Direct versus Facility Centric Load Control for Automated Demand Response

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Abstract

Direct load control (DLC) refers to the scenario where third party entities outside the home or facility are responsible for deciding how and when specific customer loads will be controlled in response to Demand Response (DR) events on the electric grid. Examples of third parties responsible for performing DLC may be Utilities, Independent System Operators (ISO), Aggregators, or third party control companies. DLC can be contrasted with facility centric load control (FCLC) where the decisions for how loads are controlled are made entirely within the facility or enterprise control systems. In this scenario the facility owner has more freedom of choice in how they respond to DR events on the grid. Both approaches are in use today in automation of DR and both will continue to be used in future market segments including industrial, commercial and residential facilities. This paper will present a framework which can be used to differentiate between DLC and FCLC based upon where decisions are made on how specific loads are controlled in response to DR events. This differentiation is then used to compare and contrast the differences between DLC and FCLC to identify the impact each has on requirements such as:

- Utility/ISO and third party systems for managing demand response
- Facility systems for implementing load control
- Communications networks for interacting with the facility
- Facility operators and managers

Finally a survey of some of the existing DR related specifications and communications standards is given and their applicability to DLC or FCLC.

1. DEMAND RESPONSE RESOURCES

DR programs differ from normal rates and tariffs in that they are designed to allow for the Utility/ISO to take specific actions to influence load profiles of their customers at critical times on the grid. These critical periods may be based on economic or market concerns or they may be triggered by grid reliability factors. These critical periods in which the Utility/ISO needs to influence the load profile of a Facility are referred to as DR Events. Much of DR today is managed as a set of programs in which the participants enter into some contractual agreement about how they will get compensated by participating in the DR Events. As the real time pricing markets evolve the notion of being compensated during a specific event period may get replaced with a purely price responsive mechanism. Automating price response will require new concepts about how customers respond to prices, giving them choice and flexibility.

During a DR Event the objective of the Utility/ISO is to create some sort of overall change in the profiles of the loads that they are serving, typically some sort of reduction. In some cases there may be a specific target load profile to be achieved while in other cases a simple reduction of any sort may be all that is necessary. From the Utility/ISO perspective the entity that they are interacting with is referred to as a “DR Resource.” To the Utility/ISO a DR Resource represents a load that is monitored (sometimes as an aggregate of other loads) to determine performance against objectives and is the entity that the Utility/ISO sends DR signals to in order to affect its load profile. The interactions between the Utility/ISO and a DR Resource can be modeled in simplistic terms as shown in Figure 1.

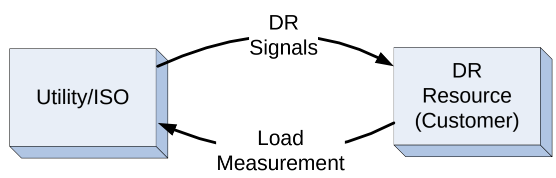

Figure 1. Interactions with DR Resources

This model shows that the Utility/ISO sends DR signals of some nature to the DR resource which are designed to effects its load profile while subsequent measurements of the DR Resource's electricity consumption are made to determine its performance. The measurements might be done in real time and be part of a closed loop control of the resource or in many cases the measurements are simply archived for subsequent access and used only for the purposes of settlement with the Customer as part of a contractual agreement. Note that load measurement might also entail more than just electricity consumption and may include device or load control states.

From the Utility/ISO perspective a DR Resource may represent the following:

- A single load profile for the purposes of load optimization
- A single touch point for the purposes of interacting with the load profile
- A single load profile whose consumption may be measured for the purposes of real-time monitoring or settlement
- A touch point where the performance or active state of the DR Resource may be monitored

The nature of a DR Resource is diverse and can range from large aggregated facilities down to small individual appliances and loads within a facility. It may also include things such as Plugin Hybrid Electric Vehicles (PHEV) and distributed generation (i.e. Local Energy Resource or LER). In essence anything that can be used to affect electricity usage in either a positive or negative fashion can be a component of a DR Resource that is used to manage its load profile.

For the purposes of this paper it is useful to classify DR Resources into of a hierarchy as shown in Figure 2.

