals. However, in the case of ramp-rate controls, it is recognized that the ramp limits may be desired at the group-level or individual device level, depending on the circumstances and the nature of the DER group, as described in the following two modes.

Individual Device Ramp Rate Control Mode

In this mode of ramp-rate control, the ramp-rate settings that are applied to the DER group are intended to be adhered-to directly to each member of the group. An example in which this mode of control may be preferred is that of a group of small solar PV plants that are distributed along a feeder. In such a case, the individual DER may have no knowledge of the conditions at the other DER. Further, there may not be any reference points of metering at which ramp rate control is desired, other than at the individual DER points of common coupling.

To achieve this control mode, the group managing entity may write the same ramp-rate settings to each member of the DER group, allowing each to manage their own ramping behavior thereafter.

Aggregated Ramp Rate Control Mode

In this mode of ramp-rate control, the settings that are applied to the DER group are intended to be adhered-to at the group-level, at a specific point of reference. In this case, the DER group managing entity may or may not disseminate the group ramp-rate settings to the individual DER equally. An example in which this mode may be utilized is that of a clustered group of DER (e.g. an industrial plant) that includes a battery storage system and a single point of coupling to the grid. In such a case, the group-managing entity may utilize the battery storage system and a reference meter to perform the "Real Power Smoothing Function" described in Chapter 17 of the EPRI "Common Functions for Smart Inverters" report[8]. In this way, the ramp rates of individual PV and other DER in the group may not be managed, and yet the aggregate ramp rate at the point of coupling to the grid would meet the group-level goal by the smoothing action of the battery storage system.

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[8] *Common Functions for Smart Inverters, Version 3.* EPRI, Palo Alto, CA: 2014. 3002002233.

Summary of DER Group Ramp Rate Control Items

Table 17-1
Information Exchanged for DER Group Ramp-Rate Control Requests

Information Name	Information Description
Action Identifier	Defining what is being requested: • DER Group Ramp-Rate Control Request
Priority	A parameter to identify the priority-level associated with this control message. Protocol mappings will identify (a) if a priority is/isn't defined and (b) a range of at least 10 priority levels. Determination of whether and how priority levels are assigned is up to power system operator/designers.
Requesting Entity ID	The unique identifier of the last entity (e.g. upstream DERMS or other actor) who created (or last modified) this request. For example, if a transmission system operator originally initiated an action, but prior to receipt the request (settings/values) was modified by a distribution system operator, then this field would contain the distribution operator's system ID.
DER Group ID	The unique identifier for the DER group for which the control is being requested
Effectivity Schedule	The time/date window for which this request is effective. This includes the start time/date and end time/date or duration. The method also supports starting immediately and indefinite durations.
Ramp Rate Control Mode	Identifier of the mode of ramp-rate control being requested (see description above): • Individual Device Ramp Rate Control Mode • Aggregated Ramp Rate Control Mode
Metering Point of Reference	(For aggregate mode) The mRID of the meter and metered quantity to which the control applies.
Normal Ramp-Up Rates	The maximum rate at which increases in DER Group real power output are permitted during normal operation.
Normal Ramp-Down Rates	The maximum rate at which decreases in DER Group real power output are permitted during normal operation.
Emergency Ramp-Up Rate	The maximum rate at which increases in DER Group real power output are permitted during power system events such as voltage sags and subsequent recovery.
Emergency Ramp-Down Rate	The maximum rate at which decreases in DER Group real power output are permitted during power system events such as voltage sags and subsequent recovery.
Soft-Connect Ramp Rate	The maximum rate at which increases in DER Group real power output are permitted during start-up.
Soft-Disconnect Ramp Rate	The maximum rate at which decreases in DER Group real power output are permitted during shut-down or disconnect.

Table 17-2
Information Exchanged for DER Group Ramp Rate Control Responses

Information Name	Information Description
Action Identifier	Defining what is being passed: • DER Group Ramp Rate Control Response
DER Group ID	The unique identifier for the DER group for which the control applies
Quantity ID	Identifier of the parameter for which the forecast applies. (see list in the request)
Success / Failure Indicator(s)	Indication of whether or not, or to what extent, the command could be accommodated. Chapter 7 describes the Success/Failure indicators and Table 7-2 identifies those that are applicable to this response.

18
DER GROUP PHASE BALANCE LIMITING

Purpose

The purpose of this function is to set phase balance limits within which a DER group managing entity must operate. Support of this function depends on the DER group managing entity knowing the system phase (A, B, C) to which single-phase DER are connected and the phasing (mapping) of poly-phase DER to the system phases. This information may be stored in the system model.

Many of the DER group control functions described herein operate (always or optionally) at the three-phase total level. For example, the real and reactive power dispatch functions may typically be called in relation to the total power, without specifying how that power is distributed across the phases of the system.

Discipline could be used in the formation of groups such that there is reasonable phase balance representation within each group. However, DER group management functions generally give the group-managing entity the liberty to provide a given service using any means deemed appropriate. As a result, phase-imbalanced scenarios could result from a dispatch action even though the members of a given group are well balanced in terms of their capabilities.

This function addresses this issue by providing a means by which DER group managing entities can be provided with:

a. Understanding of which DER are connected to which power system phase and

b. Limits on how balanced services must remain

Technical Approach

Summary of DER Group Phase Balance Limiting Items

Table 18-1
Information Exchanged for Individual DER Phase Identification Requests

Information Name	Information Description
Action Identifier	Defining what is being requested: • Individual DER Phase Identification Request
Individual DER ID	The unique identifier (e.g. mRID) for the individual DER for which phase connectivity is being identified
Phase Connectivity	Identifier of the phase connectivity for the referenced: • Single Phase Device Map to System Phase (A, B, or C) Or: • Device Phase A/1 Map to System Phase (A, B, C, or Not Applicable) • Device Phase B/2 Map to System Phase (A, B, C, or Not Applicable) • Device Phase C/3 Map to System Phase (A, B, C, or Not Applicable)

Table 18-2
Information Exchanged for Individual DER Phase Identification Responses

Information Name	Information Description
Action Identifier	Defining what is being passed: • Individual DER Phase Identification Response
Individual DER ID	The unique identifier for the individual DER for which the phase identification was applied
Success / Failure Indicator(s)	Indication of whether or not, or to what extent, the command could be accommodated. Chapter 7 describes the Success/Failure indicators and Table 7-2 identifies those that are applicable to this response.

Table 18-3
Information Exchanged for DER Group Phase Balance Limit Requests

Information Name	Information Description
Action Identifier	Defining what is being requested: • DER Group Phase Balance Limit Request
Priority	A parameter to identify the priority-level associated with this control message. Protocol mappings will identify (a) if a priority is/isn't defined and (b) a range of at least 10 priority levels. Determination of whether and how priority levels are assigned is up to power system operator/designers.
Requesting Entity ID	The unique identifier of the last entity (e.g. upstream DERMS or other actor) who created (or last modified) this request. For example, if a transmission system operator originally initiated an action, but prior to receipt the request (settings/values) was modified by a distribution system operator, then this field would contain the distribution operator's system ID.
DER Group ID	The unique identifier (e.g. mRID) for the DER Group for which phase balance limiting is to be applied
Effectivity Schedule	The time/date window for which this request is effective. This includes the start time/date and end time/date or duration. The method also supports starting immediately and indefinite durations.
Phase Balance Limit for Real Power	Limit on real power imbalance expressed as a percentage of the DER group's total (all phases) real power. Applies to both real power absorption and production.
Phase Balance Limit for Reactive Power	Limit on reactive power imbalance expressed as a percentage of the DER group's total (all phases) reactive power. Applies to both capacitive and inductive reactive power.

Table 18-4
Information Exchanged for Individual DER Group Phase Balance Limit Responses

Information Name	Information Description
Action Identifier	Defining what is being passed: • DER Group Phase Balance Limit Response
DER Group ID	The unique identifier for the DER Group for which the phase balance limiting was applied
Success / Failure Indicator(s)	Indication of whether or not, or to what extent, the command could be accommodated. Chapter 7 describes the Success/Failure indicators and Table 7-2 identifies those that are applicable to this response.

19
DER GROUP REAL POWER DISPATCH

Purpose

The purpose of this function is to request/dispatch real power from a DER group. This method has two forms:

1. A request that the real power for the group be set to a specified level
2. A request that the real power for the group be raised/lowered by a specified amount

This function applies to software applications dealing with groups of DER. As such, it does not have direct bearing on how individual DERs within the group are managed. For example, if this function requests that the real power output from a group of 10 DER be reduced to a level that is 100kW less than the present value, it may be satisfied by each DER being reduced by 10kW, one DER being reduced by the whole 100kW, or any other distribution.

