Demand Response: A Transformative Force in Wholesale Electric Markets

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ABSTRACT

The growing reliance on demand response in organized electric power markets has had major effects on these markets, affecting the choice of resources in these areas and the price levels and efficiency of the markets. Greater levels of demand response promise to further transform electric power markets. Development of a responsive market demand will lead to major changes in the way that the electricity industry operates. These changes will be further enhanced by the substantial investments underway to create a smart grid. Key developments that could transform electric power markets include the widespread use of electric car batteries or major appliances to provide electric power ancillary services and the use of demand resources as a "dance partner" for variable wind generation.

This paper explores developments in these areas and outlines a vision for a more efficient and secure electric grid based on the full participation of demand response resources. Evidence of the beginnings of this transformation is presented, along with projections of the possible size of demand response as a future resource – as much as 20 percent of the nation's peak demand absent demand response, according to a recent assessment prepared by the staff of the Federal Energy Regulatory Commission. The paper also examines other Commission activities that should help to realize the nation's demand response potential, including the development and implementation of a National Action Plan on Demand Response.[1]

Demand Response in the Electric Power Industry

Demand response is an important reliability resource in the electric power industry. It will soon be an essential component of a coming group of related power industry modernizations that will fundamentally transform how electric power is produced, transported and consumed. These changes will be brought about by demand response together with the smart grid, smart meters, smart appliances, the expected widespread penetration of electric vehicles, and an increasing reliance on renewable energy resources, especially wind and solar power.

A previous paper, "Creating Regulatory Structures for Robust Demand Response Participation in Organized Wholesale Electric Markets" (Wellinghoff, et al. 2008), set out the progress made to introduce demand response into organized power markets, which serve large regions of the United States. It explained how demand response helps maintain price stability, reliability, and operational efficiency in bid-based organized markets and set out the rulemaking initiatives of the Federal Energy Regulatory Commission (FERC) that support demand response: Commission Order Nos. 890 (FERC 2007a), 693 (FERC 2007b), and 719 (FERC 2008).

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[1] The opinions and views expressed in this paper do not necessarily represent those of the Federal Energy Regulatory Commission or individual Commissioners, and are not binding on the Commission.

This paper explains the progress and potential for deploying demand response in even more innovative ways not limited to organized, bid-based markets. It describes a vision for a more efficient and secure electric grid for the 21st century that operates in a fundamentally different way from the grid of the 20th century, based in large part on the full participation of demand response resources.

Recent power industry developments provide evidence of the beginnings of this industry transformation. The rapidly increasing utility deployment of advanced meters to enable demand response is one such sign. According to FERC staff annual reports, advanced meters grew from less than one percent of all meters in the United States in 2006 to close to five percent in 2008 (FERC Staff 2006 and 2008). This penetration of advanced meters is expected to continue to grow. The National Assessment of Demand Response Potential (FERC Staff Assessment, available at http://www.ferc.gov/legal/staff-reports/06-09-demand-response.pdf), projects that this penetration may grow to close to 40 percent by 2019 (FERC Staff 2009). Also illustrating the beginnings of this transformation is the strong interest of the Administration and the energy, telecommunications and information technology businesses, and the North American Electric Reliability Corporation (NERC).[2] Remarks by the President, while in Arcadia Florida, on recovery act funding for smart grid technology indicated that investment in smart meters in that region coupled with other technologies will reduce demand for electricity by up to 20 percent during the hottest summer days.[3]

Another telling factor is the rapid growth in the importance of the third-party demand response provider business (also known as curtailment service providers or CSPs), where a third-party provider is a for-profit business separate from either the customer or the utility that helps customers to adopt demand response technologies and practices, and also aggregates many small customers into one large block offering of demand response into a suitable power market. The growing importance of CSPs is particularly evident in the organized markets operated by Regional Transmission Organizations (RTOs) and Independent System Operators (ISOs). For example, CSPs increased their share of subscribed load of demand response resources from 44 percent to 77 percent in the New York ISO's emergency demand response programs and capacity markets from 2003 to 2008. In the ISO New England market, CSPs were responsible for attracting over 60 percent of the total demand-side capacity in ISO New England's first forward capacity auction (Cappers, Goldman and Kathan 2009).

