Energy Monitoring for Profit: Introducing Demand Response

Introduction

You've heard about the Smart Grid, the interconnected infrastructure that will embed digital intelligence into the whole process of producing, distributing, pricing, and consuming electrical energy in the U.S.?

Our earlier white paper, *Automation and the Smart Grid: Energy Management Today*, introduced you to the United States electrical grid and then proposed practical ways in which small- and medium-sized commercial and industrial businesses can reduce energy costs now, without waiting for the Smart Grid.

This white paper introduces *demand response* (DR), a concept that goes beyond reducing energy costs. DR can transform electrical energy usage from the fixed cost it traditionally has been to a future source of revenue for your business. And DR is a program you, as an automation professional, can inaugurate to significantly improve your company's bottom line.

First let's take a look at how electrical power gets to your business. Then we'll discuss four steps you can begin now to take advantage of demand response (DR) programs offered in your area.

Power To Your Business

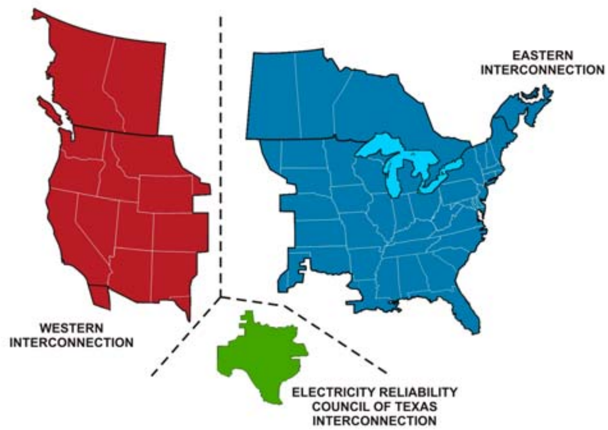
A Complex Production and Distribution System

The electrical grid in North America covers the U.S. and Canada. At the top of this system are three independently synchronized grids, shown in the image at upper right[1]: the Eastern Interconnection, the Western Interconnection, and the Electric Reliability Council of Texas (ERCOT). For the U.S., these grids are operated under the authority of the Federal Energy Regulatory Commission (FERC).

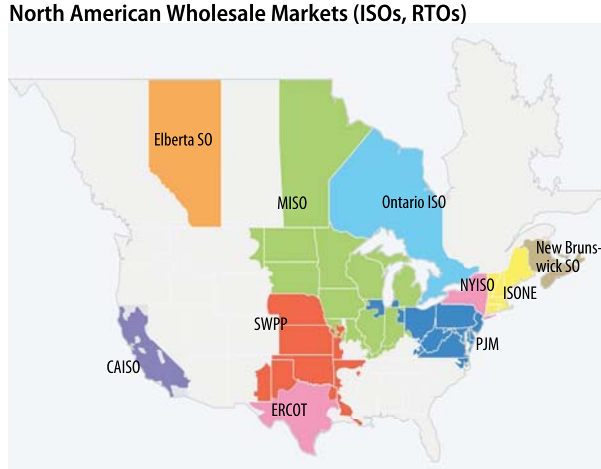
Within these three grids, some U.S. regions—New England, mid-Atlantic, Florida, Texas, California—have organized wholesale markets called Independent System Operators (ISOs) or Regional Transmission Organizations (RTOs). See the map at lower right for the locations of these wholesale market areas.[2]

Other areas—the Southeast, the Southwest, and the Pacific Northwest—have more traditional vertically integrated markets, where electricity is delivered directly from the producer to the consumer, or where federal, municipal, and co-op utilities provide energy to consumers. So generation, transmission, and distribution vary widely depending upon where your business is located.

North American Electric Reliability Corporation Interconnections



North American Wholesale Markets (ISOs, RTOs)



1. Image source: NERC, http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/NERC_Interconnection_1A.pdf

2. Image source: ISO/RTO Council, http://www.isorto.org/site/c.jhKQIZPBImE/b.2604471/k.B14E/Map.htm

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But there's still another layer: 107 additional organizations, called balancing authorities, that are responsible for balancing supply and demand in real time in specific areas—some large, some very small.

