ENERNOC

White Paper

Demand Response: A Multi-Purpose Resource For Utilities and Grid Operators

Introduction

Demand response (DR) refers to deliberate load reductions during times of system need, such as periods of peak demand or high market prices. Because reduced consumption and increased generation can both restore a system's supply and demand to equilibrium, DR can be a resource that offsets or defers the need for new generation, transmission, and/or distribution infrastructure.

The most basic DR programs are structured to maintain system reliability and prevent blackouts and brownouts. But in recent years, DR has evolved into a more dynamic resource that can also provide price mitigation and ancillary services to utilities and grid operators. This paper provides a summary of four types of DR based on their purpose and use: economic, emergency, ancillary services, and peaking alternative.

The Demand Response Landscape

DR is not a new concept. For many years, electric utilities have administered load management programs for large industrial and residential customers.

Large Industrial

For decades, utilities have historically offered large industrial customers the option to secure lower energy rates through "interruptible tariffs" in exchange for reducing power consumption during periods of system need. These programs are largely designed as a last-resort resource to be called upon in the case of imminent brownouts or blackouts. However, interruptible tariff programs tend to be limited in capability and scope: 1) notification typically occurs manually via telephone, and therefore participation is restricted to only a few large customers; and 2) in some areas, interruptible programs are leveraged more as an economic incentive to local industry rather than as a reliable load reduction tool.

FIGURE 1. DEMAND RESPONSE VS. INDUSTRIAL INTERRUPTIBLE TARIFFS AND RESIDENTIAL DIRECT LOAD CONTROL

	Interruptible Tariff	C&I Demand Response	Direct Load Control
Customer Segment	Large industrial	Commercial, institutional and industrial (C&I)	Residential
Resource Profile	Usually manual; full facility shutdown or customized curtailment plan	Manual or automated; typically requires customized curtailment plan	Utility has automated control of common applications (e.g., air conditioning, pool pumps)
Customer Profile	Generally, more sophisticated energy users	Some energy sophistication, most require guidance	Little energy interest or sophistication
Capacity	1 MW and up	100 kW and up	1-2 kW
Incentive	Reduced electricity rates	Capacity and energy payments	Nominal credit or other incentive
Reliability	Reliability varies	Metering and control technology enables high reliability	Limited visibility into performance

Residential

DR has also enjoyed success among the residential customer class through direct load control (DLC) programs that cycle air conditioning units and pool pumps.

C&I Demand Response Program

Historically, DR has not succeeded in the commercial and light industrial sector. Electric loads and business needs in these segments vary widely, and such customers do not fit easily into the parameters of interruptible programs or residential DLC. In the last half decade, commercial and light industrial DR has evolved into a more sophisticated resource for utilities and system operators. This development is largely the result of 1) the Internet; 2) improvements in hardware technology (e.g., metering, control equipment); 3) the increased need for utilities to manage peak demand in a time of rising infrastructure and resource costs; and 4) third party DR aggregators entering restructured electricity markets. Today, the capabilities of DR extend well beyond the large industrial customers and the residential sector.

Demand reductions come from various electrical loads (see Figure 2). Third-party DR providers are skilled at identifying specific curtailment strategies that achieve the maximum load reduction with the least amount of business interruption. Common curtailment strategies include slowing down variable speed motors, reducing a portion of lighting, and raising HVAC set points. In addition, in some DR programs where environmental regulations permit it, customers temporarily shift their load to on-site generation for the duration of a DR event, thereby reducing their electric demand on the grid.

