How Buildings Can Prosper By Interacting With Restructured Electricity Markets

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ABSTRACT

Restructuring of the electric power industry is presenting new opportunities that building owners and operators may wish to exploit. There are now more options than just average, seasonal, or time-of-use electricity prices. Bulk power markets now recognize that electricity prices change dramatically in real-time. Ancillary services (reliability services, such as short term contingency reserves) are also priced in real time. There are benefits to both the bulk power system and the individual customers when these markets are opened to participation by buildings. The bulk system benefits through the increased availability of reliability resources. Building owners and operators benefit through reduced energy costs, increased choice, and increased control over their own destiny.

The paper discusses the physical capabilities the building equipment must have in order to participate in real-time energy and reliability service markets. It also discusses the decision process the building operator will want to go through to minimize its energy costs, considering all of its options and costs. Since energy and contingency reserve prices are volatile, building owners and operators will want to move between these markets dynamically. It is likely that the decision process, while remaining under the building operators control, can be automated. Similarly, the requirements for price disclosure, communications, aggregation, monitoring, and certification on the bulk power system side are discussed. Finally, the paper discusses how the entire system could operate to the benefit of both the building owner and the power system.

Introduction

Historically there has been little interaction between buildings and the electric power system that supplies them. Electric utilities viewed building owners and operators as largely unwilling or unable to modify electric power consumption. Building owners received few economic signals to guide their energy use. Seasonal rates, time-of-use tariffs, demand charges and interruptible rates are the limit to most interactions. Restructuring of the electric power industry offers the promise of a much richer set of interactions. Energy and ancillary services (reliability services) are traded on bulk power markets with prices changing hourly or faster. The idea that loads can and should participate in these markets is gaining increasing acceptance.

A building owner or operator whose building can respond to real-time energy prices can reduce energy costs because prices are increasingly volatile. Spot energy prices in the Midwest now span a 500:1 range. To exploit these price differences, a building owner or operator needs to be able to control building energy consumption, consuming when prices are low and avoiding consumption during the intervals when prices are high. Building owners and operators that are unwilling or unable to curtail consumption for the intervals when spot prices are high (typically lasting for several hours) may profit by selling contingency reserves to the power system. Reducing consumption for as short as 10 minutes during a power system contingency can command a high price.

The Changing Electric Power Industry

Electricity is a unique commodity in that production and consumption must be matched essentially instantaneously. Storage is not practical.[1] Use of alternating current, while it provides the tremendous benefit of relatively cheap voltage transformation, further restricts operational options. Flow can not be easily controlled on individual transmission lines so control of the system to prevent overloads must be accomplished by redispatching generation. Consequently the production cost of electric power is highly volatile. In spite of this, historically we have elected to isolate the consumer from the power system's real-time production cost. The vertically integrated utility typically owns all of the generation, controls the system, and owns and operates the transmission and distribution network. Consumers use power whenever they choose and the power system responds to accommodate those needs. The customer does not see prices that reflect current conditions and can not benefit financially if it takes action to help the power system. Consumers pay the higher cost incurred by the system to isolate them from real-time fluctuations through higher average prices. Worse, all consumers pay even if the higher costs result from the actions of a few.

Table 1. Ancillary Services Applicable to Building Operators

Frequency Responsive Spinning Reserve: Immediate (<10 seconds) response to contingencies and frequency deviations
Supplemental reserve: Response to restore generation/load balance within 10 minutes of a generation or transmission contingency
Backup Supply: Customer plan to restore system contingency reserves within 30 minutes if the customer's primary supply is disabled

Restructuring of the electric power industry is changing all of this. Operation of the power system is being unbundled from ownership and operation of generation. Generation is scheduled through price bid markets rather than through centralized least-cost economic dispatch. Similarly, real-time markets are being created for the system operator to obtain reliability reserves and ancillary services. While most restructuring activity to date is occurring on the supply side this situation is changing. Reserves can be supplied by either generators or loads, so the traditional distinction between supply/generation and consumption/load is breaking down. Market participants can be both suppliers and consumers of different services at different times. It is better to examine the physical requirements

[1] 60 Hz alternating current electric power is never stored directly. Pumped storage plants do exist but their numbers are limited. They store energy as mechanical potential, not as electricity. In the context of this paper, they behave more like conventional generators rather than true storage devices. They arbitrage over hours, not seconds.

of the power system and the wholesale markets to determine how building owners and operators can prosper in a restructured environment than to focus only on current tariffs. It may be necessary for building owners, along with distributed generation and agile load proponents, to press for tariff changes with their state regulators to allow access to these new markets.