Organized wholesale energy markets cover about two-thirds of the U.S. population and two-thirds of overall demand[3]. In these areas, prices vary based on long-term contracts and short-term bidding, much as in any commodity market (see "How Wholesale Energy Markets Work" on page 5). Short-term bidding actually works in multiple directions simultaneously: producers bid to provide more or less energy to meet demand; consumers bid to use less energy to lessen overall demand, or (much less frequently) bid to use more energy to meet the supply.

Balancing Supply and Demand in the Grid

This complex, overlapping array of entities works to keep supply and demand within the grid in balance. *Ancillary services* are the primary tools used to do so.

The table below[4] shows these ancillary services—regulation, spinning reserves, supplemental reserves, and replacement reserves—that make sure enough energy is available in case of extra demand or disturbances on the grid. Notice that ancillary services are designated based on how fast they can kick in, with regulation at less than a minute and spinning reserves at less than 10 minutes.

Table 1. Definitions of key ancillary services

Service	Service Description		
	Response Speed	*Duration*	*Cycle Time*
Regulation	Power sources online, on automatic generation control, that can respond rapidly to system-operator requests for up and down movements; used to track the minute-to-minute fluctuations in system load and to correct for unintended fluctuations in generator output to comply with Control Performance Standards (CPSs) 1 and 2 of the North American Reliability Council (NERC 2002)		
	~1 min	*Minutes*	*Minutes*
Spinning reserve	Power sources online, synchronized to the grid, that can increase output immediately in response to a major generator or transmission outage and can reach full output within 10 min to comply with NERC's Disturbance Control Standard (DCS)		
	Seconds to <10 min	*10 to 120 min*	*Days*
Supplemental reserve	Same as spinning reserve, but need not respond immediately; units can be offline but still must be capable of reaching full output within the required 10 min		
	<10 min	*10 to 120 min*	*Days*
Replacement reserve	Same as supplemental reserve, but with a 30-min response time; used to restore spinning and supplemental reserves to their pre-contingency status		
	<30 min	*2 hours*	*Days*
Voltage control	The injection or absorption of reactive power to maintain transmission-system voltages within required ranges		
	Seconds	*Seconds*	*Continuous*

From 1950 to 1959, industrial customers accounted for half of the total demand for electrical energy; from 2000 to 2009, industry was only 28% of total demand.
- MIT, *The Future of the Electric Grid*

How Demand has Changed

The electrical infrastructure in the U.S. has remained largely the same for decades. The amount and nature of demand, however, has changed over time.

One key for the future is flattening demand. Over the last 50 years, the proliferation of residential air conditioning and other household electrical appliances has changed the balance of consumption. One study noted: "From 1950 to 1959, industrial customers accounted for half of the total demand for electrical energy; from 2000 to 2009, industry was only 28% of total demand."[5]

Industrial demand tends to be flat. Factories continually run equipment, often in multiple shifts throughout the day and night.

But residential demand fluctuates. It tends to peak at certain times, notably in the afternoon when everyone arrives home, turns on the A/C, and starts making dinner.

With a higher proportion of residential use, overall demand is less flat. So older, less efficient generation sources must still be used and additional power plants must be built to accommodate the peaks.

3. Massachusetts Institute of Technology, *The Future of the Electric Grid* (December 2011). http://web.mit.edu/mitei/research/studies/the-electric-grid-2011.shtml

4. Kirby, Brendan J., *Frequency Regulation Basics and Trends*, Oak Ridge National Laboratory (Dec 2004). http://www.ornl.gov/~webworks/cppr/y2001/rpt/122302.pdf

5. Massachusetts Institute of Technology, *The Future of the Electric Grid* (December 2011). http://web.mit.edu/mitei/research/studies/the-electric-grid-2011.shtml

Future Stresses on the Grid

Future stresses on the grid will come from the increasing use of new generation methods, such as wind and solar. In 2010, only about 10% of U.S. electrical energy was produced using renewable sources.[6] As these sources of generation become a larger percentage of the total, the grid must change to accommodate them:

- Wind and solar power are dependent on winds that change direction and force and sun that may disappear behind clouds. So their output is by nature variable and unpredictable, unlike a coal-fired plant that produces energy at a steady rate. The grid will need to be more flexible to accommodate these variations in supply.
- Prime locations for wind and solar generation tend to be in remote areas, away from population centers where the energy is needed. Distance and jurisdictional issues among regulatory bodies complicate transmission.
- Distributed generation—from solar arrays on local buildings, for example—is desirable but could cause problems within the grid. Current distribution systems are designed to handle the flow of power from upstream generation to downstream consumption, not in the other direction. If distributed generation becomes widespread, generation could exceed demand and power could flow dangerously from the substation into the transmission grid.

