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Reducing Electrical Power Demand for Industries

Burns E. Hegler
Missouri University of Science and Technology

J. Byron Nelson

Rene O. Harrell

REDUCING ELECTRICAL POWER DEMAND FOR INDUSTRIES

Burns E. Hegler and J. Byron Nelson
University of Missouri - Rolla
Rolla, Missouri

Rene O. Harrell
Ford Motor Company
Dearborn, Michigan

Abstract

A typical industry has an electric power demand that is in excess of its needs. This condition places an unnecessary burden upon the industry and contributes to the current energy crisis. Reduction of demand may be accomplished by a number of methods of control that are examined and evaluated. Standard techniques of engineering analyses and engineering economy have been used to study and analyze an industry selected as an example.

1. INTRODUCTION

This study was initiated for two reasons. First, the energy crisis has generated requests from all sectors, both private and public, for solutions to such problems as reduction in electrical demand. Second some of the responses to these requests need better engineering and economic bases. The solutions to this aspect of the energy crisis require the application of good decision techniques and selection of proper alternatives. Ample consideration must also be given to the constraints that are imposed by physical, monetary, and time limits.

1.1 POLITICAL BACKGROUND

The seriousness of the problem is exemplified in a recent article by columinist Jack Anderson.(1) Mr. Anderson quotes from White House memos he claims to have seen that indicate the administration's conservation effort is failing. The reason for the failure according to these memos is that industrial firms are more inclined to invest money in equipment that will expand immediate profits than on equipment that will save energy.

Decisions such as the above often are made expediously and without proper study. For example, the article by Anderson states that White House advisers have concluded that it will take a huge public expenditure to produce energy-saving buildings. The following discussion shows that contrarily a relatively small investment by an individual industry will save electricity charges and help to lessen the energy crisis.

1.2 PREVIOUS STUDIES

Load management or demand control is not something that is new to the utility industry. Utilities in the United States, Europe, and some foreign countries have practiced load management for years.(2) Manual forms of load dumping have been used in various forms by individual industries since demand charges came into being. It has only been recently that there has been an increase in the interest in demand control for individual industries. This can be attributed to the increase in the charges for electricity that have resulted from critical economic situations and the energy crisis. One of the first of these to be reported upon was published in 1971.(3) Many others have followed as the pressure to ease the energy crisis has increased.

There have been relatively few articles and books written that specifically address themselves to the economic feasibility of computerized control of electrical power demand. Many of the technical papers and articles that have been published deal with applications of computerized control of power demand to specific industrial cases. Another type of literature is the promotional information released to prospective clients by the suppliers of computerized demand controllers. The present study is concerned only with those references that apply to computerized control of electrical power demand.

Murphy and Putman of the Computer and Instrumentation Division, Westinghouse Electric Corporation,[4] observed that:

> A quick way to slash operating costs, especially in the industrial plant, is to reduce the demand charge that the utility places on the use of electricity. Because of the complexity of most industrial plants, a computer is the best way to store, measure, calculate and control the many variables associated with a wide range of energy consuming devices.

Fox and Pinson in a later article,[5] observed that:

> It is impossible to predict an overall reduction in the demand charge which can be expected by all or even most plants using a demand controller. However, by smoothing out the demand peaks and valleys, a demand controller typically reduces demand from 10 to 40%, and a significant number of demand control installations have paid for themselves in less than one year's operating time.

Fox and Pinson suggest two guidelines to follow when considering the investment of computerized control of electrical power demand: 1) a 20% reduction in peak demand should be obtainable, and 2) by using a typical return on investment program, which incorporates the investment tax credit and depreciation allowance (based on a standard eight-year depreciation for electronic equipment and a 15% return on investment), a savings of $500 a month justifies a $30,000 investment.

The above are suggestions and may or may not comply with an organization's criteria for analysis of investment proposals.

The Globe Newspaper Company of Boston, Massachusetts, installed a computerized system for control of electric power demand and consumption based on two conditions that justified implementation of a control system: 1) large electric bills (approximately $60,000 per month in 1975), and 2) the presence of a sufficient number of sheddable loads to limit demand. This was commented upon by Elliott in an article on instrumentation and control systems[6], that referred to the Globe Newspaper Company. He noted that:

> The power management system went online in September 1975. Since then, monthly savings in demand and usage charges combined have averaged $6500, or approximately 11% of the total bill. At this rate, the system and associated wiring was paid off by the end of 1976--despite a 16% overall rate increase imposed by the local utility.

