WHERE ARE THE CONTROLS ON THE CONSERVATION POWER PLANT?

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ABSTRACT

The concept of a conservation power plant is a powerful idea. This supply-side viewpoint of conservation has been tested in the Hood River Project and is a major element of the long-term strategy of some utilities, such as the City of Austin, which is planning to "acquire" a 553 mW conservation power plant over the next decade. The conservation power plant is, however, more than a convenient and compelling metaphor. This paper examines the problem of the control of the conservation power plant in real operation. It emphasizes three elements of control: the need for control, real-time and near-real-time measures of conservation power plant performance, and implementation strategies for controls.

The approach to the problem is based on a hierarchial analysis of electrical distribution systems. This analysis identifies the key points within a utility distribution system at which information can be collected. The strategy emphasizes the use of a great deal of information normally available within a utility, such as billing data and substation monitoring, as well as the use of limited end-use data collection. Issues of conservation implementation strategies and long-term efficacy of conservation measures will be addressed.

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INTRODUCTION

The purpose of this paper is to look at some of the detailed aspects of delivering conservation as a resource, emphasizing the active and ongoing evaluation of the performance of the conservation resource in the utility planning setting. In this context, the paper will emphasize the role of data and information in the delivery of the conservation resource to a utility.

The first part of the paper reviews the basic elements of the conservation power plant metaphor. In the second we extend the metaphor to the acquisition phase of conservation resource and develop the concept of control as applied to conservation. Next, this paper describes the information requirements for a conservation control strategy, with particular emphasis on the effective utilization of existing utility data collection schemes. Finally, it outlines some of the consequences of the conservation control model, with particular emphasis on nonengineering conservation strategies such as rates, rate designs, and information programs.

THE CONSERVATION POWER PLANT

Every element of the energy delivery and consumption process has associated costs. The metaphor of the conservation power plant helps us understand, and the concept of least-cost utility planning helps us exploit that fact. Traditionally, the role of the utility has been to manage the supply side of the process. Modern utility practice has evolved in this decade to the understanding that the energy process can be managed from the demand side as well. Least-cost utility is the fusion of the supply-side and demand-side options into a comprehensive cost minimization strategy.

The value of demand-side management has historically been associated with cost avoidance. In particular, the development of energy supplies for a utility has known costs. Building an electrical generating plant, developing a hydroelectric resource, or providing for the transmission of energy all cost money. The metaphor of the conservation plant rests heavily on the assumption that if building a generating resource has value, then so must meeting the same demand while avoiding costs of plant construction and operation. Therefore one has at least two options when planning to meet an increased demand for energy. The first is to build to meet demand. The second is to manage the demand. If the same demand is met, the two options must therefore have comparable value and may warrant comparable investment. There are several current examples of demand-side management under development to avoid supply-side investment. Among these are the various plans of the Northwest Power Planning Council (1986), the Hood River Project, and more recently the 553 Conservation Power Plant plan of the City of Austin.

The original intent of the conservation power plant metaphor was to create an understanding that conservation did have value and that it was worthy of major investment. Gradually the utility community has adopted the view that if energy demand is met through conservation at a cost less than that required to build a power plant, then conservation is an option.

Over the past 5 years, several utilities and federal power marketing agencies extended the conservation power plant metaphor in important ways. For example, the Bonneville Power Administration embarked on a very aggressive program to both understand and develop the conservation resource of the Pacific Northwest. This program has four major elements: resource assessment, technology evaluation, pilot programs, and actual resource acquisition. Bonneville's resource assessment program centered on End-Use Load and Consumer Assessment Program (ELCAP) and Customer System Efficiency Improvement (CSEI). The Residential Standards Demonstration Program (RSDP) and Energy Edge projects studied new construction practices, a technology evaluation. At Hood River, Bonneville, the effects of a large-scale weatherization program, implemented as a conservation power plant, were tested. Coupled with their aggressive regional residential weatherization program, Bonneville mounted an aggressive conservation acquisition program in the residential sector.

However, in the above examples the conservation power plant metaphor is generally implemented in a partial sense rather than in detail. In particular, conservation resource assessment is very much like a siting study, and an acquisition program is very much like a construction project. However, an important element of the conventional supply-side energy sources is the operational phase.

In a conventional power plant profit comes from operation of the plant. For example, many coal-fired power plants are approved as part of the rate base only at a particular performance efficiency. The plant is continually monitored and controlled to maintain that efficiency. As we shall see, it may be necessary to maintain the conservation power plant as well.

