VARIABLE PRICING AS A LOAD MANAGEMENT STRATEGY

ISMAIL HASSAN
Energy & Load Management Group
Faculty of Electrical Engineering
Universiti Teknologi Malaysia
Jalan Semarak 54100
Kuala Lumpur

Abstract

Variable pricing of electricity is introduced as a strategy that can achieve the desired benefits of load management and efficient rates design. The utility gains by optimal allocation and efficient utilisation of resources and substantial savings in capital investments and as a result the customer should pay less in electricity bills. Ideal pricing however must be compromised with the need for practical rate structures. In the final analysis the success of the strategy depends a great deal on correct customer response.

Keywords: *Load management, variable pricing, spot pricing, dynamic pricing, optimal allocation and efficient utilisation of resources, time-of-use rates, merit order, load factor, marginal cost, prescribed pricing.*

1. Introduction

Electricity undertakings always endeavour to provide electricity cheaply and efficiently to consumers. On the other hand they also must meet some revenue targets which represent a fair return on their investments. Only optimal allocation and efficient utilisation of resources can fulfil these two divergent requirements. This is the fundamental objective of all planning and operational strategies [1].

With uncontrolled demand, optimisation is based purely on the supply-side considerations. Load management options emerged to serve the need to have control or influence over customer demand so that plant utilisation may be further improved. Because it is generally recognised that demand can be sensitive to price [2], electricity pricing has acquired a special role in load management. This is reflected in the widespread implementation of time-differentiated tariffs which attempt to influence the pattern of electrical energy usage in a beneficial way. Variable pricing is a distinctly dynamic method of achieving the same objective.

2. Motivation For Doing Load Management

Load management generally refers to the measures taken to control, develop or shift load in such a way as to optimise the efficient use of capital and energy resources. It may consist of utility actions that directly influence the time or level of electric power usage or it may be a concept that relies upon customer response to appropriate tariffs or other similar motivations [3].

A familiar example of the former method of load management is direct utility control of designated customer appliances to clip system peaks. The latter load management techniques include the practice of time-of-use rates by many utilities to attempt to shift loads by offering customers cheap rates during off-peak hours and charging premium rates during peak hours.

An uncontrolled energy demand imposes severe limitations on the efficient generation and cheap supply of electricity in several ways. The problem is most acute when the load curve is characterised by a big ratio of peak to off-peak demands. Sufficient generating plant has to be installed to meet the maximum expected demand thus contributing to high capacity costs. Operating costs are relatively high because peak load generation involves the use of plants low in the merit order list, and the maintenance of spinning reserves to meet rapid rises in demand incurs large heat losses [4]. These costs are spiralling up all the time, fuelled by the unforeseen oil price rises of 1973/74, 1979/80 and 1990/91.

Load management attempts to improve the system loading so that more of the energy requirement can be supplied by high-merit plants, thereby reducing production costs. A 1983 estimates in the United Kingdom showed that with more equitable loading of thermal plants leading to efficiency improvement of just one percent could translate into savings of £30 million per year [5]. Limitation of peak demand not only allows better control of emergencies but also means that stand-by requirements are reduced, thus avoiding the need to provide for excessive plant margins. This results in deferred capital investment. In the United States it has been estimated that efficient demand-side planning can achieve 10 to 12 percent reduction in utility peak loads, translating into some $100 billion in capital savings from capacity deferral over 10 to 20 years [6].

Many utilities operating consumer load management schemes across the United States have been favourably impressed. They see the schemes as being cost-effective and providing a way to ease financial strains, improve load factor and offer better service options to the customer [7].

Thus load management techniques offer a set of alternative strategies to the power utility to achieve the operating objectives of economy, efficiency and security. The cost savings managed could then be reflected in the customers' bills as incentives.

3. Role Of Electricity Pricing

Practical methods of load management are based on either load control or inducement by appropriate pricing and/or other financial incentives or regulations. In many circumstances, a combination of those types of methods is employed for the greatest effectiveness such as in peak clipping when not only are high tariffs imposed during a peak period but the utility has also the option of switching-off certain loads.

Electricity demand studies undertaken by Houthakker 1951 [8], Fisher & Kaysen 1962 [9], Anderson 1972 [10], Mount, Chapman & Tyrrel 1973 [11] and many others clearly show that price is a primary factor that determines the demand for electricity. Based on this evidence many tariff structures have been devised to persuade consumers to respond in a way that leads to efficient utilisation of resources.

