Automation and the Smart Grid: Energy Management Today

Introduction

Is your company's electrical energy usage important to you? Whether still feeling the results of the recession or looking forward to competing as the global marketplace moves ahead, businesses are looking for ways to cut costs and increase revenues.

Trends in energy show utility companies raising rates and introducing more tiered rate structures that penalize high-energy consumers. And with all the talk about carbon footprints and cap and trade, energy becomes an important place to look for both savings and revenues.

So perhaps you've been formally tasked with improving energy efficiency for your company. Or maybe you've heard about the "Smart Grid" and are wondering how it will—or won't—impact your business. Perhaps you want to understand your corporate carbon footprint before regulatory pressures increase. Maybe you're a business owner or financial officer who needs to cut fixed costs. All of these and more are good reasons for finding out more about how you use electrical energy.

And you're not alone. A March 2009 article in the New York Times[1] noted an increasing trend among large corporations to hire a Chief Sustainability Officer (CSO). SAP, DuPont, and Flowserve are just a few companies mentioned who already have CSOs. These C-level officers are usually responsible for saving energy, reducing carbon footprints, and developing "greener" products and processes.

1. http://greeninc.blogs.nytimes.com/2009/03/02/companies-add-chief-sustainability-officers/

While CSOs in large corporations may have a staff of engineers and a chunk of the marketing or production budget to help them find energy solutions, small and medium-sized industrial and commercial businesses usually take on this challenge as an additional job for their already overloaded technical or facilities staff.

This white paper takes a look at electrical power in the United States today, investigates the nature of the Smart Grid, and suggests ways that small and medium-sized companies can—without waiting for future technological development—gather energy data and control electrical energy costs today.

Meet the U.S. Electrical Power Grid

In the U.S., the electrical power grid comprises all the utilities, networks, and systems used to generate power and deliver it to consumers. All over the country, generation plants produce electricity on demand; the electricity they produce immediately radiates out through a series of substations and progressively lower-voltage transmission lines until it reaches the businesses and homes that need it.

While we think of electricity as "clean" energy, the fact is that electricity is a secondary energy source. It must be produced by another source of energy, and almost overwhelmingly, that source isn't "clean." In the U.S. in 2010, coal produced about 45% of our electricity; natural gas and nuclear power accounted for another 45%. These percentages show only a small change in the last 10 years.

In 2010, only 10% of electricity in the United States was produced by renewable energy sources.

So 90% of U.S. electricity is currently generated by burning fossil or nuclear fuel to heat water, which then

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becomes steam that turns turbines to produce electricity. Only about 10% is generated by hydroelectric power or other renewables, such as wood, methane, biomass, geothermal, solar, or wind.[2]

Demand and Supply

Electricity is a little like a good, old-fashioned tomato—it doesn't travel well and doesn't store easily. Just like the tomato, it needs to be consumed very close to the time and place it was produced.

In fact, except for very small amounts stored in batteries or capacitors, electricity *is* consumed as it is produced. The demand directly dictates the supply.

In a hydroelectric power plant, for example, the demand coming from energy users at any given time draws power from the turbine. The greater the demand, the harder the turbine is to turn and the more energy is transferred from the water into electrical power. When demand slacks off, the turbine is easier to turn; the water's excess energy goes down river with the water, rather than becoming electrical power.

Since electrical generating facilities must be available virtually instantaneously to meet the demand at any given moment, some generation plants sit idle until they are needed. With surprisingly little variation, peak demand all over the country usually occurs between late morning and evening on summer days. Generation capacity must be able to meet this peak demand, yet maintaining "peaker" plants to fill the demand at these times is expensive and inefficient.

Currently, utility pricing varies by region. In some places like California, utilities have started using tiered pricing structures and offering usage curtailment programs to discourage energy use during peak times. In other places electricity costs are lower and utilities still charge flat rates, so there is no incentive for energy users to reduce demand.