CONTROL AND THE CONSERVATION POWER PLANT

Control is an important idea in modern engineering theory, management practice, and a wide range of other disciplines. Rather than trying to select a formal approach to control from one of these disciplines, we will adopt the very simple control model shown in Figure 1.

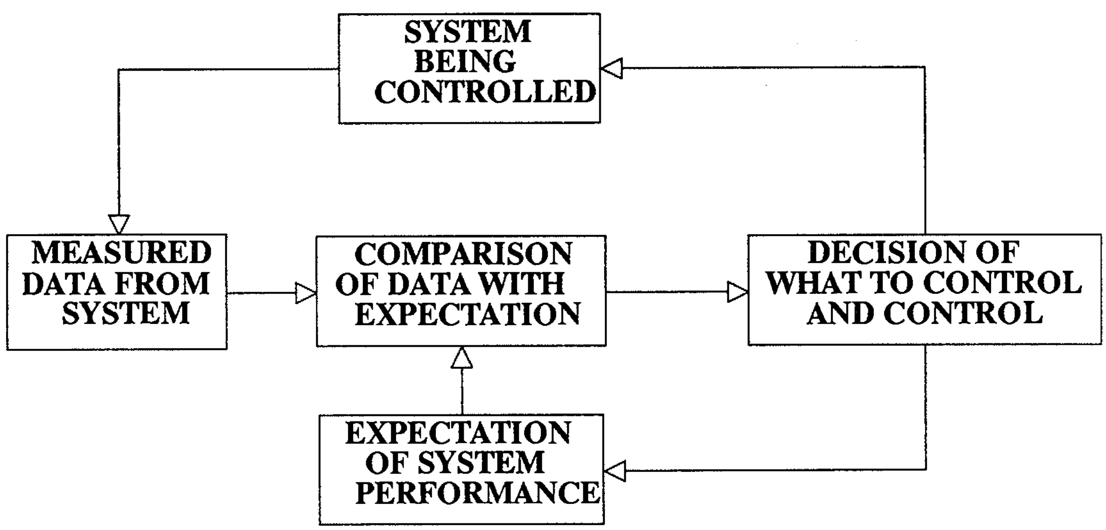

Figure 1. A simple conceptual model for control can be developed around the management of a system to match expectations. The control process has four key pieces.

The most important element of control is an expectation of performance of the system. By identifying expected performance as the key element of control we specified a goal-oriented control model. With the identification of a goal, then the control model requires that data be collected from the system and compared with the expectations for system performance. The differences between the observed and expected behavior of the system then drive the control strategy. Note that the process of exercising control modifies not only the system but also the expectation of performance. Without the latter link, the expected response to a control activity, there is no effective control of the system.

We will assert that the acquisition of a conservation resource is "the decision to control and control activity" on the right-hand side of Figure 1. The system being modified is the energy consumption system, and the expectation of performance is that the same goal be achieved with less of the energy critical resource than previously. The goals can be heating, cooling or lighting levels, and the energy critical resource could be energy, peak demand, or a particular fuel type. For the conservation power plant, it is generally some combination of energy and demand.

While conservation is inherently a "control" process, the data acquisition and comparison to the expectations portion of Figure 1 are not routine elements of the operational conservation delivery system. The data elements of the control cycle, such as energy consumption, peak demand, etc., for a conservation program are only examined in detail during the design and pilot program phases. Usually, the pilot programs establish the relationship between the set of conservation measures (the control activity) and the expected effect of those measures. The assumption is that, in the operational phase of the program, the same effect will hold. Within the framework of the control model in Figure 1, the operational phase of a conservation program, and therefore the conservation power plant, is uncontrolled.

IS IT NECESSARY TO CONTROL THE CONSERVATION POWER PLANT?

It is logical to ask whether it is even appropriate to apply Figure 1 to the full-scale implementation of a conservation power plant. After all, one of the great advantages of the conservation resource is that you can build it in to the infrastructure of the society and the laws of physics take care of the rest. This is a compelling argument. However, it only addresses one aspect of conservation and demand-side management.

