

# Load Control Under Curtailable Rates

## Both Customers and Power Companies Benefit

*Howard P. Rosenof, PE  
Business Development Manager  
Gensym Corporation*

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Under deregulation, power companies are looking at a variety of new product options, some of which involve curtailable rates. (The word "utility" is not used in this article because increasingly, power is sold by a variety of companies, not all of them traditional utilities.) Under a curtailable rate, the power company offers a discount on the price of electricity, in return for the right to order a customer to reduce its consumption of power on short notice.

Such a rate allows the power company to reduce load under supply emergencies (less frequently, under distribution constraints) or when the marginal cost of power exceeds the revenue that will be earned by continuing to supply all of the customers' demands.

In addition, deregulated power companies can use curtailable rates to attract and keep customers by offering tariffs closely matched to their needs, and to react to spot market opportunities to buy and sell power. Loads under a curtailable rate are effectively under a dispatcher's control, so that the term "dispatchable" can also be used to describe these loads.

Historically, most power companies offered curtailable rates to only a relatively small number of large industrial customers. Curtailment was implemented only under conditions of impending or actual emergency, and because of the limited number of customers involved could be managed by telephone calls. Today, some power companies are moving toward offering curtailable rates to a wider variety of customer classes, namely small industrial, commercial and even residential

accounts. Under these conditions, traditional non-automated implementations of curtailable rates will have to give way to automation and digital communication.

Gensym Corporation has investigated the behaviors of several types of controllers for power company use in managing curtailable loads, including controllers that needed only one-way communications from the power company to the customers, and controllers that depended on two-way communications. This article will discuss one such controller, based on the behaviors of intelligent, autonomous agents.

## AGENTS

An agent is a computer program that performs actions on behalf of another program. Agents have received a great deal of attention in consumer markets. It has been suggested, for example, that a prospective customer wishing to buy a particular musical recording might send agents into the World Wide Web to find the retailer offering the recording at the lowest price.

Autonomy is central to agent operation. This distinguishes agent-based architectures with the more common client-server design: A client sends a specific request to the server, and the server simply honors it. An agent, conversely, receives directions that are more general, and can modify its behavior as it endeavors to comply.

In industry, agent-like control systems (the idea is older than the name) were used at least as early as 1984 (ref. 1). Here, constrained resources (machines, typically) would be assigned to tasks (such as fastening parts) based on the value of the tasks to the enterprise. In other words, if there are several sets of parts that are ready to be fastened together, and if one such assembly is especially important to the enterprise (perhaps it's the only part remaining to be completed before a product can be completed and shipped), then the task informs the controller that its value is particularly high, and the controller assigns the machine to that task. Effectively, each task and each constrained resource is assigned an agent, and the agents cooperate with each other and with a supervisory control program to use the factory's resources to maximum advantage.

More recently, Gensym Corporation has been working with General Motors Corp. and AMP Inc. under a research program coordinated

by the National Center for Manufacturing Sciences, the largest cross-industry research consortium in the United States. Both GM and AMP have installed systems based on Gensym's Agent Development Environment (ADE), which simplifies the implementation of these systems and allows them to take make use of contemporary software design techniques (ref. 2).

## LOAD MANAGEMENT STRATEGIES

In the context of the management of curtailable loads, each such load is assigned an agent and the agent "negotiates" on its behalf. The agent acquires data from the load it represents. In the case of the storage-type water heaters assumed here, this would be at minimum one value indicating the percent of charge of the heater. Water heaters are not routinely instrumented to provide this information, but it should not be difficult do so, especially for new installations, and if it is difficult, an inferential measurement based on power input and water flow, may be sufficient.

The agent also contains knowledge of management policies and alternatives. A typical management policy might be "charge the water heater to 100 percent whenever the cost of electricity goes below x." If the facility also includes a directly fired water-heater (e.g., one that uses gas), the agent would have knowledge of the costs involved in its operation, and it would adjust its strategies to avoid paying more for electrically heated water than the cost of directly heated water.

There is no limit to the complexity or sophistication of the agent's calculations. If it operates in a restaurant, it might acquire the restaurant's reservation files and combine them with historical data representing diners without reservations, then estimate the amount of hot water that will be required to clean their dishes after their meals. It can set its bidding strategy by noting that during a weekday, there is usually a decrease in energy prices just after 8:30 PM and the dishwashing load won't start until 7:30 PM. It might, therefore, set a low value for power through the afternoon; as soon as the retail cost of electricity drops to the offer price, the load will be served. If the price offered is too low, then the agent might have to offer a higher price toward the end of the evening, perhaps even balancing the cost of overtime payments against the cost savings likely to be achieved by waiting until late at night.