If we can reduce peaks by flattening demand over days and seasons, and design the Smart Grid to flexibly respond to new generation sources, we can keep supply and demand in balance.

6. U.S. Energy Information Administration, http://www.eia.doe.gov/cneaf/electricity/epm/table1_1.html

The Smart Grid—from Both Sides

Most discussions regarding the Smart Grid are focused on the supply side, not the demand side. These discussions tend to center around public policy, government programs, changes to transmission and distribution infrastructure, and so on.

But let's take a closer look at the demand side, the energy consumer's end of the grid. Here is where you, as an automation professional—an engineer, controls technician, or facility manager—have a huge role to play.

You have the skills and interest necessary to work on the Smart Grid from the demand side, to ensure that the Smart Grid develops in ways that make sense for industrial and commercial consumers. And right now, while the Smart Grid is still in development, you have the ability to turn electrical energy use into a real source of revenue for your business.

The rest of this paper will show you how, in four steps.

1. Learn terms and see who the players are in the overall grid structure.
2. Find out about local demand-side programs that may apply to your company.
3. Get detailed data on your company's energy usage and analyze the data to understand your use.
4. Get started with the programs that work for your company.

1. Learn Terms and Players

Let's take a look at some of the players in this game as we move toward the Smart Grid (see image on the next page).

For simplicity, we've put them into three categories: energy producers, energy retailers, and energy consumers. (In practice, there's considerable overlap between producers and retailers, and in the future there will be even more.)

Energy producers are part of the *generation and transmission* section of the grid. Utilities (public or investor owned), independent system operators (ISOs), and regional transmission organizations (RTOs) that generate and/or transmit high-voltage electrical energy are in this group.

Energy retailers are part of the *distribution* section of the grid. Demand response providers (DRPs), curtailment service providers (CSPs), and energy service corporations

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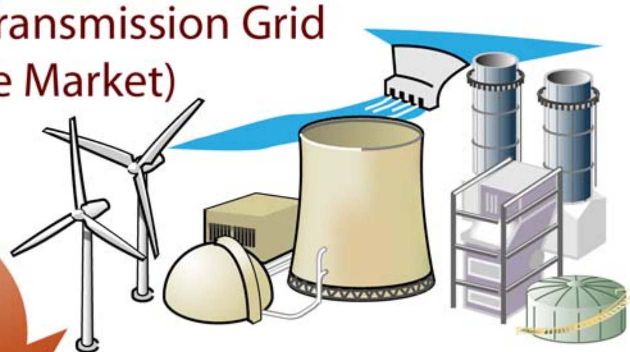
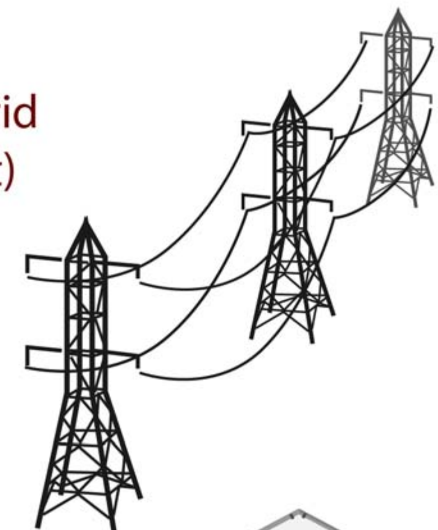
Generation and Transmission Grid
(Wholesale Market)



Energy Producers:
Public Utility
Investor-Owned Utility (IOU)
Independent System Operator (ISO)
Regional Transmission Organization (RTO)