Technical Approach

This function is not concerned with the type of devices that make up the group. Real power dispatch could, for example, be achieved by increasing or decreasing storage charging or manageable load that is included in the DER group. The algorithms and methods by which individual DER are managed is out of scope and is viewed as the responsibility of the entity directly managing the downstream DER, such as a DERMS or third party aggregator.

The defined functions for creating and managing DER groups apply to this function. It requires that the referenced DER group definition (i.e. the list of which DER make up the group) is known and agreed-to by both the real-power-requesting and real power-providing entities. As described previously, the makeup of the group could have been defined by the requestor, the provider, or any other entity, and its creation could have been a manual or automated process.

Figure 19-1 below illustrates an example real power dispatch sequence, with the group creation process assumed to have occurred at some point prior. In addition, this example shows that a status monitoring request may have also preceded the real power dispatch (shown as the UML "rectangle" referencing the status monitoring function); so that the requesting entity may know what range of adjustability is presently possible.

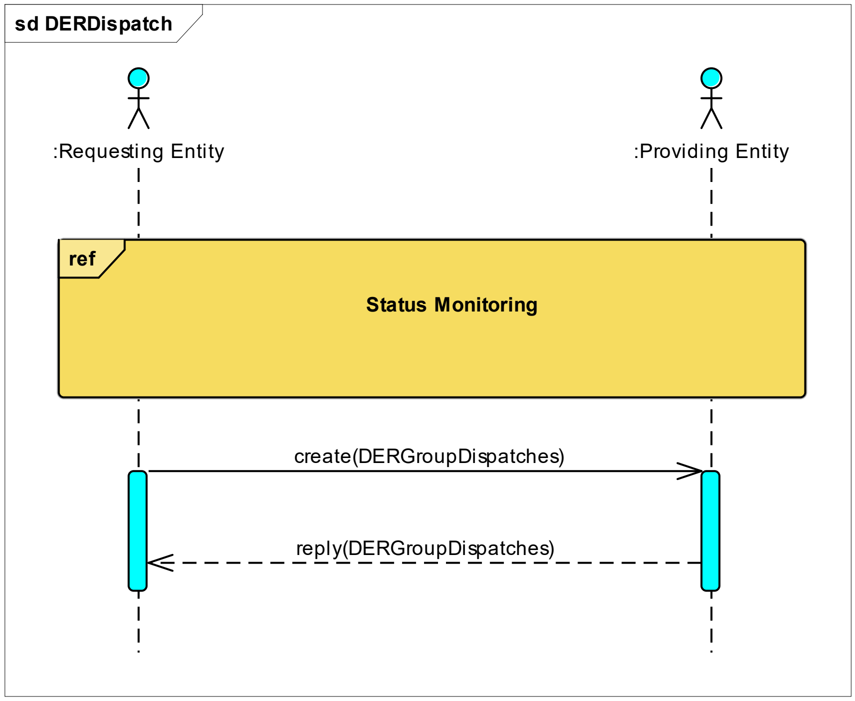

Figure 19-1
Example Sequence diagram for DERGroup Real Power Dispatch

Group creation (required) and status monitoring (optional) could occur immediately before the DERGroup Dispatch (request and reply) or any time prior. The group definitions used for real power dispatch would notionally be the same as those used for status monitoring.

Summary of DER Group Real Power Dispatch Information Items

The following information is passed in a DER Group Real Power Dispatch Request.

Table 19-1
Information Exchanged for Group Real Power Dispatch Requests

Information Name	Information Description

Action Identifier	Defining what is being requested:
	• Identifier of the type of dispatch being requested
	  o Absolute Real Power Level (W)
	  o Real Power Adjustment (W)

Priority	A parameter to identify the priority-level associated with this control message. Protocol mappings will identify (a) if a priority is/isn't defined and (b) a range of at least 10 priority levels. Determination of whether and how priority levels are assigned is up to power system operator/designers.
Requesting Entity ID	The unique identifier of the last entity (e.g. upstream DERMS or other actor) who created (or last modified) this request. For example, if a transmission system operator originally initiated an action, but prior to receipt the request (settings/values) was modified by a distribution system operator, then this field would contain the distribution operator's system ID.
DER Group ID	The unique identifier for the DER group for which a real power level is being requested
Effectivity Schedule	The time/date window for which this request is effective. This includes the start time/date and end time/date or duration. The method also supports starting immediately and indefinite durations.
Power Quantity ID	Identifier of which real power parameter is being dispatched: • Power Total (Delivered or Received) • Power Phase A (Delivered or Received) • Power Phase B (Delivered or Received) • Power Phase C (Delivered or Received)
Ramp Time	Time window (in seconds) over which the group real power is to be adjusted in response to this control action
Requested Power Level	The absolute real power level (Watts) for the identified "Power Quantity ID" of the DER group. This value is only relevant for "Absolute Real Power Level" control. To accommodate battery storage and other DER types, this value is signed, with positive values indicating power generated by the DER group and negative values indicating power absorbed.
Requested Power Adjustment	An adjustment to the real power level (Watts) for the identified "Power Quantity ID" of the DER group. This value is only relevant for Real Power Adjustment" control. This value is signed, with positive values indicating more power generated by the DER group (or less absorbed) and negative values indicating less power generated by the DER group (or more absorbed).

Table 19-2
Information Exchanged for Group Real Power Dispatch Responses

Information Name	Information Description
Action Identifier	Defining what this message represents: • Real power dispatch request response
DER Group ID	The unique identifier for the DER group for which a real power dispatch level was requested
Success / Failure Indicator(s)	Indication of whether or not, or to what extent, the command could be accommodated. Chapter 7 describes the Success/Failure indicators and Table 7-2 identifies those that are applicable to this response.

20
DER GROUP REACTIVE POWER DISPATCH

Purpose

The purpose of this function is to request/dispatch reactive power from a DER group. This method is in the form of a request that the reactive power for the group be set to a specified level.

This function applies to applications dealing with groups of DER. As such, it does not have direct bearing on how individual DERs within the group are managed. For example, if this function requests that the reactive power output from a group of 10 DER be reduced to a level that is 100kVar less than the present value, it may be satisfied by each DER being reduced by 10kVar, one DER being reduced by the whole 100kVar, or any other distribution.

This function is not concerned with the type of devices that make up the group. Reactive power dispatch could, for example, be achieved by switching physical capacitors in/out. The algorithms and methods by which individual DER are managed is out of scope and is viewed as the responsibility of the entity directly managing the downstream DER, such as a DERMS or third party aggregator.

The defined methods of defining and managing DER groups apply to this function. It requires that the referenced DER group definition (i.e. the list of which DER make up the group) is known and agreed-to by both the reactive-power-requesting and reactive power-providing entities. As described previously, the makeup of the group could have been defined by the requestor, the provider, or any other entity, and its creation could have been a manual or automated process.

Technical Approach

Figure 20-1 illustrates a real power dispatch sequence, with the group creation process assumed to have occurred at some point prior. In addition, this example shows that a status monitoring request may have also preceded the real power dispatch (shown as the UML “rectangle” referencing the status monitoring use case); so that the requesting entity may know what range of adjustability is presently possible.

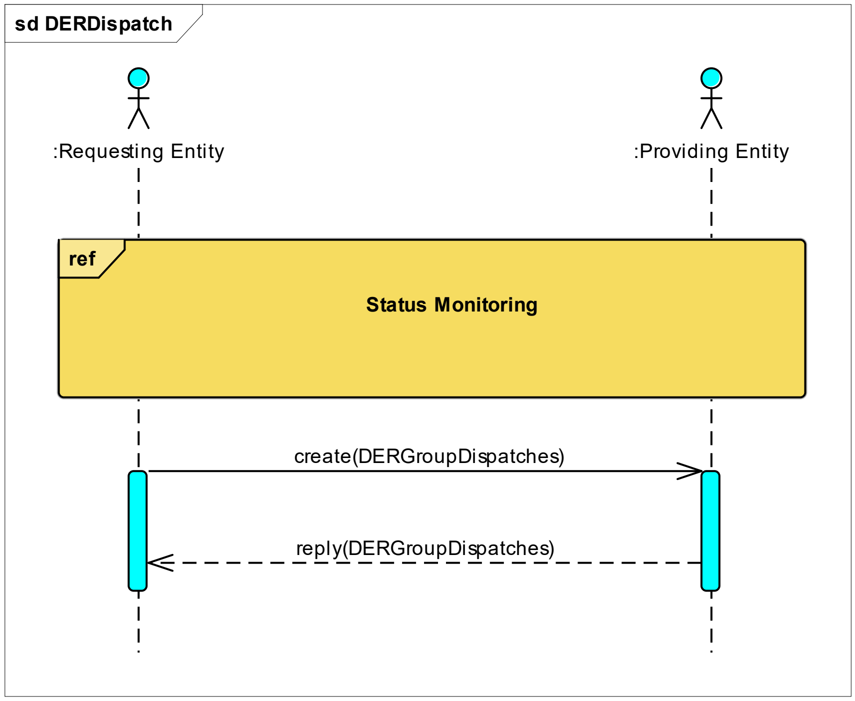

Figure 20-1
Example Sequence Diagram for DERGroup Reactive Power Dispatch

Group creation (required) and status monitoring (optional) could occur immediately before the DERGroup Reactive Power Dispatch (request and reply) or any time prior. The group definitions used for reactive power dispatch would notionally be the same as those used for status monitoring.