Conservation is a technological process related to the production, distribution, and consumption of electricity. It is a tool. In their discussion of the role of computers as tools, Winograd and Flores (1986) discuss the concept of "readiness to hand."[a]

They point out that when a tool, such as a hammer, is being used by an experienced user the hammer does not have an discernible existence from the process of hammering. They and Heidegger argue that if the hammer is "ready-to-hand," the sense of the hammer merges with the hammering and the hammerer is no more aware of the hammer than she is of the tendons in her arm. Unfamiliarity with the tool, difficulty in using it, or some other interruption leads to a "breaking down" of the "readiness-to-hand." A tool that is "user-friendly" has good "readiness-to-hand," and one that is not suffers a "breaking down." The awareness of the tool as a distinct and foreign object inhibits it utilizability. Successful technological products appear to have good readiness-to-hand either for individuals or for society. For the individual, electricity has good "readiness to hand." You turn on the switch and get heat and light. You do not have to shovel coal or fill lamps. However, we are slowly learning that building power plants and operating them within the infrastructure of society can, for a wide variety of reasons, lead to a "breaking down." Safety and waste disposal concerns decrease the utilizability and "readiness-to-hand" of nuclear plants. Similarly, acid rain or indoor air quality can be seen as decreasing the "readiness-to-hand" of an energy resource for which society is the user.

The role of societal and personal "readiness-to-hand" in conservation is quite complicated. The complications come directly from the intimate relationship between human behavior and energy consumption. In particular, conservation resources for a particular energy use are expressed as:

$$R = U \cdot M$$

where R is the resource (energy, capacity, fuel type, etc.), U is the energy use, and M is a number less than 1 that describes the change in efficiency of U. There are strong energy interaction terms and behavioral components in both U and M and therefore the conservation resource, R. While both U and M are strong functions of the technology, the key point is that two elements of the conservation resource, U and M, evolve with time and are functions of human behavior. The human behavioral elements imply that much of the societal "readiness-to-hand" of a conservation program are related to the "readiness-to-hand" for individuals.

Several good example of the relationship of the effect of "readiness-to-hand" on conservation have been identified in the ELCAP study. In the commercial and the residential sectors, automatic setback, either through an energy management system or automatic setback thermostat, is a popular measure

(a) "Readiness to hand" is one of a variety of concepts developed by the existential philosopher Martin Heidegger (1962, 1968, 1971, and 1977) and Winograd and Flores use it in their discussion of computing.

for energy conservation. This automation increases the societal "readiness-to-hand" of setback behavior by facilitating the control for the individual. However, for commercial buildings, in general, and residences with heat pumps, in particular, setback behavior consumes the peaking capacity resource for a winter peaking area such as the Pacific Northwest, a technological "breaking down" that may be quite important for some utilities.

Similarly, it is well-known that simple engineering estimates of annualized energy consumption based on the thermal integrity (UA) of a structure are generally overestimates of the actual energy consumption. Recent work completed independently by Palmiter and Miller [Pearson, Miller and Stokes (1988)], suggests that zoning behavior may be a major component of this discrepancy. It is also noted by Miller that homes with baseboard heating may preferentially consume less heat, perhaps because the independent thermostats of baseboard heaters increase the "readiness-to-hand" of zoning behavior.

These examples illustrate that conservation is more than engineered technology and products. The conservation power plant is uncontrolled because we do not deal effectively with the behavioral element of the equation. Without a sensible control model we cannot understand whether our technology encourages or discourages conservation behavior. We also cannot understand whether behavior enhances the technological performance of a conservation measure or neutralizes it. Therefore, the primary reason for exploring the application of Figure 1 to conservation is to understand and influence consumer behavior and thereby increase the utilizability of the conservation resource as it is delivered. Without doing so, the full power of conservation, and its "readiness-to-hand" for society, is lost.

HOW DO YOU CONTROL THE CONSERVATION POWER PLANT?

The control model in Figure 1 is adapted in principle from the Shewhart Cycle shown in Figure 2 and described by Deming (1982). This is the model that Deming proposed for managing production and that the Japanese have adopted on a grand scale. The Japanese national award for quality is the Deming Award, reflecting their enthusiasm for this approach.

The idea behind the Shewhart Cycle is that the control of a process heavily embodies the concepts of prediction and measurement, and that the team responsible for the management of the cycle is an intimate element of the control cycle. If we adopt the model in Figure 1 and its operation, as described in Figure 2, the answer to the question of how one controls the conservation power plant depends on data collection.

Data collection is an expensive and sometimes thankless proposition. In an attempt to do a little "least-cost data planning," an analysis of the structure of a model electrical utility was conducted. The goal of the analysis was to identify key places in which data might be collected that would enable the operation of the Shewhart Cycle for the conservation power