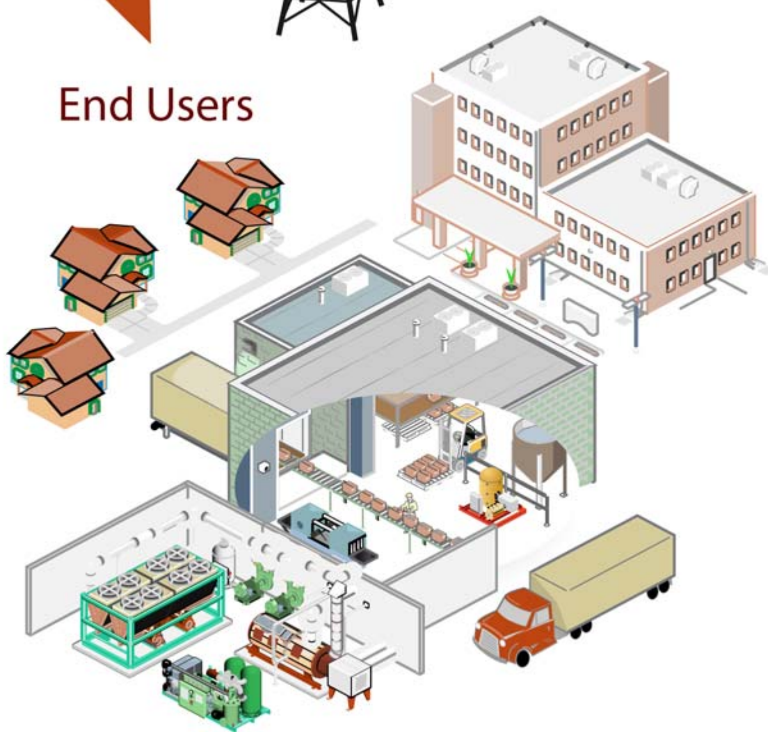
Distribution Grid
(Retail Market)



Energy Retailers:
Demand Response Provider (DRP)
Curtailment Service Provider (CSP)
Energy Service Corporations (ESCOs)

Real-time pricing (RTP)
Demand charge/Critical peak pricing (CPP)
Time-of-use pricing (TOU)
Demand Response (DR)

End Users



Energy consumers:
Commercial
Industrial
Residential

Demand-side Management
(DSM)

(ESCOs) are all in the retail group. As the image on the previous page shows, many of these retailers offer pricing and demand response programs to energy consumers.

Energy consumers are commercial, industrial, and residential customers who use the electricity the grid produces.

Where Does Your Electricity Come From?

We've seen that supplying electrical energy is a complex process, and every geographical area is different. Your first job is to find out who produces and distributes the energy your business uses, and whether you have options for energy providers.

2. Find Out About Local DSM Programs

Next, you'll want to find out about the demand-side management (DSM) programs available to you.

DSM programs can include:

- **Conservation**—simply reducing energy use
- **Energy efficiency**—using the same amount of energy but accomplishing more with it
- **Demand response**—temporarily shedding loads or shifting loads to a different time of day, in order to reduce demand during peaks

Conservation and energy efficiency mean less energy is used overall. Energy providers offer programs such as rebates, financing, and education to encourage efficiency and conservation. Appliance standards and building codes also encourage efficiency. Conservation and energy efficiency do not necessarily require you, the consumer, to change your operations, and they are not time-dependent.

Demand response programs, in contrast, do require you to change your operations and are very closely tied to time. They range from time-of-use pricing—where electricity costs more at certain times of day—to agreements where you shed load if an "event" occurs. DR events may be

Demand response is "the ability to tap resources in real time, and with enough granularity, to control the load profiles of customers, aggregate these resources, and put them up on a trader's desk."

- Pike Research

How Wholesale Energy Markets Work

Because of our current limitations in storing electricity or transmitting it over long distances, the supply and the demand for energy must balance. In some regions an elaborate balance system has developed.

