

DERMS REFERENCE CONTROL METHODS FOR DER GROUP MANAGEMENT

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ABSTRACT

Launched in March 2018, EPRI facilitated a working group of industry experts in DER integration to identify and publicly document a reference set of control methods for distributed energy resources management systems (DERMS). While prior efforts by the industry focused on developing standard service/functions for DERMS at the device-level (DERMS-to-DER) as well as at the group-level (e.g. DMS-to-DERMS), the goal of this working group was to develop reference control methods for mapping DER group-level to device-level functions.

A key output of this body of work to the power industry is a reference set of functions to enable modeling and technical analysis needed to study the business case /value proposition of DERMS. Moreover, it provides a baseline set of functional requirements for DERMS products and its specification that enables consistency in DERMS request for procurement (RFP) across the industry. Finally, as different reference control methods are documented through this initiative, it identifies gaps in the relevant communication standards upstream and downstream of DERMS by evaluating their sufficiency to support reference control strategies.

INTRODUCTION

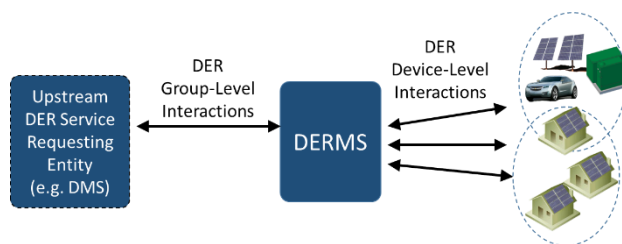


Figure 1. Simplified DERMS Concept

Distributed energy resource management systems (DERMS) are control applications that are emerging to support utilities with the integration of DER. As described in a recent EPRI whitepaper [1], DERMS are expected to manage the many individual devices on distribution systems, aggregating their capabilities and integrating with upstream systems such as distribution management systems (DMS) and bulk system markets.

Over the past decade, the electric power industry has developed standard grid-supportive functions for individual distributed energy resources (DER) and standard services for groups of DER. The device-level functions are documented in the IEC 61850-7-520 (descriptions) and 61850-7-420 (information model) and serve as the foundation for interconnection standards like IEEE 1547 [2] and grid codes like Rule-21 [3] that specify

the capabilities that DER must have in order to be connected to the grid. DER group-level services are documented in the IEC 61968-5 (Common Information Model for DER) and address the interactions between DER management systems (DERMS) and distribution management systems (DMS) as well as utility-to-aggregator interfaces.

This paper is a continuation of these bodies of work and describes a reference set of control methods for DERMS, identifying ways that individual DER can be managed to provide group-level services. These methods have been developed through the EPRI DERMS Working Group – an open forum consisting of industry stakeholders from utilities, solution providers, academics, and others. This paper summarizes the methods that were discussed and developed during the first phase of work by this group. It is anticipated that this process will continue, with new editions being released as the work progresses.

One the primary drivers behind this body of work is to enable modeling and technical analysis needed to study the business case and value proposition of DERMS. A research question identified early on is what incremental capabilities are gained through DERMS beyond what is possible with fixed DER settings. To answer this question systematically, DERMS control and monitoring methods must be defined technically. Some potential benefits from DERMS include:

- Improvements in hosting capacity from better reactive power control
- Reduced distribution system losses through time-varying reactive control
- Improved voltage quality and potential increases in consumer energy efficiency through better voltage control and conservation voltage reduction
- Management of energy storage systems that require signals to charge and discharge optimally
- Management of smart and curtailable loads that require price or control signals at peak times
- Limiting of DER energy export and improving self-consumption through real power management.

To perform the circuit-modeling studies and to compute these potential benefits, specific control logic that converts group-level commands to device-level commands is needed to be employed in evaluation and analysis.

INDIVIDUAL VERSUS GROUP DER INTERACTIONS

International industry efforts have standardized the device-level capabilities of smart inverters for solar photovoltaic (PV) and battery storage systems. In North America, grid codes based on the IEEE 1547-2018 and CA Rule 21 are making these capabilities mandatory. Standards are also being developed for DER group-level services that apply

at the DERMS to DMS interface, but there are not yet standards for the internal control strategies that a DERMS might employ to map these group-level services to device-level actions.

A DERMS is envisioned to possess the intelligence needed that can render requested services from DER groups in creative ways that optimize the service to the utility and value to the asset owners. The industry initiatives aimed at DER integration have been well coordinated, with standard group-level services being defined with awareness of the standard device-level capabilities.