This inverse relationship between profit (represented here by the achievement of needed supplies of electricity at a low price) and risk (the possibility that supplies will be excessively expensive, or perhaps not available at all) is, of course, characteristic of open markets generally. Agents that are “conservative” will consistently obtain the required power but at costs that may be above the minimum. Agents that are “aggressive” will get lower prices, but at the occasional cost of late nights and unwashed dishes. Agents that are “successful” will be those that achieve their goals.

For its part, the power company receives bids for power, from perhaps hundreds or thousands of agents. It may have certain supplies of power available under long-term or medium-term contract, at predetermined prices, and other supplies available on the spot market at varying prices. It is the task of the market-making mechanism operating on the power company’s behalf to maximize the company’s profit at reasonable risk. It will normally do this by supplying power to all loads (under its control) that are offering bids high enough to cover the wholesale cost of their power plus distribution losses, plus possibly an operating margin. It then must keep track of the transaction, and the resulting power transferred under the agreed-to price, to support accurate billing.

Once the power company determines that a particular load is to be serviced during the upcoming interval (one hour, for example) it sends a signal to the load’s controller, allowing the load to be energized. The load controller must have a monitoring function to help assure that the amount of energy specified in the bid, and offered at the price of the accepted bid, is not exceeded.

It should be emphasized that it is unnecessary for this arrangement to apply to an entire facility. Loads that are continuous, critical or otherwise not suited to curtailment can continue to be supplied under conventional tariffs.

It is assumed here that customers served under this arrangement will pay for power according to their bids, although it would also be possible to implement a true market-making system wherein there is a market-clearing price determined for the power. In such an arrangement, similar to some wholesale power markets, all customers offering bids at or above the market-clearing price would be supplied with power at that price.

It is also assumed that contracts are “take or pay”; once a bid is

accepted, the customer is required to purchase the specified power. Some other arrangement might increase the power company's risk exposure and force it to charge higher rates, obviating the purpose of the curtailable tariff.

## AN ATTRACTIVE OFFERING

A product based on price-sensitive curtailable load control could be a very attractive option for a power company. It would allow the power company to sell power at a lower cost than it could offer under conventional rates, but without the attendant risk that would ordinarily accompany such an offer. Such a product should also allow the power company to flatten its load curve, possibly permitting capital investments to be deferred or avoided.

An agent-based strategy in particular can be attractive to a power company because of its simplicity: Once it sets up its properly designed bid-management system, the power company can easily expand the system to accommodate new customers without redesign. As customers gain experience with this new arrangement, it is likely that their agents will become more sophisticated and therefore more complicated, but this increasing complexity will be of interest to the power company only if it chooses to offer agent-related services as a separate business. The "smartest" agents will be the ones that achieve the compromises between service and cost that best meet the needs of their facilities. No matter how complex the agents' decision-making logic becomes, though, their relationship to the power company will remain simple.

There is further simplification for the power company as well: The rate structure can be much simpler. One customer might accept a curtailable rate with the provision that the load under contract may not be curtailed during a specified time interval; another might require that its loads be taken off of curtailment at least fifteen minutes out of every hour; and a third might wish to limit the number of daily transitions from curtailed to non-curtailed status to limit equipment stresses. Under these conditions the power company might have to craft a large number of specialized contracts, but with agent technology the agents themselves can retain responsibility for implementing policies such as these.

## THE CUSTOMER SIDE

A customer's incentive to participate in a bid-based load management program would be based on price and the cost to the customer of a power curtailment. It is likely that such a rate would be most appealing to large accounts for which energy makes up a significant portion of operating expense. Such users may not in fact be primarily heating water but may be operating electrochemical cells, for example, but the assumption of water heaters is a convenient one for purpose of explanation. For the customer, the agent-based curtailable load tariff amounts to "intelligent load shifting" or even "intelligent load shedding."

The customer will have responsibility for the performance of its agents. Of course, third parties, including third parties associated with power companies, may choose to offer services for agent development and installation.

## SIMULATION TESTING

Gensym Corporation has built a test system, using its G2® intelligent-system software, in which the power company's load management logic and the behaviors of an arbitrary number of individual agents can be concurrently simulated. The curtailable rate is applied to a variety of water heaters in residential and commercial buildings. Each water heater has a fixed load value (on the assumption of on/off, rather than variable control) and one or more load profiles. All water heaters are assumed to be storage types rather than pass-through. In all cases, the control strategy logic is intended to apply to any number of water heaters.