In Texas, for example, electricity is supervised by the Electric Reliability Council of Texas (ERCOT). While most trades involve upfront bilateral agreements, ERCOT also conducts a "spot market" auction where some 2-5% of energy is traded in order to balance supply and demand in real time. The auction reflects grid and weather conditions, such as a sudden outage at a power plant or an unusually hot afternoon. Producers and consumers can begin bidding one day ahead, but can change their bids up to one hour before actual production and consumption occur. Bid schedules are essentially offers to increase or decrease supply or demand, for a specified price, at 15-minute intervals, at specific locations on the grid.[1]

Other wholesale markets are similar. From the supply side, bids are usually arranged by the ISO or RTO in ascending order (the "bid stack"); producers are told to generate electricity in this order until generation matches load, and all the producers receive the same price for that time period. The same sort of bid stack exists on the demand side for load reduction (or occasionally increase).

This basic bidding scenario can get pretty complicated in practice, as a recent report from the Massachusetts Institute of Technology (MIT) noted:

> *Some base-load generators, such as nuclear plants, are costly to shut down or bring back on line, and will offer their energy at a price of zero to ensure that they are always dispatched. In some cases of very light load these generators may offer their energy at a negative price to guarantee they remain on line since the cost of stopping and starting outweighs the negative energy price. Consequently the cost of wholesale energy can swing wildly during a day—from near zero to near $1,000/MWh...*[2]

Although MIT says the average is around $100 per MWh, and most days do not see this wide a swing from top to bottom prices, their comments illustrate the possibilities for demand response. Industrial and commercial consumers who are able to take advantage of DR programs can earn substantial revenue from them.

1. Hortacsu and Puller, *Understanding Strategic Bidding in Restructured Electricity Markets: A Case Study of ERCOT*, (November 2004), Center for the Study of Energy Markets. http://www.ucei.berkeley.edu/PDF/csemwp125R.pdf
2. Massachusetts Insitute of Technology, *The Future of the Electric Grid* (December 2011), http://web.mit.edu/mitei/research/studies/the-electric-grid-2011.shtml

triggered by energy price changes, additional demand, or changes to grid reliability. When an event occurs, DR programs reward immediate, short-term reductions in usage.

These are the programs you want to find out about, because these are where you'll gain revenue for your company.

You gain revenue in two ways:

- Your energy retailer pays you every month for your agreement to shed load, whether an event occurs or not.
- If an event occurs, your energy retailer pays you for shedding load.

In some DR programs, events are called 24 hours in advance; in others, you are notified and must respond within a certain length of time: 10 minutes, 30 minutes. Generally, the faster you can respond, the more you are paid.

> **"Traditionally, an engineer will say that EE [energy efficiency] is kWh, while DR [demand response] is kW....EE is the goal and DR is the premier tool to get there."**
>
> - Phil Davis of Schneider Electric, quoted on the ADS website

Sample DR Programs

What do DR programs look like? As an example, Southern California Edison (SCE), a utility company based in Los Angeles, offers several programs including these five:[7]

- **Demand Bidding**—Offers credits on your bill when you reduce demand in response to an event announced one day in advance. Available only to customers with a service account of 200 kW or higher.
- **Critical Peak Pricing**—Offers a dynamic pricing rate schedule. Charges higher rates during peak periods during events; in the summer applies discounted rates based on time of day.
- **Capacity Bidding**—Provides monthly incentive payments for capacity reduction and for actual energy reduction during events; bids must be placed one month in advance. Penalties apply if you don't participate when an event is called. Credits are paid whether an event is called or not.
- **Demand Response Contracts**—Consists of programs offered through third-party aggregators; SCE contracts with the aggregator, who then contracts with customers.
- **Real Time Pricing**—Offers rates based on the daily peak temperature in downtown Los Angeles. This program applies all year round, not just in summer.

In addition to these programs, SCE offers technical assistance in the form of demand response audits at little or no charge, and significant reimbursement for installing automation to respond to an event.

Since the grid's operation varies so much from region to region, programs also vary widely, but you're likely to find programs similar to these. In some places your local utility company is the only place to look; in other places aggregators and other energy service companies offer a variety of options.

If you don't find much now, look again in six months. The energy landscape is changing quickly, and the sooner you're involved in demand response, the better.

3. Get Detailed Energy Usage Data

You can't manage it unless you can measure it. So before you can figure out which of the demand-side programs in your area will work for your company, you must determine your patterns of energy usage.

