GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy

DER Telemetry Communication Architecture for ESOs, DSOs, and System Operators

Final

November 2017

JD Taft

PNNL-27057

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

**Available to DOE and DOE contractors from the
Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831-0062;
ph: (865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov**

**Available to the public from the National Technical Information Service
5301 Shawnee Rd., Alexandria, VA 22312
ph: (800) 553-NTIS (6847)
email: orders@ntis.gov <http://www.ntis.gov/about/form.aspx>
Online ordering: http://www.ntis.gov**

This document was printed on recycled paper.
(8/2010)

DER Telemetry Communication Architecture for ESOs, DSOs, and System Operators

Final

JD Taft[1]

November 2017

[1] Chief Architect for Electric Grid Transformation, Pacific Northwest National Laboratory.

Contents

Figures

1.0 The Problem

For proposed future states of electric power systems that have high penetrations of Distributed Energy Resources (DER), system operators with organized central power and energy markets, and the potential for distribution level markets for DER, a number of architectural considerations arise, not least among them is the issue of collecting and managing telemetry data from DERs. Figure 1 below illustrates the potentially complex nature of the problem in quasi-schematic form, with many varieties of DERs, transactive buildings, prosumer and merchant Distributed Generation (DG), and multiple competitive DER aggregators and other Energy Services Organizations (ESOs) such as remote energy managers for commercial buildings.

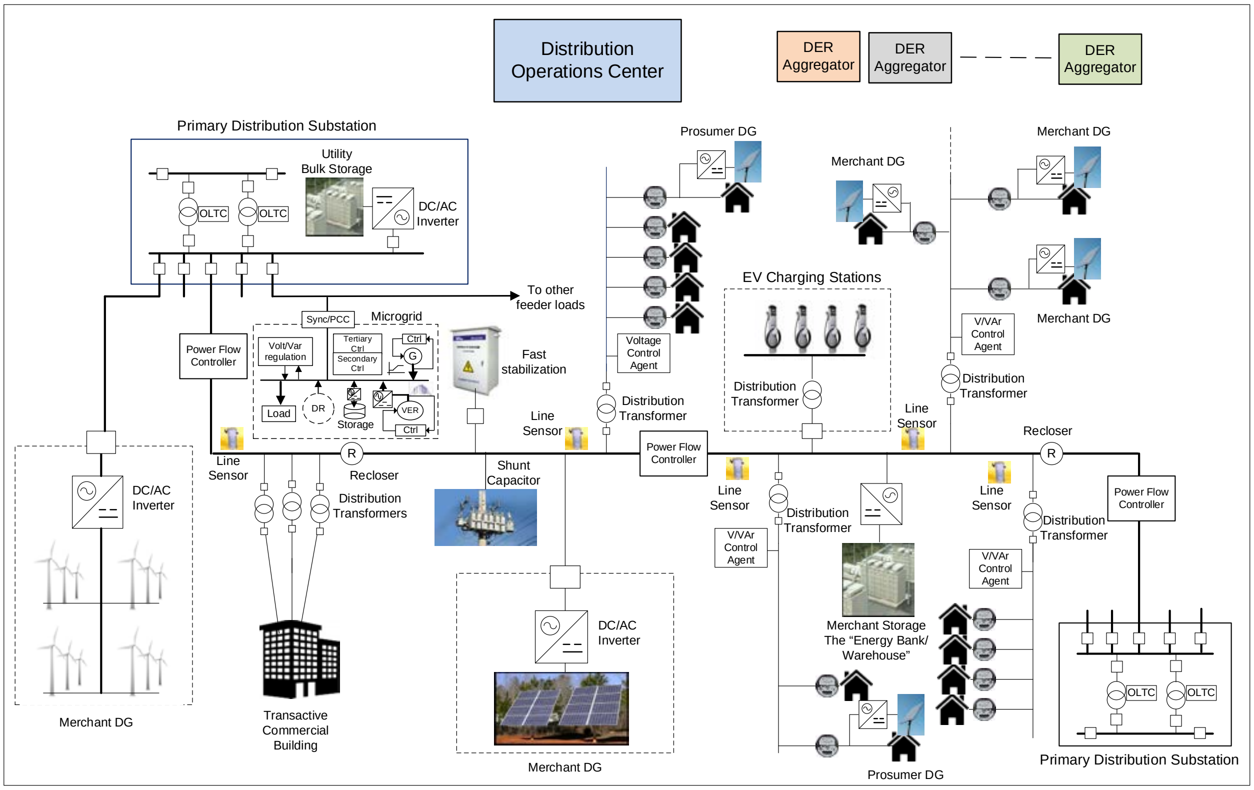


Figure 1. High DER Distribution Problem Domain System Reference Model Diagram

Such an environment requires a variety of data flows to operate in an automated fashion. Figure 2 below shows a logical data flow model, including data flows for the ISO level market, and potential DSO-level DER markets, as well as data flows for distribution operations, including Advanced Meter Infrastructure (AMI). This model focuses on distribution level control and coordination and so depicts the problem domain from the point of view of a single DSO and treats the ESOs collectively and so does not depict the complications of DER telemetry flow that arise when ESO service area interpenetration and multiple DSO operations are involved. A discussion of this model can be found online.[1]

[1] JD Taft, L Kristov, and P De Martini, A Reference Model for Distribution Grid Control in the 21st Century, July 2015, available online: http://gridarchitecture.pnnl.gov/media/advanced/Distribution%20Control%20Ref%20Model_v1.1_final.pdf