For each water heater, there is an assumed hot water storage capacity and heating time, and for each hour, an assumed hot water demand, which is determined according to different profiles for heaters in residential, commercial and restaurant service. Each water heater is assigned a maximum bid value, so that the logic of each agent is normalized to give an output in the range of 0-100 percent, which is then multiplied by the maximum bid value to yield the bid price.

It is assumed that no mixing takes place in the water heaters, so that there is a sharp separation (a thermocline) between heated and unheated water. It is also assumed that the water heaters are perfectly

insulated.

Each water heater is represented by an agent, which bids for the use of electricity. The wholesale price is variable, with both predictable and random variation. For simplicity, the simulation calculates one wholesale price at a time, and does not apply a required margin to that price; a retail sale at just above wholesale price is acceptable. If the agent bids a value which exceeds the wholesale price of power, the heater is energized; if the price is too low, the heater is not energized. Bids are changed once per minute, and for each water heater are limited by its threshold value.

Agent behavior may be at any level of complexity. In strategies simulated up to this writing, agents offer bids that are inversely related to the percentage of hot water available in the heater. An agent for a critical load might offer a bid at maximum value as long as the heater has less than eighty percent of a full charge. An agent for a less-critical load might use a cosine function, so that its maximum bid is offered only when the heater's charge level is 0. (Figure 1)

The results of a simulation run involving 13 water heaters are shown in Fig. 2.

Fig. 3 shows how the number of water heaters with cold water varies during the day. (For simulation purposes, the heaters are assumed to start out cold.)

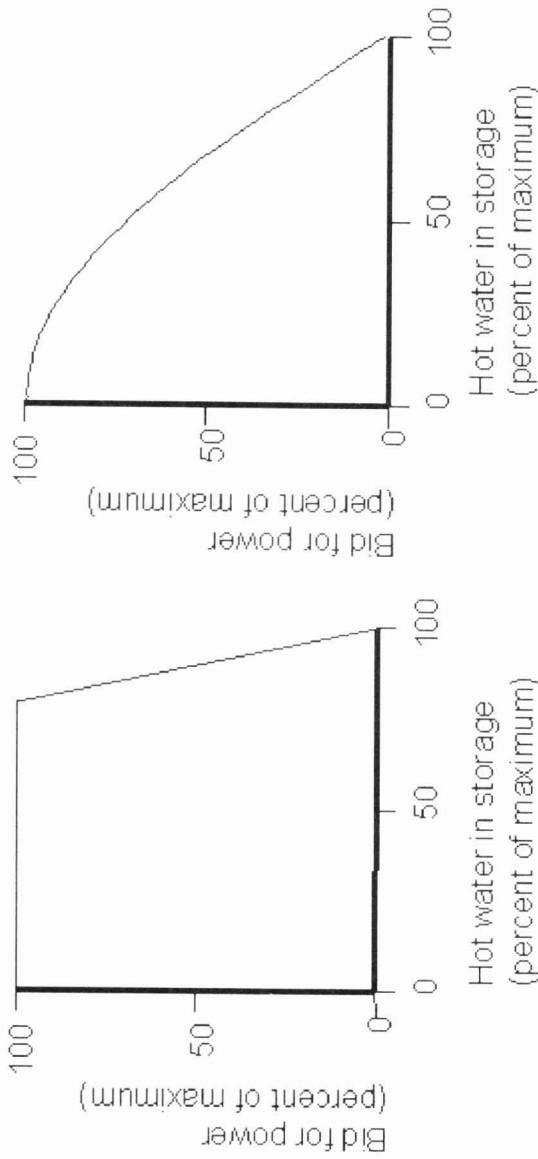
## References

1. King, J.: "Heuristic model for resource allocation in a contention environment," *Advances in Instrumentation*, 39:415-421
2. Basset, E.: "Field Notes: 'Intelligent Agents': A New Category of Software for Manufacturing Scheduling," *Start Magazine*, January/February 1998.