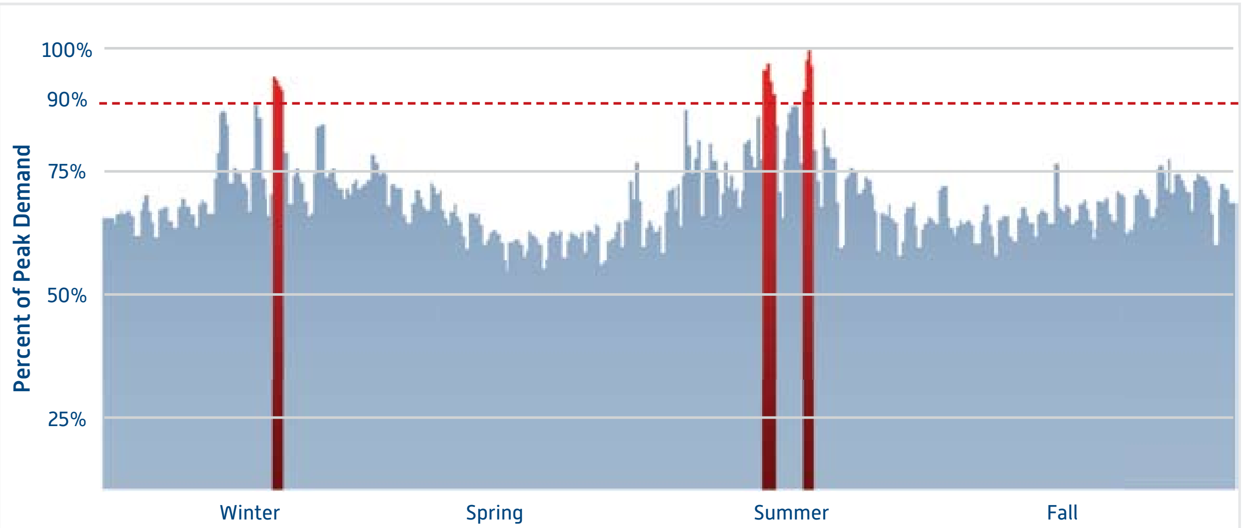
FIGURE 2. EXAMPLES OF COMMERCIAL AND LIGHT INDUSTRIAL CURTAILABLE PROCESSES

Air handlers	Internal lighting
Anti-sweat heaters	Irrigation pumps
Chiller control	Motors
Chilled water systems	Outside signage
Defrost elements	Parking lot lighting
Elevators	Production equipment
Escalators	Processing lines
External lighting	Pool pumps / heaters
External water features	Refrigeration systems
HVAC systems	Water heating

How Demand Response Resources Meet Electricity System Needs in the 21st Century

DR is ideally suited to provide capacity during peak demand periods, as it can be brought on- and off-line quickly for short periods of time throughout the year. In many systems throughout the United States, up to 10 percent of peak demand occurs in less than 1 percent of the hours in the year. DR programs can provide demand reductions during the 50 to 100 hours of the year when demand is highest, serving as a cost-effective and reliable way to relieve peak demand and improve system stability without needing to build excess supply-side infrastructure. Figure 3 shows a typical summer-peaking system where demand exceeds 90 percent of the system capacity during only a few periods in the summer months.

FIGURE 3. LOAD GRAPH OF TYPICAL SUMMER-PEAKING SYSTEM



As construction costs and concerns about climate change continue to increase, so does the value in avoiding or deferring the need for new generation. Depending on the system, demand resources may be considered a firm resource and consequently reduce the required reserve margin. These demand response programs also serve as a type of insurance policy for a system, ensuring that rolling blackouts will not occur should demand exceed forecasts (and available capacity).

DR programs are often classified by their incentive structure, i.e., capacity payments vs. energy payments. While this distinction is important, it is more instructive to examine DR programs by the purpose they are designed to serve. For example, Emergency and Peaking Alternative programs are both typically capacity-based and receive similarly structured incentives, but each is used for a different purpose and consequently has unique program parameters. That said, it is important to recognize the basic incentive structures of the different types of DR programs. In an energy-only program or market, all electricity produced (or demand reduced) is compensated based on the price for that kilowatt-hour of electricity. Conversely, in a capacity-based program, participants receive a capacity payment for being willing to curtail consumption when required, and usually an energy payment for actual load reductions as well.

DR PAYMENTS: CAPACITY VS. ENERGY

Demand response resources are paid in the same way supply-side generators are paid — by receiving capacity and energy payments.

Capacity (measured in kilowatts or megawatts (1 MW = 1,000 kW)) measures the maximum amount of energy that can be produced (or reduced) at a given moment in time. Capacity payments are in the form of $/kW per unit of time (i.e., $/kW-month or $/kW-year).

Energy (measured in the form of capacity multiplied by period, i.e., kilowatt-hour (kWh) or megawatt-hour (MWh)) is an amount of capacity supplied over a given amount of time, typically an hour. Energy payments are in the form of $/kWh or $/MWh.

Economic or Price Response Programs

Price response, or economic DR programs, involve the voluntary response to price signals. In such programs, end-users reduce consumption during periods of high wholesale prices and receive the market rate for the avoided energy they provide via their demand reduction. Generally, these resources are not firm and many end-users find the flexibility of an economic DR program attractive.

In these programs, DR can be scheduled and dispatched by utilities or system operators as part of a resource "stack," just like a combustion turbine. A DR resource can set a price at which it is willing to respond when the price of energy exceeds that strike price. In this way, DR can effectively offset the need for market purchases or other higher-priced resources. DR can also help mitigate wholesale power prices, especially in congested regions where a few power marketers disproportionately influence energy prices. When system-wide energy prices are determined by the price paid for the last megawatt (MW) hour produced (the marginal resource), small amounts of DR added to a system can have a significant deflating impact on energy prices. For example, one study showed that in five Mid-Atlantic states, a 3 percent load reduction in the top 100 hours would yield net annual economic benefits of $138-281 million.[1]

[1] "The Power of Five Percent." The Brattle Group, May 2007

Responding to price signals requires visibility into the electric market, and an energy user can work with a third party aggregator to obtain this visibility. In this framework, the user sets a price threshold at which it wishes to reduce demand; should prices reach or exceed this level, the third party can dispatch the user.