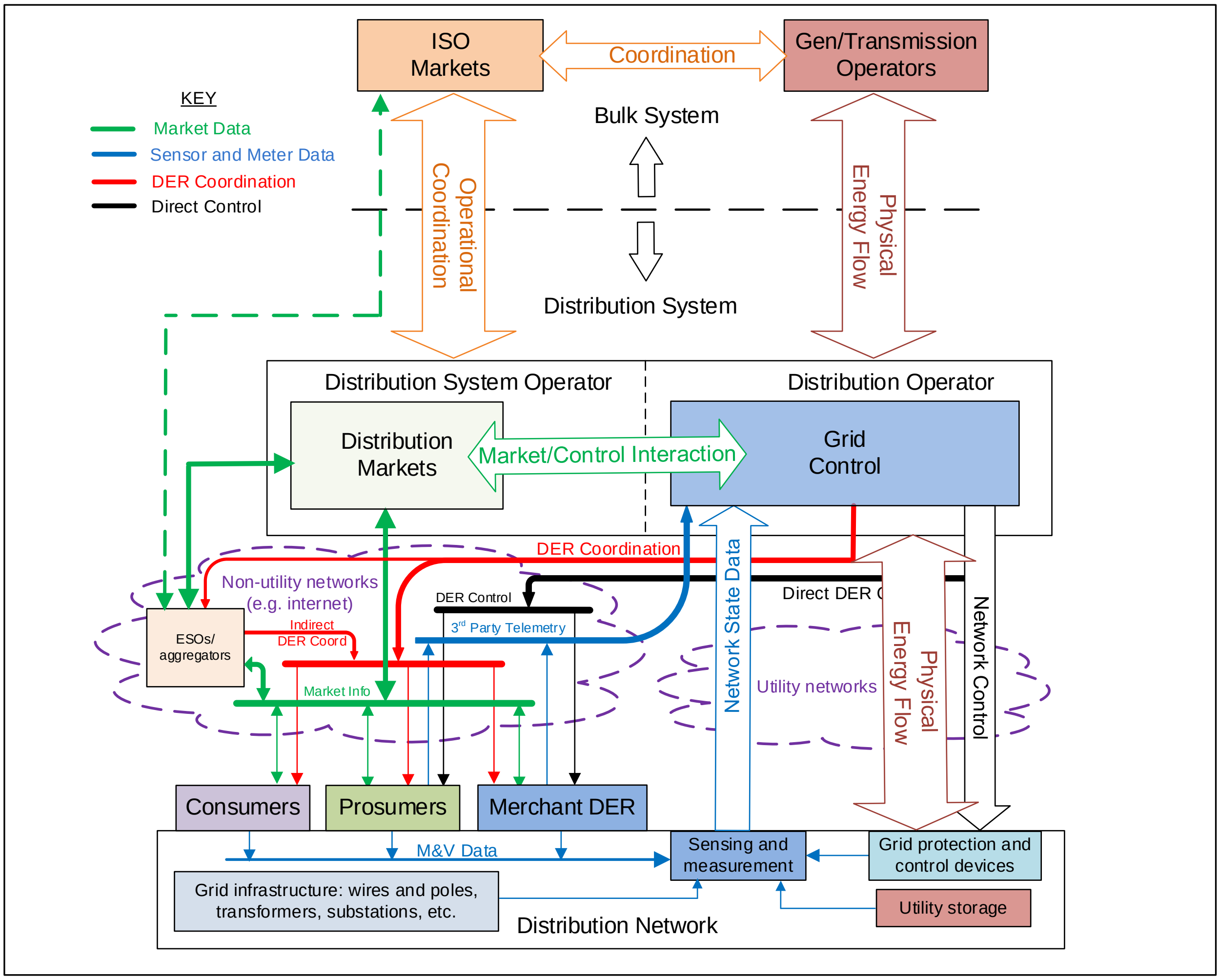


Figure 2. High DER Penetration Dual Market Data Flow Model

To understand the data flow issues, it is helpful to consider industry structure diagrams, such as the one in Figure 3. This diagram is an entity-relationship diagram that depicts the key organizations and assets as entity classes (boxes) and their relationships as annotated lines. Such models provide a starting point for understanding data flows, as well as control and coordination. Figure 3 depicts the situation where DERs are used by either a System Operator or a Distribution Operator (DO), and DERs may be aggregated through Energy Services Organizations (ESOs). In the existing model, a number of relationship lines have developed more or less organically, including some (the red and green lines) that bypass the DO. This leads to a hazard when DER penetration becomes large that impacts distribution reliability and has scaling and other issues as well.

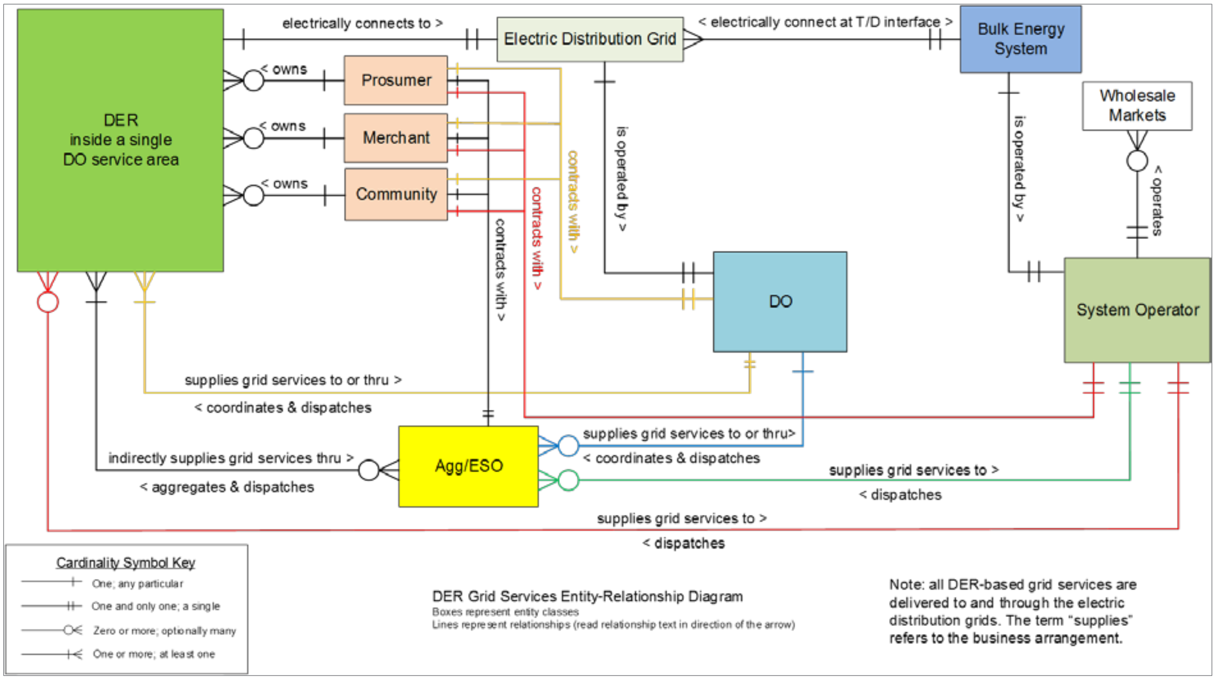


Figure 3. Existing DER Integration Industry Structure

Figure 4 illustrates the case where a Distribution System Operator (DSO) has been introduced (really a set of role and responsibilities for the DO) but the red and green bypass lines still exist because the ESOs and some DER want to participate in both bulk system and DSO level markets. This raises a number of coordination issues that may have to be faced because of the evolution from the existing arrangements in Figure 3.

