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3

The Demand Response Paradox

The Importance of Markets and Policy to Demand Response

White Paper Series

Table of contents

INTRODUCTION

Building on the previous two papers, which introduced the topic of demand response (DR) and how utilities are being driven to evolve, this paper focuses on the conditions that are needed to create a market structure that enables the value of demand response to be released. It also discusses the benefits and products that can be created through this approach.

Key areas covered in this whitepaper include:

- The industry evolution
- The link between supply and demand in the electricity market
- DR methods and products
- The challenges of balancing supply and demand
- DR in different market structures

THE INDUSTRY EVOLUTION

Though sophisticated in implementation, the current grid has a relatively simple architecture, where generation is largely predictable and deliberately dispatched. Demand is also well understood, predictable and passive, and there is little complication arising from active demand management, distributed storage or real-time information flows[1].

This is changing though, and will continue to change for many years, as more renewables are introduced and the nature of demand transforms through the electrification of heat and transport. This in turn creates greater opportunity for the utilization of demand response and causes the market for demand response to increase. But why does the change from a "load following" to a "supply following" paradigm impact the use of demand response as the industry evolves to meet changing technological and lifestyle drivers?

One of the changes that is taking place is the increasing penetration of renewable generation. The variability of generation at distributed locations means that instead of generation being dispatched to follow the current load, the future will see demand being called on to follow supply. One challenge that this creates to the reliability of electricity infrastructure comes in the form of bidirectional power flow. Introducing distributed energy resources (solar, wind, storage) at customer locations and intermediate points creates the possibility of power flows in multiple directions, which was not anticipated in the present generation of grid controls and market systems, and introduces new challenges for system operators.

It also introduces a new or modified paradigm for how distribution systems are designed. Electricity infrastructure has historically been designed to meet peak demand, but greater intermittency leads to greater peaks and lower load factors with conventional design approaches. One opportunity for demand response is to help to maintain or increase the load factors by reducing peak demand, and hence avoiding additional infrastructural investments. But the key thing that will be required is a grid that is more flexible in how it adapts to the changes that are being introduced by things like consumer generation, electric vehicles and the ability of devices to communicate with each other.

RENEWABLES

Distributed generators—solar and wind—have very different characteristics as compared to traditional central generators (coal, gas and nuclear energy). Traditionally, energy has been generated based on demand, whereas renewable energy is only available when there is wind and/or sun and has to be used (consumed or stored) at that moment. For traditional generators, supply must also be consumed as soon as it is generated, but for renewables the demand has to follow the supply. Another challenge is the unpredictability of renewable energy, which is dependent on local weather, and therefore detailed weather forecasts are crucial.

And last but not least, when demand has to follow supply we need demand response or storage possibilities. This is what this series of papers addresses and end users have to be flexible to shift usage over time to balance supply. Storage may also be needed to store energy when it is generated so that it can be used later when demand exists. Storage of energy is not addressed specifically in this paper, but will play an important role in the future, and can act both as a generator and a load. Integration of storage will be crucial as this will help with flexibility. Storage may also spawn new markets such as storage swaps between participants based on time slots and availability. As the price of storage continues to fall, adoption rates and the related impact continues to increase.

Flexibility[2]

Flexibility in the energy system can be achieved in many ways. Today, the flexibility required to keep electricity supply and demand in balance is primarily achieved through the characteristics of the generation mix.

[1] *Britain's Power System: The Case for a System Architect*. Report. Institution of Engineering and Technology, 2014.

[2] Developed by CGI to support the UK's Tomorrow Today initiative.

As the progressive adoption of low-carbon technologies changes the nature of supply and demand—both in the way that we use energy and satisfy our energy needs—the value of flexibility is increasing.

With greater intermittency in the generation mix coming from renewable generation technologies, it becomes important to have the ability to increase flexible demand to consume energy where available, store the energy produced when generation outstrips demand, or export energy through interconnection.

Storage should not only be equated with electrical batteries. Energy can equally be stored thermally (both as heat and cold), kinetically (such as in flywheels), potentially (such as in pump storage or compressed air) and chemically (through conversion to fuel sources such as hydrogen).

When demand outstrips the available generating capacity, then the ability to satisfy demand from storage—through the utilization of demand side flexibility to reduce or shift demand, or to import energy through interconnection—are all equally useful forms of energy system flexibility.

Three examples are discussed below to illustrate some of the changes that were once novel, but are now becoming increasingly common: smart electric vehicle (EV) charging, smart homes with a demand response solution, and the national study "housing dashboard" for active energy management of French households.

Electric Vehicles

"All electric" is one of the future scenarios in which electric vehicles (EVs) will pay a main role. However, EVs are a challenge for the electricity grid. What if everybody comes home at around the same time in the evening and decides to plug in their EV simultaneously? The peak capacity of the grid would need to be much bigger than it is today and could kill the business case for EVs if infrastructure needs to be rebuilt. For instance, the load on transformers at the residential level would now result in huge increases in transformer capacity to handle the peak.