Building owners can prosper by recognizing that the prices of electric energy and the reliability services (ancillary services) vary dramatically in time. These price changes are only somewhat predictable. Prices will generally be higher on hot August afternoons than they are after midnight on spring mornings. But times of extremely high prices, like the $7000/MWH and $9000/MWH prices seen in the mid west over the past two summers, are less predictable. Building owners can benefit by curtailing consumption, by selling energy to the power system (if they have on-site generation), or by selling reserves to the power system during times of high price.

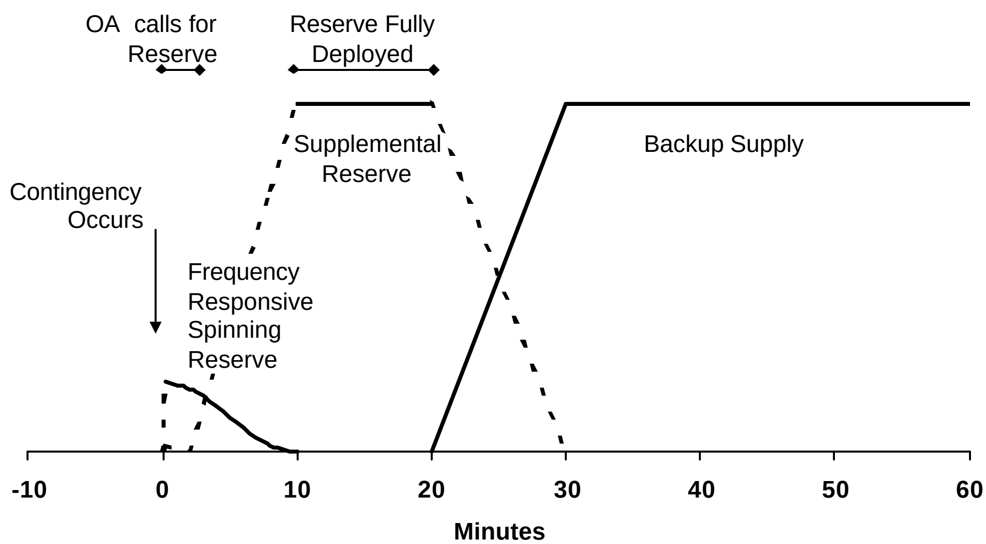

Figure 1. Required Response Times for Three Ancillary Services Buildings Might Sell

What Services Might A Building Sell?

Viewed from the perspective of the power system, table 1 presents three power systems ancillary services (reliability services) that buildings might want to sell to the power system operator (Hirst and Kirby 1998).[2] These services are required to maintain bulk power system reliability and are being opened to competitive markets. These services (Frequency Responsive Spinning Reserve,

[2] There are 12 commonly discussed ancillary services. Buildings are unlikely to be capable of selling system control, reactive supply, regulation, load following, real-power-loss replacement, energy imbalance, dynamic scheduling, network stability, or system black start.

Supplemental Reserve, and Backup Supply Plan) deal with restoring the real-energy balance between generators and loads in the event a generator or transmission line trips off line suddenly. Selling one of these services to the power system requires that the building owner and operator stand ready to reduce the building load (by the amount of reserve that it wishes to sell) when called upon to do so. These services are characterized by the required response time, the response duration, and the communications and control required to facilitate the service. Figure 1 shows the required response times for these three energy balancing functions.

Similar restrictions apply to buildings supplying ancillary services as apply to central generation stations supplying those same services. For a generator to supply contingency reserves, it must have capacity available to respond to the contingency. The generator cannot be operating at full load. Similarly, a building selling contingency reserves must have capacity it can unload when the contingency occurs by temporarily curtailing load a portion of its load. Providing ancillary services should involve a careful integration of load response with the business being conducted in the building. Since fast services generally command higher prices than slower services it is desirable to sell the fastest service possible. The ability to curtail a load instantly, as opposed to the need to ramp a generator up or down, makes building loads a very attractive fast response resource.

It is critical to evaluate the *integrated* cost to the building owner and operator of responding to power system markets. These costs will vary from time-to-time depending not only on the prices the power system presents but also upon the activities going on in the building. The building owner and operator must retain control over its own operations, responding to changing prices as appropriate at that time.

