THE POTENTIAL OF ENERGY MANAGEMENT AND CONTROL SYSTEMS FOR REAL-TIME ELECTRICITY PRICING PROGRAMS

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Abstract

In implementing an integrated electric utility network, direct communication between the utility and customers is an important component. The rapid penetration of computer building control technology in larger commercial and industrial customers provides an opportunity for the utility to implement this network by linking directly with equipment already in place: customer-owned energy management and control systems (EMCS). This paper assesses the potential use of EMCSs in utility real-time pricing (RTP) efforts by discussing the procedures and technical requirements for transferring prices to the EMCS. The perspectives and objectives of the customer and the utility will also be discussed. We will discuss how price information can be used by the customer and the EMCS to implement demand-limiting strategies, both in currently available demand-management algorithms, and in potential price-responsive cost-management algorithms.

Introduction

An electrical utility system can operate more efficiently when there is some sort of transfer of information between the utility and the customer. Currently, this information travels indirectly: information on customer loads travels to the utility through meter reading and through end-use load monitoring projects, and information on utility system costs travels to the customer in the form of prices published in tariffs. More frequent and detailed communication with customers would allow indirect influence over their loads and would be an important part of an integrated, systemwide network.

With real-time pricing (RTP)-rates that reflect the actual cost of generating electricity, utilities encourage customers to shift loads away from peak-demand periods. In an RTP rate schedule, electricity prices are highest during the utility peak hours because peaking plants are expensive to build and operate given that they are only used for a small fraction of the year. Responding to these prices by limiting operations when electricity prices are high and rescheduling and shifting of loads to times when electricity prices are low, however, takes a great degree of customer interest and involvement. Energy management and control systems (EMCSs) can be used to facilitate this response.

EMCSs are installed in an increasing number of new and retrofitted commercial and industrial buildings. A significant fraction of all commercial buildings have an EMCS already installed to control their HVAC equipment. EMCSs are becoming increasingly reliable and cost-competitive with more traditional approaches to building control. The primary function of an EMCS is to save energy and power, but EMCSs also offer capabilities which could be used for performance monitoring and utility/customer interface. Customer objectives are much different from utility objectives, which must be considered when assessing use of EMCSs for RTP response.

The focus of this paper is to explore the feasibility of using existing, in-place EMCSs in non-residential buildings for the purposes of utility real-time pricing. We will discuss the procedures and technical requirements for transferring a price report from the utility to the customer with an EMCS. We will explain how price information can be used by the customer and the EMCS to implement demand limiting strategies, using currently available demand-management algorithms, and using potential price responsive cost management algorithms.

Real-Time Pricing

Several utilities have implemented successful RTP programs, and have shown that customers will respond to higher prices during peak hours by shifting loads [Crane, 1989]. In these programs, hourly energy prices are calculated and conveyed to participating customers. These prices are then used to calculate the customers' energy bills.

The primary objective of RTP is charging customers for the real cost of supplied power. Ideally, these rates also encourage consumers to conserve or shift loads when prices rise as a result of higher generation cost. The utility increases prices at critical periods of high demand, hoping that users will lower their demand. Increasing the customer load factor increases the overall system load factor and helps decrease the capital costs of supplied power. In this way, also, greater system reliability can be provided to essential customers like hospitals when there are capacity shortages. Through RTP programs, utilities could increase system efficiency and ultimately reduce the cost of providing electricity services to ratepayers [Kahn, 1988].

In concept, real-time rates are similar to time-of-use (TOU) rates. However, they are significantly different in implementation. The primary difference is that while TOU rates change over the course of a day, they do not change from day to day. RTP rates vary from day by day. RTP therefore involves more customer attention and effort than TOU. TOU rates allow building operators and owners to make long-term or permanent modifications to their systems. Beyond what TOU encourages, RTP encourages additional incremental adjustments, such as reducing air conditioning and allowing instead the building's thermal mass to carry the building through a projected peak period.