In an article presented at the Institute of Electrical and Electronic Engineers (IEEE) 1976 Technical Conference on Industrial and Commercial Power Systems, Hall claims that if the purpose of computerized control of electrical power demand is to lower annual electric utility expense by controlling loads, then it is necessary to find loads that can be shed or scheduled in such a manner as to preserve critical processes and maintain comfort levels of occupied areas. In industrial plants, heating, ventilating, and air conditioning the (HVAC) system provides a load that can be controlled to minimize demand peaks. HVAC systems are frequently over-designed, and even those properly sized are still designed to meet worst-case requirements.[7] For this reason, most of the previous studies on computerized control of electrical power demand search for HVAC equipment as the primary controllable load. Weaver says that traditionally automatic controls have made a sizeable contribution to the conservation of energy in HVAC systems and the industry is ready for the use of more sophisticated measures.[8]

2. THE PROBLEM OF HIGH ELECTRICAL DEMAND

The demand for electricity is a controversial subject that plays an important role in the present energy crisis. The electric utilities are committed to supply the demand for electricity and consequently feel justified in billing their industrial customers for the demands that they create. The individual customers do not like the demand charge, because it increases their electrical bill. This situation is explored below.

2.1 DEFINITION OF DEMAND

An electric utility bill generally consists of at least two parts: a record of the user's actual consumption of energy, expressed in kilowatt-hours (kWh) and a notation of his demand on the system with respect to his average connected load, expressed in kilowatts (kW) or possibly kilovolt-amperes (kVA). At the end of the billing period, usually 30 days, the total number of accumulated kWh forms the basis for the energy charge. To determine the peak demand that occurs during the billing period, the utility establishes shorter periods of time, usually 15, 30, or 60 minutes, that are called demand interval and expressed as kWh/hour or kW. Peak demand is the highest kW load obtained during any demand interval within the billing period. Normally, billing demand remains in effect for one month, but this demand or a fraction of it may be levied for an entire season or year, depending on the contract the user has with the utility. Consequently, if the demand is reduced, a considerable reduction in the cost of electricity can be achieved. In addition, the demand upon the entire electrical system of generation, transmission, and distribution is reduced. Any reduction in demand for electricity makes a positive contribution to the energy crisis.

2.2 METHODS OF DEMAND CONTROL

There are three principle methods of demand control: ideal-rate control, predictive control, and instantaneous-rate control. Each of these three methods essentially measures the rate of consumption, whether the present rate exceeds a predetermined value and then dumps or adds load as required. There are other methods, but only the above three are considered in this paper.

2.2.1 Ideal-Rate Control

In ideal-rate control, the energy consumed during a demand interval is measured and accumulated by a demand controller. This accumulation is compared with a theoretical rate of energy consumption, which is based on the demand interval and the maximum allowable kW for that interval. When the difference between the ideal rate and actual consumption reaches a preset minimum, nonessential loads are shed. When the difference increases as a result of a drop in the rate of consumption, previously shed loads are restored to the total load. Ideal-rate control has the following limitations: 1) The demand controller generally must be synchronized to the demand interval prescribed by the power company, and many utilities have a policy of not providing the necessary synchronous pulse. 2) The demand controller normally puts all previously shed loads on line at or near the start of each demand interval; this produces large power surges at the beginning of each interval and defeats to some extent the overall principle of demand control. 3) It produces more switching of loads than other systems. Its chief advantages are its relative simplicity and low cost.

2.2.2 Predictive Control

With this technique, as in ideal-rate control, the demand controller is synchronized to the utility's demand interval. At the beginning of the demand interval, the controller accumulates actual energy consumption. At each measurement point, the controller measures the instantaneous rate of energy consumption and predicts whether or not the preestablished limit will be exceeded. This is achieved by adding the accumulated energy to the product of the rate and the time remaining in the demand interval. If the calculated value exceeds the preset limit, the controller begins to shed nonessential loads; if the calculated value is less than the preset limit, previously shed loads are restored.

Predictive control has these limitations: 1) As a result of the additional calculations performed by the controller, the predictive technique is generally considered to be a more complex and expensive approach to demand control. 2) It also requires that units be synchronized to the utility's demand interval so that the accumulator can be reset at the beginning of the next interval. 3) Several types of predictive control demand that controllers restore all previously shed loads at the beginning of each demand interval, thereby, creating power surges.