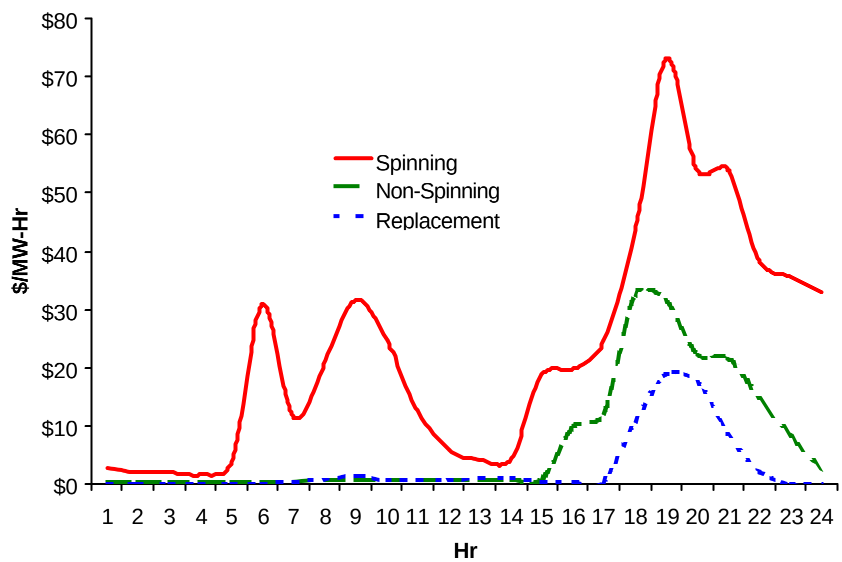

Figure 2. Average (by hour-of-the-day) Ancillary Service Prices for California for December, 1998 Weekdays

Why Utilize Buildings as a Power System Reliability Resource?

For the building owners and operators the reason is money, either through reduced power bills or through an added source of income. Figure 2 shows that average prices for these ancillary services prices in California vary dramatically from hour to hour but are frequently quite high. Note that the service names differ slightly in California but the definitions are essentially the same.

From the power system's point of view, there are several reasons that building owners and operators (and all distributed generators and loads) should be encouraged to sell ancillary services. FERC is encouraging open competitive markets for generation. FERC ordered the unbundling of ancillary services to promote competitive markets, which should improve economic efficiency and lower electricity prices. These markets should be open to any technology capable of providing the service, not just generators. This will expand supplies and reduce horizontal-market-power problems.

Beyond the argument of fairness, having building owners and operators participate as suppliers, as well as consumers, of electricity services improves resource utilization. Ancillary services consume generating capacity. When loads provide these reserves, generating capacity is freed up to do what it was designed for, i.e., generate electricity. Additionally, smaller facilities will probably respond more quickly to control-center requests than large generators. This will likely more than overcome the communications and control delays associated with their greater numbers. Building owners and operators should be a more reliable supplier of ancillary services than conventional generators. Because each facility will be supplying a smaller fraction of the total system requirement for each service, the failure of a single resource is less important. Just as a system with ten 100-MW power plants requires less contingency reserves than one with a single 1000-MW plant so too a system that utilizes a large aggregation of loads as a resource to supply reserves will require less redundancy in the basic resource than one that carries all of its reserves on a few large generators. There can still be common-mode failures in the facilities of the aggregator, but it is easier and cheaper to install redundancy in this portion of the system than with an entire 1000-MW generating plant.

Provision of Individual Services

A building owner, in cooperation with an aggregator and the system operator, would determine the amount of each service that could be provided. Metering, communication, and control requirements would then be established.

Looking at the services required to restore the generation/load balance after a contingency, ***Supplemental Reserve*** is a likely candidate for building owners and operators to provide to the power system. The resource must fully respond within 10 minutes of the contingency.[3] Response must be maintained for an additional 20 minutes, i.e., until 30 minutes after the contingency. This is a short interruption that many building occupants may find acceptable. Integration with the specific load is particularly important. Anything that inherently has some storage in the process, or any process for

[3] Specific timing requirements for each service vary from region to region. The requirements referenced here are from NERC (1998) Draft Policy 10. It is likely that this 10-minute requirement will be changed to 15 minutes for all of North America in the near future.

which storage can be readily added is a good candidate. Candidates include water pumping, building temperature control, water heaters, and air compressors.

The system operator takes some of the 10 minutes to recognize the contingency and to call for response. The aggregator's communications process will consume some time. This leaves a few minutes for the load to respond.

