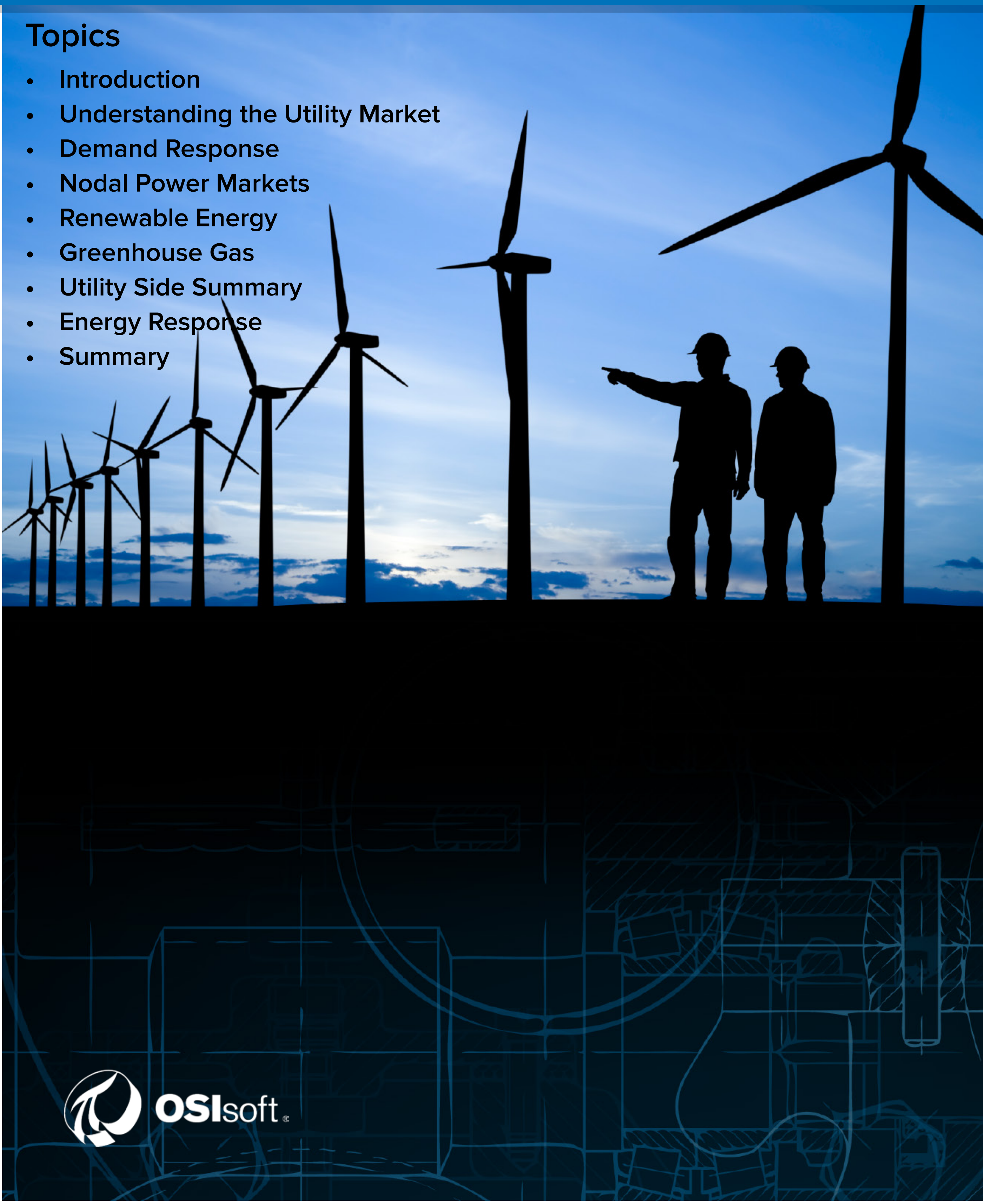
WHITEPAPER

Dynamic Energy Response

Topics



Introduction

Energy and information are a significant and growing fraction of manufacturing costs and require lifecycle cost management. New facilities will have to be built and operated in order to conserve resources, and existing facilities will have to be upgraded cost effectively. This is not new – economics, regulation, and innovation drive business economics but today the external environment is even more dynamic and requires an appropriate response.