Reaching its Limits

While computers, telecommunications, and automation systems were nonexistent or substantially different 50 or 100 years ago, our system for producing and delivering electrical energy has evolved slowly and remains in many ways the same as it was decades ago.

Hailed by the National Academy of Engineering as the most important engineering achievement of the 20th Century[3], the grid still provides the nation's power with remarkable reliability. The problem is that while both the total demand for power and intolerance of power fluctuations have dramatically increased, the system has not fundamentally changed.

> *Our nation's electric power infrastructure that has served us so well for so long—also known as "the grid"—is rapidly running up against its limitations… Our century-old power grid is the largest interconnected machine on Earth...It consists of more than 9,200 electric generating units with more than 1,000,000 megawatts of generating capacity connected to more than 300,000 miles of transmission lines.*[4]

Transmission and delivery are fairly well automated within individual substations, and data sharing among utility companies is increasing. But coordination and communication at a higher level is just in the beginning stages. Interoperability for grid stakeholders is currently immature and viewed as a major hurdle to overcome.[5]

2. U.S. Energy Information Administration, http://www.eia.doe.gov/cneaf/electricity/epm/table1_1.html
3. National Academy of Engineering, http://www.great-achievements.org/
4. "The SMART GRID: an introduction," U.S. Department of Energy brochure, September 2008
5. U.S. Department of Energy, Smart Grid System Report — July 2009, page 8

The U.S. Department of Energy describes the current grid as needing a major overhaul to meet the demands of the future and analyzes its problems as follows:

> *More blackouts and brownouts are occurring due to the slow response times of mechanical switches, a lack of automated analytics, and "poor visibility" – a "lack of situational awareness" on the part of grid operators.*[6]

Hmm. Mechanical switches, a lack of automated analytics, and poor visibility into the system? Sounds like a job for an automation engineer.

And that brings us to the future: the Smart Grid.

What's a Smart Grid?

Because there are so many stakeholders who each want to see their concerns mentioned, a standard definition of the Smart Grid has proved elusive. You'll find varying definitions—and a lot of varying timetables to get there. But in essence the Smart Grid vision is for a reworked infrastructure that embeds digital intelligence into the entire process of producing, distributing, pricing, and consuming electricity.

What does that mean in practice?

- Everything on the grid, from power plants to individual appliances, can be seen and controlled in real time—most of it automatically.
- Energy prices reflect what it costs to produce electricity in real time.
- All methods of generation and storage can be incorporated into the grid.
- The system is secure, efficient, and environmentally sound.

Everything Can Be Seen and Controlled

Because the Smart Grid allows two-way, digital communication between power provider and power user, electricity can be managed in real time, automatically. Who controls this management may be at issue (at least initially), but ideally both the user and the provider are involved at different levels.

Utilities know exactly how much electricity is being produced and used on the grid and where it's being produced and used. In this way they can see potential problems and shift supply to areas of higher demand. This more efficient operation reduces brownouts and blackouts and provides better quality electrical energy.

> **"Information technology and pervasive communications are cornerstones of a smart grid."**
> - U.S. Department of Energy

Some energy users, especially residential customers, are happy to let smart appliances and smart meters determine the most efficient way to use energy. Commercial and industrial users may want to manage at least part of it themselves, to see the details of their energy usage and control their usage in the most effective way for their business.

In the Smart Grid, real-time production and usage data benefits both providers and users. But this vision of two-way communication and automated energy management demands open standards, because data from many sources must be aggregated, integrated, and presented visually to an assortment of users in varied formats.

The standard expected to ensure this interoperability of all Smart Grid systems is IEC 61850. Developed by the International Electrotechnical Commission (IEC)[7] and originally designed for substation automation, IEC 61850 calls for the use of standard Ethernet communications.

Energy Prices Reflect Real-time Production Costs

Because electricity is consumed the moment it's generated, the power industry, more than any other industry, must understand customer demand and consumption patterns and anticipate customer needs. In the past, the industry focused on accommodating customer demand whenever it occurred. For example, prices for electricity did not reflect the additional cost of building or running "peaker" plants (by definition, plants used only during peak demand).