Smart charging is a possible solution where the grid decides which cars to charge, how fast and when. But comfort and flexibility for the end user remain crucial. There needs to be a level of override and/or set points dependent on various factors that allow the system to optimize charging based on customer value, so that those who need their cars sooner can be sure they will be charged earlier. In the Netherlands, several of these smart EV charging pilots have already been executed.

Currently, more than 65,000 EVs (both plug-in hybrids and full electric vehicles) are being deployed in the Netherlands. Here, distribution system operators (DSOs) are struggling with future challenges, such as peak loads, caused by EVs. On the other hand, balance responsible parties (BRPs) are struggling with buying electricity at the right time, knowing that the characteristics of EV charging are deviating from regular patterns and are less predictable, and that this may lead to penalties. Pilots have also been started to implement solutions where charging of EVs is scheduled based on factors such as the time when an EV has to leave for another ride.

At CGI, we have initiated a master thesis research study about end-user interaction and smart charging[3]. As a part of this study, different subscription models were tested on a group of EV drivers: usual subscription (kWh pricing), flexible subscription (each month a small bonus for being flexible) and super flexible subscription (each month a higher bonus for being flexible).

The results concluded that there was no obvious preference for one individual subscription. Each model received the same amount of votes. Yet when a panic button was added to the flexible subscriptions (with a small penalty), two-thirds of the group preferred a super flexible subscription. This confirmed that financial incentives could work well, but the perception of comfort and flexibility is very important.

Smart Homes

CGI has also developed two smart home projects in the Netherlands where financial incentives are used to stimulate end users to use energy at other times. In these projects, hundreds of houses are equipped with solar panels and heat pumps, and a local "energy computer" manages electricity use by adding smart appliances, such as smart washing machines, to the system. The objective of these projects is to implement an end-to-end solution and investigate end-user behavior. For instance, weather forecasts are used to predict the solar energy that will be generated on a daily basis and variable energy pricing (both supply and transport) is used to stimulate people to use energy at optimal times. Conclusions from these projects agree that end users will be flexible when they can save money or believe that they are saving money (perception). Also, most end users didn't use all technical possibilities such as automatically starting their washing machines. In practice, most people started their appliances manually when the pricing was low or they saw the sun shining. This is contrary to the popular belief that "set-and-forget" is the best way to engage customers.

[3] Arie van Weelden: "EV Charging Flexibility"

Active Energy Management In France

Conducted under the auspices of the Agency for Environment and Energy Management (ADEME), this research relies on several innovative technologies: optical sensors to measure consumption, the ARCHOS Smart Home tablet and several connected objects (e.g., temperature and humidity sensors, smart plugs, etc.) The TBH (Tableau de Bord Habitat) Alliance project, proposed by a consortium of companies and led by CGI Business Consulting, aims to conduct a baseline study on a nationally representative sample of 3,200 French households, to compare the potential electricity savings of different devices by demand management.

The objectives of the study conducted over more than a year and due to be completed in March 2017, are to:

- Establish a quantitative comparison of the potential energy savings for different solutions.
- Qualify the acceptability of different solutions in households.
- Determine the features most easy to use, and more efficient, in terms of energy savings.

The sample households will be divided into sub panels of several hundred homes each. Every group will be assigned one or more factors that are to be tested. This approach will allow scientific and statistical comparisons of each device, but also test multi-device approaches.

THE LINK BETWEEN SUPPLY AND DEMAND

Before looking specifically at the benefits of demand response in the electricity market, it is helpful to take a brief look at the relationship between supply and demand in general. Say's Law states that "supply creates its own demand." In certain types of economies, this result certainly holds true. In electricity today, it is more of a case that demand creates supply, but that is starting to change.

However, in a traditional economics realm, the Paradox of Thrift is the Keynesian response to Say's Law. This states that an individual who saves money will reduce their spending by that same amount. Since one person's spending becomes another person's income, decreased spending destroys income.

Just to confuse the issue even further there is also the Reverse Paradox of Thrift. In a nutshell this states that because income rises, saving grows too. This can lead to a higher desire to spend and can actually create new saving in an economy. According to the Keynesian perspective, the only time that higher demand would not stimulate output and employment is when all resources are already fully engaged.