Summary of DER Group Reactive Dispatch Information Items

The following information is passed in a DER Group Reactive Power Dispatch Request:

Table 20-1
Information Exchanged for Group Reactive Power Dispatch Requests

Information Name	Information Description

Action Identifier	Defining what is being requested:
	• Identifier of the type of dispatch being requested (Reactive Power (VAR)
	  ○ Absolute Reactive Power Level (Vars)
	  ○ Reactive Power Adjustment (Vars)

Priority	A parameter to identify the priority-level associated with this control message. Protocol mappings will identify (a) if a priority is/isn't defined and (b) a range of at least 10 priority levels. Determination of whether and how priority levels are assigned is up to power system operator/designers.
Requesting Entity ID	The unique identifier of the last entity (e.g. upstream DERMS or other actor) who created (or last modified) this request. For example, if a transmission system operator originally initiated an action, but prior to receipt the request (settings/values) was modified by a distribution system operator, then this field would contain the distribution operator's system ID.
DER Group ID	The unique identifier for the DER group for which a reactive power level is being requested
Effectivity Schedule	The time/date window for which this request is effective. This includes the start time/date and end time/date or duration. The method also supports starting immediately and indefinite durations.
Power Quantity ID	Identifier of which reactive power parameter is being dispatched: • Reactive Power Total (Delivered or Received) • Reactive Power Phase A (Delivered or Received) • Reactive Power Phase B (Delivered or Received) • Reactive Power Phase C (Delivered or Received)
Ramp Time	Time window (in seconds) over which the group reactive power is to be adjusted in response to this control action
Requested Reactive Power Level	The absolute reactive power level (Vars) for the identified "Power Quantity ID" of the DER group. This value is only relevant for "Absolute Reactive Power Level" control. The sign of reactive power values is complicated and handled in different ways in various IEC and IEEE standards. To meet the needs of this function it is required that the absolute reactive power setting can be either capacitive or inductive with real power being either delivered or received (e.g. for battery systems). The specific sign will be defined by the protocol used to support this function.
Requested Reactive Power Adjustment	An adjustment to the reactive power level (Vars) for the identified "Power Quantity ID" of the DER group. This value is only relevant for Reactive Power Adjustment" control. The sign of reactive power values is complicated and handled in different ways in various IEC and IEEE standards. To meet the needs of this function it is required that the reactive power adjustment can be either increase or decrease the present values. It also acknowledges that the present levels may be either capacitive or inductive with real power being either delivered or received (e.g. for battery systems). The specific sign will be defined by the protocol used to support this function.

Table 20-2
Information Exchanged for Group Reactive Power Dispatch Responses

Information Name	Information Description
Action Identifier	Defining what this message represents: • Reactive power dispatch request response
DER Group ID	The unique identifier for the DER group for which a reactive power dispatch level was requested
Success / Failure Indicator(s)	Indication of whether or not, or to what extent, the command could be accommodated. Chapter 7 describes the Success/Failure indicators and Table 7-2 identifies those that are applicable to this response.

21
DER GROUP VOLTAGE REGULATION FUNCTION

Purpose

This is a control function by which DER support for various voltage needs may be requested. Requesting entities could specify a target voltage or an increase/decrease adjustment. Requests could be made at any group-level; such as a whole circuit, individual feeder (or segment thereof), microgrid, etc.

The entity providing this service (e.g. a DERMS) could use a variety of settings of individual DER in order to provide this service. This includes, for example, adjustments to the target voltage of various DER (e.g. Vnom in IEC 61850-90-7), and turning on/off or adjusting reactive power functions. Use cases for this function include feeder-level conservation voltage reduction which might be turned on/off in a dispatchable way to reduce peak loading.

Figure 21-1 illustrates a voltage regulation use case example that involves a microgrid.

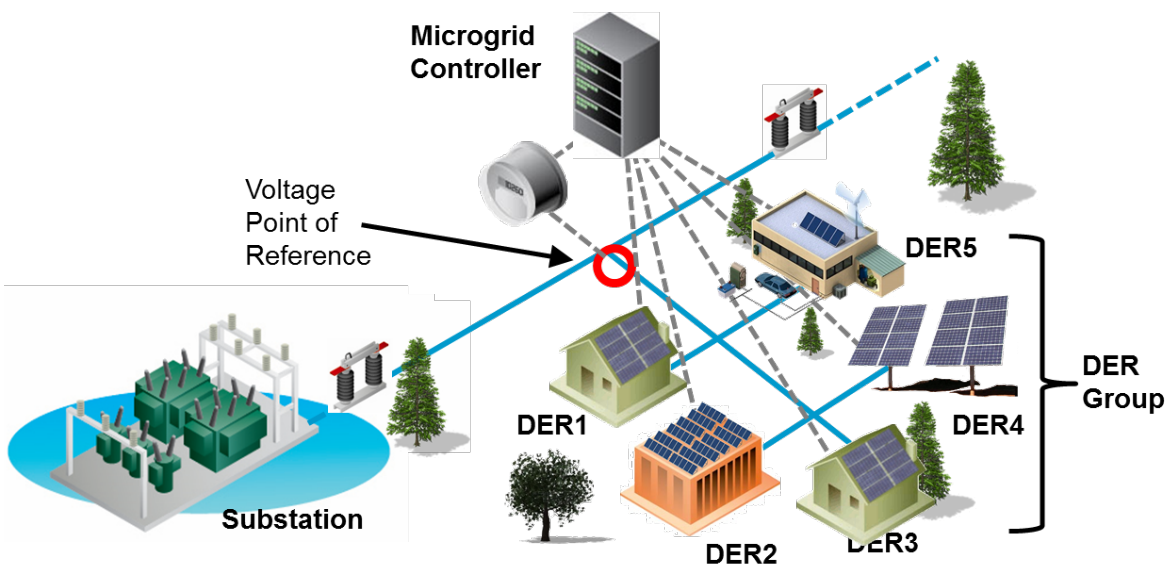

Figure 21-1
Example Voltage Regulation Function

In this example, the DER group is the set of unspecified resources that constitute a microgrid and the group-managing entity is a microgrid controller. In this example, the microgrid connects to the utility distribution system at a single point and it is to this point that the voltage regulation request is related. Upon activation of the voltage regulation function, the microgrid controller would operate (as possible) to maintain the voltage at the specified level.

The “Voltage Regulation” function specifies only the intended result, and not the control method by which the result is obtained. This is in contrast to other functions such as the “Set Group Curve” function which identify a specific control approach. For example, a microgrid controller that is carrying-out a voltage regulation function may operate fixed capacitors, may increase or decrease real power generation, may adjust reactive power levels (using any means), or any other strategy.

Technical Approach

The voltage regulation function will support the modes of operation specified in Table 21-1 and described in the following sections.

Table 21-1
Voltage Regulation Function Modes of Operation

Voltage Regulation Function Mode Number	Description
1	Single Point Reference
2	Average Reference

Mode 1: Single Point Reference

In this mode, the voltage regulation target that is applied to a DER Group is accompanied by an identifier of a single point of reference for voltage measurement, such as the mRID of a particular meter. The DER group managing entity then operates (as possible) to manage voltage at this reference point.

Mode 2: Average Reference

In this mode, the voltage regulation target that is applied to a DER Group is to be associated with the average voltage at the DER members of the group.

Use of this mode is complicated by factors that make the exact voltage uncertain at the individual DER, such as adjustable taps on distribution transformers. As such, use of this mode is driven primarily by the lack of an independent point of reference that might otherwise enable the use of Mode 1, and the DER group managing entity is left to use the average of the voltages at the individual DER as a representative indicator.