In the Smart Grid, pricing is dynamic: it's determined by the real-time cost of production, transmission, and distribution, which can vary widely over the course of a day. Energy rates are tiered or directly tied to real-time costs, so customers have a strong incentive to adjust their energy consumption to avoid peak times. With energy demand

6. "The SMART GRID: an introduction," U.S. Department of Energy brochure, September 2008

7. http://www.iec.ch/

smoothed out both voluntarily and by automated controls, the Smart Grid lowers peaks and the extra capital and operating costs they involve.

All Generation and Storage Methods can be Incorporated

Most electricity is generated by a controlled, constant force. Wind and solar generation, however, are examples of variable sources: the speed and direction of the wind change over the course of a day, and the sun's energy is moderated by clouds, time of day, and seasons.

Today, integrating these variable-output sources of electrical energy into the grid can cause problems, because the electricity they produce may or may not be in phase with non-variable sources.

Moreover, the technology for storing electrical energy is still in its infancy. Current methods of storage are expensive, their capacity is small, and their disposal causes environmental damage. New technologies for large-scale energy storage, such as super capacitors or ultra capacitors, are under development.[8]

In the era of the Smart Grid, however, these technical problems of combining out-of-phase electrical current with a steady current supply have been solved. The Smart Grid can accept energy from any generating source just as easily as traditional sources, and it can accommodate new methods of storage as well.

This flexibility means the Smart Grid can utilize distributed sources of power generation and storage. If the commercial building across the street has a photovoltaic system on its roof, and your firm makes ice at night to use in place of standard air conditioning on hot summer days, the grid as a whole can rely on you both for part of its energy needs during high demand periods or in case of emergency.

Microgrids are also a distributed feature of the Smart Grid. While they usually function as part of the larger grid, they can operate as islands. Microgrids help with power quality issues on a daily basis while offering the advantages of distributed power generation and storage in an emergency.[9]

> **"A transformational aspect of a smart grid is its ability to incorporate distributed energy resources, particularly demand-side resources, into system operations."**
> - U.S. Department of Energy

System is Secure, Reliable, and Environmentally Sound

An interconnected Smart Grid, while more flexible than a disconnected one, is arguably more open to security breaches. Critical Infrastructure Protection standards have been developed by the North American Electric Reliability Corporation (NERC)[10], an independent self-regulatory organization devoted to ensuring the reliability of the bulk power system in North America.

In the Smart Grid, the system meets these security standards and can respond promptly to any possible security breach. Distributed generation, microgrids, and the ability to automatically shift energy from one section of the system to another all help mitigate the effects of an emergency, no matter what its cause.[11]

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8. Oak Ridge National Laboratories, http://www.ornl.gov/sci/electricdelivery/powerelec_ES.html
9. U.S. Department of Energy, Smart Grid System Report — July 2009, page 33
10. http://www.nerc.com/
11. U.S. Department of Energy, Smart Grid System Report — July 2009, page 33

Another major goal of the Smart Grid is reliability: a future without brownouts or blackouts, where power quality is consistently high and loads can be shifted automatically. Contributing to its reliability are programs such as VERDE (Visualizing Energy Resources Dynamically on the Earth), being developed by the Oak Ridge National Laboratory. VERDE's visualization program overlays grid status, weather patterns, and other pertinent data on Google Earth images to produce a real-time view of the entire grid. Programs such as these increase reliability by helping operators analyze status and respond to wide-area power outages, natural disasters, and other large-scale events.[12]

Yet all of this must occur while we reduce negative effects on the environment. Cars, trucks, and planes now emit only 20% of all the carbon dioxide we produce in the U.S.; electricity generation emits 40%.[13] Cleaner generation will be needed to reduce electricity's environmental impact. Clearly the goal of a green Smart Grid will require time, effort, and the development of new technologies.