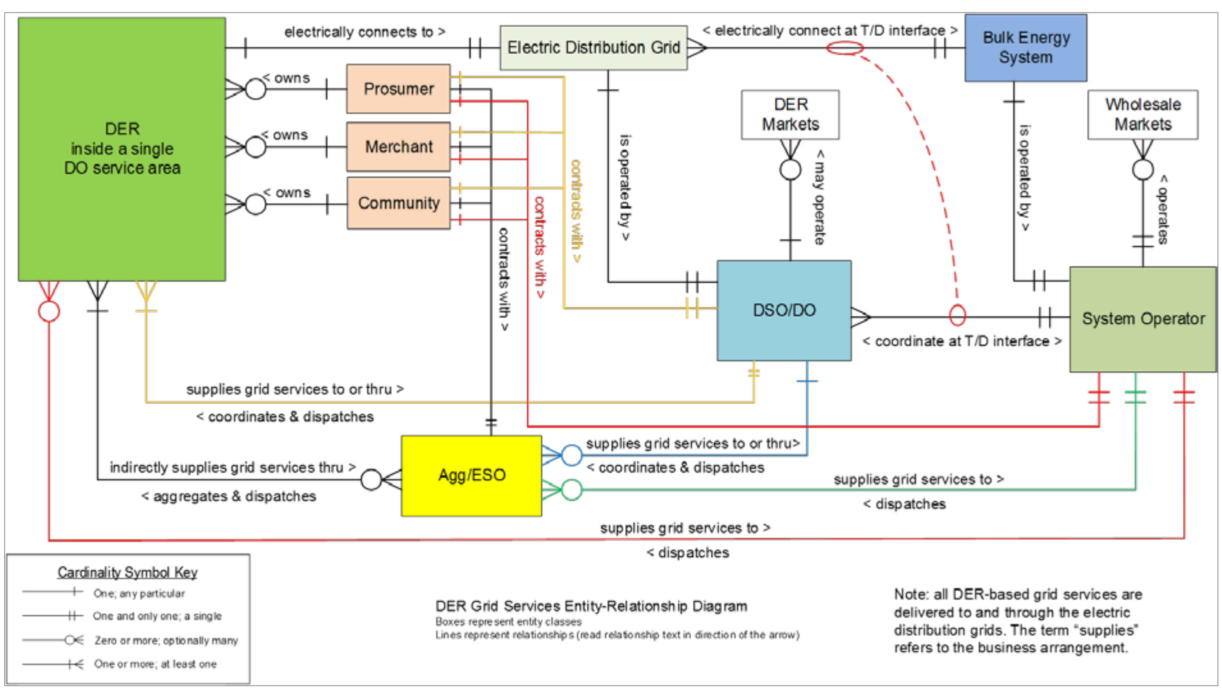


Figure 4. DSO-Based DER Integration Industry Structure with Bypassing

In Figure 5, the bypass lines have been eliminated by requiring that all DERs, whether native or through ESOs, be coordinated by the DSO, which comes to agreement with the System Operator about exchange of power and energy at the T/D interface. The DSO then coordinates the DER assets to manage distribution reliability in the DSO service area. There are multiple possible DSO models, and it is likely that electric systems would go through an evolution in terms of DSO definition and operation over time that could ultimately resemble Figure 5, but is more likely to start with something resembling Figure 4 for both technical and non-technical reasons.[2] The evolution to Figure 5 would not be likely to occur until there is sufficient penetration of distributed generation (DG) that the DSO service area has to be treated at the system level not as a simple aggregated load but as a hybrid of load and a generation tie. As of this writing, very few areas of the country have reached this level of DG penetration.