Different rates provide incentives for different load management strategies. However, many load management strategies are advisable even to customers on flat energy rates. For example, if the EMCS can allow the cooling system to operate more efficiently, then it makes sense to operate it more efficiently all the time, not just at times when the price of electricity is high. Additionally, since the utility's need to shift system load from peak times to off-peak times is constant and predictable (at least in the near term), TOU rates may provide sufficient incentive. These more predictable price differentials allow and encourage customers to make capital-intensive responses, such as installing thermal storage systems. However, the unique element of RTP is its dynamic structure. Because this dynamic rate can respond to a dynamic system load, the most appropriate response should be equally dynamic. Therefore, because an EMCS can react quickly to a changing physical and economic environment, EMCSs can be an important tool in RTP response.

Currently, customer ability to respond to RTP has been less than was hoped, partially as a result of customer production and labor constraints. Customers have a different set of objectives from utilities: primarily maintaining production, providing occupant comfort, and saving money [Brill, 1984; Harris, 1980]. By taking advantage of RTP's low off-peak rates, and avoiding its high peak rates the consumer can save money. But savings from energy conservation options are often insignificant in comparison to the perception of lost productivity. Also, the cost of employees in commercial buildings is much higher than the cost of conditioning their working environment.

Currently, the process for implementing RTP usually involves electronically sending the customer a rate schedule and making sure that the customer has received the rate information. The customer manually makes the necessary control modifications, which requires a high degree of motivation and vigilance on the customer's part. Using an EMCS to receive the utility's RTP schedule automatically and to modify building operations would simplify the facility manager's job. EMCSs could offer customers the opportunity to respond relatively easily to RTP schedules and load-management signals.

Energy Management and Control Systems

EMCSs are popular in commercial buildings for many reasons [EPRI, 1986]. The rapid development and evolution in the computer industry has made more powerful EMCSs available at a lower cost. In new commercial buildings and a majority of retrofit applications, direct digital control is increasingly reliable and competes in cost with the traditional pneumatic control systems. Commercial customers install EMCSs for energy conservation, flexible building operation, control, and maintenance, tenant submetering, and services like fire/security monitoring.

The main concern of many building managers is maintaining the indoor environment for the comfort of the personnel and/or for the operation of equipment such as computer systems. For most commercial customers, the cost of conditioning the working environment is small in comparison to the salaries of the employees. Building operators are often willing to consume as much energy as necessary to maintain proper conditions. Therefore, customers often want to incorporate energy management functions only as an added "plus" to building comfort control.

There are many potential strategies available to control different end uses in a commercial building. Several of the most common energy-management strategies implemented by EMCSs are: programmed stop and start, duty cycling, demand limiting, optimal stop and start, plant optimization, economizer control, thermal energy storage, and daylighting [EPRI, 1985 & 1986; NCAEC 1987].

In addition to these energy management strategies, EMCSs can be used to keep accurate run-time records to allow precise scheduling of equipment maintenance. This can increase the equipment efficiency. With an EMCS, a building operator can also see irregularities in building operation. EMCSs offer opportunities for individualized programming, display of building status, and storage of historical data. Many EMCSs can even call a building operator automatically in case of emergency so she/he does not have to stay near the EMCS. Multiple buildings can also be operated from one central location.

Using Energy Management and Control Systems for Real-Time Pricing

An EMCS can be programmed to respond to RTP, benefiting both the customer and the utility serving a building. Appropriate EMCS software could help customers by receiving prices and facilitating implementation of load-management strategies. Of course these can be accomplished without an EMCS, but use of an EMCS could simplify the process.

