Role of Standard Demand Response Signals for Advanced Automated Aggregation

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Abstract

Emerging standards such as OpenADR enable Demand Response (DR) Resources to interact directly with Utilities and Independent System Operators to allow their facility automation equipment to respond to a variety of DR signals ranging from day ahead to real time ancillary services. In addition there are Aggregators in today's markets who are capable of bringing together collections of aggregated DR assets and selling them to the grid as a single resource. However, in most cases these aggregated resources are not automated and when they are, they typically use proprietary technologies. There is a need for a framework for dealing with aggregated resources that supports the following requirements:

- Allows resources to participate in multiple DR markets ranging from wholesale ancillary services to retail tariffs without being completely committed to a single entity like an Aggregator
- Allow aggregated groups of resources to be formed in an ad hoc fashion to address specific grid side issues and support the optimization of the collective response of an aggregated group along a number of different dimensions. This is important in order to taylor the aggregated performance envelope to the needs to of the grid.
- Allow aggregated groups to be formed in a hierarchical fashion so that each group can participate in variety of markets from wholesale ISO ancillary services to distribution level retail tariffs.

This paper explores the issues of aggregated groups of DR resources as described above especially within the context of emerging smart grid standards and the role they will play in both the management and interaction of various grid side entities with those resources.

1. INTRODUCTION

1.1. Scope

DR programs operate at different time scales ranging from day-ahead to real time dispatches depending upon the type of grid management issues being addressed. DR resources can be used for a variety of purposes including peak shaving, load shifting and following, spinning and non-spinning reserves and regulation up/down ancillary services. In addition, the type of "instruments" (i.e. DR signals) used in the various DR programs can range from price communications, to load dispatches, to direct load control [1]. Aggregation of DR resources can play a role in each of these scenarios.

Today aggregation is typically handled by the use of intermediaries (e.g. aggregators or curtailment service providers) such that the intermediaries appear as a single resource to the Utility/ISO and manage a number of resources behind them that are not directly visible to the Utility/ISO. The DR resources are usually over subscribed to deliver contracted amount during the dispatch period. Rather than focusing on the parties that are facilitating aggregation, this paper discusses the aggregation of resources in general regardless of whether an intermediary is facilitating the aggregation or not.

There are many aspects and processes involved with managing the resources involved with a DR program. These include activities such as customer management, recruitment, deployment, and settlement. Although each of these processes can involve some sort of aggregation of the resources, this paper does not address the effect of aggregation on those processes. Instead this paper focuses on those processes in which DR resources are actually dispatched by the exchange of DR signals. This process will be defined in more detail below.

Finally, this paper focuses on so called "automated" DR programs in which DR signals are exchanged in some automated and standardized fashion between the various actors. This paper will point out what attributes of standard DR signals need to support aggregation.

1.2. Actors and Definitions

Following the definitions in [1] and [2] that were developed during the Smart Grid Interoperability Panel's (SGIP) Priority Action Plan 9 (PAP 9), the following entities will be used in this paper:

- DR Controlling entity – This is a generalized actor class and represents all the different entities that may need to manage and interact with wholesale and/or retail DR resources and includes the following actors; ISO/RTO, Distribution Company, Load Serving Entity, DR Aggregator, or curtailment service provider (CSP). This is the entity that calls upon DR resources to respond by sending those resources DR signals and possibly monitoring their response.

- DR Asset – An end use device that is capable of shedding or managing load in response to DR events, energy or price signals or other system events.

- DR Resource – A DR resource is a virtual representation of one or more DR assets or other DR Resources. It is similar to a DR Asset in that it is capable of shedding or managing load in response to a triggering event. Unlike a DR Asset, which is atomic, a DR Resource may consist of multiple DR Assets that have been aggregated to form a larger capacity or energy resource. An apartment building with multiple electricity consumers, each one having one or more DR Assets may be considered one large DR Resource by aggregating the total load shedding capacity of all the DR Assets in the apartment building and representing the sum total of this capacity as one DR Resource. A DR Resource may also consist of different types of Assets (e.g., a wind Turbine and an electric motor that work in combination to meet DR program obligations). These are the commodities that are called upon by the DR Controlling entity. In addition multiple DR Resources may be "aggregated" together to form a single DR Resource to some DR Controlling entity.