Here's where commercial and industrial consumers often find they need more than just a smart meter. Starting with overall facility usage data is a step in the right direction, but sooner or later you'll probably need to gather more

7. Southern California Edison website, http://www.sce.com/b-rs/demand-response-programs/demand-response-programs.htm

granular data on sub-panels, individual chillers, compressors, manufacturing lines, or other equipment and processes that depend on electricity.

Similarly, starting with hourly data may be sufficient in the beginning, but you can't maximize potential savings and revenue unless you have data in one-minute intervals or less. Especially for demand response programs, you must acquire detailed, near-real-time data from your facility and equipment.

As an automation professional, you're a key resource in setting up energy monitoring and dealing with the data it produces.

"Utilities, Property Managers, and BAS [building automation system] OEMs are not accustomed to managing large amounts of data that the smart grid and smart buildings are starting to produce," notes a report from a Smart Building Technology conference in September 2011.[8]

Automation professionals, however, know how to acquire data and use it in processes and business decisions, and some automation manufacturers are offering suitable products for energy.

For example, automation manufacturer Opto 22 produces an industrial-quality energy-monitoring appliance (the OptoEMU Sensor) that can be attached to pulsing meters, electrical panels, and equipment. The Sensor monitors energy usage in real time, logs data, and sends both real-time and historical data to online energy monitoring services, company databases, and control systems—using open standards including Ethernet, TCP/IP, and Modbus. A second product, the OptoEMU Sensor DR, monitors energy usage and responds to DR events or pre-set thresholds by turning equipment on or off automatically.

"In response to the 2010 FERC Survey, more than 500 entities reported offering demand response programs in the United States."

- Federal Energy Regulatory Commission),

8. Clean Makes Green website, http://cleanmakesgreen.com/2011/09/27/battery-hosts-experts-to-spotlight-it-trends-in-energy-efficiency-for-commercial-buildings/#more-318

4. Get Started with Programs that Work for You

Now that you have installed an energy monitoring system and understand your detailed energy usage, you're ready to get started with the DR programs that are advantageous for your business.

Three Steps to Move Forward

1. Develop an energy curtailment plan.

Based on the detailed usage data you now have, determine a reasonable plan for curtailing use.

You've probably already taken steps to increase efficiency and reduce overall use, especially during peak times. If not, do it now. Consider variable frequency drives for motors. Check maintenance on chillers and compressors. Look for energy-intensive processes that could run at another time of day. Think about pre-cooling buildings in the summer with cool early-morning air, ice that you make overnight when energy is cheaper, or more efficient equipment.

But for demand response, you also need to look at *temporary* curtailment. Find the flexibility within your normal usage pattern. Plan exactly where, when, what, and how fast you can curtail use if an event is called.

Remember the ancillary services table back on page 2 that shows how fast reserves must be able to kick in when demand peaks? For DR programs, responses within 10 minutes are considered good; faster response times could earn even more.

So what kinds of responses could be in your curtailment plan?

- Temporarily shutting down heavy power-using equipment or processes
- Raising or lowering setpoint temperatures for heating or air conditioning
- Reducing lighting levels
- Switching to backup generators during an event

Choose reasonable changes you can make that affect power usage but don't hamper business unnecessarily. This is not disaster planning, but planning for an intelligent, temporary reduction in use.

Consider the cost of the curtailment plan as well. If you're going to switch to onsite diesel generators, will it cost you extra in fuel and maintenance to run them? Or can running

them during events be considered part of your normal periodic testing schedule?

If you're going to shut down a process or system, what are the costs and time involved in starting it up again? For example, many HVAC systems experience rebound after an event—that is, they use extra energy to come back up to normal conditions. You may be able to minimize rebound and avoid possible demand charges by gradually ramping back up to normal.

Your curtailment plan must be suited to your company and its individual priorities. Temporarily stopping a process may work for one manufacturer but cause major problems for another. For example, a material process plant with a buffer tank could shut off transfer pumps temporarily, keeping the material in the buffer tank until the DR event is over. Another plant might not have this flexibility.