Demand response has the potential to provide as much as 20 percent of the nation's peak demand in the next ten years, according to the recent FERC Staff Assessment. According to this assessment, if advanced metering infrastructure was universally deployed and if dynamic pricing was made the default tariff and offered with proven enabling technologies almost 188 GW of peak reduction potential would be possible (FERC Staff 2009, p. 27).

This paper describes how demand response resources are being developed in three overlapping phases: providing a substitute for new electric generating capacity, providing a substitute for electric energy, and providing a substitute for traditional so-called ancillary services—and how these developments set the stage for a new vision of the electric power industry. Just as many electric power generating facilities can provide all three of these

[2] Demand response is increasingly viewed as an important option to meet the growing electricity requirements in North America, while at the same time addressing green-house gas and CO_2 legislation. Demand response supports operational and long-term planning margins. (NERC 2007)

[3] Comments of President Obama at the DeSoto Next Generation Solar Energy Center Arcadia Florida. (White House Office of the Press Secretary 2009)

services, so too can demand response resources. While these three services are therefore not entirely distinct, this paper treats them as distinct for the purpose of explaining the evolution of an industry toward the envisioned future.

Demand Response as a Capacity Resource

For much of its history, the electric power industry has relied on emergency demand reductions to keep the power system operating reliably; that is, to supply enough power at every instant to meet the aggregate demand (or load). The load was considered to be largely outside the utility's control whereas the utility had full control over the amount of generating capacity built or procured. The utility plans years ahead to meet forecasted load plus a margin to account for higher-than-expected load growth and unexpected generator outages when load peaks. It then builds or acquires enough generating resources to meet the expected demand. Early on, many utilities realized that they could reduce the amount of needed extra generation, or reserve margin, by offering large industrial customers a reduced rate if they agreed to have their service curtailed in the unlikely event that the future generating capacity fell short of load. The reduced rates, referred to as "interruptible rates," also often helped the utility to retain large customers, and were not referred to then as demand response.

Electric utilities also began to develop technological means to remotely control customer demand. Starting with Detroit Edison in 1968 (EPRI 1985), utilities began to offer lower rates to residential customers who allowed the utility to control home appliances like home air conditioners and water heaters, by radio signal. The utility could avoid building extra generating capacity by turning off the controlled appliances during an emergency. By rotating (or "cycling") which appliances were turned off during an hour, customers were not unduly discomforted for an entire hour, and utilities gained a reliable and dispatchable resource that could be used to meet peak demand.

The use of these programs grew over the years; and the combination of advances in control technology and in telecommunications capability created new innovations that today allow more precise and automated adjustments to customer demand. With these new tools, utilities and demand response providers now have access to additional capacity resources. For example, programmable and communicating devices such as smart thermostats can be preprogrammed to raise indoor temperatures when dispatched. The combination of these smart thermostats with dynamic prices (e.g., critical peak pricing) can produce even higher demand reductions since the reductions are automated. Similar innovations at the commercial and industrial level have been codified as a draft AutoDR standard (Piette, et al. 2009).

More recently, some of the organized markets (Wellinghoff et al. 2008) have developed formal market mechanisms (i.e., "capacity markets") for acquiring enough resources to satisfy the aggregate planning reserve requirements of their respective regions. Demand response resources are eligible to bid into capacity markets and sometimes have become a major resource of meeting future planning reserves. For example, the total quantity of demand resources cleared in PJM's latest auction -- for the 2012-2013 delivery year -- was over 7,000 megawatts of available (i.e., unforced) capacity, or about five percent of the total resources that cleared the market (PJM 2009a). Similarly, demand resources accounted for seven percent of the cleared capacity in ISO New England's second forward capacity auction, including 2,046 megawatts of demand response resources and 890 megawatts of energy efficiency resources (ISO New England 2009).

Demand response as a capacity resource has become an essential element of maintaining electric power system reliability. The deployment of demand response can defer or eliminate the need for new generation which can face environmental obstacles. According to projections from the NERC, equivalent to three years of demand growth nationwide could be achieved from dispatchable and controllable demand response by 2018 (NERC 2009a). Despite the success, the full potential of demand response as a capacity resource remains to be tapped. Not all states and regions of the United States have deployed dispatchable and controllable demand response. The annual FERC demand response reports and the FERC Staff Assessment indicate that the majority of current demand response is focused in the Northeastern, Midwestern and Southeastern parts of the United States due in part to the ability of demand response resources to participate in wholesale markets, which "contribute[s] to a higher overall demand response potential." (FERC Staff 2009, p. 42). If the current mix of dispatchable demand response is expanded to all states and to industry-leading customer participation rates, peak demand reduction from demand response could increase from four to nine percent, and at least twenty states could triple their "business-as-usual" levels of demand response. (FERC Staff 2009).