In order to implement EMCS-based RTP response, there are several hardware and software requirements for both the utility and customer. The different steps of the process, as illustrated in Figure 1, are:

- Transmitting the prices from the utility to the customer. *(Communications)*
- Enabling the EMCS to read the prices. *(Processing)*
- Implementing building control based on the prices. *(Load Management Algorithms)*

Communications

The software and hardware required for utility/customer communication are not extensive. An experimental RTP program in a Northern California utility used a line-printer equipped with a modem and an alarm; delivery confirmation is returned to the utility [Crane, 1989]. If an EMCS is used to receive and respond to prices, it too must have communications capabilities. The EMCS will either answer the phone to receive the transmission of the price file, or it will automatically initiate a call to the utility or to an electronic mailbox and actively retrieve the price file. In either case, the price file will ultimately be written on the disk or memory of the EMCS. If the EMCS initiates communication, more sophisticated communications software will be required, which will enable the EMCS to perform the retrieval at the most convenient time. Some method can also be made available to allow the EMCS to confirm receipt of prices and to double check them.

One useful step in implementing more widespread EMCS RTP response would be to study other potential communications paths, and to determine which is the most appropriate. This paper discusses only commercial telephone lines, but leased lines could be used, as well as signals sent along power lines or broadcast over radio frequencies. The larger the group of customers to be contacted, the more important this issue will be.

Processing

The EMCS also needs to be able to access the price file. This may involve one or more preprocessing steps. Because the prices are usually imbedded in text, unnecessary words must be stripped away so EMCS can read the prices. This could be avoided if the utility sent a "raw" data report to customers' EMCSs. Most EMCSs were not designed to read data from disk files, so another processing step would translate the numbers in the price file into EMCS point values.

The hourly prices could then be used just as any other variables, such as temperatures or pressures, and printed in reports, displayed on the console, or operated upon. The software for preparing these types of reports and displays and performing control operations is standard in most EMCSs, so the preprocessing program is the only software that must be added to most systems. It will, however, be unique for each EMCS model. If the utility has defined a standard price file format, this EMCS software can be developed either on a custom basis by a vendor familiar with the system, or on a production basis by the system manufacturer.

Load Management Algorithms

Once the data have been read into the EMCS, they can be used in several ways. One way is to present the price information to the operator in an informative format. This could be in the form of a report that presents prices in a historical context, calculates the impact of the prices on different operating strategies, or suggests possible alternative responses. It may be possible in some cases to use the EMCS to respond automatically to RTP prices without. operator. intervention. Whether the EMCS responds automatically or under the operator's control, the EMCS would be a useful tool in implementing demand-managing strategies.

Many of the traditional EMCS load-management strategies listed earlier can already achieve the required load-shaping goals, or can be adapted to take price into consideration. An earlier report outlined these conventional and adapted load-management strategies, along with the required software and hardware and their present availability and adaptability to RTP response [Akbari etal, 1989]. It also discussed the building comfort and operational effects of these strategies, and their effects on both customer and utility loads.

As an example of RTP adaptation, in a variation on the standard demand limiting algorithm, both price and demand can be used as limits. A table of the building demand limit as a function of both price and time of day would be created, and loads would begin to be shed when this demand limit is approached. Determination of demand limits would mean determination of the maximum amount the facility is willing to spend on energy for that hour. In another method, end-use-specific price limiting, a price limit would be set for each end use, and operation disabled or reduced when that price is reached. When the price comes back down, the end use would resume normal operation. How this price would be set and how this strategy would be implemented in practice are separate issues. One feature of this strategy is that end uses would be shut down or set back regardless of total building demand.

Both of these strategies could easily be implemented in most EMCS models with little or no software or hardware modifications beyond reading of the price files. As in all demand limiting implementations, the level of the limit is very important. It is not uncommon, even in existing installations, for the demand limit to be set so high that it is never approached, so that load shedding never takes place.

Additional Benefits of EMCS-Based RTP Response

Beyond enhancing the ability of customers to respond to RTP, EMCSs with the proper software would benefit the utility in several ways. The EMCS could provide information on how and to what extent customers shifted their loads; for example, an EMCS could record specific load-relieving measures such as changing temperature setpoints, turning off processes, etc. This information is important to the utility in evaluating the effectiveness of the RTP rate structure.