Frequency Responsive Spinning Reserve is both easier and more difficult for distributed resources to provide. Because the service responds to system frequency, each facility has the triggering signal available at all times. The service only has to be provided until it is replaced by Supplemental Reserve, 10 minutes, creating a shorter interruption. Full response is required within 10 seconds (the specific time is ill-defined but it is certainly within seconds), however, which may make it harder for some loads to provide. Having each facility in an aggregation responding at slightly different frequencies could create a typical generator droop characteristic.

Frequency Responsive and Supplemental Reserves restore the system's generation/load balance and maintain it for 30 minutes. Thirty minutes after a contingency occurs the customer that was receiving the lost generation is responsible for making other arrangements or curtailing its load. The ***Backup Supply*** plan is a pre-arrangement that tells the system operator how to proceed for each load's loss of primary supply. Some loads may find it attractive to provide Backup Supply for other loads. The 30-minute warning provides time for communications and for the responding facility to take actions to reduce its own costs.

Past Use of Load Control

At first this all sounds like traditional utility load control, but there are major differences. Load control has been and is currently used in a number of locations (NERC 1997). Some implementations have been successful but the idea has not been universally adopted. This is at least partly because of traditional rate structures, which provide little flexibility to customers. The customer must agree up front to be subject to utility control, usually for a year or more. There is no ability to enter and leave the market as the customer's economic conditions change. The customer often gets paid a flat fee (or a reduced energy rate) independent of how or if the resource is actually used. This provides little flexibility for the load and little incentive to actually perform.

Similarly, in the energy market, the costs of peaking generation or peak reserves are typically spread over an entire season or year. Charges (both operating and capital) are not assigned exclusively to the hours when the generation or reserves are required. Assigning the costs to the hours when they are needed would result in much higher prices for those services during specific hours (and lower prices at other times). Under either good economic regulation or a truly competitive market, the result would be the same total revenue collection (that required to pay for the resource). Providing a price signal that accurately reflects the real-time cost to provide the service will encourage all suppliers, loads and generators, to offer supply when it is needed most.

Supplier Control of Its Facility

While automatic deployment is necessary when selling some reserves, it is often important to allow the customer to decide when it will participate and when it will not. Just as the price of hourly energy and each of the ancillary services vary, so do customer economics. For many customers there are times when less flexibility exists and the load cannot be interrupted without high costs being incurred. These times are often independent of anything happening on the power system and are therefore unrelated to the price of the service. For the right price, a residential customer might be willing to automatically curtail air-conditioning use for 30 minutes to supply contingency reserves on most days, for example. This same customer would probably be unwilling to curtail use at any price on the evening when he was holding a dinner party, however. Similar restrictions might apply for an industrial customer such as a continuous chemical processing plant while it is taking a monthly inventory and needs a stable process. In both cases the customer choice not to participate is unrelated to the utility economics; neither load is trying to avoid providing the service when it is highest in value. In fact, the chemical plant may intentionally select times for its inventory when the power system is not stressed, such as at night or on weekends. It would do this not because of a concern for the power system but because that may be a time when the chemical process is stable as well due to reduced activity at the chemical plant.

Time-of-day may be particularly important for buildings. An office building operator might be willing to sell frequency responsive spinning reserve late in the afternoon when the price is high (see Figure 2) and it is nearing the end of the work day. The building operator could offer to curtail use of the air-conditioning compressors for 10 minutes, for example, knowing that the building temperature will only rise a few degrees and the building has all night to re-cool before the work force return. The building operator might be unwilling to sell reserves at noon when the price is low and there is still a hot afternoon to live through, however.

The utility or ISO needs information about which facilities will be supplying services ahead of time. The building operator must declare that it is available before it enters or leaves the market. Perhaps this declaration would be one day in advance for the following 24 hours. Both the utility/ISO and the building operator will need the ability to change the availability on shorter notice, perhaps with economic consequences. A building operator who experiences technical difficulties and is suddenly incapable of supplying the service must be able to leave the market. Conversely, if the power system finds itself unexpectedly short of reserves it will need to be able to call for additional reserves quickly, perhaps by raising the current price. Indeed, this is how the day-ahead, hour-ahead and real-time markets are intended to operate in California's competitive bulk-power system.