There is little a user can do about regulation, epoch technology breakthroughs, or market changes except monitor their effect and be prepared to change their business strategy; improved management of energy and information, however is under their control.

This discussion is divided into two parts:

a). Provides a description of the utility market, the changes that we can expect, and the reasons behind these changes; and

b). Describes the guidelines for the industrial user to develop a dynamic energy response

Understanding the Utility Market

Deregulation has catalyzed many changes in the energy market. Figure 1 shows the daily peak demand at the California Independent System Operator (Cal ISO) load center that manages power to the 11 Western states, western Canada and western Mexico. Cal ISO power comes from over 800 power producers and purchases from neighboring utilities especially the Northwest with their hydroelectric resources and western coal state generation. They schedule power to the large wholesale users and the distribution utilities who sell it to residential and C&I (commercial and industrial) customers.

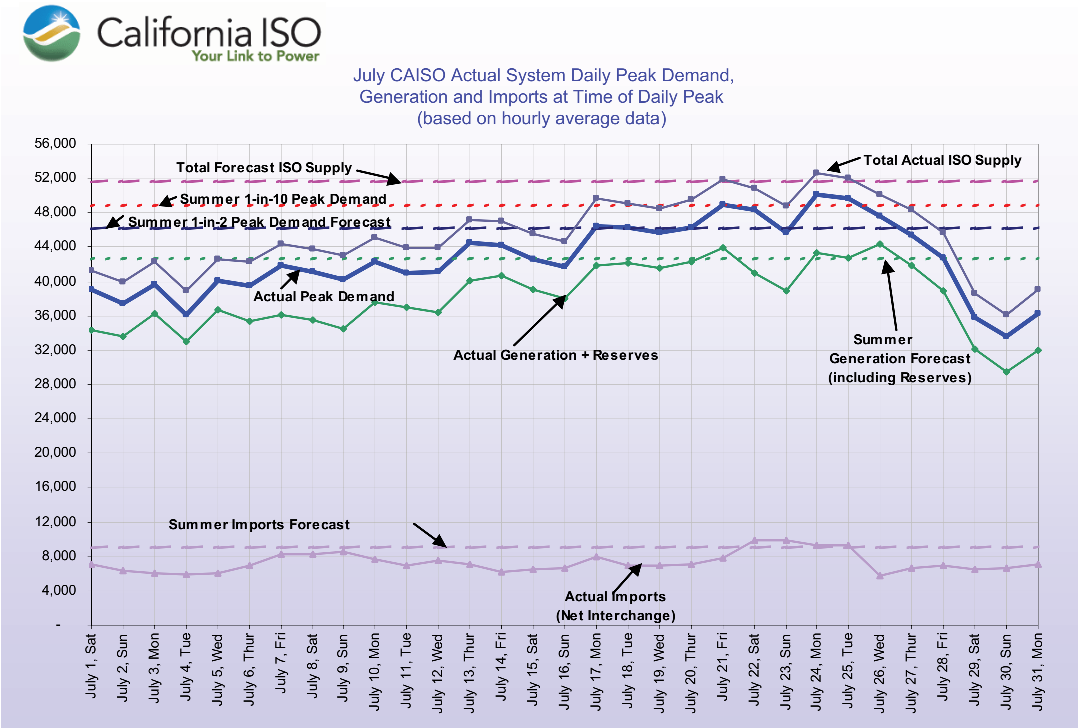


Figure 1 - System Daily Peak Demand
See it live: http://www.caiso.com/Pages/TodaysOutlook.aspx

Pricing is by negotiation and PUC (Public Utilities Commission) approved tariffs. Daily peaks for most of the years run from 25-35 GW but in July of last year the highest was over 50 GW resulting from a sustained heat wave. This peak demand could only have been satisfied by maximum conservation, maximum use of interruptible power, all available generation regardless of its efficiency, and purchase from adjacent areas using the day-ahead market. This peak caused a Stage 2 Emergency and if it weren't for energy conservation measures and large hydroelectric reserves from the Northwest, it would have caused major disruption.