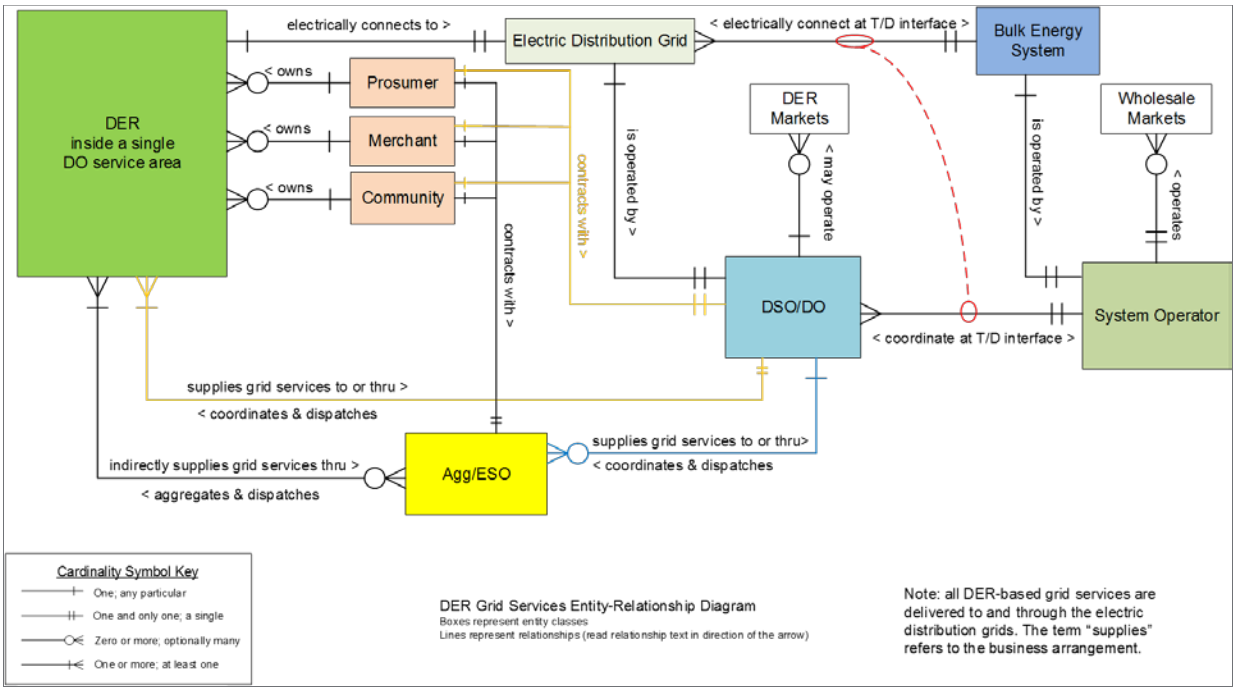


Figure 5. DSO-Based DER Integration Industry Structure without Bypassing

To understand the issue of telemetry data flow across the entire system, consider the model of Figure 6 below, which assumes the structure shown in Figure 4 (DSO structure with bypassing). In the case where there may be a number of DSOs in the service area of a given ISO, and there may be many competitive ESOs that have interpenetrated service connections to DERs across multiple DSO service areas, the distribution of DER telemetry data to all concerned parties has a number of complicated cases. It may be the case that a single ESO handles all the DER aggregation in s single DSO service area, but more likely there will be more than one handling DER assets in one DSO service area, so that the DSO must deal with more than one ESO, even if the DERs are in adjacent physical locations. Any given ESO may have DER assets in more than one DSO service area and so will have to deal with more than one DSO. The ISO may have to deal with many DSOs and ESOs, as well as potentially some number of individual DERs spread across various DSO service areas.

[2] P De Martini, L Kristov, and Lisa Schwartz , Distribution Systems in a High Distributed Energy Resource Future – Planning, Operation, Market Design, and Oversight, LBNL Future Electric Utility Regulation series, October 2015 , available online:
http://gridarchitecture.pnnl.gov/media/advanced/FEUR_2%20distribution%20systems%2020151022.pdf

Note that telemetry collection is only part of the issue. The other half is dispatch and that is complicated by the need to disaggregate dispatch directives in a way somewhat analogous to how Area Control error (ACE) is converted to Unit Control Error (UCE) in the bulk energy system, but in this case the issue is far more complex when distribution level locational effects are included. In the case where DERs can participate in both bulk system and DER level markets, there is a need to separate the financial transaction data flows for the dispatch data flows so that dispatch can be coordinated to maintain distribution level reliability. This document addresses only the DER telemetry data flows.