2.2.3 Instantaneous-Rate Control

This technique is based on a measurement of the rate of power consumption at brief intervals and on a comparison of this rate with a preset limit. If at any time within the demand interval the instantaneous rate exceeds the preset rate, nonessential loads are shed. As long as the instantaneous rate is below the preset rate, previously shed loads will be restored. This approach is based on an instantaneous rate of consumption and is independent of the actual demand interval. The advantages are: 1) The accumulator is not reset by the beginning of the next demand interval, and power surges can be avoided. 2) There is no required demand interval, consequently the synchronous pulse does not have to be provided by the power company. 3) The rate of power consumption is held at a predetermined target value, which produces a more evenly distributed rate of power consumption. The limitation of this technique is the expense of computer assistance. Figure 1 illustrates how the instantaneous-rate control systems functions.

2.3 OTHER ELEMENTS OF DEMAND CONTROL

As indicated above, the selection of a method is just one of the elements that must be considered for demand control. The proper decision requires study of the resources that are required, such as: financing, operation and service equipment, and personnel. Also, much thought and planning must be accomplished to integrate such a system into the operation of the organization. Chief among these is the load reduction program. Load selection and timing are extremely important. The effect upon the environment and production must not be neglected.

2.3.1 Economic and Social Aspects

In general, demand control requires the investment of capital in a computer and control devices. It also requires an investment in time, money, and personnel to install and maintain the demand control system. To be economically feasible, the savings in reduced charges for electricity should outweigh the cost of the system based upon economic criteria; however, some thought should be given to the social responsibility of the organization. It may be in the best interests of the company and society to spend money for capital investment and maintenance for power demand systems that do not necessarily meet the typical economic criteria that are associated with the capital investments.

2.3.2 Control Strategy

A computerized demand controller has the capability of being a fully automated system, which is capable of continuously monitoring the electrical consumption of a facility. In addition to its monitoring function, the demand controller has the ability to respond with control actions that ensure that the demand rate does not exceed a predetermined demand limit. The predetermined demand limit is determined by the usage trends of the facility. The control action taken includes stopping or throttling the operation of selected devices for prescribed periods. This control strategy generally is determined by the facilities personnel, because they have a thorough knowledge of the operations.

2.3.3 Load Control

It is also necessary to give careful consideration to the loads that are controlled. If loads that pertain to production are reduced or dumped, the production of the organization must not be affected adversely. Some of the easiest loads to control without affecting production directly are the HVAC loads. Usually these loads can be varied by alternating the shut-down times or reduction times or certain parts of the loads without causing too much discomfort to personnel and loss of productivity.

3. FINANCIAL EVALUATION PROCEDURES

Far too often organizations make capital investment commitments without properly evaluating the economic consequencies or determining whether or not they are making the best possible investment among available energy alternatives.

3.1 PAYBACK PERIOD AND RATE ON INVESTMENT

Measures such as payback period (PP) and return on investment (ROI) are often used because they are simple to operate, even though they do not reflect the time value of money and overlook certain important economic factors, such as changes in future cost and cost savings, taxes, and investment tax credits. Also, individual returns of investment are usually used to compare energy conservation alternatives; whereas, an incremental ROI analysis is required because it is a ratio measure. This fact is illustrated in the following example:

	Alternative (Ten-year Life) A	B
First Cost (FC)	\$50,000	\$100,000
Salvage Value	0	0
Annual Depreciation (D)*	5,000	10,000
Annual Savings (S) (Fuel Cost Savings-Operating Cost)	25,000	40,000

*straight line depreciation

	A	B
$ROI = \frac{S - D}{FC}$ (100%)	40%	30%

In looking at these individual ROI values, most organizations would select alternative A. If the minimum acceptable ROI at a particular company is 20%, however, the incremental first cost of \$50,000 between B and A will earn an incremental ROI of 20%, the minimum acceptable amount. Therefore, B should be selected.

3.2 LIFE CYCLE COSTING METHODS

Some organizations evaluate energy capital investments by using measures that make allowances for the time value of money. Unfortunately, they often follow exactly the guidelines specified in Government handbooks, such as the National Bureau of Standards, Handbook 115 issued by the Department of Commerce. Individual benefit/cost ratios and internal rates of return are used to compare various alternatives; whereas, an incremental B/C or incremental rate of return analysis is required to make a proper comparison similar to the ROI example previously discussed.[9] In addition, the effects of taxes, tax credits, and rates of inflation are typically overlooked.