The FERC has taken several actions to remove barriers to a demand response resource acting as a capacity resource. One of the obvious barriers came from utility operating rules that were written years ago with generating resources in mind, so that the exclusion of demand response resources was more inadvertent than deliberate. In cases before the FERC seeking approval of capacity procurement practices, the Commission has insisted that demand response resources be allowed to bid into the capacity market on fair terms if they are equally capable of bringing future supply and demand into balance—in this case by reducing peak demand. An additional, related barrier to demand response acting as a capacity resource is the lack of evidence of measurable reductions and sustained availability during system emergencies. System operators have been reluctant to depend on uncertain demand resources. Activities by the North American Energy Standards Board (NAESB) and NERC to develop standardized measurement and verification approaches and databases of demand response programs address these concerns.[4] The consistently positive results of recent pilots also should help change perception. Results from pilots conducted in the District of Columbia and Connecticut replicate and confirm the findings from earlier pilots that customers are interested in demand response and that critical peak pricing programs combined with enabling technologies like smart thermostats produce significant reductions.[5] One recent RTO test of the availability of reliability-based demand response also demonstrates that customers participating in capacity market programs reduce their consumption as directed.[6]

Demand Response as an Energy Resource

Demand response as a capacity resource is used primarily to shave peak load so as to keep the lights on. In contrast, demand response as an energy resource is used primarily to operate the power system more efficiently so as to reduce the price of electricity for all customers.

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[4] For example, NERC will be commencing a demand response availability data system this year (NERC 2009b).

[5] For example, customers with enabling technologies reduced their summer 2008 peak reductions by over 30 percent (PowerCentsDC 2009).

[6] When PJM tested their reliability-based demand response programs in 2009, it found that in aggregate, committed Demand Side Resources performed at 118% of their committed capacity values (PJM 2009).

Because a utility has more than enough generating and other resources at most times to supply customer demand, it has to choose which resources to deploy. Typically, it chooses resources in order of operating cost, starting with the lowest cost first.[7] As a practical matter, this means that low cost resources such as wind and nuclear power are run first, followed by coal generation and natural gas. As demand and the cost of meeting that demand rise during the daily cycle, some power customers may find it attractive to offer to reduce their consumption from normal levels in return for a payment. This use of demand response as an energy resource has begun in some areas—especially through the demand response bids of large industrial and commercial customers into the RTO and ISO markets and through the efforts of third-party demand response aggregators to aggregate the demand responses of smaller customers. Almost all of the RTOs and ISOs in the United States now allow demand response bids into day-ahead or real-time spot markets. The ISO/RTO Council reports that demand resources participating as energy resources grew from 2,000 MW at the end of 2007 to 4,400 MW at the end of 2008 (IRC 2009).

While this is a good beginning, demand response as an energy resource has not yet been deployed anywhere to a significant fraction of its full potential. Further progress depends on greater education at the customer level, better means to track, measure, and verify performance, and the development and wide-spread deployment of enabling technologies including advanced metering and the associated communications infrastructure. Significant work is underway at NAESB and NERC to measure demand response; and, as indicated earlier, significant growth is also projected in advanced metering deployment. Aggressive advanced metering deployments in California and Texas, along with the substantial increase in advanced meter installations (over 18 million meters) that will be funded by the American Recovery and Reinvestment should greatly increase the number of customers with the necessary enabling technology (Irwin 2010).

Further changes in how the industry operates will be enhanced by the substantial investments already underway to create a smart grid, essentially a common framework for two-way communications capability among the various components of an electric power system (e.g., generators, transmission and distribution systems, customers' machinery, appliances and meters). This capability can support a large variety of applications. Examples include reliably increasing the uses of variable wind generating resources, greater penetration of electric storage devices, and deployment of synchrophasor technology for high-voltage grid stability. The FERC is helping to enable demand response and smart grid by actively engaging industry and the National Institute of Standards and Technology in the fulfillment of its responsibilities under the Energy Independence and Security Act of 2007 (EISA). The Commission issued a smart grid policy (FERC 2009) setting forth its priorities for smart grid, including that demand response standards are one of several priorities for smart grid standards development; and it offered a means to reduce regulatory risk for early adopters of smart grid technologies. More recently, the Commission took action to address compensation for demand response resources participating in the organized wholesale energy markets. In a Notice of Proposed Rulemaking, the Commission proposed to pay demand resources the locational marginal price in all hours thus compensating those resources in a manner that reflects the marginal value of the resource, comparable to treatment of generation resources (FERC 2010).