The best examples of load management by pricing are provided by peak and off-peak tariffs, the earliest implementation of which had been in the United Kingdom and France [12]. These tariffs have been developed to draw demand away from peak periods when the supply cost is highest into off-peak periods when the cost is much cheaper. Figure 1 shows how the domestic usage of electricity has responded to the implementation of off-peak tariffs in the United Kingdom during the 1960s [12], while figure 2 indicates the results of measures encouraging consumers to use off-peak electricity and discouraging electricity usage at peak times in England and Wales [13].

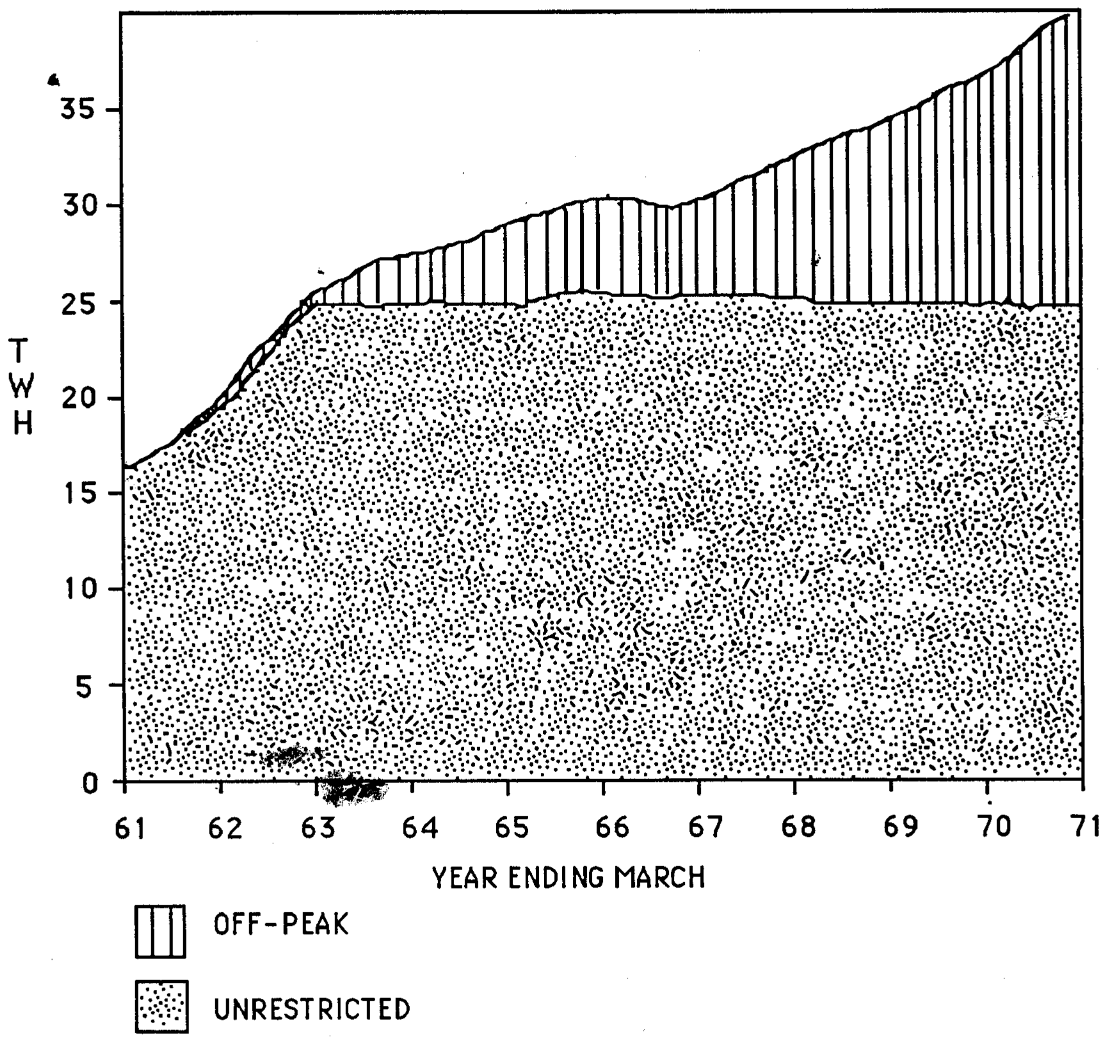

Fig. 1: *Growth in domestic electricity consumption for space and water heating, 1961-1971, in the United Kingdom.(Source: Electricity Council)*