So what does this mean for the electricity grid? Well, if you take these laws one at a time, they could have the following implications:

- **Say's Law**
  The electricity grid has analogies with Say's Law. Today people do not consume power just because it is being generated, but instead, the load (demand) creates generation (supply). However, as renewables become a greater part of the generation portfolio, Say's Law will have more applicability, since load will need to start responding to renewable generation.
- **Paradox of Thrift**
  The electricity parallel here is obvious. If the individual consumes less energy, this reduces a utility's or energy supplier's revenue. Thus, reducing energy use diminishes an energy provider's income. This discussion gets more complicated as we consider mechanisms for generator pricing and transmission constraints.
- **Reverse Paradox of Thrift**
  Here we have a situation where higher income allows investment in energy-saving technologies. This includes the purchase of new appliances and more efficient home insulation, where higher consumer income results in consumer energy savings, which in turn results in reduced income for energy providers.

The interesting thing, from an electricity perspective, is that if we assume that overall energy use is generally trending flat (i.e., not increasing or decreasing), then with or without energy efficiency, utility income due to power sales will decrease as more and more renewable generation sources are commissioned (assuming that they are not utility owned). In fact, total U.S. electricity sales have declined in four of the past five years[4], and will continue to decline. The only year-over-year rise in electricity use since 2007 occurred in 2010, as the country exited the 2008-09 recession. In addition, we also see that the electric power generation sector in the U.S. lost more than 5,800 jobs between January 2011 and June 2014, despite a gain of nearly 1,800 non-hydro renewable electricity generation jobs, according to data available from the Bureau of Labor Statistics (BLS)[5].

[4] U.S. Energy Information Administration, December 20, 2013.

[5] U.S. Energy Information Administration, December 19, 2014.

DR METHODS AND PRODUCTS

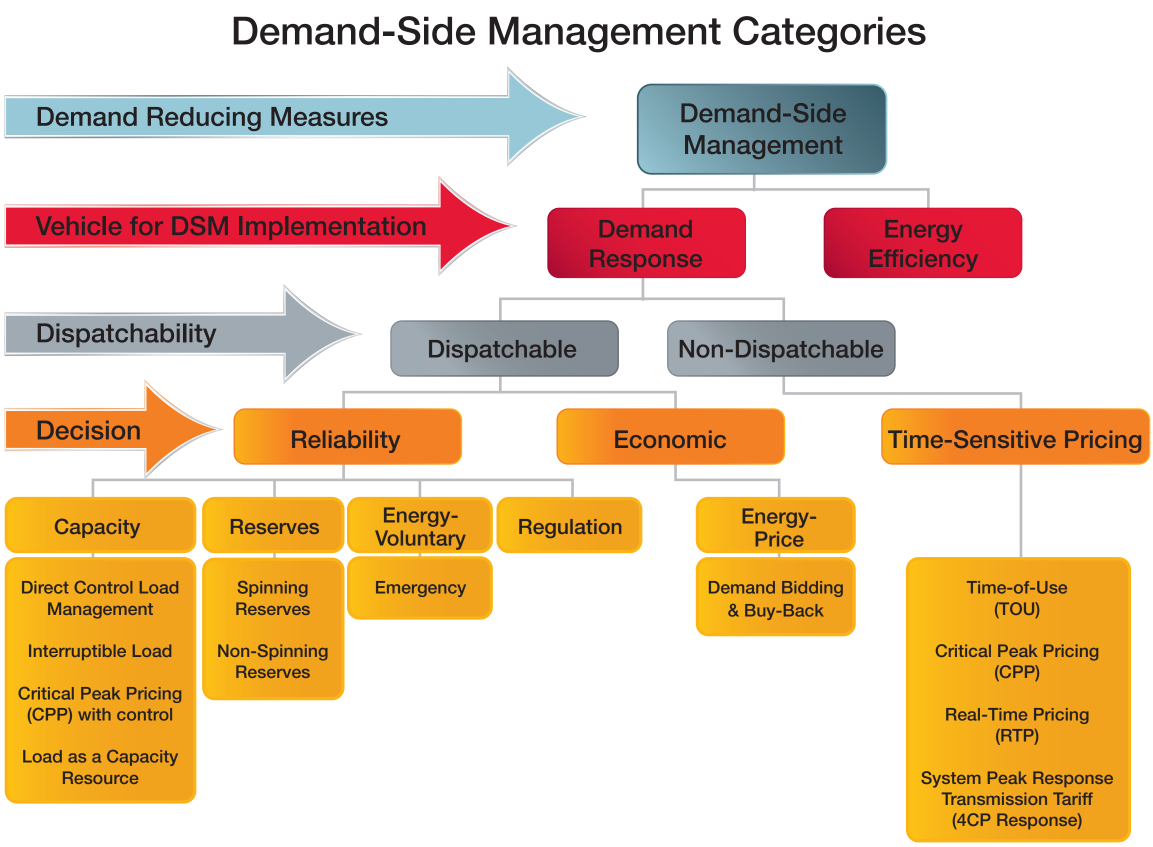
In order to balance supply and demand within the electricity grid, each side needs to have some level of responsiveness to control signals. This does not assume that control is either centralized or decentralized, but just that a system of control exists whose purpose is to reliably and safely balance supply and demand.