Since then, the demand in the West has continued to grow faster than new generation is brought on line, as we build new homes in hotter locations, and new industry such as data centers. Hot areas are especially bad for demand because, not only are air conditioners used more, they are less efficient. All the while, neighboring areas continue to build. A similar heat wave in 2007 may necessitate aggressive load shedding measures and, even so, may not be able to prevent disruptions such as rolling blackouts.

In the EPRI document prepared last summer proposing intelligent use of resources, they note that we need energy improvements, demand response, and dynamic systems with smart equipment to better utilize the power that is available. The four building blocks for these will be:

- Communication infrastructure between utilities and users
- Innovative rates and regulation to encourage the right activities
- Innovative markets to help users pay for the investments
- Smart end user devices to optimize the use of delivered resources

Under current legislation, building new generation or cogen facilities is not cost effective because 96% of the year they would have to compete with existing facilities that have been paid off and have no burden of covering debt service. It is for this reason that even after construction, some of the inside-the-fence cogen plants built in the last decade are run as steam generation and do benefit the grid because their owner is paid less than their marginal production costs. As our neighbors try to cope with their own issues including resistance to new hydroelectric dams, greenhouse gas regulation, and soaring new construction, they will not have as much power for sale as in years past.

This is not just a matter of blackouts or temporary problems, it affects the whole economy. The NY Times has already identified our inability to deliver power as a limiting factor in the growth of the high tech industry in Silicon Valley. Data centers are the core of many new industries (e.g. Google) and power is currently the second largest total cost of ownership for a data center. Intel predicts that within three years the cost of energy will exceed the cost of the hardware itself due to rising energy costs and decreasing computing costs – a trend that will continue.

Normally the grid management works well and reliability is maintained but as stress is applied, maintaining reliability becomes much more of a challenge. In China, which currently produces only 85% of their demand, Dr. Jun Zha of the China State Grid described their reliability management system which uses sophisticated instruments for measuring the state of the grid over 100 times per second, which show how dynamic the situation is under stress and how to respond. In the case of the Central China blackout last year, this analysis gave them a 45 minute warning in after-the-fact analysis. Obviously, we have a strong desire to avoid this kind of condition in the US but we can learn from their experiences.

Regulators, operators, and legislators have proposed a number of new initiatives designed to mitigate problems, however, simultaneously adding regulations that can exacerbate the problem. The four emerging rules changes that I feel will have the most dramatic affect on the industrial users are:

- Demand Response Programs
- Nodal Power Markets
- Renewable Energy Portfolio Standards
- Greenhouse Gas Regulation

These programs are being rapidly adopted across the country. Federal, state, and local laws have already been passed and many programs are in the implementation stage. A good understanding of how these affect each energy user will be very important.

Demand Response

Fluctuations in demand, not the total load, can create spikes and one approach would be to shift demand from one time to another – from the afternoon of the business day to the night, from the weekday to the weekend, and from summer to winter. Although many users can assist, there has been no good set of financial incentives in place to provide a return on investment to the user. Some of these are simply operational changes. For example, a paper company can make its heavy grades (higher steam requirements) or run its refiners (high power load) at night, a refinery can control its product slate by the crude it purchases, and a multiregional company can shift production from one site to another or ship intermediate materials to help balance the power between regions. Some of these incur additional operational expenses and some require capital – e.g. the construction of an ice plant or other energy storage facilities.

Different users have different flexibility that only they know how to manage. In California, the largest single growth of commercial electrical demand is from the construction of new data centers and there are good strategies available to manage power in the data center by managing the systems but have to be designed into the facility such as running a DC operation to reduce power or building cogen facilities to make use of waste heat for air conditioning. Also, data centers have backup power generation and these centers could produce peaking power if allowed by local air permits and if they are designed for that service.

In order to implement demand response, utilities are installing new metering systems that permit them to communicate a price for power based on the current demand (i.e. demand response) and send that price offer to the users electronically. At the consumer level, the vision is to have everyone's "beer refrigerator" cut off the compressor at critical times in the afternoon or the "smart dryer" to schedule itself to run at better times, but, frankly, a refinery or data center consuming 50 MW normal demand has a much bigger affect on the grid.