Summary of Information Items for the “Voltage Regulation Function”

Table 21-2
Information Exchanged for “Voltage Regulation” Function Requests

Information Name	Information Description
Action Identifier	Defining what is being requested: • Start / Stop Voltage Regulation Function
Priority	A parameter to identify the priority-level associated with this control message. Protocol mappings will identify (a) if a priority is/isn’t defined and (b) a range of at least 10 priority levels. Determination of whether and how priority levels are assigned is up to power system operator/designers.
Requesting Entity ID	The unique identifier of the last entity (e.g. upstream DERMS or other actor) who created (or last modified) this request. For example, if a transmission system operator originally initiated an action, but prior to receipt the request (settings/values) was modified by a distribution system operator, then this field would contain the distribution operator’s system ID.
DER Group ID	The unique identifier for the DER group for which the voltage regulation request relates
Effectivity Schedule	The time/date window for which this request is effective. This includes the start time/date and end time/date or duration. The method also supports starting immediately and indefinite durations.
Voltage Regulation Function Mode	Indicator of which mode of operation is to be used in applying the curve function to the members of the group (see Table 21-1).
Measurement Reference Point (optional)	For Mode 1, which uses a single point of reference, this parameter specifies the unique identifier (e.g. mRID) of the meter or other measurement device.
Voltage Control Point	A percentage value (% of Vnom) – the target control voltage.
Start Time/Date	The time/date at which this function is to take effect.
Randomization Time	A time window over which the DER Group managing entity is to delay before beginning to activate the new setting (for example, reference IEC 61850-7-420)
Ramp Time	A time over which the DER group managing entity is to transition to the new settings once it begins to activate the function. (Note: the ramp time follows the randomization time if both are used).

Table 21-3
Information Exchanged for Voltage Regulation Function Responses

Information Name	Information Description
Action Identifier	Defining what command is being responded-to: • Voltage Regulation Function Response
DER Group ID	The unique identifier for the DER group for which the response applies
Success / Failure Indicator(s)	Indication of whether or not, or to what extent, the command could be accommodated. Chapter 7 describes the Success/Failure indicators and Table 7-2 identifies those that are applicable to this response.

22

DER GROUP PRIMARY FREQUENCY RESPONSE FUNCTION

Purpose

This function is intended to allow DER groups to be utilized for primary frequency response services. This function differs from the regulation function of Chapter 24 in that it does not involve an ACE signal provided in a telemetry stream. This function has two forms:

1. Frequency droop (Watts as a function of df/dt)
2. Synthetic inertia

Technical Approach

<To be addressed here in a future revision>

Table 22-1
Information Exchanged for DER Group Primary Frequency Response Function Requests

Information Name	Information Description

Table 22-2
Information Exchanged for DER Group Primary Frequency Response Function Responses

Information Name	Information Description

23

SET DER GROUP CURVE FUNCTIONS

Purpose

Individual DER, particularly inverter-based DER, may be capable of providing a number of curve functions. These functions, such as volt-var control, were developed during early industry efforts regarding solar and battery storage systems and are now documented in the EPRI "Common Functions for Smart Inverters" report[1] and the IEC 61850-7-420 standard. The term "curve" refers to the functions having a controlling-variable (e.g. local voltage or frequency) and a controlled variable (e.g. real or reactive power produced) the relationship of which is determined by a set of X-Y configuration points and associated piece-wise linear "curve" as illustrated in Figure 23-1.

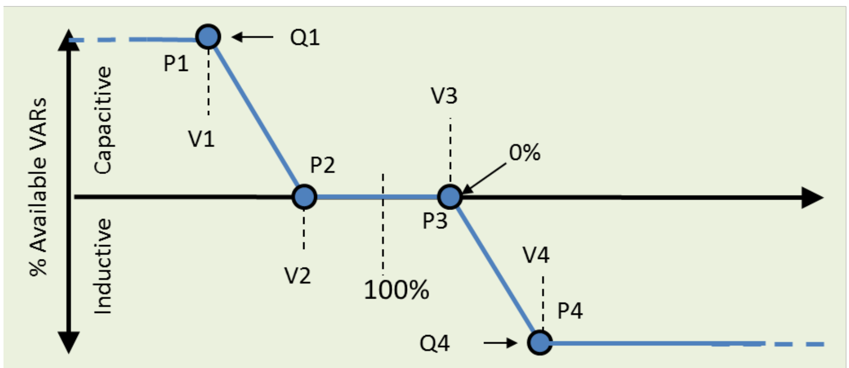

Figure 23-1
Example Curve Function for a Single DER

The purpose of the "Set DER Group Curve" function is to enable curve-type functions to be applied to groups of DER. This is not straight-forward for several reasons, most notably because the controlling variable may be different at each DER. For example, consider a group made up of solar inverters that are scattered along a feeder. Since the voltage of the feeder may be high near the substation and low at the end of line, the same volt-var curve would result in very different actions by each component in the group.

Advanced distribution management systems and other tools for planning and system operators need to know how curve settings are applied to groups of DER in order to make proper use of the function.

Technical Approach

The Set DER Group Curve function will allow DER groups to be set with the curve types identified in Table 23-1.

Table 23-1
List of Curve Functions for DER Groups

DER Group Curve Function Reference ID	Curve Function	Description
1	Volt-Var (Watts-precedence)	This curve function is a “go-to” control type. The reactive power of the DER group varies with voltage according to the curve settings. The specified Var levels are a percentage of “available Vars”, where the definition of “available vars” is that quantity which can be achieved without compromising the real power output of the group.
2	Volt-Var (Vars precedence)	This curve function is a “go-to” control type. The reactive power of the DER group varies with voltage according to the curve settings. The specified Var levels are a percentage of the maximum installed Var capability of the group. In this case, the real power output of the DER group may be reduced in order to provide the required reactive power.
3	Frequency-Watt	This curve function is a boundary/limiting type. The real power of the DER group is hereby limited according to the curve settings as a function of the grid frequency.
4	Volt-Watt	This curve function is a boundary/limiting type. The real power of the DER group is hereby limited according to the curve settings as a function of the grid voltage.
5	PowerFactor-Watt	This curve function is a go-to control type. The power factor of the DER group is hereby managed according to the curve settings as a function of the grid voltage.

Curve functions for DER Groups may be called in any of the five modes of operation listed in Table 23-2 and described in the following sections.

Table 23-2
DER Group Curve Function Modes of Operation

DER Group Curve Function Mode Number	Description
1	Local Reference
2	Single Point Reference – Even Distribution
3	Single Point Reference – Unspecified Distribution
4	Average Reference – Even Distribution
5	Average Reference – Unspecified Distribution

Mode 1: Local Reference

In this mode, the curve settings that are sent to a DER Group are to be distributed as-is to all members of group. For example, the same volt-var curve could be set in all members of the group. Because the voltage (controlling variable) may be different at each DER, the resulting %

reactive power level may also be different. This mode may be preferred in cases in which particular local behaviors are the goal and the sum effect of the group is less of a concern.

Figure 23-2 provides an illustration of this mode. In this example, the volt-var curve shown in the upper left hand corner is applied to the DER Group made up of five resources. This curve is then applied to each DER which respond based on their local voltage. Because the voltages vary as shown in the voltage-profile, the level of reactive power output also varies as summarized in Table 23-3.

Table 23-3
Local Reference Volt-Var Mode Example

DER	Local Voltage	Resulting Reactive Power Level
1	1.04pu	100% of Var capacity, Inductive
2	1.02pu	35% of Var capacity, Inductive
3	1.00pu	0% of Var capacity
4	0.99pu	0% of Var capacity
5	0.98pu	35% of Var capacity, Capacitive