1.3. DR Business Processes

As noted above, this paper only addresses the business process involved with the actual execution of events in a DR program. The diagram below shows a simplified breakdown of the sub-processes involved in the execution of a DR event.

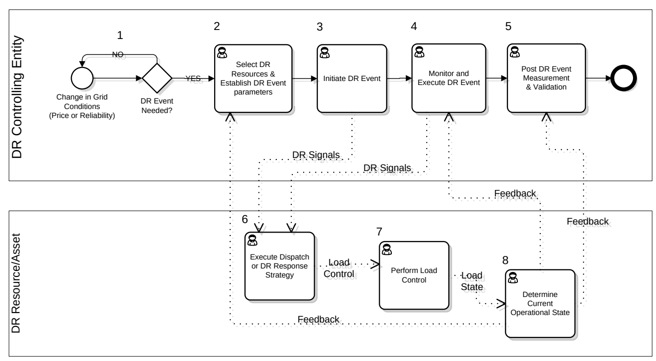

Figure 1: DR Business Process

In general the process above involves the following simplified sub-processes:

1. The DR Controlling entity monitors grid conditions (reliability or price signals) and decides to call a DR event.

2. The DR Controlling entity uses the specific grid conditions it is trying to address as a set of objectives for selecting DR Resources . It may use feedback from the DR Resources (e.g. availability, current operating state, bids, etc.) as part of the factors to consider which DR Resource to select.

3. Of those resources selected the DR Controlling entity initiates a DR event by sending a DR signal to the selected DR Resources.

4. The DR Controlling entity monitors the performance of the DR Resources and may change the DR signal it is sending to the DR Resources as a result.
5. After the completion of the DR event the DR Controlling entity performs any post event measurement and verification.
6. The DR Resource upon receiving a DR signal executes a DR strategy.
7. The DR Resource performs some sort of load control as part of the DR strategy.
8. The DR Resource measures its current operational state (e.g. current usage) and provides it as feedback to the DR Controlling entity.

2. REASONS FOR AGGREGATION

The diagram below shows the relationship between each of the entities defined above.

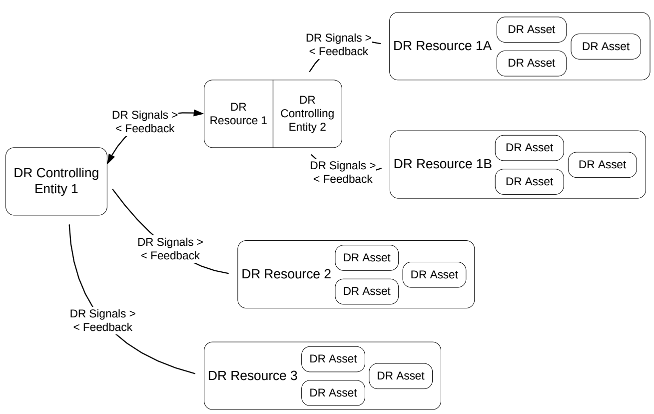

Figure 2: Actor Relationships

Note that in the above diagram DR Resource 1 is an aggregation of resources 1A and 1B.

In general aggregation is the collection of DR Resources and Assets together in such a way that they can be presented to some DR Controlling entity as a single DR Resource. There are a number of ways in which aggregation can be accomplished.

The simplest and most common is shown above in Figure 2 wherein DR Resource 2 is simply a collection of DR Assets. This is common where the DR Resource is a single customer that represents a single facility which uses a number of different loads (i.e. Assets such as HVAC and lighting) that they control at their discretion when a DR signal is received. Note that in this scenario no assumptions are made as to what happens once the DR signal is received by the DR Resource to control the DR Assets. In other words the notion of a "DR signal" may or may not be used with the context of the interactions with the DR Assets to control their loads.