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[7] This practice, known as economic dispatch, is generally followed by electric utilities throughout the world. See, for example, (FERC Staff 2005).

Demand Response as an Ancillary Services Resource

Because demand response as an energy resource contributes to power system efficiency and price stability, its use is not confined to peak load times. Nevertheless, because electric customers typically prefer to buy power than not do so, most of them are likely to offer to provide a demand response service only when the price of power rises to a higher-than-normal level, which often coincides with a peak period. Demand response as an ancillary service, however, can be valuable at any time of day.[8]

Many demand response resources may be especially well suited to provide certain ancillary services traditionally provided by generators and are able to respond rapidly to a utility's direction to reduce output by a specified amount. Separate dispatch of a collection of demand response resources can produce a fine tuned response that can quickly bring supply and demand into balance by reducing demand instead of increasing supply. For example, customers with under frequency relays in ERCOT can be a Load acting as a Resource and provide responsive reserves in ERCOT. These resources have been deployed multiple times in the past several years; most notably during March 2008 when generation from wind resources in ERCOT dropped unexpectedly (ERCOT 2008). In PJM, in 32 percent of the hours where a synchronized reserve market cleared in the Mid-Atlantic area all of the cleared synchronized reserves came from demand resources (Monitoring Analytics 2009). And, as NERC indicates, "With legislation and regulation supporting the construction of renewable resources which are variable in nature (e.g., wind and solar), demand response resources may increase to provide ancillary services." (NERC 2009a)

Widespread use of demand response to provide these ancillary services holds much promise, but its use for these purposes is limited at present. Contributing to the limited widespread use are existing reliability rules and market designs that make it difficult for demand resources. For example, the ability of demand resources in PJM to provide synchronized reserves is limited to 25 percent of reserve requirements. Here again, the development of smart grid technologies is expected to open expanded opportunities for a much wider range of customer classes and types of equipment and appliances to provide ancillary services. The expected penetration of "smart" major appliances and plug-in hybrid electric vehicles will expand opportunities for demand response to provide ancillary services.

Because demand response shows much promise as an ancillary service, the FERC has also been especially active in removing obstacles to their deployment. For example, the FERC has required public utilities to allow demand response resources to provide whichever ancillary services they are technically capable of providing. In the RTO and ISO markets, the Commission relaxed the requirement that demand response resources be available at all times, thus allowing the provider the choice, for example, of providing energy or reserves.

[8] Aside from providing energy each day and planning reserves for the future, some generators are held in reserve each day to provide several related standby functions, known collectively as ancillary services. To keep supply and demand in balance at all times, the electric system operator must have extra generators standing ready to serve with little or no notice in case a generator producing power suddenly goes out of service. Such generators are called operating reserves. Also, some generators must standby to follow random variations in customer demand. Generators that provide these related services are said to provide ancillary services that go by such names as energy balancing, load following, voltage control, and frequency response services, depending on the utility system.

A Vision for Demand Response as an Electric Power Resource

We are on the verge of a new opportunity to use demand response to help meet this nation's power supply needs in the 21st century. With interest in the integration of significant amounts of renewable energy, wide-spread deployment of plug-in electric vehicles, and more efficient use of our existing transmission and generation infrastructure, demand response is poised to complement these initiatives, having a central role in shaping the way the grid is managed and energy consumed. The full integration of demand response on a comprehensive and sustained basis requires an industry and regulatory structure that encourages and enables demand response from myriad applications and from all customers--industrial, commercial and aggregated residential. This structure must also compensate each customer for the value of the service it provides. Such a structure will allow the Nation to use demand response to provide a wide variety of electric power services.

To get there, however, several changes to today's industry practices are needed. Demand response must be recognized as a resource that is as valuable as generating resources and must be treated comparably to these traditional resources. The enabling technology that provides for advanced power-use metering and two-way communication between utilities and customers must be in place. Importantly, customers need both rate structures that support demand response and clear, readily available information about each appliance's power consumption and usage cost for customers to make sound decisions about when to reduce demand. Together, these changes will help to ensure that the contributions of this flexible, readily available resource are realized.