Analyzing your detailed usage data and understanding your own processes and business will help you develop your energy curtailment plan. Your CSP may also have suggestions you'll want to incorporate.

Initially you may plan on a manual response to events. When a phone call or other notification comes through, your company personnel respond by turning off equipment or otherwise shedding load. Manual response is probably a good way to start, as long as you can be sure responses will be timely and complete. If an event is called and you do not respond within the time specified or shed the required load, there is usually a penalty.

2. Measure and verify.

You must be able to measure detailed energy usage in order to verify your response to a DR event. Minimally you'll need to acquire data at one-minute intervals. The same monitoring units and software that monitor your energy usage should be able to log historical data to verify response.

Don't leave verification up to the utility company or service provider; make sure you have historical data on hand so that you know exactly how fast you responded to an event and how much energy you saved. This data will help you refine your curtailment plan and prove your response if there's ever a dispute.

This step—measure and verify—is especially important when first starting a DR program, so you can fine-tune your initial energy curtailment plan. But it's also important to keep measuring and verifying as time passes. Pricing, programs, and your processes and needs will change over time. If you have the data, you can make adjustments promptly.

View and analyze data through online energy services

3. Automate response.

Once you're satisfied that your curtailment plan works and you've verified actual response to events, you'll probably want to automate your response. Automation adds speed and accuracy to DR programs just as it does to processes.

Automation can take several forms, from control systems and protocols you already use to new standards specifically designed for DR. The most promising of these is OpenADR, a proposed standard for exchanging information between a server (at your CSP) that sends event notifications and a client (at your end) that automatically responds to the event.

In many ways automating your response to a DR event is just another automation application. Using open standards for control—for example Ethernet, Modbus, or OpenADR—gives you flexibility for future changes. And in energy, change is certain.

Conclusion

The ways we produce and use electrical energy, and the ways we balance supply and demand in the grid, are changing rapidly. Demand response offers a way for companies to take advantage of these changes and improve the bottom line.

As an automation professional, you're in the best position to help your company be proactive in addressing energy needs and costs. Now is the time to begin.

- **Start monitoring energy usage**. Gather detailed, real-time data and analyze patterns.
- **Develop a curtailment plan** that works for your company.
- **Find a local DR plan** and track results. Consider automating responses.

You'll find that energy monitoring and demand response will not only reduce energy costs, but significantly increase your company's profitability.

About Opto 22

Opto 22 was started in 1974 by one of the co-inventors of the solid-state relay (SSR), who discovered a way to make SSRs more reliable. Opto 22 has consistently built products on open standards rather than on proprietary technologies. The company developed the red-white-yellow-black color-coding system for input/output (I/O) modules and the open Optomux® protocol, and pioneered Ethernet-based I/O.

Opto 22 is probably best known for its high-quality SSRs and I/O, all of which are manufactured and supported in the U.S.A. Because the company builds and tests its own products, Opto 22 guarantees all solid-state SSRs and SNAP I/O modules for life.

The company is especially attractive for its continuing policy of providing free product support, free training, free documentation, and free pre-sales engineering assistance.

About the OptoEMU Sensors

Designed specifically for energy monitoring and demand response, the OptoEMU Sensor and the OptoEMU Sensor DR are inexpensive, simple tools to acquire your energy data and automate demand response today.

The Sensor connects to pulsing meters, electrical panels or subpanels, and electrical equipment. It can send energy usage data to an online energy monitoring service, such as Pulse Energy (www.pulseenergy.com) or eSight (www.esightenergy.com), so you can view and analyze the data on any authorized computer or mobile device. The OptoEMU Sensor can also send data to control systems and company databases, so you can use the data to directly manage energy usage and costs.

The Sensor DR connects to pulsing meters to acquire usage data and can respond to DR events or pre-set thresholds by turning equipment off or on. The Sensor DR can also send data to an online service, to control systems, and to company databases for further analysis and action.

Built to industrial standards, the OptoEMU Sensor and OptoEMU Sensor DR are easy to use and configure. Product support is free.

For more information, visit optoemu.opto22.com or contact Opto 22 Pre-Sales Engineering (phone 800-321-6786 or email systemseng@opto22.com).