Demand response can be both dispatchable and non-dispatchable. For direct control (dispatchable demand response), utilities today may choose to reduce load based on either price or reliability drivers, or perhaps both. The customer in these scenarios does not see these drivers and is usually remunerated in the form of an annual payment for participation in the scheme. For non-dispatchable demand response (see Figure 1), customers are sent a price signal, which either causes them to take action or action is taken automatically through pre-programed equipment that the customer may choose to override or accept. The customer does not respond to the system state, but to prices. The choice is simple for customers, but the impact of their choices is part of a hierarchical and coordinated control scheme.

The following diagram[6] is useful to illustrate the difference between dispatchable and non-dispatchable demand response, as well as the drivers that call on demand response, based on economics or reliability, described earlier.

Dispatchable

"Dispatchable demand response" refers to planned changes in consumption that customers agree to make in response to direction from someone other than themselves. It includes direct load control of customer appliances (such as those for air conditioning and water heating), directed reductions in return for lower rates (called curtailable or interruptible rates), and a variety of wholesale programs offered by regional transmission organizations (RTOs) or independent system operators (ISOs) that compensate participants who reduce demand when directed for either reliability or economic reasons. This direction to reduce load can be in response to acceptance of the consumer's bid to sell its demand reduction at a price in an organized market (wholesale price-responsive demand response) or to a retail provider.



[6] *Demand Response Availability Data System (DADS): Phase I & II Final Report. Report*. Princeton: NERC, 2011.

Of course, the number of customers that would want to actively participate in a trading market is open to debate, but participation through a third party is probably a viable and attractive option. This may be nuanced, but as we move down in the scale of dispatchable loads, potentially to domestic virtual power plants, then it's unlikely that consumers themselves will "bid." It is more likely that their energy services contract will have an availability component that the energy services company or aggregator will be able to call upon. This would provide the trading desk of energy retailers with a hedge against their exposure to the wholesale market—allowing them to lengthen or shorten their position appropriately. And by lengthening their position in a rising wholesale market, they can either reduce their exposure if they have a short position, or increase their length and sell to make a profit.

It may indeed be that the greater value of demand response rests with the energy retailers/traders rather than the network operators, who are managing demand on specific networks and against the capacity constraints of that infrastructure. But supply and demand has to be balanced and demand response has the potential to provide an extensible and flexible solution as loads become more responsive.

Non-Dispatchable

"Non-dispatchable demand response" refers to programs and products in which the customer decides whether and when to reduce consumption, based on a retail rate design that changes over time. This is sometimes called retail price-responsive demand and includes dynamic pricing programs that charge higher prices during high-demand hours and lower prices at other times[7].

From a control perspective, dispatchable demand response provides the ability to know what the outcome of the control action will be. With non-dispatchable demand response, there is less surety of the outcome for utilities, since it involves an element of customer behavior that needs to be modeled. A customer may accept a set point adjustment on a 100-degree day to help maintain system reliability that is stressed by air-conditioning use, but after a heat wave that extends over several days, the consumer may decide that staying cool is more important than avoiding higher prices.

Products Of Demand Response

The way in which demand response is used allows it to be treated as a product that can go beyond simple reductions in peak period consumption to include shifting consumption from peak to off-peak hours, and also provide the products described below. The focus of demand response in coming years will be the evolution of the potential use of customers' flexible distributed energy resources to provide a greater set of services to markets and transmission and distribution operations[8].

Today, demand response can be categorized as one of the following products[9]:

- **Energy**
  Demand resources are compensated based solely on demand reduction performance during a demand response event.
- **Capacity**
  Demand resources are obligated over a defined period of time to be available to provide demand response upon deployment by the system operator. The maturity of the load as a capacity resource is an important step in the evolution of demand response and other flexible distributed energy resources to potentially provide a broader range of bulk power system services. These include a growing set of ancillary services[10].
- **Reverse Paradox of Thrift**
  Here we have a situation where higher income allows investment in energy-saving technologies. This includes the purchase of new appliances and more efficient home insulation, where higher consumer income results in consumer energy savings, which in turn results in reduced income for energy providers.
- **Reserve**
  Demand resources are obligated to be available to provide demand reduction upon deployment by the system operator, based on reserve capacity requirements that are established to meet applicable reliability standards.
  - **Spinning reserve**: Unloaded capacity from units already connected or synchronized to the grid that can deliver energy in 10 minutes and run for at least two hours.
  - **Non-spinning reserve**: Extra generating capacity not currently connected or synchronized to the grid that can be brought online and ramped up to a specified load within 10 minutes.

[7] *National Action Plan on Demand Response*. Report. Washington, D.C.: FERC, 2010.

[8] Newport Consulting, Paul De Martini. DR 2.0: *Future of Customer Response*. Report. Association for Demand Response & Smart Grid, 2013.