Another common scenario is one which involves an intermediary such as is shown with DR Resource 1 in Figure 1 above. An example of this scenario is one in which some aggregator creates a collection of other DR Resources (Resource 1A and 1B in Figure 1) and presents them as a single DR Resource to some DR Controlling entity. Note that in this scenario the aggregator is both a DR Resource and a DR Controlling entity. Upon receiving a DR signal it must disaggregate the signal and send its own version of a DR signal to each of the DR Resources in its portfolio.

A third aggregation scenario not shown in Figure 2 does not involve intermediaries. As shown in Figure 3 below the DR Controlling entity is aware of all the various DR Resources and forms ad hoc aggregation groups and them manages those as a single DR Resource.

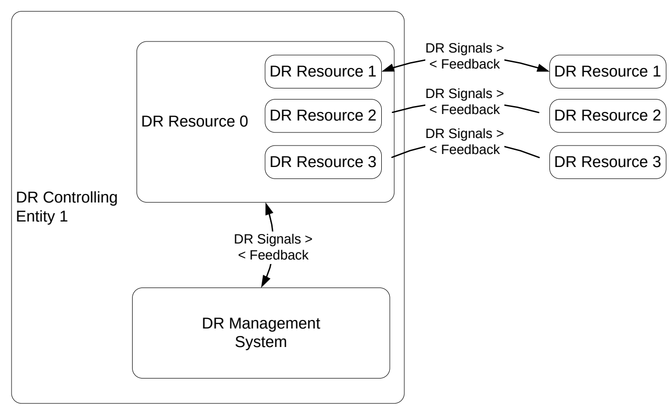

Figure 3: Ad hoc Aggregation Internal to DR Controlling Entity

This type of aggregation is more dynamic and allows for flexibility in how aggregation is performed in order to meet desired objectives. Advanced optimization techniques can easily be used to develop the desired ramp, amount of DR and duration needed to fulfill the needs of the grid. On the down side it adds more complexity to the DR Controlling entity by requiring the management of a lot more DR Resources than if it simply relied upon intermediaries to facilitate the aggregation.

Note that in many cases some form of real-time feedback or telemetry is required from the DR Resources. This may be true whether the DR Resource is aggregated of not. Obviously in the case of aggregated DR Resource, this can be problematic since the feedback must from the individual

DR Resources or Assets in the aggregated group must be collected.

2.1. Benefits of Aggregation

There are a number of benefits to be gained from aggregating DR Resources including the following.

- Reduce uncertainty. Over subscription of DR Resources in an aggregated collection means that deviations among individual DR Resources can be offset by other DR Resources in the collection.
- Increase reliability. The increased number of DR Resources in an aggregated collection allows it to still satisfy objectives if one or more of the individual DR Resources becomes unreliable and is not able to comply.
- Increase predictability. The increased number of DR Resources in an aggregated collection means that statistical deviations among individual DR Resources can be made less significant and allow for more predictability in the collection as a whole.
- Increase size of DR Resources. The increased number of DR Resources in an aggregated collection creates a larger load.
- Reduce complexity. The DR Controlling entity need only interact with and manage a smaller number of resources.
- More accurate load shaping. The increased number of DR Resources in an aggregated collection allows for much granular control to allow specific load profiles to be created.
- More flexible load profiles. The increased number of DR Resources in an aggregated collection allows it to mix and match different load profiles of the individual DR Resources together to create a load shape that can take many more forms than the load profiles of the individual DR Resources.

3. ROLE OF STANDARDS IN SUPPORT OF AGGREGATION

It is important that DR Controlling entities and DR Resources use a standard means of exchanging DR signals that support the following:

- Lower the cost of aggregation as DR Resources and Assets will have embedded capabilities to respond to standard signals.
- Allow individual DR Resources to be easily moved between different intermediaries and avoid stranding assets.
- Allow individual DR Resources to be easily used in a number of different aggregation schemes including the notion of ad hoc aggregation groups.
- Support multiple levels of aggregation.
- Allow DR events to be initiated and propagated from top to bottom with common semantics.
- Allow DR Controlling entities to specify objectives that can be easily utilized and propagated to the DR Resources at the lower levels of the aggregation hierarchy.