4. THE CASE STUDY

The plant examined by one of the authors[10] for this study is fairly typical. It consists of a food-processing plant having one-half million square feet of area and experiencing peak loads of more than 2500 kW demand. The electricity charges are well over one-quarter million dollars. For a number of years, the industry has been concerned about energy conservation and the need for reduction of its charges for electricity. One of the principal reasons for this concern over charges is a billing policy of its electric utility. One specific provision of the billing requires that the industry be billed for 90% of the peak demand for each month of the 11 month period after the peak demand is established.

4.1 MANAGEMENT'S OBJECTIVES

The demand charge associated with the difference between the actual and billed demand is the key factor behind the management's commitment to a program of reducing electrical utility expense by controlling demand.

After reviewing the many different types of demand-limiting controllers, the instantaneous-rate control was chosen as the technique used to control demand. Furthermore, a computerized demand controller was chosen as being the most suitable equipment available. These decisions were based on: 1) a desire to minimize power surges when loads are restored, 2) the number of loads to be controlled, and 3) the degree of automation of the plant. The computerized demand controller would also have to have the capability to exercise control action throughout the demand interval, regardless of the rate of energy consumption.

It was further determined that only HVAC equipment be controlled because there was no desire to interrupt the process operations and production schedules. The chiller, although part of the HVAC equipment, was not to be turned off because of the difficulty involved in bringing the unit back on line. Also the engineering staff chose a target value of 2100kW as an feasible demand limit. The project was required to meet the following economic criteria: 1) a payback period of 1.7 years or less, and 2) a return on investment of 30% or greater.

4.2 ENGINEERING STUDY

An extensive study of the plant's electrical distribution system, electrical wiring diagrams, and equipment layout was conducted in order to determine the quantity and power requirements of the HVAC equipment. Many of the HVAC units, when operated under full load conditions, were found to be oversized with respect to air flow capacity in relation to the space they serve. To achieve demand and consumption savings, loads had to be turned off or idled in order to reduce the peak demand within the demand interval and to lower the energy consumption of the facility. The minimum percentage of time in which each HVAC unit had to operate was determined by the plant's engineering staff.

4.3 ANALYSIS

Actual demand and consumption figures for the years 1974 through 1976 were obtained from the local electric utility company. A graph of actual demand (Figure 2) for these years shows that relatively high peak demand periods occurred during the plant's summer operations. This mainly was a result of the use of refrigeration and air conditioning equipment required in the preservation of food items and in the maintenance of comfort levels for the personnel in the plant. A reduction in the demand peaks in these summer periods would result in reduced demand charges for subsequent months.

4.4 EVALUATION

In order to obtain the desired demand limit of 2100 kW, all kW in excess of 2100 kW had to be effectively reduced. This reduction is the function of the computerized demand controller. With a predetermined demand limit established, the controller monitors the demand usage and sheds or idles the nonessential loads to prevent the usage rate from exceeding the demand limit. The plant's peak demand could be reduced from the high summer demands as shown in Figure 2, to a limit of

2100 kW with the use of the controller. Note the high billing demands that existed.

Shedding loads for demand reduction also resulted in some savings in the consumption of electricity. A summation of the estimated consumption savings in each period resulted in daily consumption savings of approximately 6570 kWh. Assuming a 30-day month, the montly consumption of the plant was reduced approximately 197,100 kWh with the existing control strategy. By using present billing rates the annual electric expense of $314,265 was reduced to $260,675, an annual savings of $53,590. The 19% reduction of demand also reduced the consumption by 21%. Therefore by using an average first cost of $70,000, the payback period for the project is determined to be approximately 1.3 years and the calculated ROI to be approximately 66%. These values are within the economic criteria established for this case by the corporate management.

5. CONCLUSIONS AND SUMMARY

In this study, the implementation of a computerized demand controller shows that peak demand can be reduced 19%. During periods when the peak demand is below the demand limit, the demand controller has the capability of reducing energy consumption. Energy consumption savings also are realized by exercising control action throughout the demand interval, regardless of the usage rate. The reduction in consumption is estimated to be reduced 21% for this particular application. Savings associated with the implementation of the demand controller are calculated with the HVAC loads in an idle condition. Additional savings are realized when these loads operate under fully loaded conditions.