[9] *Demand Response Availability Data System (DADS): Phase I & II Final Report*. Report. Princeton: NERC, 2011.

[10] Newport Consulting, Paul De Martini. *DR 2.0: Future of Customer Response*. Report. Association for Demand Response & Smart Grid, 2013.

- **Regulation**
  Demand resources providing a regulation service automatically respond to changes in grid frequency (similar to the governor action on a generator), and are also subject to continuous dispatch based on instructions from the system operator (similar to automatic generation control). The provision of a regulation service does not correlate to the demand response event timelines, deadlines and durations. Existing DR programs continue to provide significant value, but increasingly gaps are being identified between electric system operational requirements and demand response program performance that will require program enhancements and potential technology upgrades[11] that could be fulfilled by a more flexible and responsive demand response.

SUPPLY AND DEMAND AT THE SPEED OF LIGHT

Demand response is a tool that helps the industry balance supply and demand, and also provides capacity. Going back to basics, the sellers in a market are on the supply side of the market and the buyers are on the demand side. Conceptually, this is pretty simple, but supply and demand themselves are not this simple. Demand is a relationship showing the quantity buyers will buy at various prices. But for most electricity consumers, this is not true, at least today.

For many people, the price is fixed, and we use what we need. Accordingly, most residential and small commercial consumers still buy electricity on rate structures that do not vary from either an ex-ante (day ahead) or real-time perspective[12], and are not dependent on changes in the overall supply and demand conditions, marginal costs or wholesale market prices. This is perhaps true for most countries.

For the sellers of DR, there is debate as to whether they belong on the supply or demand side (see later discussion on FERC 745), and the sellers of DR may potentially be considered on the demand side. This leads to the nuances around the providers of storage and whether they fit in the supply side or the demand side and whether they change their position based on whether there is a shortage or a surplus of tradeable electricity in the market.

In many (non-electricity) markets, the demand relationship can be expressed as a table or a graph, showing prices and the corresponding quantities of electricity demanded. This relationship is used by the buyer to make decisions on what to buy and when. The notion of price may be expanded to include time, travel, inconvenience and the discomfort that the buyer must give up or endure to obtain the product or service. This is equally true for time-of-use or dynamic electricity markets, but in the case of electricity, the decision of a buyer or a group of buyers to defer a purchase not only impacts the market pricing, but it also impacts the ability of the market to operate through its influence on reliability, if enough buyers make similar decisions.

The balance of supply and demand for electricity has to occur instantaneously. As we move from central generation, with the utility as the distributor and in many cases also the seller of power, to a world of liberalized electricity markets where there are many sellers and buyers of power, with buyers also acting as sellers, the balancing challenge suddenly gets a lot more complicated. A more flexible and responsive demand response is just what the industry needs. The economic and regulatory models may be changing, but the same "pesky laws of physics"[13] that applied 100 years ago still have to be obeyed today, and none of our new financial instruments will work if we cannot control the flow of power.

MULTI-AGENT COORDINATION

In the future, intelligent distributed coordination will be essential to ensure that electricity infrastructure runs efficiently. The PowerMatcher open source software developed by Toegepast Natuurwetenschappelijk Onderzoek (TNO)[14] is a multi-agent coordination system facilitated by the Flexible Power Alliance Network[15] (FAN) that has been developed to provide this kind of coordination. The heart of the system is an electronics market, where local control agents negotiate using strategies based on short-term micro-economics.

[11] Ibid.

[12] Joskow, Paul, and Catherine Wolfram. Dynamic Pricing of Electricity. Technical paper. 2013.

[13] Erich Gunther, Remarks at Grid 3.0 workshop at NIST, March 2015.