EMCSs with built-in capacity to respond to RTP rates might also increase RTP's marketability, by reducing the perceived effort required to respond. The more customers there are on RTP rates, the more electrical peak demand could potentially be managed. The availability of appropriate software can improve implementation of utility initiated load management strategies based on RTP.

EMCS-based RTP response could be part of a more advanced integrated utility customer communication-computation-control (UC-3C) system in which the EMCS serves as a multi-function utility/customer interface. Such a communications network could be the backbone for advanced sensing and control of the supply, distribution, and demand systems. EMCSs could also combine RTP capabilities with other features such as monitoring capabilities in ways that are advantageous to both the utility and the customer. Combining these capabilities is practical since many of the hardware and software requirements overlap those of RTP. As production of electricity moves toward cogeneration, self generation, and a more competitive market, utility versatility becomes essential. Additional services, such as remote account metering, electronic bill payment, and customer service communication could be offered to the customer through an enhanced EMCS.

Since utilities would clearly benefit from customer ownership of EMCSs, it would be advisable to study ways to provide customer incentives. A rebate might be used to reward customers for installing an EMCS, or for installing an EMCS with the appropriate software and hardware, or for installing the appropriate system and actually joining an RTP project. The EMCS criteria for the rebate may include a list of characteristics, a list of EMCS models which are known to have the appropriate characteristics, or EMCS manufacturers who have worked with utilities to develop a special RTP model.

Conclusions

This discussion of RTP-response routines and earlier studies of current and projected EMCS capabilities suggest that the EMCS can be used as an RTP interface [Akbari et. al, 1989]. However, customer installation of an EMCS with RTP-response capabilities is only a small part of the picture. How the customer chooses to use this resource and operate the building is an equally important issue. The greatest problem encountered in RTP demonstration projects has probably not been customers' inability to implement the control that they deem necessary, but the customers' lack of concern about energy use or difficulty in accepting reduced or shifted services [Crane, 1989]. Production constraints and the value of occupant comfort often make load shifting costly and, when compared to its limited potential savings, not economically feasible in many facilities. The addition of an EMCS makes control easier to implement by providing more complete price and building information and by simplifying implementation of demand management strategies, but it does not solve the production and comfort problems. Each customer must make his or her own prioritization of economic and operational issues.

Our specific conclusions concerning the feasibility of using EMCSs to act as a utility/customer interface for RTP rates are:

- EMCSs are currently used in larger commercial and industrial facilities, but are by no means universal.
- There is a trend toward greater use of increasingly sophisticated. systems-but penetration is (and will probably remain) very low among smaller facilities.
- Most EMCSs appear to have adequate hardware capabilities to become an effective interface between the utility and customer for implementation of RTP rates.
- There is a need for modification of EMCS software in order to facilitate receipt of RTP rates and implementation of load-management control decision.
- There is a need for protocols for inter-system communications. Utilities could make an important contribution here, if future customer incentive and demonstration projects include criteria that reinforce recent industry initiatives toward standardizing communication protocols.
- Even where present, EMCS capabilities are often not used to their full potential. Utilities can play an important role in helping to motivate and educate commercial and industrial customers, not only to install controls where appropriate, but to train staff and set management policies that encourage effective use of the systems.

Most commercially available systems will require some degree of customization to specific facilities in order to provide the required RTP response capabilities. Such customization is, however, common practice even for the most conventional control functions.

Other customer communication opportunities could be provided, such as automatic metering, billing and payment.

It is important to note that human resources play an important role in the application of EMCSs to load management in response to RTP. Plant engineers, especially at small and medium-sized sites, are often too busy to assess the potential of this technology. They are also concerned about who will assume responsibility for the EMCS, who will operate the system, and how to obtain training in the event of a personnel change. There is also some concern about the complexity of the technology, especially for plant engineers of smaller facilities who have not had a great deal of exposure to microprocessor control or to computer technologies in general.