1. High fidelity bidirectional meters connected to settlement systems to pay users for cooperating (called AMI – Advanced Metering Initiative) and these meters must also be supported by the business software of the use
2. Higher price for power in times of stress (for either additional demand or avoided use)
3. Prices that change minute to minute in an unpredictable manner instead of monthly billings according to a fixed tariff

Big users that participate in maintaining reliability of the grid would have to be aware of their role (e.g. shutdowns of a cogen plant or start up of a paper machine at the wrong time could affect the regional reliability) and maintain contact with dispatch.

Demand response requires controls programs to effect the changes automatically in a safe and secure manner as faults could put people or property in jeopardy thus the systems that make the changes will be owned, maintained, and operated by the user.

The bigger issue is financial – the C&I users can change operation to make it cheaper to produce power but have not done so in the past because the utilities have not offered sufficient financial incentives for these benefits.

To give some indication of the value of demand response, consider this unlikely scenario using GE turbines—if you converted all gas-fired generation in California to GE LM100 units (one of the most efficient aero-derived units made), the state would save approximately 93,000,000 MMBtu of fuel, or $650 million yearly but if you converted all gas-fired generation in California to GE's new H machine (under construction in Southern California and a base load unit), the state would save approximately 234,000,000 MMBtu of fuel, or $1.6 billion.

Nodal Power Markets

Often there is sufficient power in a region, but it is not in the area that needs it and cannot be wheeled to that area due to limited transmission capability. In addition, our system of transmission inter-ties was designed for areas to exchange power during times of need, not support financial strategies requiring routine use, thus can result in congestion on the transmission paths. A nodal power market is a power supply strategy that uses locational marginal pricing (LMP) to compute the cost of serving each "node" of the power grid. When nodes are experiencing congestion the utility increases the cost to deliver power to users that utilize that node. In the past, the cost of congestion was "socialized" or spread across many residential and industrial customers. Each node will exhibit different price volatility depending upon it current state of congestion. To see the affect on pricing of LMP, one can look at the pricing display for ISO of NY:

http://www.nyiso.com/public/market_data/zone_maps.jsp

and note that this display updates with different prices per power at each node every two minutes. With MRTU, large electrical users will be allocated, based on historical usage, a quantity of congestion revenue rights (CRRs) that they can use or sell providing a user with adequate supply benefits from conservation.

LMP is quite complex even without the CRRs. Since a utility cannot measure congestion directly, the prices at each node are the result of running a "state" model to obtain a prediction of congestion. In the previous example of the State Grid of China, they face the shortage issue on a perpetual basis and are therefore installing a system of WAMS (Wide Area Monitoring System) which use satellite linked phasors monitored 100 times per second to actually measure congestion. These phasor data are converted in large display processors, using Fast Fourier Transforms, and the difference between nodes is the measure of congestion.

Renewable Energy

Many legislators are implementing laws that require a certain portion of the energy supply from "renewable energy" resources. As a "feel good" law, this will pass easily in every area that chooses to put it on the ballot but large increases in renewable generation will add stress to the grid for maintenance of reliability. In California, wind generally picks up at night and dies down when most needed—on very hot days during peak demand. It also comes onto the grid via the distribution systems which are not as reliable as our transmission systems. Many think that because of this variation, we will have to install a MW of peaker unit power (very high production costs) for every MW of renewable power making it doubly expensive.

To stimulate renewable energy investment, the market is managed by a system of certificates, called REC's (renewable energy certificates). For most users, the introduction of renewable energy portfolio requirements will result in an increase in the price of their power. However, some users qualify for these credits themselves (e.g. hog fuel boiler in a paper mill) and might find a good market for their REC's.

This certificate is the most mature of the energy certificates (or certs) and generally well known but gives us an indication of how federal and state lawmakers will manage the greenhouse gas issue. mitigate the challenges associated with diverse, mobile data sources.