Technologies for the Smart Grid

So the Smart Grid envisions a future with reliable, secure power that's automatically adjusted for the greatest efficiency. But you know from experience how long major automation projects can take, and this is perhaps the largest automation project ever seen.

The U.S. Department of Energy lists five fundamental technologies that will drive the Smart Grid:

- *Integrated communications, connecting components to open architecture for real-time information and control, allowing every part of the grid to both 'talk' and 'listen'*
- *Sensing and measurement technologies, to support faster and more accurate response, such as remote monitoring, time-of-use pricing and demand-side management*
- *Advanced components, to apply the latest research in superconductivity, storage, power electronics and diagnostics*
- *Advanced control methods, to monitor essential components, enabling rapid diagnosis and precise solutions appropriate to any event*
- *Improved interfaces and decision support, to amplify human decision-making, transforming grid operators and managers quite literally into visionaries when it comes to seeing into their systems*[14]

While capabilities are always improving, notice that most of these technologies are already available to automation professionals:

- Ethernet and other Internet-based open standards allow integrated communications.
- Accurate sensors and measurement devices are available.
- Control and monitoring methods are familiar.
- Today's operator interfaces allow detailed and secure interaction with the devices and systems that need managing.

You: A Player in the Smart Grid

As an automation engineer, you don't need to wait for the Smart Grid, "smart" machines, or newer technology.

Your company can use the tools available today to manage energy use.

And you can also take advantage of programs from utility companies and energy aggregators to reduce costs or even gain a source of revenue.

What can companies do today about energy?

Working with your utility or power broker, you can become a player in the Smart Grid right now, using these three steps:

1. Get detailed data on your company's energy usage.
2. Control energy usage and costs.
3. Gain a revenue stream through utility company rebates, credits, and curtailment programs.

12. Oak Ridge National Laboratory, http://www.ornl.gov/sci/electricdelivery/vis_VERDE.html
13. "The SMART GRID: an introduction," U.S. Department of Energy brochure, September 2008
14. "The SMART GRID: an introduction," U.S. Department of Energy brochure, September 2008, page 29

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1. Get Detailed Data on Energy Usage

First data; then control. The first step is to get detailed data on your company's energy usage—exactly what it costs in real time to turn on a motor, run a process, or have the building air conditioning set to 78 degrees, for example. In some cases you may already be monitoring equipment, such as refrigeration units for regulatory purposes, and you can use or expand this data.

You can add I/O to your current automation system to measure energy use or put in a small, separate cell control system just for the purpose. In either case, using Ethernet networking and open standards simplifies the process of reporting energy data to your computer network for analysis. Look for vendors offering Ethernet-based programmable automation controllers (PACs), switches, wireless radios, and other components that can communicate with office computer systems using open standards.

One example is the Ethernet-based OptoEMU Sensor[15] from automation vendor Opto 22. A PAC-controlled appliance designed for energy monitoring, the OptoEMU Sensor connects to pulsing meters, electrical panels, and equipment. Energy data is sent in real time over a wired or wireless Ethernet network; it can be seen online through an authorized computer or mobile device, using a website that provides software as a service (SaaS).

Initially you may choose to monitor energy usage on a large scale, for example from an electrical panel that serves a specific building or process. Noting the change in energy usage when certain motors, compressors, parts of the process, or even lights are drawing current will be revealing.

15. http://www.opto22.com/lp/optoemu.aspx

In some cases wiring directly to an individual pump, motor, or other heavy energy user may be an easier way to determine its share of the overall load. As an added benefit, monitoring assets may help pinpoint problems, such as required maintenance when a motor suddenly starts using extra energy.

A small system should be scalable, however. Seeing energy usage at this level may reveal that data is needed at a more granular level. And once you analyze the data, the next step will be to control use, preferably via the same system. So choosing a system that can be easily expanded and that can provide control as well as monitoring is the smart way to begin.