But first it is important to understand the fundamental differences between device-level versus group-level management of DER. Table 1 below outlines some of the key differences between these two management paradigms and their required interfaces. Managing DER using groups not only reduce the communications requirements and functional complexity but also allows for additional operational flexibility for individual DER within a group; as long as the specified group objective is satisfied, there is freedom for individual DER within the group to vary its output.

	Device-Level Interface	Group-Level Interface
Number of Connections	Many; one for each DER device.	Few; DER are aggregated in groups.
Frequency of Interactions	Frequent; variable resources (e.g., solar) may require frequent or continuous monitoring and adjustment to setpoints to maintain constant output across multiple DER.	Less Frequent; individual DER setpoints within a group can fluctuate while the group setpoint remains constant.
Device-Type Awareness	Inherently device-type specific; e.g. temperature setting for thermostats versus charge/discharge for storage systems.	Generally agnostic of the type of downstream DER that are used to provide the service.
Functional Complexity	Grid support functions can be complex; e.g. device-level var functions (e.g., volt-var, watt-var, power factor)	Services are simple in nature; e.g. set total reactive power setpoint of a group.

Table 1. Group-Level and Device-Level Interface Characteristics

REFERENCE CONTROL STRATEGIES FOR GROUP-TO-DEVICE MANAGEMENT

DER Group-Level Functions, as set forth in this paper, 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. The results of the research are a reference set of

control methods for DERMS. These control methods can be used for managing multiple levels of DER aggregations including homes (e.g. through home energy management systems), facilities or buildings (e.g. through building management systems), microgrids (using a microgrid controller), smart communities, feeder/substation level controllers, DER aggregators and distribution operators.

The process of forming a DER group is straightforward, with standard messages that include a list of unique identifiers for each member of the group and a unique group name. After the formation of DER Groups comes the monitoring as well as dispatch or limit functions that enable services to be provided by a group of DER (e.g. distribution grid services, bulk system services).

Two DER dispatch functions are identified and detailed in this paper – DER Group Real Power Dispatch, DER Group Reactive Power Dispatch – as well as a basic status monitoring function. The control methods outline the sequence and logic of how DER Group dispatch functions are disaggregated to individual DER devices that make up the group.

DER Group Status Monitoring

A step that naturally precedes the control of a DER group, the purpose of the status monitoring 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 each service that the DER group is capable of performing. At the present time, status monitoring for the real and reactive power dispatch functions are the most mature.

The status monitoring function makes it possible for upstream systems to know what levels of service are available before making its request. With this knowledge, feasible commands/requests can be sent to the group based on group capability available, as well as other considerations including program rules, interconnection agreement, etc.

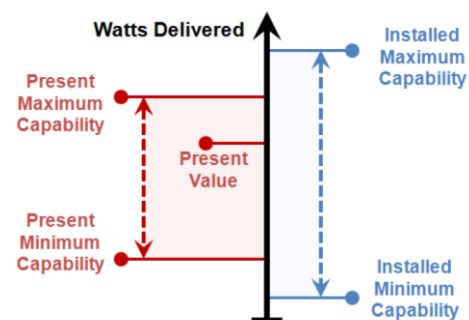


Figure 2. Installed Capability and Present Status Parameters

Shown in Figure 2, the present status of an individual DER can be represented by three quantities (shown in red): 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 three “present” quantities can be time-varying.

In addition to status information are “capabilities”, which are name-plate oriented and generally fixed quantities

once a DER is in operation. Capabilities are represented by two quantities (shown in blue): installed maximum capability and installed minimum capability. Defined in this way, the present values (red) will always fall inside or equal to the installed capabilities range (blue).

The objective in this approach is that a requesting entity (e.g. distribution management system, or DMS) could request the real power (watt) or reactive power (var) 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 or var value within the red range and get the expected response.

Once the individual DER status information is known, it is the responsibility of a DERMS to aggregate these individual statuses into a DER group status. While this task may seem trivial at first (i.e. simple sum of the individual DER statuses equals DER group status), there are many possible complexities that can occur. For example, if an individual DER becomes unreachable (e.g. loses communications) or its output limited such that its present value or maximum/minimum capabilities are unknown, an alternative method summing may need to be applied – e.g. estimation based on last known status, forecasting methods, last uncurtailed value.