OpenADR is an emerging standard that can be used to exchange DR signals between DR Controlling entities and DR Resources and strives to satisfy the above requirements.

3.1. Logical Architecture

The Energy Interoperation Technical Committee (EI TC) of the Organization for the Advancement of Structured Information Standards (OASIS) is currently developing a specification in support of the SGIP's PAP 09 process related to standard DR signals. This specification is currently being profiled by the OpenADR Alliance and is the basis for OpenADR 2.0.

In the EI TC specification, there are some important concepts that can be used to support the aggregation of DR Resources. As shown in Figure 4 below, within the EI TC specification is the notion of Virtual Top Nodes (VTN's) and Virtual End Nodes (VEN's).

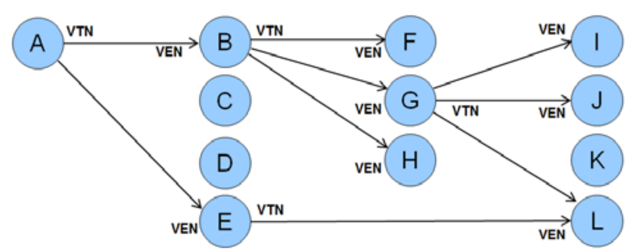

Figure 4. Virtual Nodes

Within the context of this paper VTN's can be associated with DR Controlling entities and VEN's can be associated with DR Resources. As can be seen entities such as B can be a VEN to entity A and at the same time a VTN to entities F, G, and H. This is identical to the aggregation concepts presented above and allows standard DR signals to propagate from entity A all the way to entity I in the figure above. Thus the notion of standard DR signals being exchanged between multiple levels of an aggregation hierarchy is key to the specification.

3.2. Resource Target Attributes

One of the core concepts in the EI TC specification is that a VTN has limited visibility and does not interact directly with entities "behind" a VEN. In reference to Figure 4 above, VTN A does not interact directly with VEN F. It is VTN B that is responsible for interacting with VEN F. It is therefore necessary that VTN A have the ability to include attributes in any DR signal it sends to VEN B that will allow it to interact with the right resources it is responsible for in order to meet the objectives of VTN A.

One of the attributes that may exist in a DR signal to accomplish this is the notion of a set of "target" attributes. The VTN may send a DR event that contains target attributes that helps the VEN select the appropriate set of VEN's that it should interact with. Figure 5 below is a snippet from the EI TC schema and shows the attributes that may be associated with a so called target.