It is critical to avoid providing an incentive for a resource (either load or generation) to declare itself available when it is not (as is done in the United Kingdom). Equipment failures are inevitable but service providers should have an incentive to maintain the reliability of their resources. They should never find it profitable to sell a service that they know they cannot deliver.

Certification vs Metering

Most of the generators on a typical power system are relatively large and expensive. It is reasonable for the system operator to monitor unit output and bus voltage every 2 to 8 seconds. The amount of data and the expense per MW are both reasonable. When the operator calls for response the response can be monitored in real time.

Providing the same information from hundreds or thousands of individual loads would be prohibitively expensive and would provide an overwhelming amount of data that could not be managed in real time. An alternative to real-time monitoring of each individual resource exists. Buildings could be certified, either individually or in aggregation, for the provision of each ancillary service. Certification would consist of exercising the resource under controlled conditions to determine the reliable response (NERC 1999). Testing of the contingency reserves, for example, would not be announced to the buildings. The response would be measured on control-area metering. Periodic testing would monitor continued capability. Recording meters at each building could also be audited to verify performance for both actual events and tests.

Aggregation and Communication

The major objection often voiced to customer supply of ancillary services is that the system operator cannot deal with the large number of individual resources and that the communications requirements would be overwhelming. These are valid concerns but ones that can be addressed. Aggregators can provide a genuinely valuable function here. By handling the communications with a large number of distributed facilities they can present the system operator with a single point of contact for a reasonable amount of capacity, similar to the system operator's interface with large, central generating resources. They can also be an interpreter between the electrical system and customers. The system operator is not interested in learning the details and concerns of each customer. Similarly, customers are in businesses of their own and have neither the time nor the interest in learning all about the power system. The aggregator can bridge this gap, creating a valuable resource in the process.

Communications are inherently different with an aggregation of resources than with a single entity. As mentioned above, it is not currently practical to collect data from thousands of individual facilities every 2 to 8 seconds. It is practical, however, to send instructions to those facilities as fast as necessary. That is because it is the same signal going to large groups of the facilities. That signal could be "deploy now" or it could be "the current price for response is $X/MW-Hr".

Customer Economics

In competitive bulk-power markets, customers will have many choices with respect to their use of electricity and their payment for electricity services. In the context of this discussion, they can choose to participate in hourly markets and face spot prices that can vary widely in response to supply/demand relationships. Alternatively, they can sell reserve services (options) as discussed above. Decisions on whether to participate in spot markets or sell reserves will be based on the customer's flexibility in modifying its electricity use (in particular, its fixed and variable costs to modify its electricity use in real time), the prices of energy and reserve services, the frequency with which outages occur, and the opportunity costs it incurs when it forgoes consumption. For example, higher reserve prices and less frequent outages will lead customers to sell reserve services, forgoing opportunities to reduce consumption at times of high spot electricity prices. On the other hand, increasing flexibility (i.e., declining cost) in modifying electricity use will lead to more decisions to participate in spot energy markets.

Most importantly, it is the building owner that must be free to make these decisions, in near-real-time as conditions change both within and external to the facility.

Conclusions

Real-time electricity prices are volatile, they reflect the changing costs associated with balancing supply and demand in an environment where there is essentially no ability to store the traded commodity. Costs associated with the load change dynamically as well. Electricity prices are important but they are only one of several cost factors the building owner must juggle as s/he strives to maximize its own profit. In many cases it may be advantageous to sell reliability services to the power system. Avoiding peak prices may require reducing demand for 4 to 8 hours or longer. Selling contingency reserves may only require standing ready to reduce load for 10 to 30 minutes in the event of a power system contingency. There are design, contracting, and operations decisions that must be considered: Design and build systems that maximize flexibility, negotiate contracts that provide flexibility, make operational decisions based upon the real time prices of electricity, ancillary services, and the impact on current operations. Seasonal diversity between gas and electricity prices generally helps with the highest electricity prices (or curtailments) coming in the summer and the highest gas prices (or curtailments) coming in the winter. It may be easier to introduce storage on the load side. Thermal storage is easier to build than electric energy storage. Even short term storage (10 minutes) can have real value. It is important to look beyond existing tariffs to the underlying physical requirements. If the load can be designed and operated in a way that benefits both itself and the power system, tariffs can likely be changed to compensate the load for its actions.

With so many opportunities, building owners and operators should seize the initiative. Determine what markets you want to sell into. Pressure "the system" to accept responsive buildings as a viable resource. Improve both the reliability of the power system and the profits of building owners and operators.

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