DER Group Real Power Dispatch

The purpose the DER Group Real Power Dispatch function is to request/dispatch a specified level of real power from a DER group. A DER group real power dispatch can be requested in two ways:

- *Specified Power Level*: A request that the real power for the group be set to a specified level.
- *Specified Power Level Adjustment*: A request that the real power for the group be raised/lowered by a specified amount.

Figure 3 below illustrates the power level adjustment implementation. Positive values indicate more power generated by the DER group (or less absorbed) and negative values indicating less power generated by the DER group (or more absorbed). A real power adjustment request is made to the DERMS to increase the real power output of the DER group. Based on the group request, the DERMS then must apply a control method that will calculate the setpoints for individual DER devices that comprise the DER group.

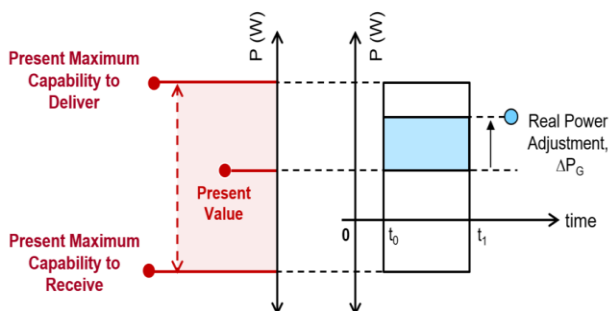


Figure 3. Specified Real Power Level Adjustment for a DER group

Under this function, the working group identified several

general categories of control methods by which a group-level request could be mapped (or disaggregated) to individual device-level commands:

Control Method	Description
Uniform Distribution	Sets/limits the real power level of each member of the DER group to the same power level to achieve the total specified group power level.
Weighted Distribution	Sets/limits the real power level of each member of the DER group based on predefined “weighting factors” to achieve the total specified group power level (see below).
Priority-Based Dispatch	Sets/limits the real power level of each member of the DER group based on a “priority list”, to achieve the total specified group power level. Each DER is completely dispatched/ curtailed before proceeding to the next on the priority list.
Economic-Based Dispatch	Sets/limits the real power level of each member of the DER group to achieve the total specified group power level while minimizing the total economic impact (e.g. cost or price) across all individual devices constituting the group.

Table 2. Reference Control Methods for DER Group Real Power Dispatch

Following from table 2 above, “weighting factors” and “priority lists” can be formulated based on a variety of user-defined criteria. Below are some possible criteria identified by the working group:

- *DER type* – e.g., non-dispatchable DER is weighted more heavily or prioritized over dispatchable.
- *DER size* – e.g., large DER is weighted more heavily or prioritized over small.
- *DER ownership* – e.g., utility-owned DER is weighted more heavily or prioritized over customer-owned.
- *DER capability* – e.g., utility-owned DER is weighted more heavily or prioritized over customer-owned.
- *Order of Interconnection* – e.g., DER interconnected last is weighted more heavily or prioritized over interconnected first.
- *Carbon Emissions* – e.g., high carbon-emitting DER is weighted more heavily or prioritized over low carbon-emitting.
- *Combination of methods* – the above methods can also be used in combination to formulate “weighting factors” or “priority lists”.

DER Group Reactive Power Dispatch

DER Group Reactive Power is similar to DER Group Real Power Dispatch and many of the same methods for group-to-DER control can be applied. However, reactive power dispatch introduces additional considerations for the DERMS due to the fact that often times providing reactive power (either capacitive or inductive) may come at the expense of generating real power.

The ability for a group of DER to provide reactive power may depend on individual DER’s present real power status

as well as the DER's owner(s) willingness to curtail real power. A PV system owned by an individual utility customer would likely prefer to generate as much real power as possible while providing reactive power support only when there is available "head room". One should take into account arrangements between the DERMS operator and DER owners that may limit the availability of reactive power for dispatch.

GROUP-TO-DER DISPATCH EXAMPLES

In this section, some examples of DER group-to-device dispatch for real power are provided. These examples can also be applied to reactive power dispatch, save for the additional considerations noted above.

Example 1. This example illustrates the use of the Uniform Distribution method in a scenario where three DER (Energy Storage) of different sizes constitute a DER group. In this scenario, the three DER are able to provide equal contributions of 30 kW to meet the requested 90 kW real power level for the group. The charge/discharge management function of each DER is used to set its real power level.