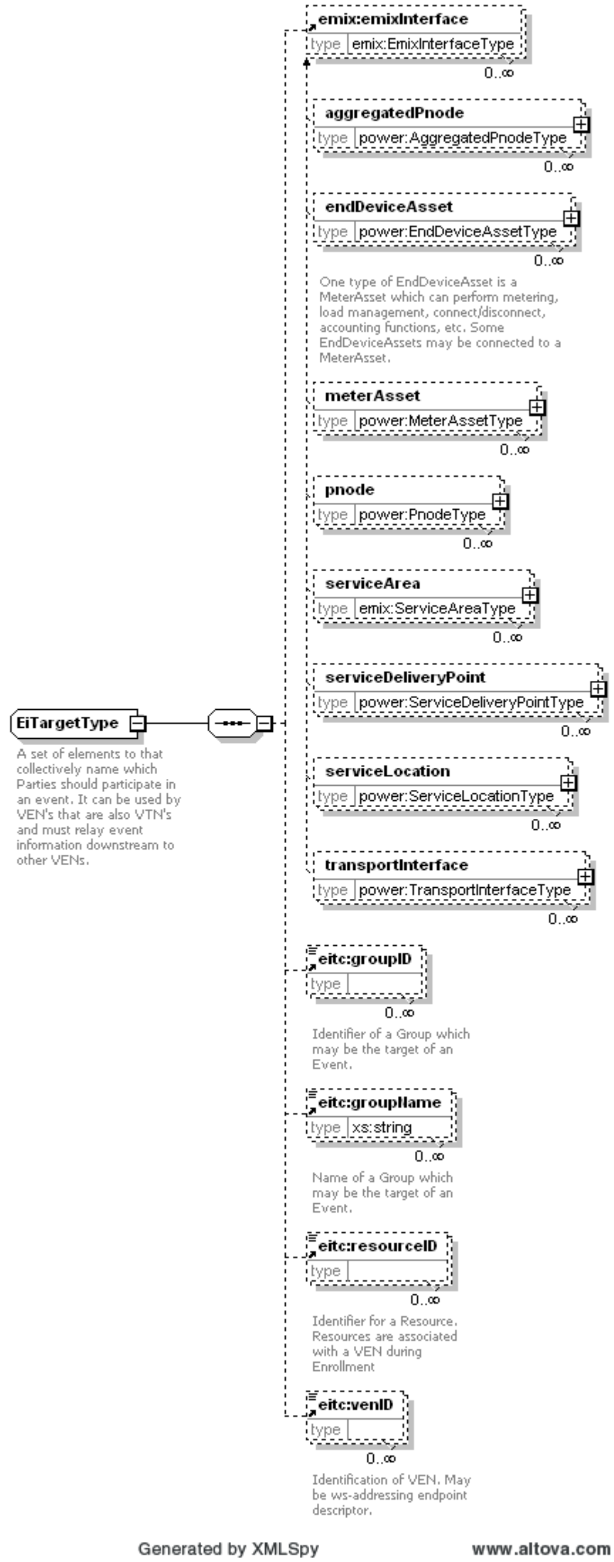

Figure 5. EI TC Target Attributes

Note that the attribute include the following specifications:

- Resources at specific grid locations. This would be used if the DR Controlling entity wanted to affect change at a specific grid location such as substation, etc.
- Resources at specific geographic locations. This would be used if the DR Controlling entity wanted to affect change at a specific geographic location.
- A general grouping attribute for create user defined groups of resources. This can be used to establish program specific grouping attributes such as resource type or size.

In addition to these target attributes it is also possible to construct signals that have specific performance attributes that can be used by some intermediary to select the appropriate set of DR Resources to propagate a DR signal.

4. CONCLUSION

In this paper, we explored the use of standard signals for aggregation of DR Resources and Assets. Standard signals lower the cost of aggregation by facilitating the development of embedded systems and growing communication capabilities for DR Resources and Assets. While there are benefits to be gained from using intermediaries for facilitating aggregation, especially on the business process side, the use of standards can facilitate advanced automated aggregation of DR resources without an intermediary. Standard signals also provide customers with choice and provide intermediaries a more competitive business environment where they can deliver additional services with the sub-metering and telemetry equipment they install.

In those cases where intermediaries exist, it is important that established standards such as OpenADR is used for interoperability in order to gain the maximum flexibility in the use of DR Resources and avoid stranded assets. Aggregation optimization is a growing area of research and OpenADR can be used to develop and test advanced optimization algorithms and ad hoc optimization.

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Biography

Ed Koch is a co-founder and CTO for Akuacom, Inc., a leader in Automated Demand Response (Auto-DR) software, acquired by Honeywell International in May 2010. Mr. Koch is responsible for managing and developing Akuacom's engineering resources and R&D activities, as well as leading all technology, intellectual property and architectural decisions. Mr. Koch served as the lead for the Open Automated Demand Response (OpenADR) Standards Working Group at the Lawrence Berkeley National Laboratory (LBNL). Mr. Koch continues to be actively involved in various Smart Grid standards efforts within NIST, UCAIug, OASIS, NAESB, and the OpenADR Alliance.

Sila Kiliccote is the Deputy of the PIER Demand Response Research Center at Lawrence Berkeley National Laboratory. She leads research, development and deployment activities using OpenADR with commercial and industrial facilities for ancillary services markets. Her areas of interest include dynamic optimization of building control strategies for demand response applications; load and demand reduction analysis methods for identifying flexible demand response; and development of tools for demand response stakeholders. Mrs. Kiliccote received the "Leadership in Smart Grid Acceleration" award at Grid Week in 2010.