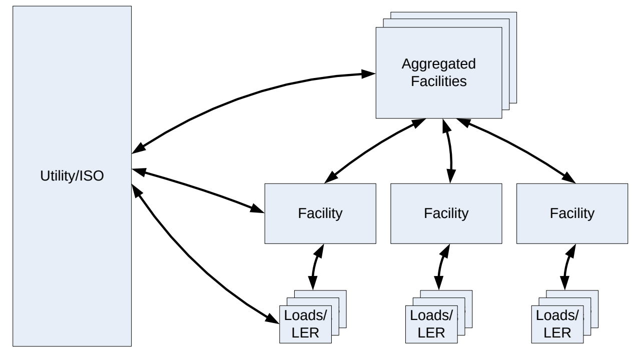

Figure 2. DR Resource Interaction Hierarchy

This classification is general and does not delve into the details of the loads or LER being controlled as part of the load profile of a DR Resource. The hierarchy shows that there may be some DR Resources that are an aggregation of multiple Customer facilities such as is done in many DR programs that support aggregator programs. In these scenarios there is typically an intermediary such as an aggregator or third party service provider that represents its aggregated portfolio to the Utility/ISO as a single load profile and is the touch point with the Utility/ISO. Intermediaries typically have a great deal of latitude in determining how to control the various loads within their portfolio in response to DR signals from the Utility/ISO as long as they are meeting their contractual obligations.

At the next level down you may have interactions between the Utility/ISO and individual facilities, each of which are in essence an aggregation of individual loads and LER within the facility. Just as in the case of aggregators, facilities managers/owners may have complete freedom to determine how the individual loads and LER within their facility will react to a DR signal. This scenario is referred to as Facility Centric Load Control (FCLC).

At the lowest level are interactions directly between the Utility/ISO and the individual loads within a facility. If the purpose of such an interaction is to explicitly control the state of the load then this is referred to as Direct Load Control (DLC).

It is important to note that not all interactions directly between the Utility/ISO and an individual load are classified as DLC. A counter example would be the so called "prices to devices" interaction model wherein energy prices are sent to appliances, but there is no explicit command to put the appliance in a specific state. This has also been described as sending ***objectives*** as opposed to ***directives***.[1] While this may represent a direct interaction between the Utility/ISO and an individual load, it is not DLC because the information in the interaction does not contain specific instructions for the control of the load itself. Rather the end-user chooses how price responsive they want to be given their real time operational preferences. These preferences can be pre-programmed with automation systems.

Note that interactions between the Utility/ISO and the higher layer DR resources subsequently result in additional interactions that result in specific loads and/or LER being put into a specific state as depicted in the diagram. Thus while an aggregator may be a single DR resource from the perspective of the Utility/ISO, that resource will be composed of multiple facility and load DR Resources from the perspective of the aggregator. **Thus any standards that cover the interactions between the Utility/ISO would be equally applicable to the interactions between an aggregator and the DR Resources in his portfolio.**

2. INTERACTION MODES AND DR SIGNALS

As depicted in the previous section, some condition on the Grid is eventually translated into specific load control states by a series of one or more multi-level interactions between the Utility/ISO and DR Resources.

The interactions themselves are negotiated via "DR Signals" that are exchanged with the DR Resources. A DR signal may contain a variety of different types of information or "instruments" that may affect the load profile of the DR Resource. The type of information used depends upon many factors ranging from contractual agreements to requirements on the DR Resource's response. For the sake of this analysis the type of information that is encapsulated within DR signals can be categorized as follows:

- Supply State
- DR Resource State
- Load Controller State

Each of these is covered in more detail below.

<u>Supply State</u>

Supply state refers to information about conditions concerning the supply of electricity that may affect a DR Resource's load profile. Such items may include the following among others:

- Price of electricity
- Source of generation (e.g. hydro versus coal)
- Carbon content
- Reliability of supply or grid conditions

The nature of this information is such that it does not include any specific instructions for how the load profile of the DR Resource is supposed to change. All decisions as to what the desired load profile should be in response to the information within the DR signal are entirely within the DR Resource itself.