The utility may take a role in the development of enhanced EMCSs for RTP. Vendors will install what the customer wants, and the customer will not pay for anything that is not needed in his or her specific facility. There is a unique opportunity for the utility to influence the market by providing incentives to install systems with the necessary capabilities.

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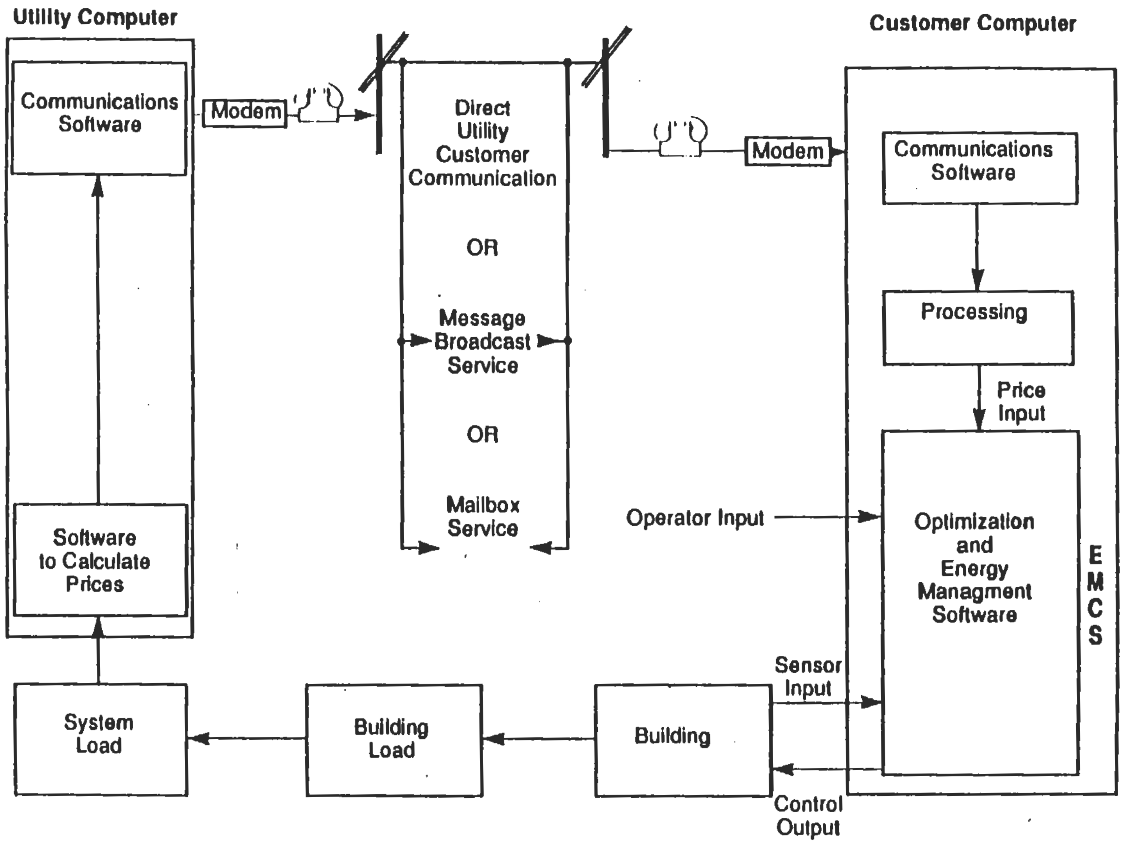

Figure 1. Schematic diagram of information flows in EMCS-based RTP response. The communications path for the transfer of the prices from the utility to the customer can take several forms. Most of the required software and hardware already exist in typical systems, or can be easily added.