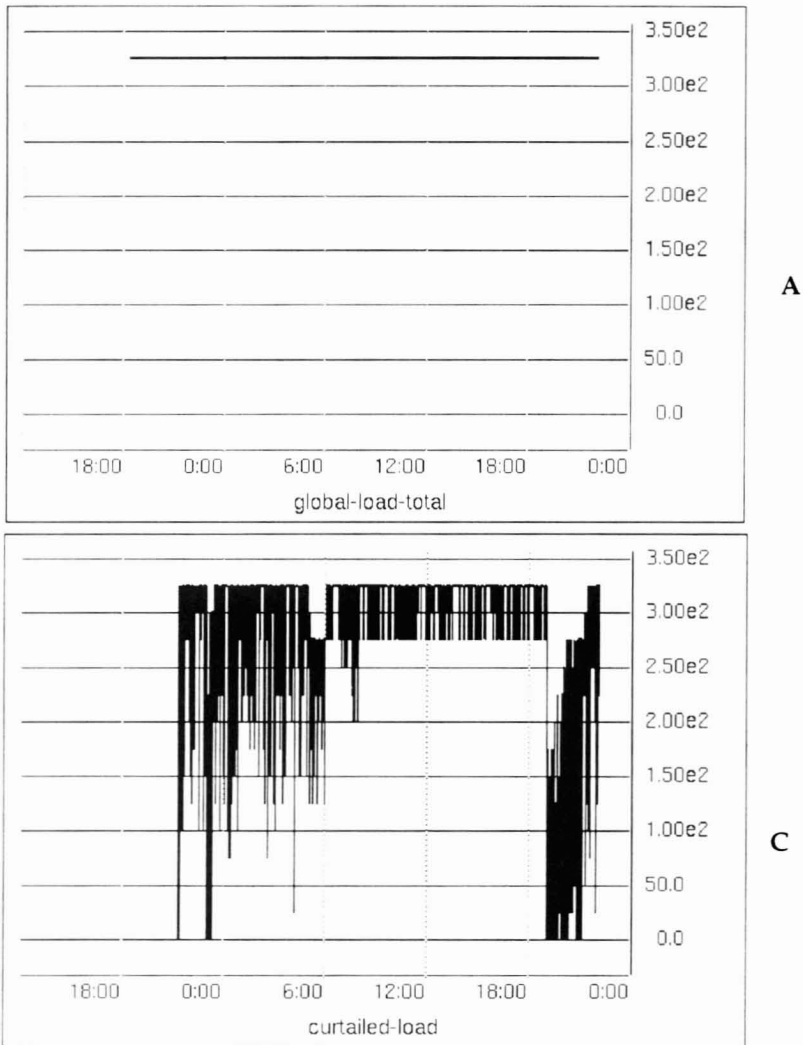
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## ABOUT THE AUTHOR

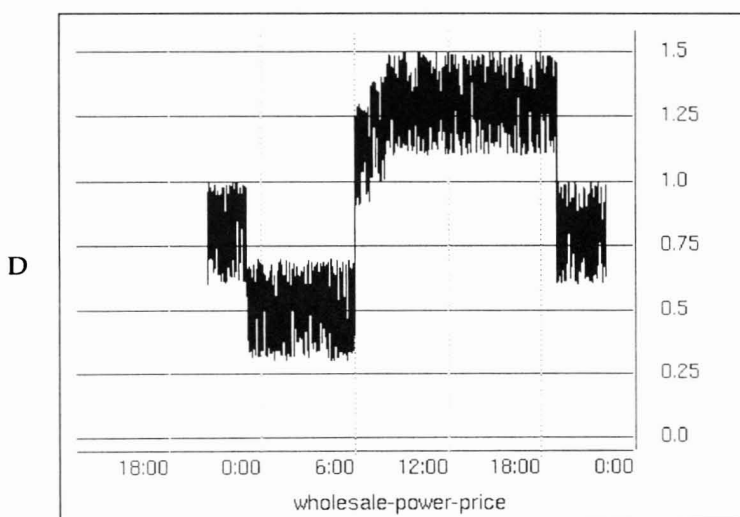
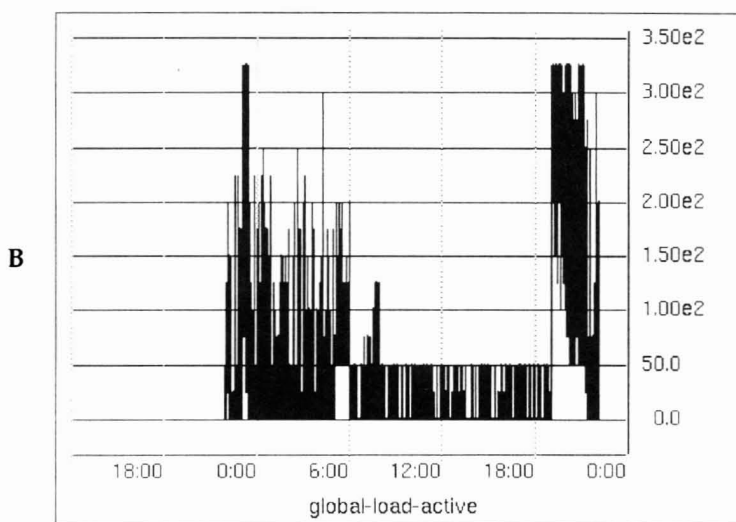
**Howard P. Rosenof, P.E.**, is business development manager at Gensym Corporation. He received a BS degree from Cornell University in 1970, and the master of science degree in electrical engineering from Northeastern University in 1973. He is responsible for marketing to industries which together account for approximately half of Gensym's revenue. Mr. Rosenof develops and implements business strategies for the process industries including chemicals, oil and gas, metals and