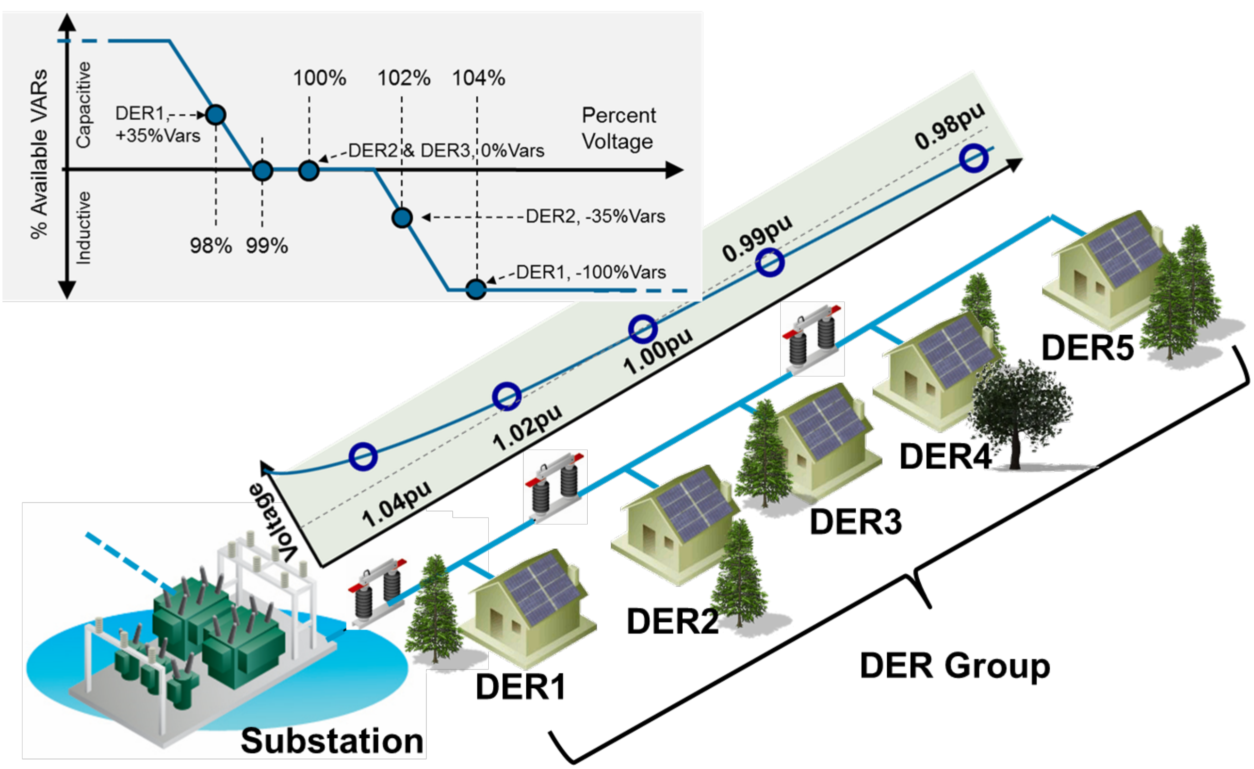

Figure 23-2
Local Reference Mode

Mode 2: Single Point Reference – Even Distribution

Mode 2 involves the identification of a single point of reference as the measurement point for the controlling-variable of the curve function. The DER Group is provided with the curve settings, along with the identification of a particular metering point on the power system that determines the controlling variable (horizontal axis) of the curve function for all DER in the Group. The entity calling this group function and the entity providing the group function must understand the unique identifier of the reference metering point.

This mode could be used, for example, when a group of DER are clustered together within a single facility or downstream of a single distribution transformer with a single point at which they tie to a distribution circuit. In such a case, it may be desirable to have all the DER in the group act based on the parameters observed at that single point of coupling.

Figure 23-3 provides an illustration of the single point reference mode. In this example, the same volt-var curve used in the previous example is applied. But since a single point of reference is identified at which the voltage is 1.02pu, all DER in the group operate at 35% of Var capacity, inductive.

Mode 2 does not specify whether or not the members of the DER group have direct access to the measurements at the point of reference, nor does it imply that the individual members must be operating in an equivalent curve mode in order to achieve the intended effect. Indeed, the individual members may not have the capability to follow a remote measurement. For example, the entity managing the DER Group (a DERMS) could directly monitor the voltage at the point of reference, then continuously send fixed Var settings to group members in order to achieve a volt-var function at the DER Group level.

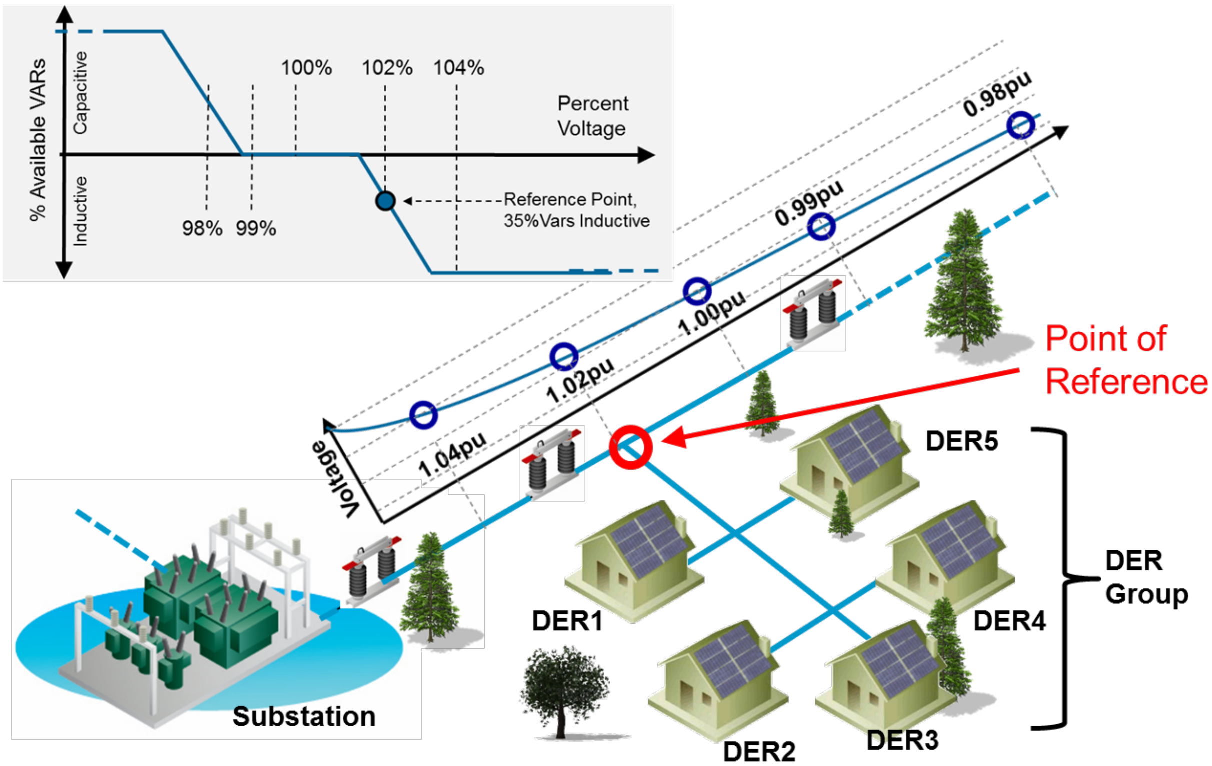

Figure 23-3
Single-Point Reference Mode

Mode 3: Single Point Reference – Unspecified Distribution

Mode 3 is the similar to Mode 2 in that a single point of reference is specified. However, Mode 3 does not require or assume that the service provided is evenly distributed among the members of the group. Instead, Mode 3 requires only that the aggregate effect follows the specified curve.

For example, consider the volt-var settings, circuit arrangement and point of reference of Figure 23-3. If the individual DER that make up the group have the Var capacities listed in Table 23-4, Examples for DER Group Curve Functions in Mode 3 Table 23-4, then the total Var capacity of the group is 20,000 [Vars]. Per the example volt-var curve and voltage at the point of reference of 1.02pu, the Var level should by 35% of capacity inductive. For this DER group, this amounts to 0.35*20,000 = 7,000[Var].

Since Mode 3 has no requirement for how the overall level is achieved, the entity managing this DER Group could achieve the 7,000[Var] total in any number of ways, as illustrated by the three examples described below and summarized in Table 23-4:

- Example 1: The DER Group managing entity gets all of the required Vars from one DER in the group.
- Example 2: The DER Group managing entity gets the same quantity of Vars from each member of the group.
- Example 3: The DER Group managing entity has each member of the group provide in proportion to their capacity in order to achieve the required total Vars.

Table 23-4
Examples for DER Group Curve Functions in Mode 3

DER	Var Capacity	Example 1 Settings	Example 2 Settings	Example 3 Settings
1	3,000	0	1,400	1,050
2	4,000	0	1,400	1,400
3	7,000	7,000	1,400	2,450
4	2,500	0	1,400	875
5	3,500	0	1,400	1,225
Total	**20,000**	**7,000**	**7,000**	**7,000**

Like Mode 2, Mode 3 does not specify whether or not the members of the DER group have direct access to the measurements at the point of reference, nor does it imply that the individual members must be operating in an equivalent curve mode in order to achieve the intended effect.

Mode 4: Average Reference – Even Distribution

Mode 4 is identical to mode 2, except that the reference voltage is defined as the average of the local voltages of the members of the DER group. In this mode, the average voltage is to be determined by a simple average, not weighted by the size of the individual DER at each location.

The result is the same in that the individual DER may have no direst way of knowing the average voltage, so the DER managing entity may constantly adjust the settings of the group members, using fixed or curve-based settings to achieve the desired aggregate effect.

Mode 5: Average Reference – Unspecified Distribution

Mode 5 is identical to mode 3, except that the reference voltage is defined as the average of the local voltages of the members of the DER group. In this mode, the average voltage is to be determined by a simple average, not weighted by the size of the individual DER at each location.

The result is the same in that the individual DER may have no direst way of knowing the average voltage, so the DER managing entity may constantly adjust the settings of the group members, using fixed or curve-based settings to achieve the desired aggregate effect.