The most typical example of this type of DR signal is real-time or dynamic electricity prices that may be sent to a DR Resource. Note that this type of DR signal may be used with any of the DR Resource types shown in Figure 2 including directly with loads themselves (e.g. prices to devices).

<u>DR Resource State</u>

DR Resource State refers to information that specifies what the load profile of the DR Resource should be as a result of receiving the DR signal. Examples of this type of information include the following among others:

- Specific consumption levels (can be either up or down)
- Dispatch instructions
- Load profile specifications

This type of information is more specific than Supply State in that it specifies what the load profile of the DR Resource should be. It does not specify how individual loads of the DR Resource should be controlled and thus the intelligence for determining how to control individual loads is entirely within the DR Resource itself. It could include information about the load shifting or shedding, and the certainty or predictability of the load shape change.

Typical examples of this include dispatch instructions that may be sent from an ISO to an aggregator. Note that this type of DR signal may be used with any of the DR Resource types shown in Figure 2.

<u>Load Controller State</u>

Load Controller State refers to specific commands sent to the controller of a load that specifies the state that the load should be in. Examples of this include existing DR programs such as AC cycling in which air conditioners within residences are turned on and off. This is the type of information that is used for DLC.

[1] Conversions with Gale Horst, Whirlpool.

Interaction Mode Hierarchy

An important characteristic of the different DR signal types discussed above is that as you move from Supply State to Load Controller State each one is more specific in terms of precise actions that are to be taken. One could in fact consider each type as being derived from another to form a hierarchy as shown in Figure 3.

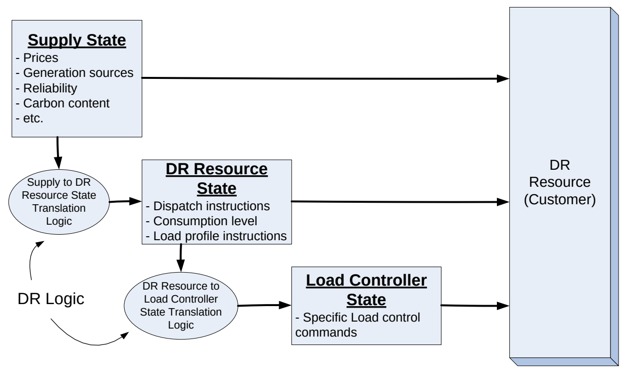

Figure 3. Interaction Mode Hierarchy

To go from Supply State (e.g. a price) to a DR Resource State (e.g. shed 100 KW) requires some sort of logic as depicted in Figure 3. Furthermore to go from DR Resource State (e.g. shed 100 KW) to specific Load Controller States (e.g. change set point on thermostat) requires another set of logic.

DR Logic

One could conduct a detailed analysis of the ramifications or pros and cons of these different types of DR Logic and where that logic resides, but for the purposes of this analysis it is convenient to lump both the DR Logic representations in Figure 3 into a single category which is simply called "DR Logic" as shown in Figure 4.

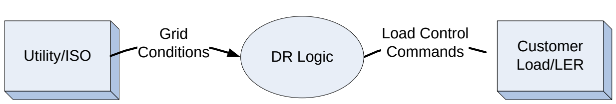

Figure 4. DR Logic – Translation from Grid State to Load/DER state

In essence DR Logic is the intelligence that transforms Grid conditions into specific load/LER states within facilities. In some cases it might be referred to as a "Shed Strategy."

By doing this we can further define what constitutes DLC versus FCLC by specifying where the DR Logic resides with respect to the facility as shown in Figure 5.

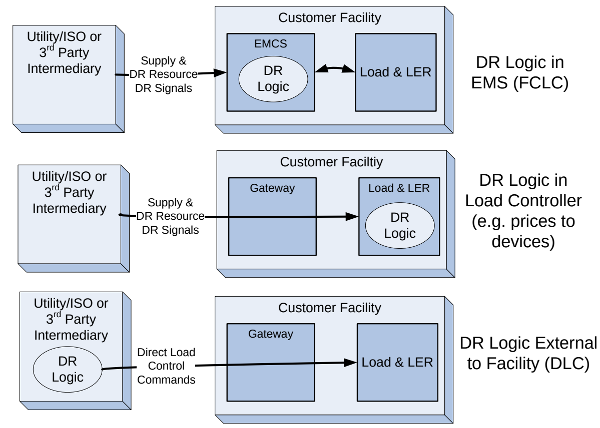

Figure 5. Location of DR Logic

In the top scenario of Figure 5 the DR Logic is encapsulated entirely within the facility and the clearly constitutes FCLC.