Greenhouse Gas

The carbon footprint of both commercial and industrial energy customers has come under scrutiny and was spotlighted recently by the signing of California AB32 by Governor Schwarzenegger. AB32 places a restriction on the type of electrical power that can be sold into the state to bring about a reduction in the state's contribution to greenhouse gasses. Although there are some challenges to the California law, there is little doubt that it will be either enforced or superseded by a Federal statute. In any case, the user will have to measure and report their greenhouse gas emission and likely be required to either reduce them or buy new certs similar to the REC's.

The greenhouse gas that is targeted is CO2 and the limits in AB32 for imported power will barely allow the cleanest gas-fired production. Even with sequestering of the CO2, coal is well over the limit, difficult and expensive to use as a clean energy source and, of course, nuclear power is politically untenable in California and can be expected to be of little help. These point to a substantial increase in the price of power.

This program will require an intimate tie between the systems in the process areas and the electrical grid as each user will be required to measure their carbon footprint and manage the purchase/sale of carbon certificates to meet regulatory limits. In some situations, the sale of certs could be a better business than the products and the maximum profit could come from shutting down a process.

Utility Side Summary

In summary, I have picked four initiatives that will be superimposing compliance and operational tasks on each user—some of which could be beneficial if they are expected and leveraged; some of which will have all the administrative headaches of compliance but few financial benefits. The biggest difference between these and the historic compliance tasks are the close integration with the power grid and the dynamic nature of this integration and the metering requirements.

Dynamic Energy Response

In order to design the response, we must first look at the effect of the laws that are coming. From pervious legislation, we can predict that regulators will focus first on systems to reliably measure and report the current emissions before requiring compliance. This was the tact used with numerous initiatives including OSHA PSM, EPA Discharges to a Navigable Waterway, and Reformulated Gasoline. These follow the same continuous improvement philosophy embodied in the improvement of quality with ISO 9000, air safety with the FAA NTSB. The goal will be to use a system of incident investigations, recommendations, and continuous improvement in order to affect a goal.

This same procedure was mandated for air plane crashes, environmental accidents, lapses in quality, or flaws in the delivery of reformulated gasoline. In these cases, the enforcing authority (usually the US Government) would audit not the compliance but the system for reporting compliance. This gave rise to a complete system of exception reporting focused on the primary goal of the regulation. Early success has led to the addition of more and more regulations – some of which have conflicting goals. Sometimes it is not clear how to lower congestion while lowering greenhouse gasses if the former requires increasing cvoal fired base load. At some point, the lack of economic growth and jobs need to be considered part of the price.

The electrical power consumer will have to design a response to these new laws and obtain economic benefits from rules that encourage a rapid, directed response. In the past, an “energy management” program may have only required careful monitoring of the integrated usage over the month with a prediction of the ultimate consumption and some load shedding if a peak was approached. Tariffs only looked at usage and demand to determine the power bill thus little data was monitored. To meet these new requirements, especially the carbon footprint, meters will provide much higher fidelity information of power, current per phase, load factor, and other important parameters. The bottom line is that billing today is essentially a monthly reading and internal monitoring will be in the “minutes” – both of these times will devcrease to support the next generation energy billing.`

Once the measurements are available and the new laws published, users will have to reengineer their manufacturing processes so that some management of electrical energy on a minute to minute basis and then compute the specific effect (e.g. mw/ton) for each product and raw materials. Consider how each of the new laws might affect users.

Greenhouse Gasses—Industries that use hydrocarbon fuel for process heat will find themselves subject to internal monitoring for their “carbon footprint.” Some industries where CO2 is a process stream or byproduct (e.g. refining, mining, steel, and hydrogen production) in addition will have to be especially diligent. Electrical demand will also have a CO2 penalty. There are only a few ways to reduce greenhouse gasses:

- Alternative Energy (i.e. wind, solar)
- Different Fuels (e.g. coal -> natural gas)
- Conservation and Efficiency
- New Processes

In the short term, conservation and efficiency are available; all the others take time, capital and/or technology breakthroughs. With "global warming" as a major news story, we can expect additional legislation modeled after California's AB32. Users must first calculate their contribution to greenhouse gasses and, like all reporting to the regulators, calculations will have to be performed according to a set of complex rules about data management, backup, verification, and change management.