Summary of Information Items for "Set DER Group Curve Function"

Table 23-5
Information Exchanged for Set DER Group Curve Function Requests

Information Name	Information Description
Action Identifier	Defining what is being requested: • Set DER Group Curve Function
Priority	A parameter to identify the priority-level associated with this control message. Protocol mappings will identify (a) if a priority is/isn't defined and (b) a range of at least 10 priority levels. Determination of whether and how priority levels are assigned is up to power system operator/designers.
Requesting Entity ID	The unique identifier of the last entity (e.g. upstream DERMS or other actor) who created (or last modified) this request. For example, if a transmission system operator originally initiated an action, but prior to receipt the request (settings/values) was modified by a distribution system operator, then this field would contain the distribution operator's system ID.
DER Group ID	The unique identifier for the DER group for which the curve function is to be set
Effectivity Schedule	The time/date window for which this request is effective. This includes the start time/date and end time/date or duration. The method also supports starting immediately and indefinite durations.
DER Group Curve Function Reference ID	An indicator of which type of curve function (see Table 23-1)
DER Group Curve Function Mode	Indicator of which mode of operation is to be used in applying the curve function to the members of the group (see Table 23-2).
Measurement Reference Point (optional)	For Modes 2 and 3, which use a single point of reference, this parameter specifies the unique identifier (e.g. mRID) of the meter or other measurement device.
Curve Settings	Array of X-Y points that define the piece-wise linear curve to be applied. This data is based on the existing curve settings model in IEC 61850-7-420, including the length of the array and the potential to support hysteresis.
Randomization Time	A time window over which the DER Group managing entity is to delay before beginning to activate the new setting (for example, reference IEC 61850-7-420)
Ramp Time	A time over which the DER group managing entity is to transition to the new settings once it begins to activate the function. (Note: the ramp time follows the randomization time if both are used).

Table 23-6
Information Exchanged for Set DER Group Curve Function Responses

Information Name	Information Description
Action Identifier	Defining what command is being responded-to: • Set DER Group Curve Function Response
DER Group ID	The unique identifier for the DER group for which the response applies
Response Time Indicator for the given group, curve, and mode	An indicator of the response time of the DER Group's ability to follow the indicated curve. Depending on the type of curve, the mode of operation, and the nature of the measurement and communication systems that exist within the DER Group, the speed with which a group curve is followed may vary.
Success / Failure Indicator(s)	Indication of whether or not, or to what extent, the command could be accommodated. Chapter 7 describes the Success/Failure indicators and Table 7-2 identifies those that are applicable to this response.

24
REGULATION FUNCTION

Purpose

This is a function by which DER Group managing entities may provide regulation services to system operators or balancing authorities. This regulation function specifically refers to services that relate to an Area Control Error (ACE) signal, and is separate from the "Primary Frequency Response" function which is addressed separately in this document.

This has also been referred-to as a "Frequency Regulation" service, but the working group preferred to use the more correct term of just "Regulation" service. This terminology reflects the fact that ACE signals are reflective of multiple components:

- Frequency – this component reflects the present frequency error (delta-frequency)
- Power net interchange – this component reflects the present net power import/export for the balancing authority
- Time error – this component reflects the time error of the system (cumulative phase error)

Technical Approach

Some system operators define a symmetrical, bi-directional Regulation Service whereas others define separate "Regulation Up" and "Regulation Down" services. This body of work will be designed to support both, with each utilizing the appropriate message content for their service type.

It has been noted that the telemetry requirements in some markets differ based on the type of end device providing the regulation service, for example load vs generation. To the extent possible, this body of work will be agnostic to the type of end device providing the service. This is consistent with the concept of a DER Group Managing entity as the actor providing the service and allows for the possibility of mixed resource types in the same group as well as intelligence in the DER Group Managing entity as it determines the optimal way to provide a given service.

The technical approach involves two primary messages – the request signal passed from the entity requesting the regulation service to the entity providing it, and the response returned.

Although multiple components are involved in the dispatch signals (frequency, energy balance, time, etc.), they do not need to be sent to the service providing entity individually, but rather are factored into the ACE request signal according to the algorithms of the system operator.

In contrast to many DER Group management functions, regulation services may involve fast and frequent control signals (e.g. 2-4 seconds) and require status responses at the same rate. Such signals have been widely utilized in protocols like DNP3 and ICCP for conventional generator dispatch.

Response messages for regulation services may be used for both real-time operator feedback and settlement. Accordingly, the information exchanged in these messages must support the basic factors upon which payment and performance are based. Performance includes:

- Delay – a measure of how quickly the resulting service responds to ACE control signals
- Correlation – a measure of how well correlated the response is to the control signal over time
- Accuracy – a measure of how precisely the service responds to dispatch targets

Figure 24-1 illustrates a continuous telemetry stream associated with the regulation service. This illustration includes data provided to the downstream DER group-managing entity and upstream to the service-requesting entity as described in Table 24-1 and Table 24-2. The baseline is the point of reference (a power level which may be positive, negative, or zero) around which the regulation signal is being managed. The vertical axis in Figure 24-1 is the regulation signal (offset from baseline), so the baseline signal is shown as zero.

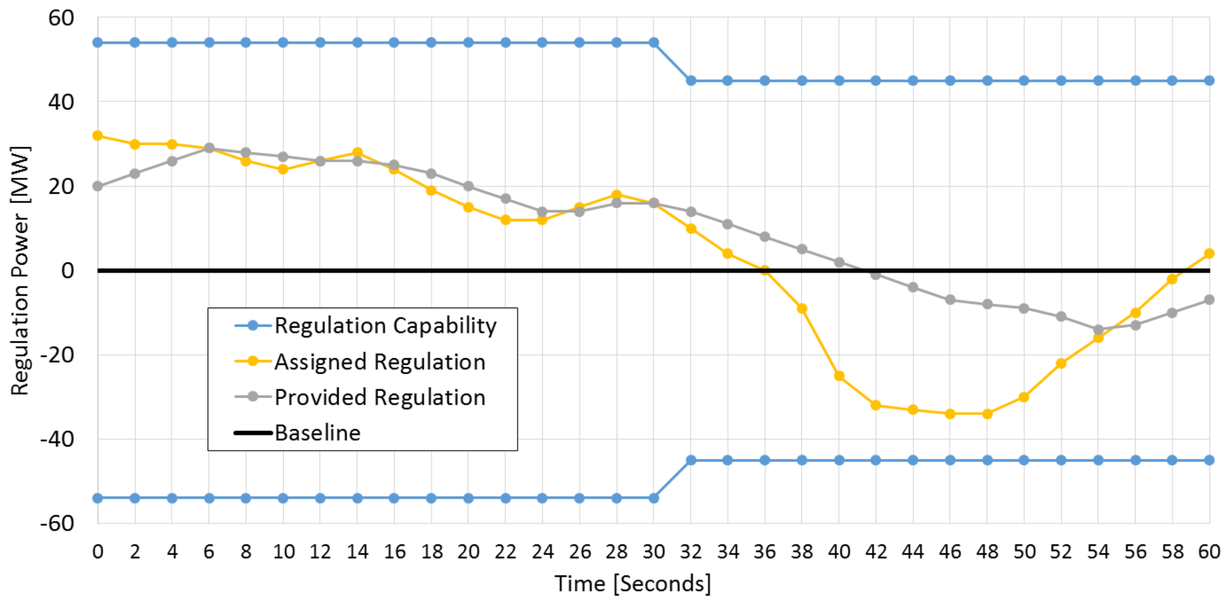

Figure 24-1
Regulation Data Example

Summary of Information Items for the "Regulation Function"

Table 24-1
Information Exchanged for Regulation Function Requests

<table>
<tr><th colspan="2">Information Name</th><th>Information Description</th></tr>
<tr><td colspan="2">Action Identifier</td><td>Defining what is being requested:
• Regulation Function Request Message</td></tr>
<tr><td colspan="2">Priority (optional)</td><td>If applicable, a parameter to identify the priority-level associated with this control message. Protocol mappings will identify (a) if a priority is/isn't defined and (b) a range of at least 10 priority levels. Determination of whether and how priority levels are assigned is up to power system operator/designers.</td></tr>
<tr><td colspan="2">Requesting Entity ID</td><td>The unique identifier of the entity who generated this control signal.</td></tr>
<tr><td colspan="2">DER Group ID</td><td>The unique identifier for the DER group for which the regulation signal(s) apply.</td></tr>
<tr><td rowspan="4">This set of parameters is required for each regulation program in which the entity is participating.</td><td>Regulation Program Identifier</td><td>Identifier of the particular regulation program to which this set of parameters applies:
• High Filter, Bi-Directional Regulation
• Low Filter, Bi-Directional Regulation
• High Filter, Up Regulation
• Low Filter, Up Regulation
• High Filter, Down Regulation
• Low Filter, Down Regulation</td></tr>
<tr><td>Assigned Baseline Power</td><td>If the entity providing the regulation service is also involved in the energy market, this quantity represents the present setpoint, or baseline power level. For example, the baseline power level for a generator for the present hour, expressed in Watts. This parameter may be set to zero if not applicable.