In the bottom scenario the DR Logic is contained entirely within the Utility/ISO or some third party intermediary and load control commands are sent directly to load controllers within the facility. This constitutes DLC.

The middle scenario depicts a situation where there is interaction directly between the Utility/ISO and the load itself, but the DR Logic itself is contained with the load controller. For the sake of this analysis this is defined as a FCLC.

Thus by definition in this paper when the DR Logic is within the facility it is considered FCLC and when the DR Logic resides within the Utility/ISO it is considered DLC.

Note that the distinction between FCLC and DLC could also be characterized as "Collaborative" versus "Managed" from the view point of the relationship between the facility and the external entity that it is interacting with for the purposes of DR.

As will be discussed in subsequent sections the distinction of where the DR Logic resides will help form a basis for comparing DLC and FCLC.

3. UPSTREAM INTERACTIONS

It is useful to define the concept that there may be "upstream" interactions from the DR Resource that are used to determine the performance of the DR Resource itself. Such interactions may include the following:

- Collection of information prior to the DR event to allow the Utility/ISO to predict the expected load profile of a DR Resource. This information may be used to both determine which DR Resource should receive a DR signal as well as what information to send the DR Resource in the DR signal.

- Monitoring of the DR Resource during DR Events to insure that they are behaving as expected. If there is a "closed loop control" of the DR Resource this monitoring may result in changes to the DR signal that is being sent to the DR Resource.
- Collection of information after the end of the DR event to allow post mortem activities such as analytics and financial settlement between the Utility/ISO and the parties that participated in the DR event.

The types of information that may be exchanged as part of an upstream interaction include the following:

- Consumption measurements
- Bids
- Forecasts of load profile behavior
- Opt-in or out status
- Load controller states (e.g. on/off, set points, etc.)

4. DLC VERSUS FCLC

DLC and FCLC can be compared and contrasted along a number of different dimensions as detailed below.

Load Profile Behavior

For the sake of analysis, consider the load profile of a specific DR resource. In the case of DLC the precise state of loads are controlled where in the case of FCLC they are not. Because of this, the load profile in the case of DLC will be more predictable. On the other hand because FCLC typically represents an aggregation of loads within the facility, there is a great deal more flexibility in responding to a DR signal and therefore FCLC has the potential to present a more reliable response to a DR signal. For example the Utility/ISO may know precisely the load reduction they may get by turning off a load using DLC, but if that load is already off then they get none. On the other hand a facility using FCLC can decide to alter the behavior of various loads in order to achieve a specific load reduction and supply the necessary response even if certain loads are already off.

In order for the Utility/ISO to get the same sort of flexibility and reliability with DLC that they have with FCLC they need to add complexity to their systems in order to aggregate all the DLC based resources and perform aggregated load optimization and control across them all.

Facility Requirements

Because FCLC does not dictate specific load control actions to be taken within a facility, there is a great deal of flexibility at the point where the DR signal is consumed and the resulting load control automation is implemented.

This level of flexibility in combination with automation is a huge benefit to those entities with the wherewithal to deal with it. Traditionally this has included larger commercial and industrial facilities that have the technical means, the expertise, and the desire to implement automated load control strategies that best suit their business. Included in this category are third party service providers like curtailment service providers and third party control companies.