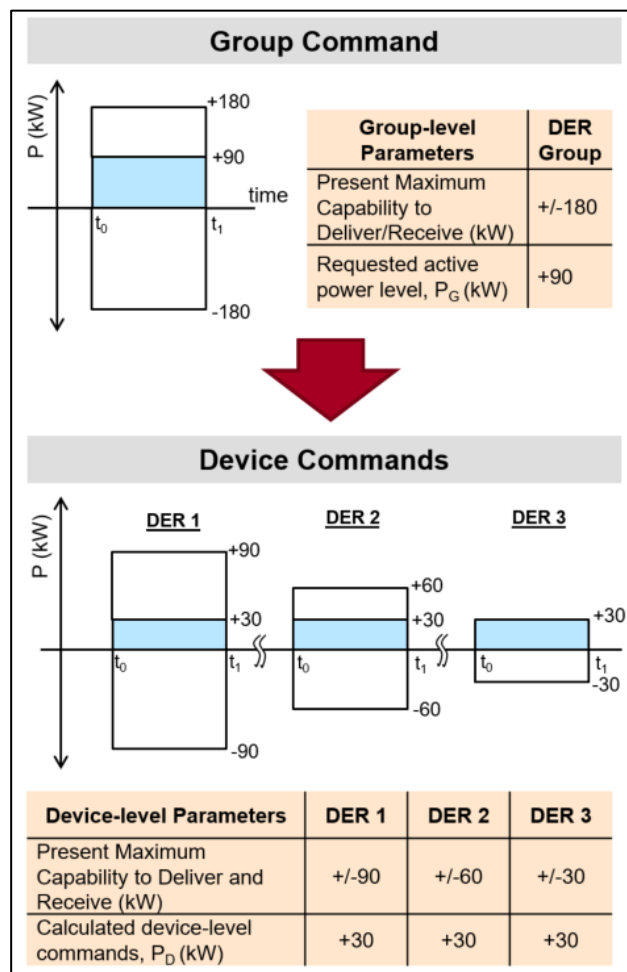


Figure 4. Example 1: DER Group Real Power Dispatch, Uniform Distribution Method

Example 2. Consider a DER group comprised of three battery storage devices with different remaining energy to be fully charged. The remaining energy for an energy storage is determined by its current State of Charge (SoC) and the resulting kWhr. By assigning different weights for the charge rate of DER in the group, this method provides flexibility to the operator to charge them at different rates based on the calculated remaining energy before being fully charged. In this way, the DER with the largest remaining energy (DER-1) can charge faster than the other DER with smaller remaining energies which can charge slower, thereby, all the DER gets fully charged at the same time. In this scenario, the group-level request of -100kW (negative sign denoting charge request) is achieved as a factor of the weights assigned to each DER in the group. The resulting assignment of device commands is -40 kW for DER1, -30 kW for DER2, and -30 kW for DER3.

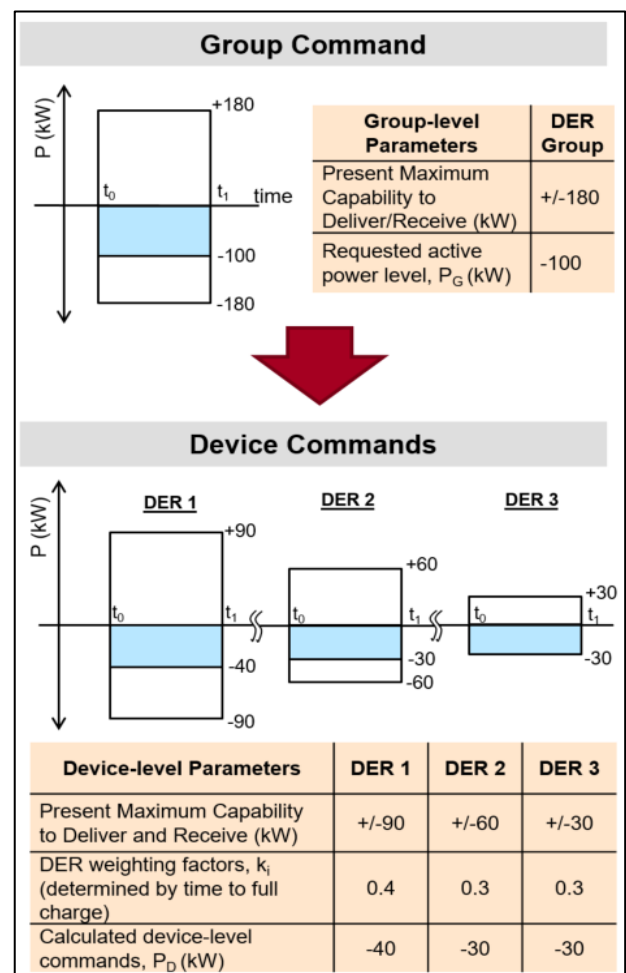


Figure 5. Example 2: DER Group Real Power Dispatch, Weighted Distribution Method

Example 3. In this example, a three DER group to manage a transformer capacity constraint using the proposed PBD method is considered. The operator decides to call the DER for capacity support based on the sequence of interconnection. Based on PBD, since DER-3 was the last to be interconnected, it is completely dispatched before proceeding to the next DER, DER-2 in the interconnection list. The charge/discharge management function of each

DER is used to set its real power level.