Examples of Economic-Based DR Programs

PJM's Real-Time Economic Load Response Program	End-users can bid load reductions into the real-time energy market; end-users may voluntarily curtail when the price of electricity (locational marginal price, or LMP) reaches pre-determined levels to reduce use of the highest-priced electricity
ISO New England's Day-Ahead Load Response Program	End-users can bid load reductions into the day-ahead energy market; an end-user must reduce during the hours in which its bid clears; intended to reduce prices in the real-time energy market

Emergency or Reliability Programs

Emergency or reliability DR primarily differs from economic DR in that response is not voluntary. Generally, participants in these programs receive a payment for being available, known as a capacity payment ($/kW), and are typically compensated for their demand reductions during events through an energy payment ($/kWh). Third party aggregators, or large industrial users that are allowed to directly participate in the market, are contractually obligated to provide a set amount of capacity and face financial penalties for non-performance. Aggregators may be able to handle non-participation or non-performance across some sites through portfolio management, but must ensure that their portfolio as a whole provides the contracted demand reduction in order to avoid penalties.

Most capacity-based demand resources are dispatchable and quick-starting so that utilities and grid operators can call on these resources when needed. Notification in capacity-based DR programs varies dramatically — some programs give participants as little as 10 minutes advanced notification of a DR event, while others provide day-ahead notification.

Emergency programs are called infrequently and typically dispatched once a defined "trigger" has been met. These triggers are usually system characteristics that correspond with reliability issues, such as actual or forecasted capacity shortages or the achievement of a specific system condition. For example, ISO New England's Real-Time Demand Response (RTDR) Program is an emergency DR program, and resources are only called during an emergency condition. Curtailment RTDR resources can only be dispatched when the ISO has reached Operating Procedure 4 (OP4), Action 9, and emergency generation resources in the RTDR program only are dispatched once the ISO has reached OP4, Action 12.

Examples of Reliability DR Programs

PJM's Emergency Load Response Program	A program that is only activated during a "system emergency," which occurs directly before rolling brownouts; participants receive 2 hours advanced notification prior to the start of an event
ISO New England's 30-Minute Real-Time Demand Response Program	A program that is only activated during a "system emergency" (Operating Procedure 4, Actions 9 and 12), which occurs directly before rolling blackouts; participants receive 30 minutes notification prior to the start of an event
Consolidated Edison's Distributed Load Relief Program	A program that is designed to reduce demand during periods of local distribution constraint on the ConEd system
The Electric Reliability Council of Texas' Emergency Interruptible Load Service	A program designed to decrease the likelihood of firm load shedding (rolling blackouts)

Ancillary Service Programs

In certain markets, DR is eligible to provide ancillary services, including spinning reserves and regulation services. End-users that can provide near instantaneous response to dispatch signals without a significant impact on business operations are effective ancillary services resources.

In PJM Interconnection, DR resources can bid into both the Synchronized Reserves and Regulation Markets. Similarly, the Electric Reliability Council of Texas (ERCOT) has in excess of one gigawatt (1,000 MW) of DR participating as Responsive Reserve Service. With the successful participation of DR in these programs, other regions, as well as regulated utilities, are also exploring the capabilities of DR as an ancillary service. A recent Federal Energy Regulatory Commission Order[2] has also recommended that ISOs/Regional Transmission Organizations (RTOs) "accept bids from demand response resources in their markets for certain ancillary services, comparable to any other resources."

The short duration of an ancillary services event (typically 10 to 60 minutes) can lower the barrier to entry for some commercial and industrial customers, because in some cases demand reductions are more palatable for shorter periods of time. Conversely, the short response times (usually 10 minutes or less) required present the most obvious challenge for commercial, institutional, and industrial customers. Because DR aggregators can automate demand reductions for certain customers, the response time requirement of ancillary services programs may not represent an additional challenge. For other customers, however, a short response time may make participation impossible, as the curtailment of certain industrial processes is not tenable in such a short timeframe.

Since system imbalances occur on a regular basis, ancillary services programs are dispatched around the clock and far more frequently than other DR programs. Curtailment strategies for ancillary services therefore must also be highly repeatable in order to manage potential customer fatigue.