In the example of the OptoEMU Sensor, the Sensor is fully compatible with Opto 22's SNAP PAC System and systems that communicate using OPC or Modbus/TCP. Systems that use distributed intelligence offer the best flexibility, because they employ a central controller but offset many I/O functions to local, less expensive processors. Distributed intelligence makes it easier to add more I/O points for additional monitoring or to add more complex functions such as analog control, without negatively impacting the system's efficiency.

Analyzing Data. The detailed data you get from monitoring usage can then be analyzed for patterns:

- Which equipment or processes require the most energy, and which ones the least?
- What patterns do you see in energy use over a 24-hour period? Seasonally?

Now is the time to start looking at adjustments, too:

- Could that old energy-hogging motor be replaced with one that has a variable frequency drive?
- Could some processes run sequentially rather than concurrently to reduce the electrical load at certain times of day?
- Could a slight change in temperature make a big difference in compressor runtime?

2. Control Energy Usage and Costs

The next step is to tie usage to costs and control both.

Pricing structures vary depending on where your company is located and who your energy provider is. However, the trend is toward dynamic pricing based upon total usage

during a billing period or even time of use (TOU) during each day. TOU billing is a definite move toward the real-time pricing envisioned in the Smart Grid, and it already exists in some areas, including much of California.

If your energy provider charges a flat rate, your only opportunity for reducing cost is to reduce usage overall. But if your utility company or energy broker prices electricity dynamically, your opportunities are much greater.

Tie the energy data you're acquiring from your machinery, processes, and building to your electric rates, and then see what savings are possible. For example, you could schedule a high-energy-use process for early in the day, when demand and energy costs are low. Or you could shed loads when overall usage approaches a higher-priced tier.

Ideally you've thought ahead and chosen a data acquisition system that you can now expand to control the energy-using machines and processes in your business. Based on your usage data and analysis, start with one or two areas in which control can most effectively reduce costs; then move on from there.

The key is to control energy use in the most effective way for your individual business. A large corporation may want to hire an automation company to advise them and install an energy-management system.

For small- and medium-sized industrial and commercial businesses, however, their own engineers and technicians know their company's facilities and processes intimately, and are usually the best ones to analyze use and make energy decisions. A systems integrator who specializes in energy use can provide extra help if needed.

Your utility company can also help. Many offer free energy audits or testing programs to help you identify electrical problems and ways to save electricity. Testing may include power factor studies, locating transient voltage problems, and load profiles, which show energy usage over a given time period. Energy providers can also advise you about cash rebate and curtailment programs that not only save you money but can even provide a revenue stream.

3. Gain a Revenue Stream

Once you've acquired and analyzed detailed energy data, tied it to rates, and found ways to reduce usage and costs, you're ready for the third step: gaining a revenue stream from energy. This third step requires looking at energy in a different way.

A 2009 white paper from Rockwell Automation encouraged manufacturers to start thinking differently about energy: to think of energy not as a cost that must be controlled, but as another raw material required to manufacture a product. The cost of energy to produce an individual product then becomes another item on the product's bill of materials and is reflected in the product's price and decisions about production. Rather than considering energy an overall cost of doing business, its cost is broken down by function so that decisions can be made about where to use it most wisely.[16]

Concern in the U.S. about cap-and-trade legislation for carbon emissions, which are most often tied to energy use, fits into the same picture. If a business must buy carbon credits, it will need to look closely at where and why that purchase is required. Conversely, selling credits is an opportunity for income and will be weighed against the potential profits obtained by using them. In both cases, tying the credits to their specific use—per product, per process, per location—will provide the greatest opportunity for wise financial decisions.

More immediately, many utility companies and power brokers offer programs right now that can be a source of income for your business. These include cash rebates and curtailment programs.

Cash rebate programs give energy customers money for replacing older, less-efficient equipment with new efficient models. For example, cash rebates

16. Phil Kaufman and Marcia Walker, "Industrial Energy Optimization: Managing Energy Consumption for Higher Profitability," Rockwell Automation, October 2009

are often available to customers who add variable frequency drives or buy motors, chillers for HVAC systems, refrigeration equipment, or lighting devices that use significantly less energy. You get the cash rebate plus a lower energy bill.