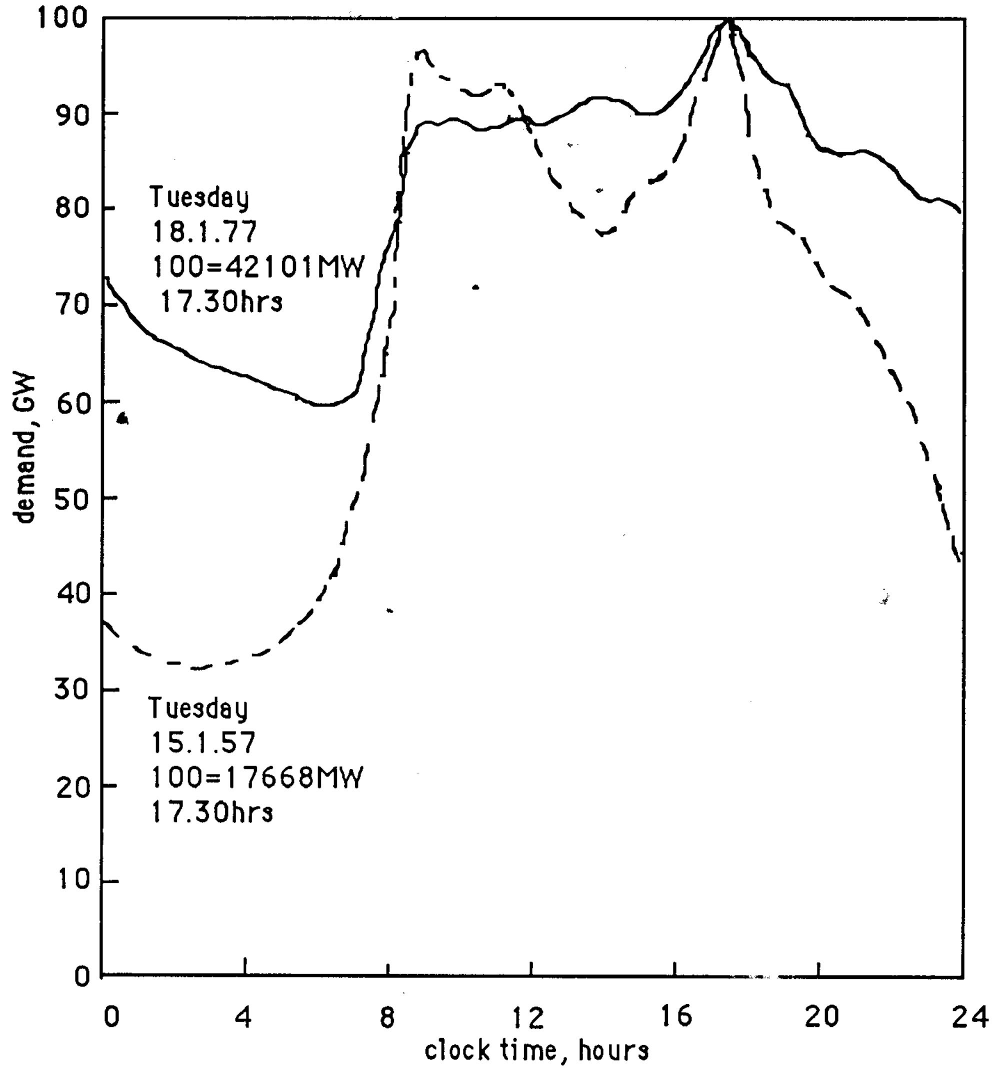

Fig. 2: *Day of maximum demand on CEGB 1956/57 and 1976/77 adjusted to the same level of system peak demand at 1730 hours.*

A strong point in favour of the use of pricing in load management is the underlying philosophy of offering free choice to the optimal allocation except perhaps in an emergency situation.

To put the subject into the right perspectives it is necessary to state that electricity pricing has been generally approached in the wider planning contexts. Nevertheless the results should be consistent since there is a common objective that binds pricing and load management together, that is the optimal allocation and efficient utilisation of resources.