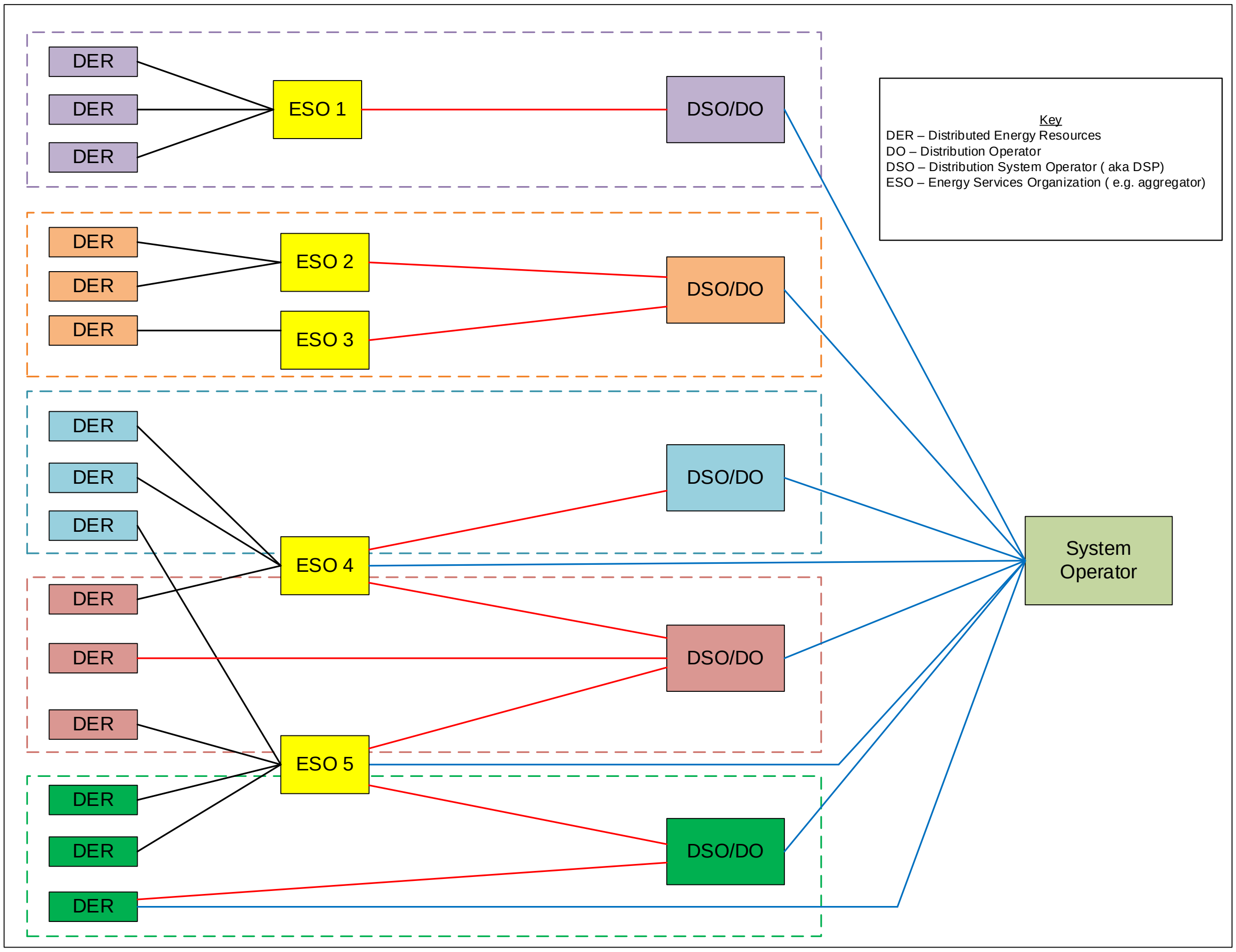


Figure 6. DER Telemetry Data Flow in a Multi-DSO Multi-ESO System

1.1 Telemetry Flow Granularity

The DER telemetry problem may not just be a question of the number of organizations involved. In any DER integration approach that makes use of locational value, the data flows must also reflect the appropriate spatial granularity. This means that telemetry aggregation[3] may only be applied to the specified level of spatial granularity, and so the number of telemetry data flows can in fact be much larger than the number of organizations that act as data sources. Each aggregator may have to supply multiple

[3] The term aggregation has two meanings: data aggregation is the collection and *summarization* of data, so that the aggregator output data stream is smaller than the sum of the input streams; communication aggregation is the merging of multiple inputs data streams into a single output stream so that the aggregator output stream has the same volume as the sum of the input streams. Here telemetry aggregation means data aggregation.

DER telemetry flows, one for each circuit segment[4] being used in the locational model for each Do service area.

Due to interpenetration, multiple aggregators may provide DER telemetry data streams not just for any given DO, but for any given circuit segment inside a given DO service area. Consequently, a DO may receive DER telemetry streams from multiple aggregators for the same circuit segment, as well as from individual DERs in that segment. Of course, the ultimate limit on DER data granularity is at the level of the individual DERs, but the existence and function of aggregators inherently intended to gather DERs into a small number of groups, so that each group may be treated by the DO through a single interface. This is essential to the aggregator's business model but that model does not contemplate the effects of this in an environment where there are multiple competing aggregators on a single distribution system. In such an environment, not only are the telemetry problems more complex, but competition among aggregators may cause the association of DERs to aggregators to be time-varying.

More will be said about the roles of aggregators later after consideration of some key principles and description of three models for DER telemetry architecture.

[4] Here a circuit segment is a portion of a distribution feeder circuit that has been defined for the purposes of locational value. It may be more or less than a circuit section – its definition depends on circuit capacity and hosted DER density as well as circuit structure.

2.0 Point to Point Communications Approach

A simple approach to providing telemetry data flow is to provide point to point communications from each device and organization to each organization needing the data. This potentially would create a very large number of interfaces and connections, too large to be practical. Standard networking techniques can resolve this issue in a cleaner fashion.

To examine this idea, it is necessary to first recognize the difference between logical and physical communications. Logical networks are based on the view of data flows from sources to sinks and this leads to many apparent communication links. However, it is certainly not the case that these must be implemented using corresponding physical links. It is only necessary that the underlying communication networks be capable of providing all the required logical paths. The issues are twofold:

1. How many physical communication networks and therefore network interfaces must be involved?
2. How many secure logical data paths must be used?

The answer to the first question depends on the entity type. In the public network case, for DERs only one ISP connection is needed, either to an internet or cellular service provider, or to a backbone telecomm service provider (if the DER will interface directly to a DSO or system operator without going through an ESO). The ESOs may need *logical* connections to as many internet or cellular services providers as are used by their entire set of DER clients, along with a connection to a telecomm service provider for communication with DSOs and the system operator, but in practice, the ESOs do not need to connect to each ISP; they only need one connection to one SP, just as the others do. DSOs and the system operator will also each need one interface to a telecom service provider. Figure 7 illustrates a set of connection cases. Note that for reliability reasons, DSOs and System Operators may use dual network connections with duplicate service providers.

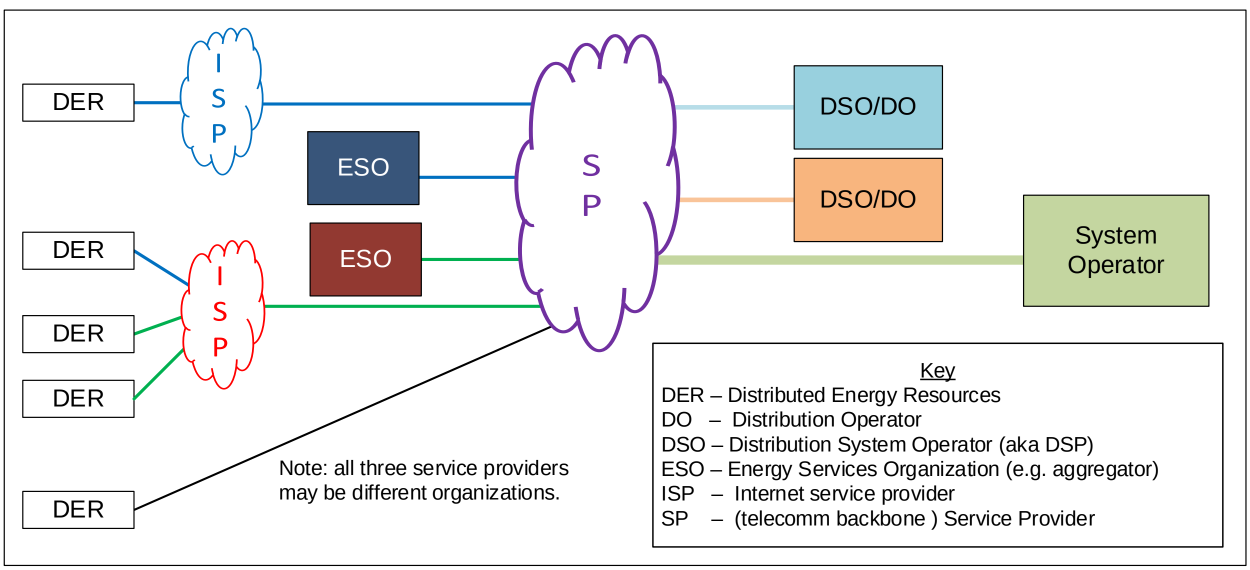
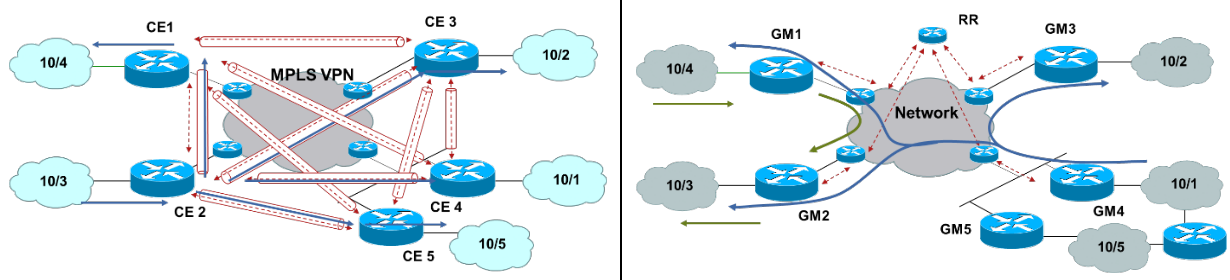