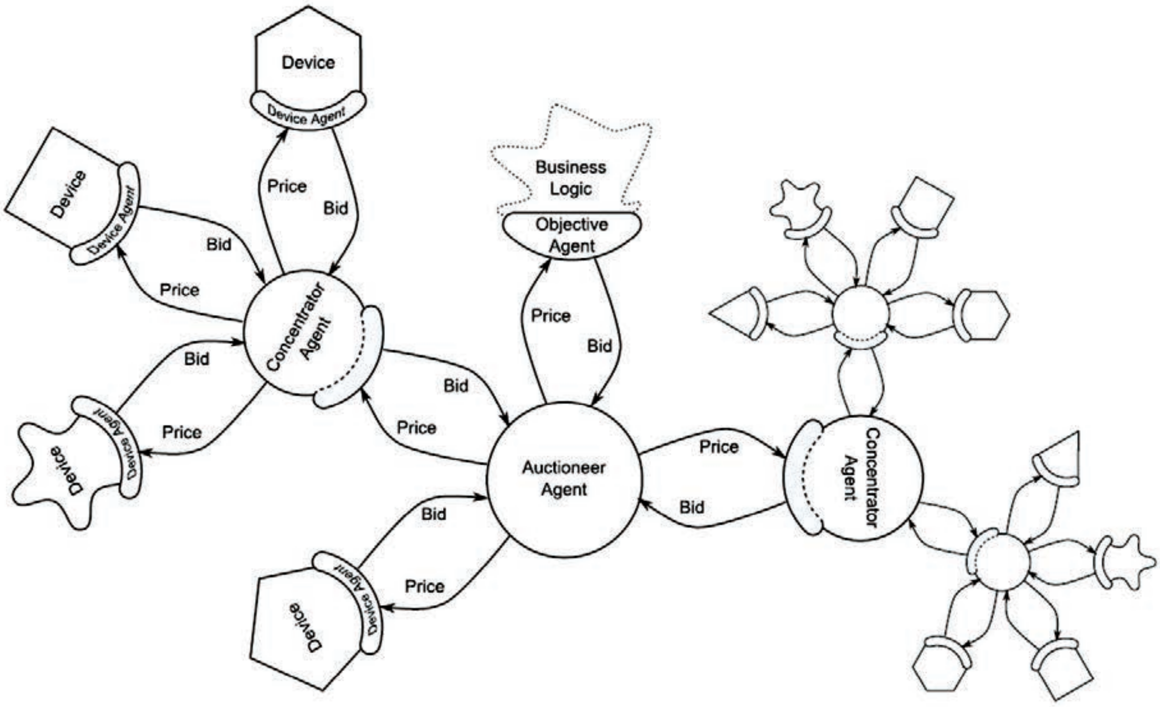
[14] Netherlands Organization for Applied Scientific Research. Headquartered in Delft.

[15] CGI is member of FAN.

PowerMatcher is a general purpose coordination mechanism for balancing demand and supply in clusters of distributed energy resources (DER), including power sources created by technologies such as distributed generation, demand response and electricity storage connected to the distribution grid. These "clusters" can be electricity networks or micro grids with a high share of distributed generation or commercial trading portfolios with high levels of renewable electricity sources. PowerMatcher was used as the basis for the Realtime Energy eXchange (REX) software platform developed for Alliander by CGI to connect end users with existing energy trading markets and with the imbalance market, so they can buy and sell energy whenever it suits them best.

MAKING DR WORK IN DIFFERENT MARKET STRUCTURES

There is considerable geographical variation in the amount of existing demand response. This variation is driven by several factors, including the rate of load growth (or decline), the cost of avoided capacity, and the regulatory disposition at the individual jurisdiction level toward demand-side programs. While these factors may vary across countries, many developed nations face the common prospect of aging infrastructure and are seeing increasing amounts of renewable generation being deployed.