Rebates or financial assistance may also be available for installing self-generation systems, such as solar photovoltaic and wind power, or equipment to permanently shift loads. An example of permanent load shifting is thermal energy storage, such as making ice or chilled water during the night when energy is cheap and then using it for cooling during hot summer days. Check the return on investment before purchase, keeping the rebates or financial assistance in mind.

Curtailment programs pay your company money each month in return for your promise to curtail energy use, either automatically or when requested. You are paid both for agreeing to reduce your available capacity and for actual reductions.

- *Dynamic demand programs* use devices attached to a specific piece of equipment (for example, a compressor on an air conditioning unit). These devices, usually provided by the utility company at little or no cost to you, can sense stress in the grid and automatically respond by temporarily shutting off power to that equipment.
- *Demand-response programs* are not usually automatic: instead, your utility provider calls you to request load shedding, and you respond within a specified period of time (such as 30 minutes) by reducing your overall energy use to a predetermined level.

  It's important to realize that if you don't respond within the time required or to the level agreed upon, you'll be penalized. If your business is on a smart meter, you may be able to automate the request and your response; or you may prefer to keep your response under human control.

These curtailment programs can offer substantial income—an effective revenue stream. Curtailment programs may be offered by private aggregator firms as well. Ask your local utility provider for programs in your area.

Help from Your Automation Company

The broad communications capabilities in today's PACs and I/O mean that your current automation company may very well have products that will help you acquire energy data and control usage. You may be able to simply tap into your current infrastructure to get the data you need for energy management.

Automation vendor Opto 22, for example, offers a highly scalable, reliable system with distributed intelligence, based on Ethernet and open communication standards. If you already use their SNAP PAC System, you can add energy management capabilities in one of two ways: either by adding an OptoEMU Sensor energy monitoring unit, or by adding a few I/O modules such as the SNAP-AIPM-3, which monitors 3-phase power. Minor changes to your PAC Control strategy, which runs in the programmable automation controller, would incorporate energy data into the control program.[17]

These products are also useful if you prefer to keep energy management separate from your regular automation system. An inexpensive, scalable small system can acquire all energy data and control individual devices or equipment—pumps, motors, or compressors, for example—that are not part of the larger automation system. Built on open communication standards, this small system can also provide input to the main automation system; for example, it can send actionable data to an Allen-Bradley® PLC or to a Wonderware® human-machine interface (HMI) for operator response.

If you need to monitor or control additional equipment, additional units can be easily added.

Starting Now

The national automation project known as the Smart Grid will take decades to complete. Now that you know more about it, however, you can see how your company's interest in energy management can fit right in, even before the Smart Grid arrives.

17. http://www.opto22.com/site/snap_pac_system.aspx

Starting now to manage your company's energy usage and costs will give your business a competitive edge today and for the future.

Here are some easy ways to begin:

- Begin thinking about energy as a raw material and even as a source of revenue.
- Use automation technology and products available now to acquire the data you need. Analyze energy usage in as granular a form as you wish.
- Use readily available products based on open communication standards to send this data to company computer networks, online software services, and operator interfaces.
- Based on the data you acquire, set up automated or operator-driven control for devices and processes to use energy in the most efficient way for your business.
- Take advantage of rebate and curtailment programs offered by your utility company or other energy provider to acquire new equipment and even produce a new revenue stream.

OptoEMU Sensor™
Energy Monitoring Unit

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, both 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 SNAP I/O modules for life.

In a time of financial uncertainty and increasing budget restraints, the company is especially attractive for its continuing policy of providing free product support, free training, free documentation, and free pre-sales engineering.

About the OptoEMU Sensor

Designed specifically for energy monitoring, the OptoEMU Sensor is an inexpensive, simple way to start acquiring your energy data 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.

Built to industrial standards, the OptoEMU Sensor is 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).