Note: For load groups providing regulation services, the baseline is communicated from the DER group managing entity to the service-requesting entity (see below).</td></tr>
<tr><td>ACE, Regulation Signal</td><td>This quantity is a requested deviation from the baseline power level. For example, if a DER group baseline is 100MW, and this value is set to -5MW, then the target is 95[MW].

For unidirectional programs, this parameter is limited to be only in one polarity.</td></tr>
<tr><td>Ramp Time</td><td>This optional quantity may be sent to specify the ramp rate at which providers of this service must transition to the power level specified in the ACE regulation signal. Alternatively, the ramp time, or time constant may be verified as part of the process of enrolling in the particular regulation program (e.g. a required response time for high-filter and another for low filter program participation).</td></tr>
</table>

Table 24-2
Information Exchanged for Regulation Function Responses

<table>
<tr><th colspan="2">Information Name</th><th>Information Description</th></tr>
<tr><td colspan="2">Action Identifier</td><td>Defining what command is being responded-to:
• Regulation Function Response</td></tr>
<tr><td colspan="2">DER Group ID</td><td>The unique identifier for the DER group for which the response applies</td></tr>
<tr><td rowspan="4">This set of parameters is required for each regulation program in which the entity is participating.</td><td>Regulation Capability</td><td>This parameter informs the upstream service-requesting entity of the real-time regulation capability of the DER group. Although this capability may be pre-determined in some scenarios (e.g. determined during the enrollment process), its inclusion here provides a means by which the downstream DER group managing entities may inform upstream entities of their present condition.

This parameter is provided in Watts, and as indicated in Figure 24-1 applies symmetrically both positive and negative for bi-directional regulation or in just one polarity for up-regulation or down-regulation services.</td></tr>
<tr><td>Provided Regulation</td><td>This parameter identifies the present level of regulation (deviation from baseline) being provided by the DER group.

This parameter is provided in Watts, and ideally would be equal to the previous assigned regulation.</td></tr>
<tr><td>Baseline Power</td><td>This parameter informs the service-requesting entity of the present baseline power level from which regulation offsets are based.
• For market-dispatched DER groups: this serves as a feedback mechanism by which the DER group-managing entity may echo-back the assigned baseline value to the service requesting entity.
• For load-based DER groups: this serves as a means for the DER group managing entity to inform the service requesting entity of the power-level basepoint around which the resource is being regulated.</td></tr>
<tr><td>Regulation Feedback</td><td>This is a feedback mechanism by which the DER group-managing entity may echo-back the assigned regulation value to the service requesting entity.</td></tr>
<tr><td colspan="2">Success / Failure Indicator(s)</td><td>Indication of whether or not, or to what extent, the command could be accommodated. Chapter 7 describes the Success/Failure indicators and Table 7-2 identifies those that are applicable to this response.</td></tr>
</table>

25
PROVIDE PRICE TO DER GROUP

Purpose

This is a function by which energy price signals can be provided to a group of DER (e.g. via a DERMS or DER aggregator). This function is not a bid/offer mechanism but implies that such markets (or other price-determining mechanisms), if they exist, have been conducted. This function is then useful for subsequent dissemination of settled price signals to DER group managing entities.

The price signals may be unique for the targeted DER Group or may be the same as that of other DER Groups or geographic regions. This function provides only price signals, and does not specify how receiving entities (such as a DERMS) may utilize the price information. Price information may be passed downstream to individual DER systems, which may modify their actions in response. For example, battery storage devices may manage charging/discharging in response to a price signal. Price information may also be used directly by a DERMS as a factor in how DER are managed.

Price signals could be provided for real power, for reactive power, or for other services that DER may render. This is different from (and may be parallel to) the function titled "Request Cost of Service from DER Group" in that in this scenario, the higher level entity is informing of the present value of a commodity such as Watt-hours.

Technical Approach

Energy markets and the utility industry overall are highly experienced at associating price signals with real energy (kWh), but are not very experienced with pricing other energy quantities or grid-supportive services that groups of DER may be able to provide. Nevertheless, it is conceivable that prices could be established for any service and such pricing and signaling could play a role in future power systems that include greater levels of distributed generation. With these factors in view, this focus group has identified a pricing framework that is capable of supporting price messages for a wide range of grid-supportive services.

Quantities for the Provide Price Function

The following potential services have been identified.

Table 25-1
Quantities to Which Price Signals May Apply

Quantity or Service	Description
Real Power Production (Watt-hours)	Rate for real power generated. Positive values are paid to the service-providing entity, negative values are charged to the service providing entity.
Real Power Consumption (Watt-hours)	Rate for real power consumed. Positive values are paid to the service-providing entity, negative values are charged to the service providing entity.
Reactive Power Capacitive (Var-hours)	Rate for capacitive reactive power. Positive values are paid to the service-providing entity, negative values are charged to the service providing entity.
Reactive Power Inductive (Var-hours)	Rate for inductive reactive power. Positive values are paid to the service-providing entity, negative values are charged to the service providing entity.
Dynamic Reactive Current	To be omitted or developed in ongoing focus group work. There is no known method for metering this service.
Volt-Var Control	To be omitted or developed in ongoing focus group work. There is no known method for metering this service. Best approach may be just metering provided capacitive and inductive Var-h provided.

Table 25-2
Information Exchanged for Price Signal Function Requests

Information Name	Information Description
Action Identifier	Defining what is being requested: • Providing price signal(s) to a DER group
Priority	A parameter to identify the priority-level associated with this control message. Protocol mappings will identify (a) if a priority is/isn't defined and (b) a range of at least 10 priority levels. Determination of whether and how priority levels are assigned is up to power system operator/designers.
Requesting Entity ID	The unique identifier of the last entity (e.g. upstream DERMS or other actor) who created (or last modified) this price signal. For example, if a transmission system operator originally initiated an action, but prior to receipt the request (settings/values) was modified by a distribution system operator, then this field would contain the distribution operator's system ID.
DER Group ID	The unique identifier for the DER group for which the price signal(s) apply.
Price Signal(s), Scaling and units	The price signal or signals. The protocol mappings to support this request shall include any definitions of scale factors and/or units needed to enable clear interpretation of the price signals.
Quantity Identifier(s)	Identifier(s) of the quantity or service to which the price signal(s) apply. See Table 25-1.
Requirements Associated with the Price Signal(s)	The level of service provided (e.g. Watt output) and duration of the service that are required to be met in order for the price signal to be effective. For example, the DER group managing entity may be required to maintain a certain minimum output level for a certain duration in order to receive the indicated price.
Effectivity Schedule	The time/date window for which this price signal is effective. This includes the start time/date and end time/date or duration. The method also supports starting immediately and indefinite durations.
Delay Time	A time over which a random delay is to be applied, following the start time, prior to the provided price signal(s) taking effect.

Table 25-3
Information Exchanged for Price Signal Function Responses

Information Name	Information Description
Action Identifier	Defining what was requested: • Providing price signal(s) to a DER group
DER Group ID	The unique identifier for the DER group to which this response applies
Success / Failure Indicator(s)	Indication of whether or not, or to what extent, the command could be accommodated. Chapter 7 describes the Success/Failure indicators and Table 7-2 identifies those that are applicable to this response.

26
REQUEST COST OF SERVICE FROM DER GROUP

Purpose

This function exchanges the cost of a specified service from a DER group. This information could be, for example, exchanged prior to actionable services being requested or rendered in order to aid in decision making.

Entities requesting this information (e.g. utility DMS) would specify the DER group, the type of service desired (e.g. reactive power), quantity needed (100KVars), duration of the service (1 hour), and other factors as needed to enable a cost to be provided. Entities providing the cost information (e.g. DERMS, third party aggregators) could incorporate any number of (unspecified) factors into the cost calculation.

This function could be used, for example, by a calling entity requesting a DER group to provide an “offer to sell”. In such a scenario, the DER aggregator is offering a function that involves some aggregation of downstream devices and indicates the financial reimbursement associated. As with other group-level functions described in this document, interactions to/from an individual DER are out of scope. This function applies to communications to/from a DER group-managing entity such as a DERMS or third-party aggregator.

Note: *This function is under ongoing development at the time of this publication. The focus group has expressed an interest in being able to express costs of service in a non-linear fashion (e.g. piece-wise linear curve). For example, the cost of reactive power dispatch could be low in a range where no watts are lost, then step up to a higher cost above that range.*

27

MANAGE POWER AT A POINT OF REFERENCE

Purpose

The purpose of this function is to request that a DER group operate so as to hold, or limit, power to a specified level at a remote point of reference. This is a more complex, higher-level function than the separately defined “Real Power Dispatch” and “Reactive Power Dispatch” functions in that this function tasks the DER group managing entity to:

a. Be aware of a measurement value at a remote point of reference, i.e. a measurement that cannot be determined by summing measurements from the DER within the group.
b. Make ongoing adjustments in order to maintain the remote measurement at the specified value.