[2] Federal Energy Regulatory Commission Order 719

Examples of Ancillary Services Markets Open to DR

PJM's Synchronized Reserves Market	Demand resources can bid into this market alongside generation to provide synchronized reserves resources; requires end-users to curtail quickly (i.e., within ten minutes) for short periods of time (i.e., 15 minutes)
ISO New England's Demand Response Reserves Pilot	A pilot program that is testing the ability of demand resources to provide operating reserves; requires end-users to curtail quickly (i.e., within 15 minutes) for short periods of time (i.e., 1-2 hours) approximately 2-4 times per month
The Electric Reliability Council of Texas' Responsive Reserve Service	Demand resources, known as Load Acting as a Resource (LaaR), can provide Responsive Reserve Service; resources are required to reduce automatically through an under frequency relay (UFR) when grid frequency falls below a certain level and in 10 minutes notification when ERCOT goes into its Emergency Electric Curtailment Plan (EECP), step 3

Peaking Alternative

Peaking alternative programs share many of the characteristics of emergency programs, but are dispatched more frequently (i.e., not only during emergencies). Like emergency programs, participation is not voluntary (capacity obligations are guaranteed) and there are typically both capacity payments and energy payments. Unlike their emergency counterparts, these programs are highly flexible and can be dispatched in periods of high prices, system need, and/or during shoulder periods. In many ways, the structure of a peaking alternative program resembles a Power Purchase Agreement (PPA) that a utility might sign with a generator. Typically, a peaking alternative program has a maximum number of dispatch hours and a defined program window (i.e., time of day, day of week). Most peaking alternative programs are found in the service territories of regulated utilities, but some open markets, like the Ontario Power Authority, are developing this type of DR resource.

Because peaking alternative programs can provide many of the benefits of a peaking power plant, utilities and system operators are deploying this resource in place of traditional generation, especially as economic challenges and concerns over greenhouse gas emissions grow. Some peaking alternative programs are quick-starting, allowing the DR resource to provide ancillary services like spin/non-spin reserves or to count towards resource adequacy requirements. Others are subdivided into zones that can be dispatched independently, allowing utilities or grid operators to address distribution-level constraints within their systems.

Examples of Peaking Alternative Programs

PNM Peak Saver	PNM can dispatch its Peak Saver resources with 10 minutes notification for up to 100 hours a year during the summer months of June-September
Tampa Electric Networked Demand Response	Tampa Electric can dispatch its DR resources with 30 minutes notification for up to 88 hours per year, year round
Ontario Power Authority's DR3	The OPA will dispatch DR3 resources up to 200 hours per year, 25 times (4 hours per event); the purpose of this program is to reduce energy costs and emissions

Conclusion

DR is increasingly recognized as a reliable and cost-effective way to meet system resource needs. Each of the four DR resource types described in this whitepaper — emergency, economic, ancillary services, and peaking alternative — provides a different type of valuable service to utilities and grid operators. The wide variety of DR program types allows for a diverse group of customers to participate and allows utilities and system operators to meet their needs in a cost-effective and environmentally-responsible way.

Appendix A: DR Program Design Goals and Elements

Below is a summary table that compares the program parameters of all four types of DR as discussed in this paper.

	Economic	Emergency	Ancillary Services	Peaking Alternative
Program Compensation	Energy payments ($/kWh)	Capacity & energy payments ($/kW-month and $/kWh)	Availability & energy payments ($/kW-hour and $/kWh)	Capacity & energy payments ($/kW-month and $/kWh)
Performance Measurement	Difference between load-adjusted customer baseline and actual load	Difference between load-adjusted customer baseline and actual load	Difference between pre/post-event and event load	Difference between load-adjusted customer baseline and actual load
Response Time	Day-ahead or day-of	30 minutes to day-ahead	Less than or equal to 10 minutes	10 - 60 minutes
Program Availability: Days	Markets are 24/7/365; resources can bid in reductions	Typically business hours, working days; also 24/7 programs.	Markets are 24/7/365; resources bid in hours of availability	Typically business hours, working days; may also include weekends or 24/7 program hours
Program Availability: Hours per Year	Dependent on market bid	As defined by system conditions	Dependent on market bid	60 - 100 hours
Program Availability: Duration	1 - 4 hours	1 - 8 hours	10 - 60 minutes	1 - 8 hours
Event Trigger(s)	Economic dispatch	System conditions, such as actual or forecasted operating reserves shortage	System contingencies	At utility's discretion
Program Penalties	None; Loss of incentive payments	Loss of incentive payments and/or non-performance penalties below pre-determined threshold level	Loss of incentive payments and/or system tariff penalty payments	Loss of incentive payments and/or non-performance penalties below pre-determined threshold level
Event Frequency	At end-user's discretion	Low	At end-user's discretion / High	Medium-High
Metering Requirements	Preferably 5-minute interval data (15-minute or 1-hour data can suffice)	Preferably 5-minute interval data (15-minute or 1-hour data can suffice)	1- or 5-minute interval data	Preferably 5-minute interval data
Communications Requirements	Ability to receive day-ahead and real-time hourly energy prices	Ability to receive and confirm system operator requests, preferably with real-time performance transparency	Ability to receive and confirm system operator requests, preferably with real-time performance transparency	Ability to receive and confirm system operator requests, preferably with real-time performance transparency

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