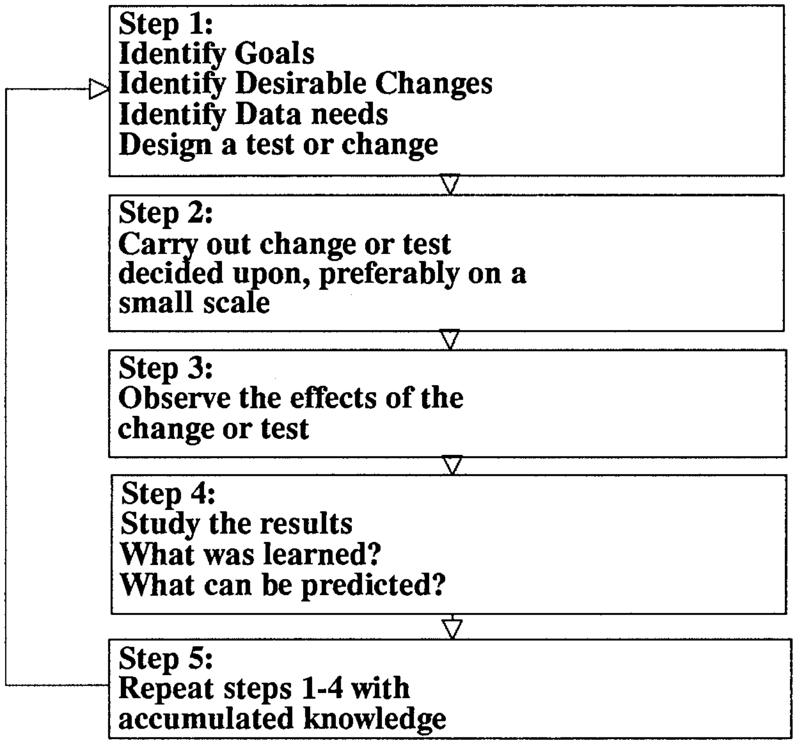

Figure 2. The Shewhart cycle reflects the notion that one can, through the process of good selection, prediction action, and measurement, control quality

plant. The analysis showed that there are three classes of data that can very effectively be used for control, and that much of the basic data collection is already done in many utilities. These three are billing data, time-resolved substation data, and financial data (costs and revenue). These data are generally collected, and some of their properties are as follows.

Billing Data

The great bulk of conservation programs are carried out at the consumer level. The intent of many of these programs is to achieve energy savings from the customer. Those savings, if significant, should manifest themselves in the consumption data for individual customer contained in the utility billing records. Except for utilities with extensive estimated billing programs, these data have 1 to 2 month time resolution.

Time-Resolved Substation Data

Data collection activities at substations are common practice at some level throughout the electric utility industry. This data generally includes measures of power and power factor with some time resolution. The data collection strategy within a utility usually allows the aggregation of the data to a total system demand and identifies key measures of system capacity.

Financial Data

Costs of service, disaggregated in a variety of ways as well revenues, are common data within utilities. The extent to which these data are disaggregated to match the first two data sets varies considerably.

If it is possible to use a large amount of existing data, the problem shifts the process of data collection to the sometimes intellectually daunting task of predicting the detailed performance of a utility as reflected in the three classes of data. Only through the prediction process can one use the data for control of the conservation power plant.

USING DATA FOR CONTROL

Following the Deming approach and the model for control, we will now give illustrative examples of how the three data types presented in the previous section might be used for control.

Billing data has been used for a variety of ongoing utility planning activities, and a number of tools already exist that make use of the data. In spite of some limitations, PRISM has proven to be one of the most powerful tools for the analysis of residential billing data. Hirst (1986) gives one of the best analyses of billing data, and it amply demonstrates the value of PRISM. While his analysis applies only to a pilot program, his conclusion illustrates the point being made here:

> "If utilities purchase "conservation resources" as cost-effective alternatives to conventional supply resources, they must have confidence in the durability (persistence over time) of these energy efficiency improvements."

In his analysis, Hirst finds a resource that appears to slowly diminish with time. The result is significant. In building the conservation power plant, acquiring the resource, we expected a level of performance that is shown to vary unfavorably with time. It is essential to note that Hirst had to analyze the measurements to find the decrease and its magnitude. That decrease in resource is significant for a utility planner, and Hirst amply discusses the way the information might be used and interpreted. His work suggests that we might ask how many utilities with major weatherization programs, full-scale acquisition or pilots, routinely analyze billing data to determine resource durability.

Goldberg and Fels (1986) have extended PRISM with the refraction method, obtaining even greater insight into the behavioral elements of residential space heating. In their analysis they see distinct evidence of a pure behavioral effect, temperature setbacks, and distinctly separate evidence for weatherization. Their work shows that a large sample base for billing data can give great power in understanding the societal "readiness-to-hand" of some conservation measures, even those that are purely behavioral, such as thermostat set points.

In terms of the power plant metaphor, public information programs to remind people to keep their thermostats at 65° or to close off unused rooms can almost be seen as "maintenance."