Although FCLC does give maximum flexibility and control of loads by the facility owners it does come with a price versus DLC. In order for a DR signal to be put to useful work in the case of FCLC, the DR Logic must be implemented within the facility in such a way that it results in appropriate automated load control commands within the facility. In order for this to occur the following conditions must exist at the point at which the DR signal is consumed:

1. **There must be equipment** (e.g. EMCS) with the capabilities of receiving, processing, and interpreting the DR signal.
2. **There must be equipment** (e.g. EMCS) with the means of automating the control of loads, either directly or by sending messages to the appropriate load controllers.
3. **There must be equipment** (e.g. EMCS) with the means of being programmed by the facility owner (or someone acting on their behalf) so that it can transform information within the DR signal into specific load control actions. This is the so called "load control strategy" that is used to take advantage of the information provided by the Utility/ISO in a DR signal.
4. **There must be a person** with both the motivation AND expertise to analyze a facility and its operations and develop load control strategies specific to that facility that will be employed as a result of receiving a DR signal. The complexity of this task will depend upon the complexity of the facility and the loads which may be used as part of a load control strategy.
5. **There must be a person** (i.e. programmer) with both the motivation AND expertise to take the load control strategies referred to in bullet 4 and program them into the equipment referred to in bullet 3. Note that this is not meant to imply that

the programmer is an engineer, but may simply be an owner of a device that performs this programming task by configuring parameters through a simple user interface. The complexity of this task will be related to the complexity of the load control strategies combined with the complexity of the programming interface of the equipment referred to in bullet 3.

Note that items 1 – 3 above are requirements on the equipment within the facility while items 4 and 5 are requirements on humans who must operate the equipment.

There is nothing in the above descriptions that dictate that each of the entities be different although they may. Certainly all the functionality in items 1 – 3 could be encapsulated within a single device and items 4 and 5 could be fulfilled by a single person.

In the case of FCLC, items 1 – 3 above tend to add cost and complexity to the equipment deployed within the facility as compared to devices that might simply receive a direct load/device control message from some third party outside the facility.

Items 4 and 5 represent humans with a certain willingness and expertise that may not need to exist in facilities using DLC.

When evaluating the five factors listed above, it is impossible to make definite conclusions as to which facilities will be capable of supporting FCLC and which will not, but it is possible to make the following general statements with respect to the size of the facility and/or its operations[2]:

- The larger the facility the more likely it will have an infrastructure in place to automate the control of its loads.
- The larger the facility the more likely it will have personnel dedicated to the operation of the facilities and more specifically dedicated to managing the energy consumption of the facility.
- The larger the facility the more likely it will have the financial means to incur any additional costs in equipment required to support FCLC.
- The larger the facility the higher its energy costs and thus a greater willingness to lower those costs by using interactions that leverage the flexibility offered by FCLC.

All this supports the conclusion that the larger the facility the more likely it will be willing and able to support FCLC.

It is anticipated that as technology progresses and the marketplace develops it will become less expensive and easier to deploy equipment that can take advantage of FCLC, but there will still remain the issue of the willingness of the facility owner to deal with automating their facilities load response. An analogy to this issue is programmable thermostats. While they are becoming more widely used they are far from ubiquitous and even in places where they are installed it is not clear how many people take the trouble to actually program them.

As people become more educated and the process of automating becomes easier, the facilities which will be capable of supporting FCLC will become more widespread, but even then there will most likely always remain a need for third party service providers to provide services to these types of facility owners to deal with the automation of their loads using DLC. Some Utilities are considering offering these types of services in conjunction with their AMI deployments, especially for the residential and small commercial space.

In general FCLC adds cost and complexity to facilities versus DLC, but with those costs come added flexibility and control over the loads by the facility owner.

<u>Utility/ISO System Requirements</u>

By definition the DR Logic will be implemented within the entity that is performing DLC, i.e. the Utility/ISO. This means that there will be added complexity in the Utility/ISO systems to implement the DR Logic as opposed to FCLC.

If the Utility/ISO wants to support DLC over a wide range of different types of devices they must either model these devices and be able to send them commands or support some type of interface that allows them to interface with the device in some sort of generic fashion (i.e. SEP). In addition, because there are commands being sent to specific devices there may need to be customized instructions sent to a wide range of devices whereas in the case of FCLC there are more generic DR signals sent to a much small set of entities. Take for example the example where a relatively generic DR signal such as a price may be sent to all the facilities versus the variety of commands that may need to be sent to the plethora of individual load controllers within all the facilities. All these considerations represent a much higher level of complexity for the Utilities to support DLC than does FCLC.