5.1 REVISED ECONOMIC CRITERIA

Frequently, capital expenditures, such as energy conservation control systems, are evaluated and justified by using the economic criteria of the payback period and the annual ROI. Even though these two criteria are easy to calculate and understand, they do not take into account the time value of monetary funds. Consequently, life-cycle cost measures, such as the internal rate of return, should be used, in the case-study reported upon here the computerized demand controller had an estimated initial cost ranging between $65,000 and $75,000, an estimated life of ten years with zero salvage value, and an estimated annual energy-cost savings of $53,590. The annual rate of return before taxes ranged between 71.12 and 82.24%. With an assumed ten-year straight-line depreciation pattern, a 10% investment tax credit, and an effective tax rate of 50%, the rate of return after taxes fell between 42.53 and 48.62%.

5.2 GENERAL APPLICATION OF CONTROL

These methods of demand control are not applicable to all commercial and industrial activities, especially those that have high load factors; however, almost any activity of any size could profit from some control of its energy use. This control may range in complexity from simple visual surveilance and manual control to a highly sophistacated total control by a computer of all of the energy used.

5.3 FUTURE DEVELOPMENTS

Research and development in the field of demand controllers has been neglected in the past. The incentive of the present energy crisis, ever-increasing energy costs, and future requirements for conservation of energy should increase the interest in further development and applications of demand control systems. New methods and approaches to demand control need to be devised, and applied research into the satisfactory opperation of existing applications is required, because little information in these areas exists.

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BIOGRAPHIES

Burns E. Hegler
Professor of Engineering Management
University of Missouri - Rolla

Burns E. Hegler has his B.S., M.S. and Ph.D. degrees in Electrical Engineering from Kansas State University. His 20 years of teaching are balanced with more than a dozen years in industry where he has worked as an engineer in the aerospace, electrical utility and naval shipyard industries. His recent papers are in the areas of energy, management, wood products, public works, and other areas of safety and education. His chief areas of interest are industrial safety and energy management.

J. Byron Nelson
Associate Professor of
Engineering Management
University of Missouri - Rolla

Dr. Nelson received a BSIE from Iowa State and graduate degrees in IE from Purdue University. He was previously with the IEOR Department at Virginia Polytechnic Institute and State University and employed at RCA, Sylvania Electric, and U.S. Gypsum. His current research includes inspection performance, cost estimating, and energy management. Dr. Nelson is a Senior Member of AIIE and a member of ASEE and HFS.

Rene O. Harrell

Rene O. Harrell received a Bachelor of Science degree in Mathematics in May 1976 at Southwest Missouri State College in Springfield, Missouri and the degree of Master of Science in Engineering Management at the University of Missouri - Rolla in August 1977. He is presently employed by the Ford Motor Company. His area of interest is computerized control of the use of electricity.