4. Variable Pricing

In the following discussion the term variable pricing is regarded as being conceptually synonymous with spot or dynamic pricing. Variable pricing is not an isolated concept. By tracing the evolution of tariff structures it will be shown that it simply represents the next step towards achieving the ideal pricing in terms of optimal allocation of resources.

The general approach to electricity pricing has been on the basis of meeting a set of specified objectives which commonly includes the following [13], [14], [15], [16]:

- (i) achieving economic efficiency through optimal allocation of resources,
- (ii) fulfilling the financial obligations of the utility,
- (iii) charging consumers equitable rates.

A wide spectrum of tariff structures have emerged across the world because, in the first place, the set of pricing objectives is utility-specific. Moreover utilities differ in the ways they go about resolving the conflicts often present in their objectives. More significantly, pricing approaches have changed in a somewhat distinct pattern throughout the history of tariff-making with regard to the costing methods used by which prices are set.

In the beginning prices were set based upon the average historic, financially-derived costs computed using data obtained directly from the utility's accounting books. The limitations of this approach are discussed fully in reference [16] but the important point to note is that the objective of achieving economic efficiency has been totally disregarded. Consumers are conveyed prices not designed to move them in the direction of optimal allocation and efficient utilisation of resources.

During the middle of 1960s arguments were put forward by economists to convince the electricity supply industry that fixing prices by marginal costing is the ideal method to promote optimal allocation and efficient utilisation of resources. Marginal cost is the extra cost of producing an additional unit of output. Despite early misconceptions and controversies marginal cost pricing is the declared policy of most power utilities in the world today [13].

Long-run marginal cost (LRMC) refers to the marginal cost for an extended period of time (eg. 10 years) during which the total system capacity can change. This cost has been widely used as a result of treating pricing as an integral part of long term planning and therefore must be related closely to investment decisions. However, it is not ideally suited for use in meeting revenue requirements which are usually set to cover a much shorter time period, say 1 or 2 years.

Today short-run marginal cost (SRMC), that is the marginal cost for a short period of time (eg. 1 year) during which system capacity does not alter, is increasingly thought to be the more appropriate basis for pricing. It reflects the short term cost more closely and setting prices based on SRMC can recover part of the fixed capacity costs, thus avoiding excessive tampering of ideal costs [17].

Because of the usual practice of operating generating plants in merit order, that is putting more efficient plants into operation first followed by less efficient ones to meet a given demand level, SRMC increases with increasing output. Since electricity demand varies with time, ideally prices should be variable continuously with time. In practice this objective has to be compromised with several constraining requirements such as tariff simplicity and economics of implementation.

It becomes clear from the preceding discussion that variable pricing is simply an improved manifestation of pricing based on SRMC. Early objection to the idea of having a fully time-varying price has been the uneconomic implementation costs to be incurred in extra metering and communications equipment. For variable pricing to be implemented, besides the communications channels, a two-way metering device is required. An example of such a meter is the credit and load management unit (CALMU) developed by the South Eastern Electricity Board, England which has undergone more than a decade of successful field trial. Many other similar systems are being tested for reliability in conjunction with field evaluation of various load management schemes. The technology for implementing variable pricing continues to build up while simultaneously the cost is following a downward trend. These developments stimulate a great deal of recent interest in the subject.

Schweppe [18] envisaged the establishment of an "energy market place" in the future (year 2000 by his reckoning) whereby customers and utilities interact and cooperate in the buying and selling of electricity. 'Spot' price becomes the mechanism for the maintenance of equilibrium between supply and demand. Berrie [19], [20] was an early proponent of spot pricing in the United Kingdom and spread optimism of its eventual implementation. The development of the basic concepts and theories of spot pricing and initial studies of some of its implications and potential applications were undertaken at the Massachusetts Institute of Technology (MIT), U.S.A. [21].

5. Practical Variable Pricing Structures

The basic idea of variable pricing is to charge a price for electricity at any instant of time based on the SRMC of production at that instant. The price is thus variable over time and reflects the utility's extra cost of providing further required energy. Under variable pricing there are two components of price:

(i) the SRMC for a particular instant of time,
(ii) a premium component when there is a shortage of available capacity.