At some point, users should expect a "tax" on greenhouse gasses and possibly "certs" that they can purchase to meet the regulations. Aside from conservation and efficiency gains, these certs are the most likely enforcement mechanism, similar to the REC (Renewable Energy Certificate) that is already in use via companies like APX in the Bay Area. Greenhouse gas and energy efficiency certificate markets are already emerging.

Demand Response - Many users can easily shift demand and help smooth out the peak loads for the grid and this law could be a benefit allowing them to be paid for their trouble. Demand response requires two-way communication between the user and the grid operator so that when particular behavior is required, they can send a price signal to the user to respond. With consumers, the signal might be used directly to effect some control, but most industrial system will accept the signal as an external input and only with great care will they manipulate the process to shift the time/demand relationship. Some example of this are:

1. Change time or order of products for production
2. Shift production to alternative location
3. Make versus purchase (power) decisions
4. Shift to lower electrical consuming devices (e.g. steam turbines rather than electric motors)
5. Capital investment (e.g. new heat exchangers, absorption chillers to use waste heat for air conditioning)
6. Shut down production
7. Block processing (i.e. use different feedstock during times of power stress)
8. Store energy intensive intermediates (e.g. hydrogen) for times of low demand.

In a paper mill these strategies would require computations between the orders and the schedules. In refining, the oil traders would have to be aware of the requirements when they buy the crude oil and schedule the products at the different refineries. Each user is different and would have to reengineer their operation systems to be able to accept information on electrical power. Some products, e.g. oil from seeds, salt, fertilizer, oxygen, have a very high energy content. Other strategies would be to utilize back up equipment (e.g., boilers, steam turbines, diesel generators) to pick up load via distributed generation. These, of course, are air pollution requirements permitting. It is easy to create scenarios that increase greenhouse gasses but lower electrical demand and this trade off will not be a constant.

Data centers would employ totally different strategies – Intel recently reported on their ESOA (Enterprise Service Oriented Architecture) which is the first step and measuring resources required for different services in the data center. There is still work to be done on measuring the specific power per service in order to take advantage of the new laws, but we have already seen articles that discuss turning off some of the processors or turning down the clock speed to adjust the power consumption – unheard of a few years ago.

LMP (MRTU) – Congestion Regional grids are implementing some form of congestion based pricing in order to better manage the transmission system. This is similar to the use of metering lights on a freeway – better management of the traffic onto the freeway can increase the capacity of the freeway by as much as 20%. Considering the cost of adding a lane to a freeway in an urban area, it is easy to see why market based management has appeal. In the case of transmission line, it is often not an option to build new lines into urban areas because of the resistance.

The "metering light" for the transmission grid is the LMP or MRTU pricing. The user is now faced with a price for power that changes every few minutes and yet another cert system that has to be managed financially. This strategy, however, is the only strategy that specifically addresses the nodal congestion problem with purely market forces. One of the challenges is that congestion is rarely measured directly so that the pricing is set by a model that predicts the congestion at each node.

It is important to note that this cannot be scheduled far in the future because congestion is most often caused by sudden, non linear events – equipment down, faults in the lines (e.g. heat, trees), or storms and outages. Normally these are handled easily by the control center operator with normal dispatch techniques, but as the reserve decreases, due to demand increases faster than available generation the grid become more stressed. LMP market design creates rapidly changing power pricing and large electric customers need to be able to respond rapidly to mitigate their energy cost exposure.

The dynamic response of a user has to involve the financial decisions of the user. These changes are not predictable thus the response must be automated. In Europe, the user is charged if they use more OR LESS than they have forecast. Systems that respond are generally called APC or advanced process control and the power price is a new target for the optimization.

Summary of Dynamic Energy Response

I have reviewed only a portion of the considerations for use of energy and there is no perfect plan for everyone. I was attempting to show that the simple demand/usage monthly billing model of last generation energy management programs is not sufficient. The modern system must have, at a minimum:

1. Real time carbon accounting and energy usage measurement
2. Historical baseline for computing gains over time
3. Real time pricing
4. Enterprise energy certificate position
5. Rule engine for selecting optimal production strategy based on constantly changing power prices and emissions cost

From these the user should:

Measure and understand

Implement rules for optimization

Provide models for planning

Present usage to all

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