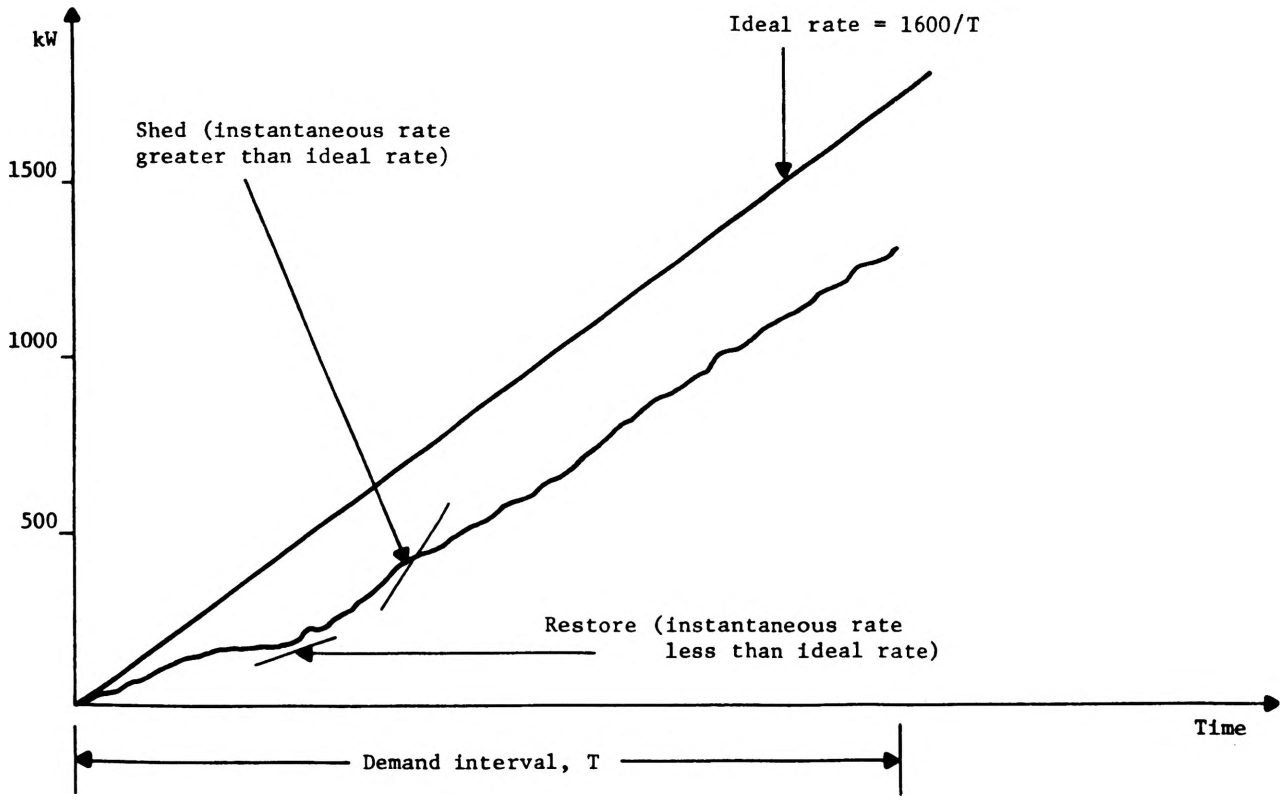

Figure 1. Instantaneous-Rate Control

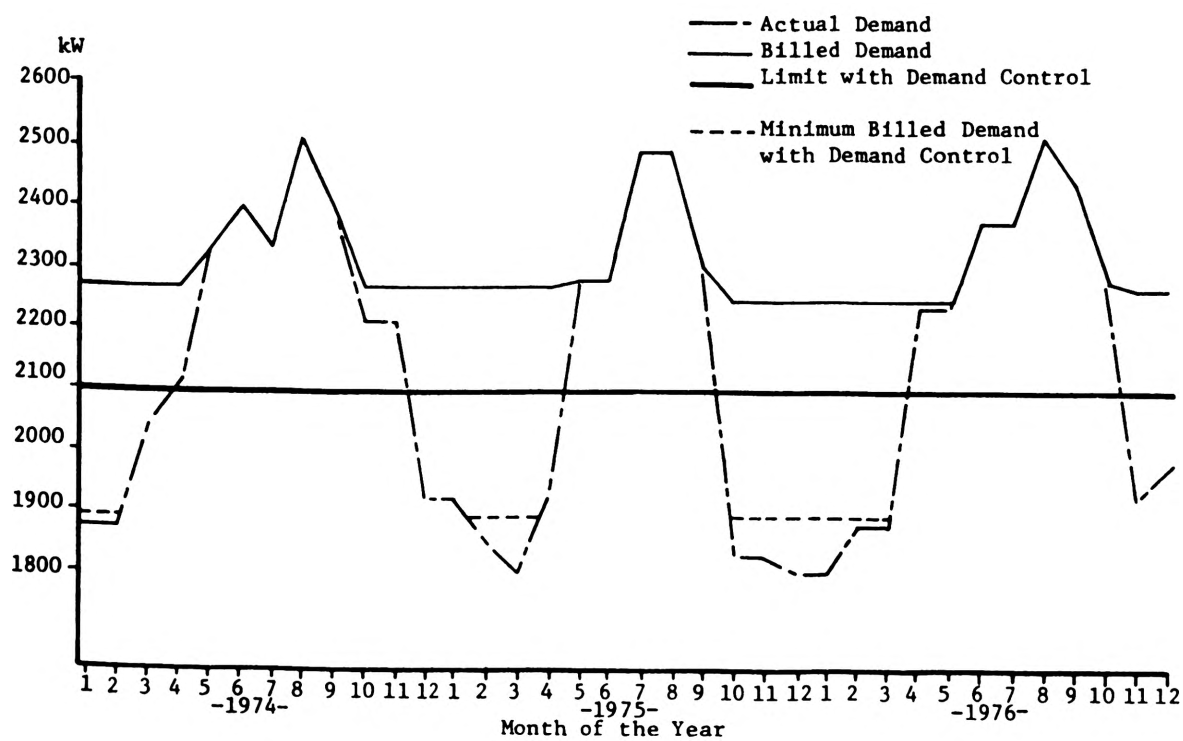

Figure 2. Demand Values for Case Study