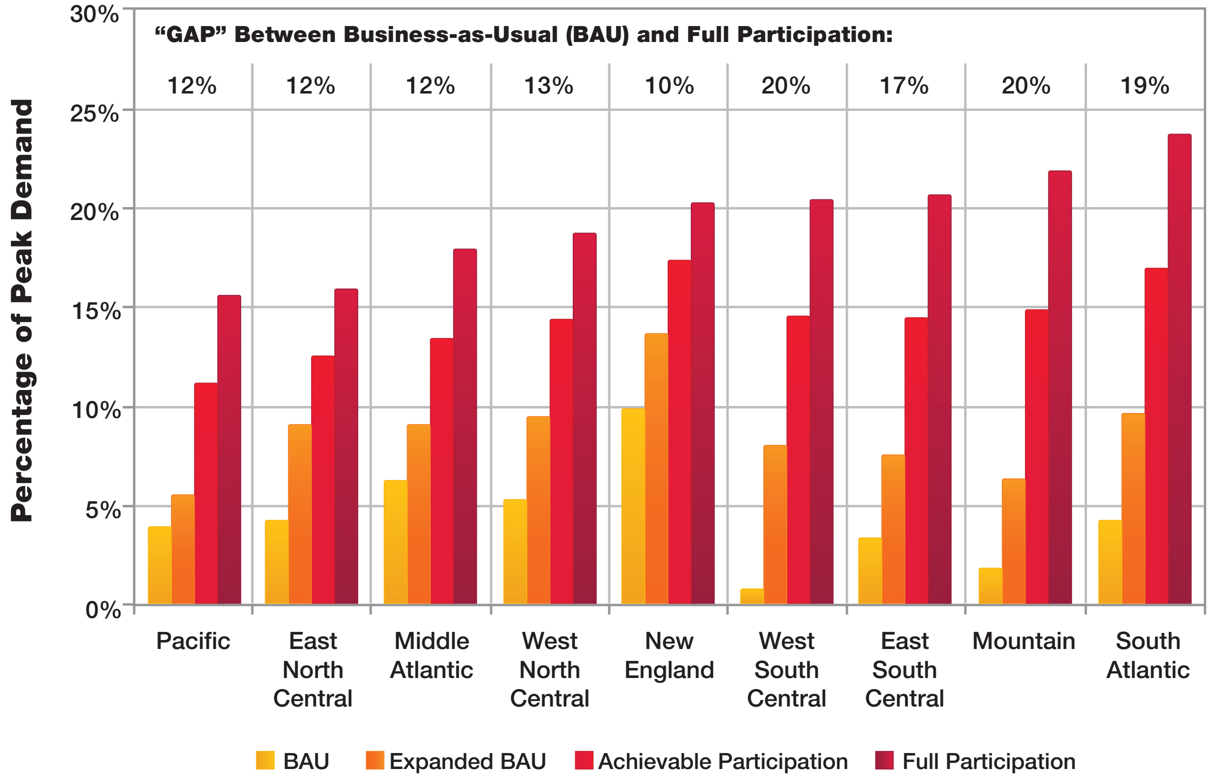


Within a PowerMatcher cluster, agents are organized into a logical tree. The leaves of this tree are a number of local device agents and, optionally, a unique objective agent. The root of the tree is formed by the auctioneer agent, a unique agent that handles price formation by searching for an equilibrium price. In order to obtain scalability, concentrator agents can be added to the structure as tree nodes.

The agents communicate in an event-based manner. Device agents update their bids whenever there is a change in the system state significant enough to justify a bid update. One of the key activities of a PowerMatcher cluster of agents is the delivery of near real-time balancing services.

During the past decade, demand response resources have significantly increased their market share in organized markets. For example, demand response resources that are capable of providing reserves may participate in the day-ahead and real-time ancillary services markets. Furthermore, demand response resources may offer operating reserves and regulation services. The figure below shows the regional variation within the United States in the potential for demand response[16].

[16] *National Action Plan on Demand Response*. Report. Washington, D.C.: FERC, 2010.



REQUIREMENTS FOR OPTIMAL USE OF DR

An infusion of demand response resources has aided in providing greater grid reliability, mitigation of generation market power, and an overall decline in fuel-adjusted power prices in organized wholesale markets[17]. But what determines how much difference demand response will make in any given market and how much acceptance there will be for this solution? In other words, what conditions need to exist to create the markets where demand response can be used?

This is discussed in the following section.

Monetization of DR

Like any market, demand response will only prosper if there are benefits to be reaped and financial gains to be made. For DR to be successful, there needs to be an opportunity for demand-side participants to make money, and for the services that they offer to be beneficial from a control and balancing perspective. There may well be other services and capabilities that can be incorporated, but these reflect a minimum requirement.

There is no doubt that demand response can have a huge effect on market prices, shaving off the lucrative peak periods when generators could count on their biggest rewards. In 2013 alone, it delivered $12 billion in customer savings in the markets operated[18] by PJM[19]. But as discussed previously, savings to a customer could mean revenue losses to energy generators. This, above all, has resulted in pushback against demand response. This pushback raises questions about the monetization of demand response and how demand response resources should be compensated. In a congressional testimony in April 2014, Nicholas Akins, chairman, president, and CEO of American Electric Power complained that "demand response continues to be paid similar capacity prices to steel-in-the-ground generation." Recent developments in the United States have highlighted the battle of how to treat demand response resources, such as when in 2011 the Federal Energy Regulatory Commission (FERC) passed Order 745, which stipulated that demand response must be paid the same as supply-side resources. However, in May 2014, the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit) ruled that demand response was a retail transaction and, thus, subject only to oversight by state utility commissions. The court ruled that a buyer was a buyer, but a reduction in consumption could not be a "wholesale sale." This appeal judgement was subsequently reversed by the Supreme Court of the US in January 2016.

[17] ISO/RTO Council, 2009 State of the Markets Report, at 26 (2009)

[18] PJM Interconnection is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania,

[19] FERC Order 745 and the Epic Battle Between Electricity Supply and Demand, Power Magazine, December 18, 2014.

Another strategy is to redefine demand response as a load reduction, subtracting it from customer needs before considering buying capacity, rather than as a resource on the supply side. This would take demand response out of wholesale markets altogether, sidestepping legal issues. This also seems more in line with a "conventional" economic perspective, but if one order can cause this much trouble, how will we create the necessary regulation and legislation to make it possible for demand response to provide the benefits that it promises in the future and how will they be monetized? Furthermore, will we see a similar battle as exhibited between state and federal regulators in the United States being reflected in national jurisdictional disagreements in Europe?

How demand response is monetized obviously affects who benefits from it and how the market for demand response evolves from here, but it seems clear that more and more non-dispatchable demand response will come into these markets and that means that price will be the main signal, whether the incentive is to increase or decrease load.