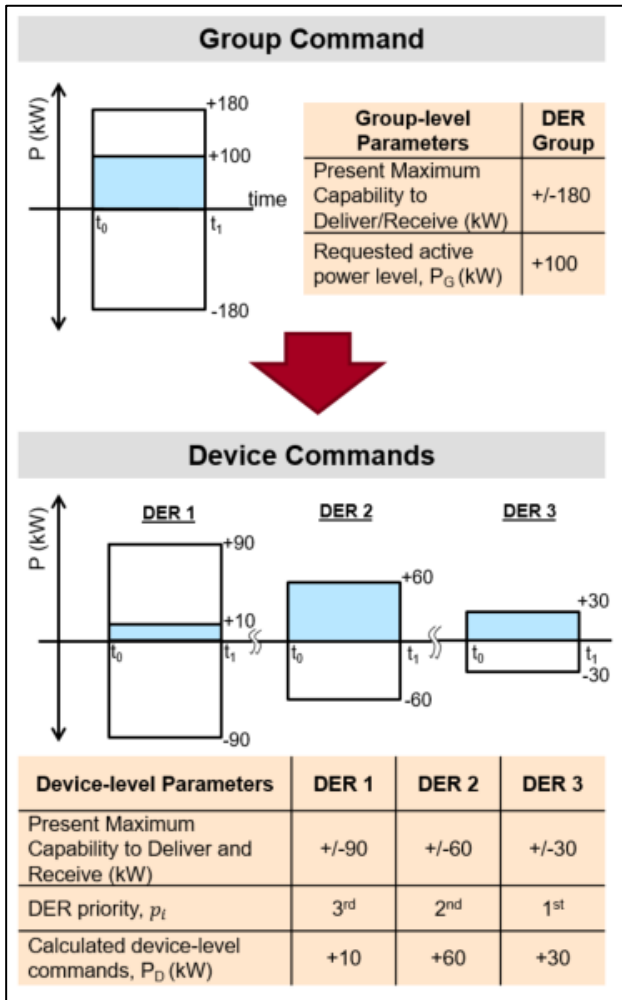


Figure 6. Example 3: DER Group Real Power Dispatch, Priority-Based Dispatch Method

CONCLUSION & FUTURE WORK

The control methods documented herein reflect the Phase 1 work of the DERMS Working Group. It is recognized that these methods represent only a subset of the wide range of possible methods. Going forward, the working group expects to expand the set of documented methods and to refine and clarify those described herein.

Consistent with the vision and purpose for this body of work, there is no intention to try to optimize or perfect these methods because this is viewed as the role of commercial solution providers. Instead, it is the intention of these reference methods to remain relatively simple and straightforward.

In parallel with this overarching effort, EPRI is utilizing these DERMS reference methods as the basis for research aimed at better understanding the technical and economic benefits that DERMS may provide. This is currently being done through in-depth power system modelling to evaluate the incremental value (e.g. increased hosting capacity) that can be realized across distribution systems when utilizing a DERMS.

Another important area of future work that been identified by the working group is establishing metrics that can be used to evaluate DERMS system performance. Performance metrics for DERMS may inherently be tied to individual use cases (or applications) for which the DERMS is being deployed. For a distribution system operator focused on safety and reliability, important DERMS performance metrics may be voltage or current levels maintained below distribution equipment limits. For a market system operator, metrics related to grouped asset responsiveness and output stability may be valuable. For third-party DER operators, cost and energy production may be the relevant performance metrics.

It is anticipated that the DERMS Working Group will reconvene in the coming year and continue this development through the open process.

REFERENCES

- [1] "Understanding DERMS" EPRI, Palo Alto, CA: 2018. 3002013049
- [2] IEEE Std 1547-2018, IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power System Interfaces
- [3] <http://www.cpuc.ca.gov/Rule21/>