[2] Note that the notion of “large” does not simply refer to the size of the facility, but also includes factors such as the amount of electricity consumed (e.g. industrial facilities) and perhaps entities that own large numbers of distributed facilities (e.g. chain store retailers).

There will also be added complexity in the Utility/ISO systems to support the aggregation and load optimization across the larger number of devices than in the case of FCLC.

Finally since DLC represents interactions with potentially a much larger number of entities than does FCLC there will be added complexity needed in the Utility/ISO systems to support the deployment and maintenance of the individual load controllers for DLC versus FCLC.

Therefore while FCLC may add cost and complexity to the facility systems, DLC will add cost and complexity to the Utility/ISO system that will be required to support DLC.

DLC may be more certain than FCLC because it is more predictable - however as more loads have the capability to respond to DR signals, people may prefer to have their own control of end-use loads and FCLC systems. Research is needed to understand the predictability of FCLC which are related to the value of the DR from the facility manager or home owner's perspective.

Communications Requirements

By its nature FCLC represents a more distributed system than does DLC since much of the DR Logic is more distributed among the facilities as opposed to being centralized with the Utility/ISO. What this means is that in general the communications channel between the Utility/ISO and the facilities must support more throughput with DLC than it would with FCLC since there are more individual entities that will need to be communicated with in the case of DLC versus FCLC. As an extreme example, take the scenario where the Utility/ISO is broadcasting a price to all the facilities versus sending individual load control commands to individual devices within each facility.

5. STANDARDS

There are a large number of standards related to facility automation including BACnet, Zigbee, LonMark, OPC, etc. just to name a few. Although these standards are relevant to facility operations and will play a role in how a the loads within a facility are managed, they are less relevant in defining the inter-domain interactions defined in this paper. The existing specifications and standards that are most talked about in relation to standardizing these interactions include:

- OpenADR – A specification developed at the Demand Response Research Center of Lawrence Berkeley National Laboratories. This specification gives a fairly complete model for FCLC in commercial and industrial facilities, but does not deal with DLC.
- NASESB OASIS – NAESB has numerous standards that are related to DR applications, particularly in the wholesale markets. Some aspects of their standards are relevant to FCLC.
- IEC 61968 (CIM) – This standard is focused on Utility operations and is being extended to support automated DR for both FCLC and DLC applications.
- IEC 61850 – This is a communications standard for distributed monitoring and control and is being harmonized with 61968. It could support aspects of FCLC and DLC.
- SEP (1.0 and 2.0) – This is an interface specification for interacting with residential energy management systems and is being developed by the Zigbee/Homeplug alliance. It has aspects relevant to both FCLC and DLC and is focused on residential applications that are serviceable through lower bandwidth AMI networks.
- Multispeak – This standard is focused on Utility operations and has some aspects FCLC.

As part of the National Institute of Standards & Technology (NIST) Smart Grid Roadmap there have been devised a number of Priority Action Plans (PAP's) that entail the cooperation between different standards organizations. PAP 03, 04, and 09 are the most relevant to automated DR and there are plans in place that include the participation of organizations such as OASIS, UCAIug, NAESB, and the Zigbee/Homeplug alliance, just to name a few. The current plans specifies that the efforts of all these various group with be harmonized as an IEC standard that will support all forms of DR including FCLC and DLC.

6. ACKNOWLEDGEMENTS

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Biography

Ed Koch is founder and CTO of Akuacom. Akuacom specializes in enterprise systems for automated energy control and monitoring in commercial and residential buildings, especially as it applies to Demand Response Programs. Prior to that Ed was the founder and CTO of Coactive Networks which specialized in creating solutions for linking distributed control networks used in energy management systems to IP networks and enterprise applications.

Mary Ann Piette is a Staff Scientist at Lawrence Berkeley National Laboratory and the Research Director of the PIER Demand Response Research Center. She has at LBNL since 1983 and has extensive experience evaluating the performance of energy efficiency and demand response in large facilities. The DRRC plans, manages, conducts and disseminates DR research for the California Energy Commission. Ms. Piette has a BA in Physcial Science and a MS Degree in Mechanical Engineering from UC Berkeley and a Licentiate from the Chalmers University of Technology in Gothenburg, Sweden.