Enablers

For demand response to be effective there needs to be a sufficient quantity of load that can be incremented or decremented to balance generation supplies. There also needs to be a method to communicate response signals for the purposes of reliability and/or market price from the entities managing them to the loads that are expected to respond. These technical enablers must be present for DR to be viable. For some services, such as frequency regulation, the load may not need a separate mechanism to provide signals, but it can still respond to actual variations in system frequency, as is done for generator coordination using droop control.

The enablers must be able to create a situation that makes it possible for balance to be managed in real time, all the time. This implies a level of automation and does not just require customers to respond manually. This in turn means that devices, such as smart meters and intelligent appliances, and customer values are all helpful to make DR work. But none of these enablers will be enough to make DR succeed without a mechanism for managing the flow of money (i.e., the markets that bring together supply, demand and control). Opportunities will be created for demand aggregators and energy retailers/traders through the ability to utilize demand response and these will provide ways to engage customers in DR.

Barriers

Over the coming decade, a number of significant evolutionary milestones are expected that enable flexible customer distributed energy resources (DER) to provide market and grid services. DR will evolve from today's use of load as a capacity resource, expanding to a much broader use of flexible DER. A primary focus now, and continuing over this decade, involves creating differentiated services, resolving market access issues and creating successful customer value propositions. More specifically, barriers to unlocking value from flexible distributed energy resources exist. Among them are:

- Lack of power system service definitions and performance requirements
- Insufficient technology investment
- Revenue availability and monetization
- Market access
- Customer adoption and engagement

In addition to these barriers, there are those barriers that may not exist as yet, but that could be created by regulation, risk exposure, or general uncertainty.

A more thorough review of DR benefits will be developed and discussed more fully in a planned future paper that will review DR markets. Benefits need to be realized by all participants in DR transactions in order to provide them with the incentive to participate, and there are many participants, services and benefits to consider. Complexities may also arise where there are different and sometimes contradicting goals and benefits between parties.

Market Challenges

There are different types of DR, resulting in differences with respect to the benefits they can deliver and their timescales for response. What are the requirements for the optimal use of DR? Should market design incorporate both dispatchable and non-dispatchable DR? How will the industry use DR in the transition from a "load following" to a "supply following" model? Given the untapped potential of DR, who should be developing the programs to create DR markets? Who will benefit most from these markets and how can the industry unlock the "DR potential" from its consumers?

These are questions that relate back to markets. Given that dispatchable DR would introduce more security (from a balancing perspective), and assuming that customers will value non-dispatchable DR, how will market design incorporate the relevant risks and transfer these to concerned parties? And what conditions/services/price points are required to gain broader consumer participation? These are issues that will be addressed in a future paper on DR markets.

SUMMARY

The traditional utility model is predicated on load growth, but efficiency has severed the link between a population/economic surge and energy growth. The Energy Information Agency (EIA) forecasts average annual electricity growth of only 0.7% in demand over the next 20 years[20]. With decreasing reliance on traditional generation over time, it is predicted that the old model of generation following load will be superseded by a future model of load responding to supply[21]. In the transition between these two paradigms, the new problem is one of finding the means to manage that change efficiently, while maintaining the economic balance of resource adequacy, stability, supply security and reliability. During this transitionary era, the grid has to support a hybrid set of solutions that will require flexibility and coordination with current centralized systems.

This change, along with the shorter timescales for adding DER when compared to traditional generation sources and the increasing technical capabilities to facilitate coordination between DER, users, and devices, creates a need to re-evaluate our service regulation cost for utilities. Investor-owned electric utilities point to a paradigm shift caused by the need for large, new capital additions at a time of declining sales growth and reduced credit worthiness. They urge the development of new regulatory frameworks that provide for cost recovery outside the traditional rate case[22]. Perhaps a regulatory tool to stimulate innovation is required such as a tiered recovery mechanism based on levels of customer participation and/or customer satisfaction[23]. There seems little doubt that regulatory models must evolve to address the ability for edge devices to offer services.

In Europe, the absence of a single market model and the lack of regulatory mandates have been major factors slowing down the growth of the demand response market, where the sector is primarily driven by smart grid roll outs and energy price volatility. Energy-intensive commercial and industrial (C&I) consumers have been major contributors towards the overall DR market. In the residential segment, DR is largely undermined in Europe. However, it has significant scope for growth, which is now corroborated by the increasing mass deployments of smart meters and shipments of energy management devices that can be used for interfacing with DR platforms. This market is estimated to grow at a CAGR of 36.3% from 2014 to 2019[24].

The potential for a DR market exists, and is significant, but the enablers and policies need to be in place to support it, and make it easier for service providers to offer the same service across jurisdictional boundaries.

[20] Annual Energy Outlook 2014. Report. Washington, DC: U.S. Energy Information Administration, 2010.

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