The more traditional offerings of demand response (e.g., reliability based programs) will continue, and innovative contributions of demand response will emerge as technology and transparency make in-roads. Demand response programs now are mostly reliability-driven (e.g., curtailable rates for large commercial and industrial customers and direct control of end-use loads) and already have the capacity to offset four percent of current U.S. peak demand. (FERC Staff 2009, p. 27) The uses of demand response for such reliability purposes can be expanded. For example, although often overlooked, everyday residential appliances, if harnessed, can provide peak shaving. Examples include clothes dryers and dishwashers. Thermal loads (e.g., refrigerators) can be shifted to off-peak periods.

New uses of demand response that go beyond providing reliability are just beginning. For example, with the anticipated, significantly increased use of wind generation, not only is it likely that considerable transmission investment will be needed to tap remote resources, but additional ancillary services will be required. Demand response has the potential to reduce the amount of transmission capacity needed by reducing the peak load, reduce the amount of ancillary services needed by reducing the peak, and to directly provide such ancillary services as short-term reserves and frequency support.

Further, the expected deployment of plug-in electric vehicles is both a challenge and an opportunity for the electric power industry--a challenge because it places new demands on electric companies and an opportunity because it provides them with a new tool for managing demand, provided demand response capabilities are deployed from the outset. Electric vehicle owners should be encouraged through rates and/or incentives to allow utility control of the timing of evening and overnight car charging. After all, strategic control of charging by the utility can help manage stresses on the power system. Further, the ability to fine-tune control of simultaneous charging of many cars can provide ancillary services; for example, a utility signal to suddenly reduce aggregate battery charging is equivalent to the deployment of an extra generator to provide an operating reserve. Fine-tuned control of vehicle charging allows the utility to "follow load" up or down within the hour and also to maintain control of grid frequency by reducing vehicle demand instead of dispatching ancillary services generators. Moreover, the utility can actually interrupt battery charging and instead withdraw power from the batteries in lieu of deploying generators, provided of course that the equipment is designed to allow this and the appropriate rate rewards are in place. Three electric vehicles in PJM are already demonstrating the feasibility of this vision (PJM 2010).

Such demand response capabilities require forward planning. Because of the great potential for demand response to contribute to meeting our Nation's new energy needs, we need to begin comprehensive planning now to expand the availability of demand response opportunities at the wholesale and retail levels. Planning for the participation of loads as a resource should be part of overall grid planning. The system contributions (e.g., storage, ancillary services, energy, capacity) and value of demand response (including locational and temporal aspects) must be considered upfront in the planning process. The Department of Energy recognized the importance of demand response and in its funding opportunity announcement for interconnection-wide transmission planning required that respondents consider all available technologies (to the extent economic) including demand management (U.S. DOE 2009a, p. 7 and 23). Subsequently, in December 2009 the Department of Energy awarded $60 million to promote collaborative long-term analysis and planning in the Eastern, Western and Texas electricity interconnections (U.S. DOE 2009b). For example, the winning proposal from the Western Interconnection is examining planning scenarios that explicitly include significant levels of demand resources (WECC 2009).

The Commission is acting to help bring this vision to reality. Through its forthcoming National Action Plan for Demand Response--a requirement of the EISA (EISA 2007), the FERC issued a plan to realize the potential for demand response by seeking to develop more dispatchable demand response (dispatchable to price and non-price directions), seeking to foster the full deployment of advanced metering initiatives and dynamic pricing, employing competitive market forces to develop more customer demand response, and planning for the deployment of many innovative demand response applications that create greater consumer control over energy usage and create new cost-saving opportunities for consumers.[9]

In conclusion, only with comprehensive consideration of all types of resources and all resource providers will electric plans be fully supportive of the emerging electric energy technologies that can meet new environmental goals at least cost. Demand resources have been mostly overlooked in the history of the electric power industry. The time is right to recognize the large potential of demand response as a resource.

[9] FERC staff released a Draft National Action Plan (FERC Staff, 2010) for comment in March 2010. FERC is required to complete a National Action Plan by June 2010. See Docket No. AD09-10 in FERC's eLibrary system: http://www.ferc.gov/docs-filing/elibrary.asp for more information.

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