Substation data is also quite interesting. Potentially the most exciting application of this data is in conjunction with financial data. Net revenue analysis (a technique developed by Mike Baker, Paul Reiter, and Rob Pratt) employs two very simple concepts:

1. For a utility, every kWh of electricity delivered to a customer has a cost associated with it. The cost varies with the resources being tapped and customer being serviced.

2. Utilities collect revenues based on the consumption of electricity.

In a net revenue analysis one attempts to distribute all of the utility costs over the hours of the year, giving an hour-by-hour cost/kWh.[a] Then the utility rates can be used to develop a revenue profile. While we are suggesting here that the revenue profile be developed for a substation or point of delivery, it can just as easily be developed for individual customers of particular end uses. The difference between the cost and revenue, the net revenue, shows the ways that a customer, an end use, or a point-of-delivery is either a revenue asset or revenue liability.

Applying net revenue analysis at the substation level is a little more difficult than it would be for a single customer. The difficulty comes in trying to distribute the revenue over time for the demand being met by the particular substation. Schemes based on either the billing records of the customers serviced out of the substation or more delphic distributions could be used.

Ultimately one ends up with a net revenue analysis for each of the delivery points in the system and for the system as a whole. The exciting element of this approach is that generally conservation programs are end-use specific. Individual end uses have unique temporal energy consumption profiles associated with them. Therefore, net revenue analysis at the substation level allows several key activities to take place that are important elements of the Shewhart cycle.

1. <u>Identification of goals.</u> The net revenue analysis, in conjunction with knowledge of the energy consumption patterns of particular end uses,

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(a) This is in some cases an arbitrary process, but the distribution of cost can be a very powerful statement of utility policy.

should suggest particular energy conservation programs with particular end-use targets.

2. Predictions are possible. The consequences of a program can be predicted. During the implementation and operation phase, these predictions can be explicitly examined and the program modified appropriately.

3. Phased approach is possible. The cyclic nature of the Shewhart cycle suggests that phased implementation is a desirable approach. In the current case, conservation programs can be phased by setting priorities based on net revenue. For example, if one wants to test a particular program in a pilot program or in the first phase of a multi-year effort, net revenue analysis might suggest that the customers served by a particular substation would give you the greatest observed effect either in the data or, even more importantly, in revenue.

This approach can open up to experimentation the whole realm of conservation programs, including rates, rate structures, and public information campaigns. Behavioral conservation can have substantial value. As long as the control is durable, the resource can be too. The development of a pilot controlled conservation power plant could demonstrate and offer insight into the value of such an approach.

CONCLUSIONS

This paper suggests that the conservation power plant metaphor be extended beyond a simple justification for large conservation programs. Rather than being a simple and attractive metaphor, the concept of a conservation power plant should be used as an analogy in which we use our great knowledge of the engineering on the supply side to understand the delivery of a demand-side resource.

An important element of the analogy is control. In particular, methods need to be devised that allow the delivery of conservation to take place in a predictable fashion and that promote the infusion of conservation in a cost-effective fashion within the industry. The effective use of data and prediction are key to exercising this control, and such tools as PRISM and net revenue analysis offer important ways to begin to bring the conservation power plant under control.

With the model of control offered here, not only can one explicitly examine the implementation and durability of conservation technologies, but one can develop and control conservation programs based on customer behavior.

EPILOGUE: USE OF RESEARCH QUALITY DATA

One of the key points of this paper has been that control of the conservation power plant may be achieved with data already available within a utility. Several colleagues and at least one reviewer have asked about the possible role of detailed end-use metering in controlling the conservation power plant. In this regard it is significant to note that one of the largest end-use research projects in the country has changed its name from the End use Load and Conservation Assessment Program to the End use Load and Consumer Assessment Program (ELCAP).

Consistent with this change there are two possible uses for detailed high time resolution end-use-specific data. The first is to use the data as a conservation incentive for large customers. There is no reason why the utility has to take full responsibility for operating and controlling the conservation power plant. By providing a large customer with basic metering equipment, some analysis tools, and a well-designed rate structure, the customers could achieve savings for both the utility and themselves.

A second use for detailed data would be in the residential sector in analogy with television rating services. The intent of this usage would be initially to see how individuals respond to rates, arrival of bills, or public information campaigns. With time the sample could be used to study appliance choices, self-financed conservation, and the changes in the conservation pattern as the household ages or even at the change of occupants. The sample size for such a study may be too large for practical implementation of the latter strategy, but the next few years of ELCAP data analysis and data collection will tell a great deal about the possible value of the technique.

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