Figure 7. Entity DER Telemetry Connection Class Model

Logically (question 2), ESOs must have two classes of connections: to their DER asset clients, and to the entity into which they aggregate (could be the DSO or the ISO or both). DERs still have only one connection type. This is clear from Figure 3. Similarly, DSOs have three connection classes: one for DERs, one for ESOs and one for the ISO. Likewise, the ISO has three connection classes: one for DERs, one for ESOs, and one for DSOs. In each case, all of the connection classes can map onto a single communication link. The individual data flows must be managed separately of course, and have different sources and destinations, so secure virtual connections are needed. A simple conceptual approach would be to set up Virtual Private Networks (VPNs) for each point-to-point data flow involving ESOs, DSOs, and the ISO, but this recreates the connection complexity problem in software. The problem can be resolved by using any of the commercial implementations of GDOI.[1] This protocol provides for group cryptographic key management and is the basis for products that provide multi-party VPNs. Standard products exist for both public and private networks. Figure 8 illustrates the difference in terms of complexity.



Point to Point VPN N^2 mesh Inefficient	GDOI: Always on any-to-any encryption Efficient

Figure 8. Comparison of Point-to-Point VPN and GDOI

Even given the above discussion, this approach requires management of a large number of individual data flows, with some entities like the ESOs and DSOs having potentially significant challenges at scale. If it were not for the DSOs, the ISO would have an even worse scaling problem in this regards, so one of the values of the DSO model is to provide system partitioning (via layering) that helps contain the scaling issues. The existence of multiple interpenetrated ESOs may be necessary or desirable for other reasons, but does contribute to the data flow complexity problem.

[1] Group Domain of Interpretation, IETF RFC 3547.

3.0 Data Layer Middleware Approach

Another approach would be to create what amounts to a middleware layer, by setting up a centralized database system that would be the receptacle for all DER telemetry. All DER elements would transmit their telemetry to this database, and all authorized users of DER telemetry would obtain it from this database as illustrated in Figure 9.