**Figure 1: Comparison of two simple agent strategies: The agent on the left attempts to keep the hot water tank fully charged at almost all times. It offers its full bid as long as the stored hot water is less than about eighty percent of capacity. The agent on the right places a lower value on having a large amount of hot water in storage. It is willing to offer its maximum bid only when there is no hot water in storage at all.**



**Figure 2: Results of a simulation run involving 13 water heaters. Most curtailment takes place during the day, under conditions of peak load.**  
**A. Global Load Total: Maximum possible load**  
**B. Global Load Active: Instantaneous load**  
**C: Curtailed Load: Loads that are not energized**  
**D. Wholesale Power Price**



building materials, and food and pharmaceuticals; utilities including electric power, water, wastewater and gas industries; and the nuclear, mining, and environmental industries.

Mr. Rosenof is a registered Professional Engineer in Massachusetts and New York. He is a senior member of the Instrument Society of America (ISA) and served as president of its Boston section. He is listed in *Who's Who in Science and Engineering*, Second Edition. He is co-author

of a book, *Batch Process Automation: Theory and Practice*, published in 1987 by Van Nostrand Reinhold Company.

Gensym Corporation; 125 Cambridge Park Drive; Cambridge, MA 02140; 617-588-9243; fax 547-1962

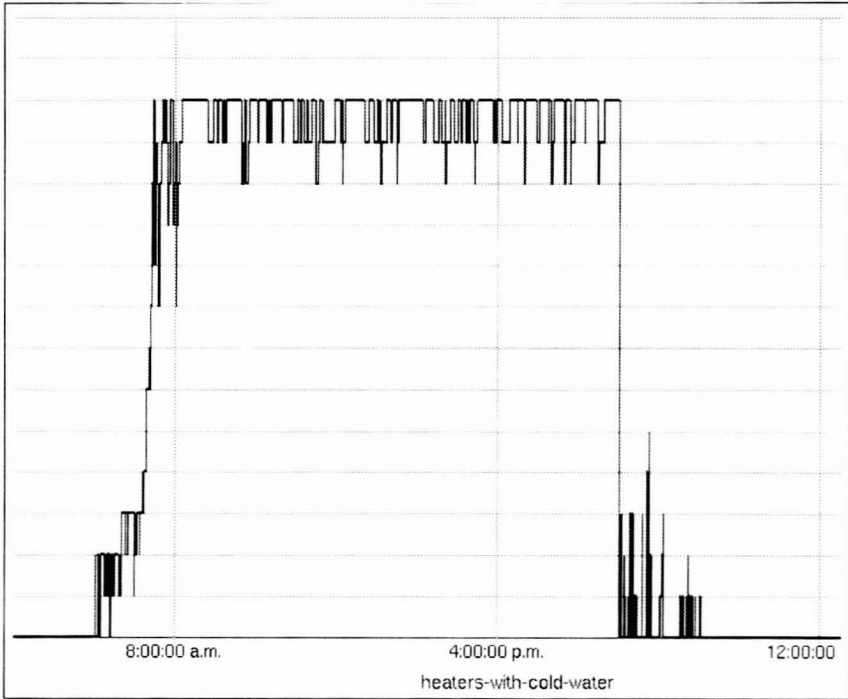


Figure 3: Curtailment may or may not lead to one or more heaters running out of hot water; it depends on how much hot water the heaters had accumulated ahead of time. Under the conditions assumed for the simulation shown in Figure 2, water heaters do run out of hot water, especially during times of peak loading.