It is noted that in some system architectures, the same overall result may be achieved by the requesting entity, using the separately defined “Real Power Dispatch” and “Reactive Power Dispatch” functions.

This function does not specify how individual DERs within the group are managed, only the net effect at the specified point of reference. In addition, this function is not concerned with the type of devices that make up the group.

Technical Approach

This function allows the calling entity to specify real and/or reactive power. In addition, it allows the calling entity to request either:

- Hold: DER group managing entity acts to maintain real or reactive power at the specified level
- Limit: DER group managing entity acts to limit real or reactive power at the specified level

<To be further developed here in future work>

Summary of Manage Power at a Point of Reference, Information Items

The following information is passed in a *Manage Power at a Point of Reference* Request:

Table 27-1
Information Exchanged for Manage Power at a Point of Reference Requests

Information Name	Information Description

Action Identifier	Defining what is being requested:
	• Identifier of the type of dispatch being requested
	  ○ Real Power Hold
	  ○ Real Power Limit
	  ○ Reactive Power Hold
	  ○ Reactive Power Limit

Priority	A parameter to identify the priority-level associated with this control message. Protocol mappings will identify (a) if a priority is/isn't defined and (b) a range of at least 10 priority levels. Determination of whether and how priority levels are assigned is up to power system operator/designers.
Requesting Entity ID	The unique identifier of the last entity (e.g. upstream DERMS or other actor) who created (or last modified) this request. For example, if a transmission system operator originally initiated an action, but prior to receipt the request (settings/values) was modified by a distribution system operator, then this field would contain the distribution operator's system ID.
DER Group ID	The unique identifier for the DER group for which a reactive power level is being requested
Effectivity Schedule	The time/date window for which this request is effective. This includes the start time/date and end time/date or duration. The method also supports starting immediately and indefinite durations.
Point of Reference ID	Identifier of the point of reference at which the specified power is to be held/limited.
Ramp Time	Time window (in seconds) over which the managed power is to be adjusted in response to this control action

Table 27-2
Information Exchanged for Manage Power at a Point of Reference Responses

Information Name	Information Description
Action Identifier	Defining what this message represents: • Manage Power at a Point of Reference response
DER Group ID	The unique identifier for the DER group for which a manage power function was requested
Success / Failure Indicator(s)	Indication of whether or not, or to what extent, the command could be accommodated. Chapter 7 describes the Success/Failure indicators and Table 7-2 identifies those that are applicable to this response.

28
CONNECT/DISCONNECT DER GROUP

Purpose

This is a control function by which all DER in a given group may be disconnected-from or reconnected-to the grid. Notionally, a DERMS or other entity providing this service could do so by leveraging the standard “Connect/Disconnect” function that has been identified for individual DER in the IEC standards.

Use cases for this function could include lockout for grid maintenance, soft shutdown or restart around planned outages, etc.

Technical Approach

The Connect/Disconnect request shall include a simple Boolean indicator of which state is required.

The connect/disconnect request shall include the following timing parameters:

- A start date/time for the action, or a “now” indicator
- A delay time over which a random delay is to be placed prior to starting the connect/disconnect action
- A time-window over which the DER group members are to be disconnected or connected (as linearly as possible given DER sizes)

Summary of Information Items for “Connect/Disconnect DER Group Function”

Table 28-1
Information Exchanged for Connect/Disconnect Function Requests

Information Name	Information Description
Action Identifier	Defining what is being requested: • Group Disconnect • Group Connect
Priority	A parameter to identify the priority-level associated with this control message. Protocol mappings will identify (a) if a priority is/isn’t defined and (b) a range of at least 10 priority levels. Determination of whether and how priority levels are assigned is up to power system operator/designers.
Requesting Entity ID	The unique identifier of the last entity (e.g. upstream DERMS or other actor) who created (or last modified) this request. For example, if a transmission system operator originally initiated an action, but prior to receipt the request (settings/values) was modified by a distribution system operator, then this field would contain the distribution operator’s system ID.
DER Group ID	The unique identifier for the DER group that is to take the action
Effectivity Schedule	The time/date window for which this request is effective. This includes the start time/date and end time/date or duration. The method also supports starting immediately and indefinite durations.
Delay Time	A time over which a random delay is to be applied, following the start time, prior to beginning to connect or disconnect the members of the group.
Time Window	A time window, following the delay time, over which the DER group managing entity is to disconnect the members of the group.

The response from DER Group managing entity shall indicate:

- Success: All DER in the group are confirmed: connected/disconnected as requested.
- Failure: One or more members of the group are not confirmed to have responded.

In the case of Failure, the response shall include a list of the mRID of the group members that failed to confirm.

Table 28-2
Information Exchanged for Connect/Disconnect Function Responses

Information Name	Information Description
Action Identifier	Defining what was requested: • Group Disconnect • Group Connect
DER Group ID	The unique identifier for the DER group to which this response applies
Success / Failure Indicator(s)	Indication of whether or not, or to what extent, the command could be accommodated. Chapter 7 describes the Success/Failure indicators and Table 7-2 identifies those that are applicable to this response.
(Optional) Array of non-confirming group members	The mRID list of any DER that did not confirm.

29
SPECIFY BELLWETHER METERS

Purpose

This function allows an entity (e.g. a DMS or DERMS) to request from am meter-managing entity (e.g. AMI system headend) that a provided list of meters (notionally a limited and supportable number) be activated to provide more real-time, operational data for control system purposes. This function is based on the premise that AMI meters may normally only report data a few times daily for billing purposes. This function would allow a few on each feeder or area to act as sample points for system voltage – providing feedback to control algorithms.

Included is a method to return meters to normal operation. How a given meter is selected to be a bellwether meter is out of scope, but could for example be the highest and lowest voltage points on a given feeder.

Implementation

Table 29-1
Information Exchanged for "Specify Bellwether Meters" Function Requests

Information Name	Information Description
Action Identifier	Defining what is being requested: • Specify Bellwether Meters • End Bellwether Status
Effectivity Schedule	The time/date window for which this bellwether specification is effective. This includes the start time/date and end time/date or duration. The method also supports starting immediately and indefinite duration of the specification.
Meter IDs	List of unique meter IDs
Update Rate	The time interval in which bellwether meters are to report data
Bellwether Quantities	List of metered quantities to be provided by bellwether meters

Table 29-2
Information Exchanged for "Specify Bellwether Meter" Responses

Information Name	Information Description
Action Identifier	Defining what command is being responded-to: • Specify Bellwether Meters • End Bellwether Status
Success / Failure Indicator(s)	Indication of whether or not, or to what extent, the command could be accommodated. Chapter 7 describes the Success/Failure indicators and Table 7-2 identifies those that are applicable to this response.

Many functions identified in this specification include a response field that indicates the success and/or failure of requests. These indicators are listed and defined in Table 29-1.

Table 29-2 identifies the response fields that are associated with each DER Group function.

30 NEXT STEPS

This effort has been an important step in the development of common functions for group-level integration of distributed energy resources. The resulting functions look beyond how DER contribute based on their geographic position, and to their collective connectivity in the distribution network, according to the representation in system models such as CIM and MultiSpeak.

This body of work has been developed in an open process and is a contribution to applicable standards bodies. It is anticipated that this work will be mapped into several communication protocols in order to serve the needs at various levels of aggregation and in various regions, including IEC 61850, IEEE P2030.5, CIM, and MultiSpeak. These use cases, requirements, and proposed information exchanges may be vetted by standards development organizations and the final protocol implementations may have additional features not identified at this stage.

The process to have new capabilities incorporated into standards take significant time, however, early adopters may be able to develop early versions of systems based on the approaches developed in this report. EPRI is working with utilities to develop and evaluate concept systems while standards developments are in process.

A wide range of additional interactions are applicable to DER group management at various levels of aggregation and it is anticipated that such will be added to this body of work going forward. Additional test workshops and continued focus-group action is envisioned in order to develop additional capabilities.

Going forward, EPRI aims to continue working with NREL to conduct interoperability workshops to provide all stakeholders with an opportunity to test and evaluate their implementations of these functions in a laboratory environment. Following this, it is anticipated that collaborative field demonstrations will be carried out.

US Department of Energy, Office of Energy Efficiency and Renewable Energy's SunShot Initiative provided the impetus for this body of work. Going forward, programs such as SEGIS (Solar Energy Grid Integration Systems) could help accelerate development by technology providers and field testing of these and other functions that support the interaction between utility and third-party DERMS and other applications such as DMS, GIS, and AMI.

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