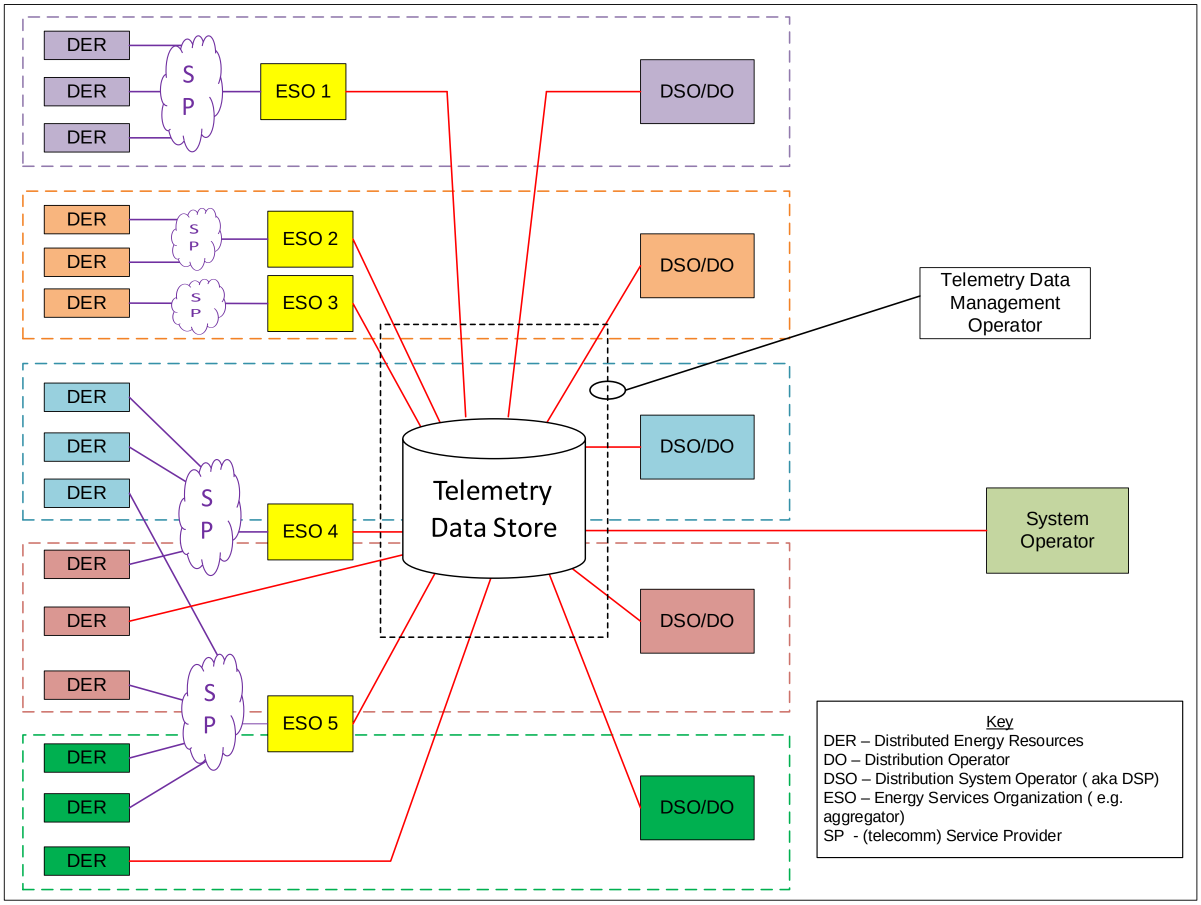


Figure 9. Database/Middleware Layer Approach to DER Telemetry Collection

Such an arrangement would simplify some aspects of communication architecture but would require the creation or designation of an organization to host, operate, and manage the database system (a Telemetry Data Management Operator or TDMO role), and would require each DER owner or aggregator to have the necessary software and configuration information to be able to deposit data. Data collection would have to be automated and so the issue of pull from a data collection head end vs. push from individual data sources, and the timing/synchronization of data transfers will arise. The database can act as a buffer between DERs and the ISO so that data sampling rates can be decoupled (meaning that DERS would not have to report on a six second interval, even if the ISO wishes to query the database at that rate). The TDMO would have the responsibilities of providing interfaces to all of the DERs and ESOs, to the DOs and to the ISO and would have the responsibilities for database management, data collection, access control, cyber security of the data store, and integrity of the stored DER telemetry data. The middleware/database approach is rather similar to the AMI data management issue faced by individual distribution utilities, except for the complicating factor of the ESOs. In the AMI case, the meter data repository and associated applications perform data validation, editing, and estimation (VEE) and resampling (requesting retransmission of data that was missed or dropped) to deal with the fact that meter data collection is not a perfect process (consistent with the normal failures aspect of ultra-large complex systems) and it is likely that the TDMO would find it necessary to provide similar functionality. ESOs may be required to bear some of this responsibility, but that still leaves the individual DERs that are not routed through ESOs to consider.

If data is to be retained for historical purposes (almost certain to arise as a requirement in such an approach) then the amount of storage capacity needed will grow over time at linear or greater than linear rates, depending on DER penetration growth. Mechanisms would be needed to control access to data and to assure data privacy and confidentiality. Competitive ESOs for example, may not want other ESOs to be able to see which DER assets they aggregate, and private DER owners may not want their operational data to be openly available either. Improper data access could also be used to game markets.

This arrangement simplifies the telemetry data acquisition networking issues somewhat, but recall that telemetry collection is only half of the issue. The other half is dispatch.

4.0 Network Solution

Both of the above methods requires network communications, but neither takes full advantage of network capabilities. Dosing so leads to another approach that resolves many of the issues listed above. The basic idea is to make use of the MPLS network as a streaming publish-and-subscribe mechanism so that DERs can stream their telemetry data into the network, and any authorized user can subscribe to that data stream. THE MPLS PIM/SSM[1] protocol is the basis for this capability. This method is used to stream audio and video in IP networks and has also developed for transport of Phasor Measurement Unit (PMU) synchrophasor measurement data at the bulk energy system level.[2,3] PMU data transport is essentially a many-to-many data flow problem, similar to the DER telemetry data flow problem being discussed here. Owners of the data sources can control who subscribes using IGMP[4] on IPv4 networks and Multicast Listener Discovery (MLD) on IPv6 networks; encryption can again be supplied using GDOI as described earlier. Figure 10 illustrates the structure of this approach.

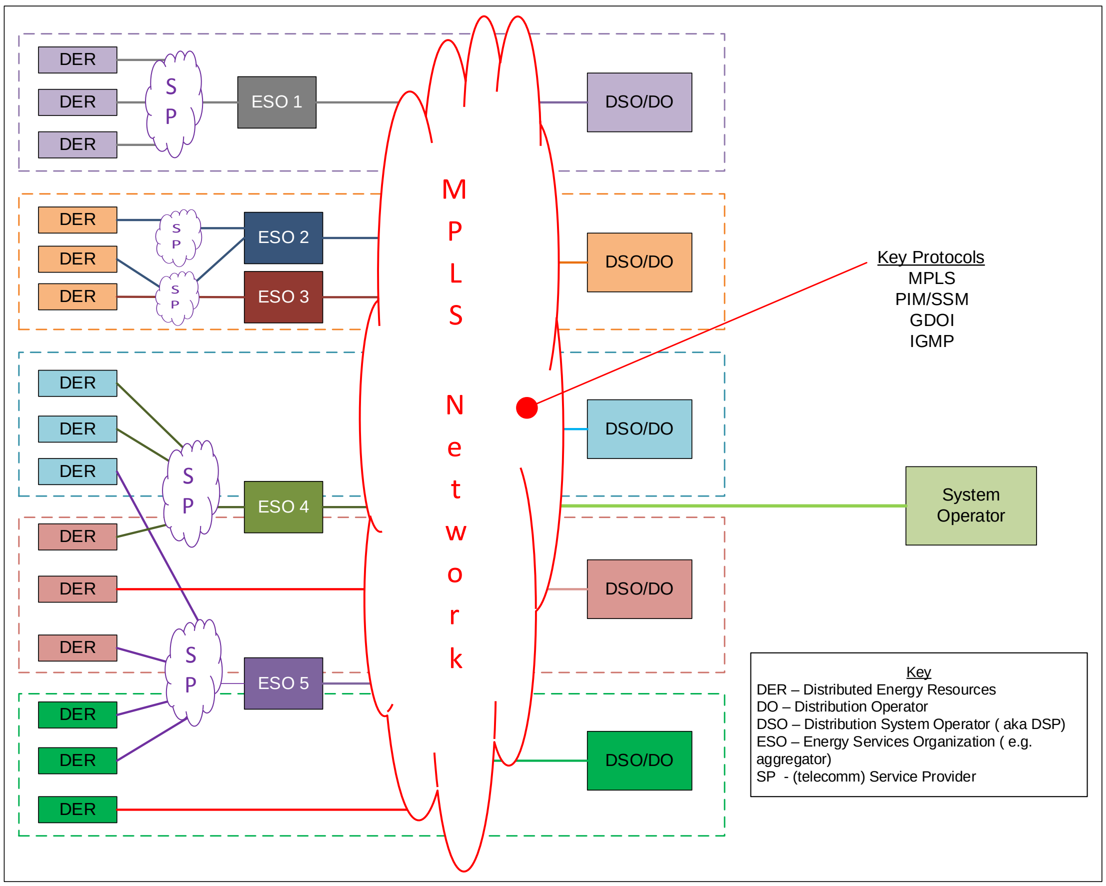


Figure 10. Network Approach to DER Telemetry Collection

---

[1] Protocol Independent Multicast/Source Specific Multicast

[2] P Myrda, et. al., Recommended Approach to a NASPInet Architecture, available online: https://www.computer.org/csdl/proceedings/hicss/2012/4525/00/4525c072.pdf

[3] Cisco staff, PMU Networking with IP Multicast, available online at https://www.cisco.com/c/en/us/products/collateral/routers/2000-series-connected-grid-routers/whitepaper_c11-697665.html

[4] Internet Group Management Protocol, RFC 1112, RFC 2236, RFC 4604.

In the network approach, aggregators/ESOs communicate with their client DERs in whatever form they wish (typically over IPS IP networks using IEEE 2030.5 (SEP 2.0)[5] as the application level protocol. Communication between ESOs and DSOs or ISOs can be via the DER-extended version of OpenADR.[6] Communication between DSOs and the System Operator can be worked out to suit and could be via OpenADR or ICCP.

The use of MPLS and SSM for telemetry is the basis for the WECC PMU data transport system implemented by Harris Corp. The concept has been adapted for use in general electric distribution system communications and has been called out by the Hawaii PUC in its recent guidance for grid modernization.[7] This approach has considerable advantages in terms of flexibility, future-proofing of investments, and minimization of system integration complexity and costs.[8]

---

[5] https://standards.ieee.org/findstds/standard/2030.5-2013.html

[6] Plan for extensions announced in June 2017: https://globenewswire.com/news-release/2017/06/20/1026385/0/en/OpenADR-Alliance-To-Extend-its-Automated-Demand-Response-Standard-to-Help-Utilities-Manage-Their-Distributed-Energy-Resources.html

[7] HPUC Order 34281 available online: http://dms.puc.hawaii.gov/dms/DocumentViewer?pid=A1001001A17A05B01613H26476

[8] JD Taft and P De Martini, Sensing and Measurement Architecture for Grid Modernization, February 2016, available online: http://gridarchitecture.pnnl.gov/media/advanced/Sensor%20Networks%20for%20Electric%20Power%20Systems.pdf

5.0 The Roles of the Aggregator

DER Aggregators have evolved over a number of years to perform a set of functions that include:

- Recruitment of individual DER owners
- Communication with the DERs
- Summation (aggregation) of DERs into a utility program or market
- Forecast of DER capacity and availability
- Provision of DER response to utilities via markets or programs
- Relaying of utility dispatch to individual DERs
- Participation in Measurement &Verification and settlement

In general, this group of functions evolved in a setting where locational value was not a dominant factor and, in the case of distribution utilities, there may have been only one aggregator, who was selected to participate in a program. The problems described above did not arise in such settings.

As DER penetration increases and utilities use of it becomes more sophisticated, the roles of the aggregator, the distribution utility, and the system operator are bound to change. For the distribution utility, the distribution system operator roles and responsibilities will come into play, in any of several models and likely in an evolving fashion. The role of the system operator will evolve somewhat as well, so that the Business As Usual model will change to accommodate the new relationship to the Distribution System Operator and interface with the Distribution System Platform. This means that old interfaces and data management models will adapt to deal with these changes, and so inevitably communications and data management systems will change.

For the aggregator, these changes could result in new approaches to dealing with both the distribution owner and the system operator. Some new data paths may become available, and some old data paths may disappear. It is likely however, that in an environment with high DER penetration and a distributed approach to DER coordination, not only will the aggregator's interfaces change, it is also likely that the aggregator will find a new role (in addition to its more traditional ones) in completing the distributed coordination framework for DER.[1] In this model, the aggregator would not only agglomerate DER, it would become an integral part of a larger coordination framework by hosting portions of the distributed optimization network on behalf of the DERs they aggregate.

[1] JD Taft, Architectural Basis for Highly Distributed Transactive Power Grids: Frameworks, Networks, and Grid Codes, June 2016, available online: http://gridarchitecture.pnnl.gov/media/advanced/Architectural%20Basis%20for%20Highly%20Distributed%20Transactive%20Power%20Grids_final.pdf

6.0 Final Comments

This report has examined three approaches to managing DER telemetry transport: direct networking, middleware (centralized database), and network as publish-and-subscribe mechanism. Choices related to this issue should be done in the context of a full architectural approach. In such an approach several key issues must be addressed because they are strong determinants of the whole system architecture, and therefore of the data management and communications architecture. These key issues include:

- What is the expected penetration level of DER?
- On what time scale(s) will DER operations be conducted?
- Does locational value of DER matter?
- Do DSOs and DSO DER markets exist?
- How are peer-to-peer energy transactions coordinated if they are allowed?
- Are DERs and ESOs allowed to participate in both bulk system and DER markets?
  - Does a capacity contract in one eliminate participation in the other?
- Coordination of DER dispatch from the System Operator and the DO/DSO
  - How to avoid competing or conflicting dispatch commands?
- How will disaggregation of DER dispatch be done?
  - Similar to breaking ACE into UCEs
  - Must account for DER location, type, functional capability, availability, etc.
  - Must account for local distribution grid conditions, constraints, etc.
  - Who performs this?

Resolution of these issues determines a great deal about system structure as well as assignment of roles and responsibilities and therefore informs both communications architecture and interface specification. Proceeding in a bottom-up manner runs significant risk of high integration costs, stranded investments, and unrealized benefits. Doing this in an organized manner, starting from objectives and taking into account constraints such as legacy systems, will result in clean structures that simplify downstream decisions and integration, and offer opportunities for futureproofing of investments.

GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99352
1-888-375-PNNL (7665)

http://gridmodernization.labworks.org/