The success of a variable pricing strategy relies a great deal on positive customer response. Whatever the potential benefits, a pricing structure that is beyond the capability of the customer to respond to, is definitely not destined for success. Ideal pricing has always to compromise with the need for simplicity, although increasing technological availability as well as better customer awareness are helping to narrow down the extent of the compromise. A continuously variable electricity price is ideal but would not be practical for implementation because not only it incurs possibly the greatest expense in metering and communications equipment but also it is unlikely that consumers are able and willing to respond in the same dynamic manner that the price varies. Proponents of variable pricing [21] suggest the following different structures:

(a) Five-minute spot pricing - Price is updated every five minutes based on all available information about demand and generation availability.

(b) Twenty four-hour update variable pricing - Hourly variable prices for an advance 24-hour period are updated daily.

(c) Time-of-use pricing - A price pattern is updated at long intervals, perhaps as rarely as once a year.

The five-minute spot price is almost continuously variable so that the full benefits of variable pricing could be gained. However, owing to the relatively higher cost of metering and real-time communications equipment, it should be offered only to large industrial consumers.

The 24-hour update variable price patterns offers much flexibility with regard to daily changes in power system demand and generation status. Consumers under this type of pricing face the daily decision task of optimally scheduling their electricity consumption based on the price patterns offered by the utility.

Time-of use pricing is most practical because of its simplicity but lacks the required flexibility to deal with rapidly changing conditions of power system operation.

6. Potential Benefits Of Variable Pricing

Prescribed pricing, under which tariffs are set in advance, is ill-equipped to deal with uncertainties in power demand and plant availability. Load management schemes have to be instituted in order to have some control over demand. Variable pricing keeps demand in check by imposing a premium price component on top of the SRMC in anticipation of occurrences when the capacity of the utility to supply further required energy falls short. The price surcharge should persuade consumers to reduce loads. Customers with cogenerators may be encouraged to produce either to provide themselves with cheaper alternative supply of energy or possibly to gain from the high spot price by selling generation to the utility. The combined effect is a reduction in demand so that the system resources are not perilously stretched to the limits.

Consumers benefit from a reduction in electricity prices which should take place owing to the reduction or complete removal of plant margins, the elimination of wasteful spinning reserves, reduction in costly peak generation and rescheduling of loads to off-peak times thus increasing the use of low-cost plants.

Table 1 illustrates what might be saved by variable pricing for England and Wales [19]. The figure of approximately £ 1000 million per annum is simply too staggering for power utilities not to take serious note of variable pricing.

7. Conclusions

The basic concepts and practical forms of variable pricing have been presented. It represents another option for the power utility to strive for optimal allocation and efficient utilisation of resources. However, the ideal result will be achieved only if customers on variable pricing respond in the way that the utility intends. Thus there is an urgent need for the evaluation of customer response before variable pricing can be fully implemented. Much further work is also required to be done in studying the implications of variable pricing in the planning, operation and control of power systems.

Type of saving	Savings on plant margin (percentage points)	Amount of plants saved (MW)	Savings (£million per annum)
Saving in oil burn			600
Savings in planning plant margin due to eliminating provision for:			
1. Non-availability at winter peak	18	9,000	210
2. Demand being wrongly forecast	10	5,000	110
3. Both the above	28	14,000	320
Savings in operating plant margin due to eliminating provision for:			
1. Non availability at winter peak	16	8,000	180
2. Demand being wrongly forecast	5	2,500	50
3. Both the above	21	10,500	230
Remote meter reading and administration			200
Grand total			1,000 - 1,400

Saving in oil burn: Between 1973-74 and 1979 -80 the power station oil-burn in England and Wales fell from a 24 per cent share of fuel consumption to a 12 per cent share. Because of the high price of oil, all oil stations are well down on the merit order. Most, if not all, of oil-burn, which amounted to about £450m in 1979 price levels or about £600m in 1981 price levels, might be saved with interactive control.

Saving in planning plant margin: Any savings in planning margin would come in England and Wales from coal-fired plant. Interactive control could make savings in the planning plant margin. At 1980 price levels the Net Effective cost for coal-fired stations is £21/kW/annum, including associated transmission in 1980 price levels, say £23/kW/annum in 1981 price levels. Saving in operating plant margin, spinning spare, hot standby etc: Because short-term errors in forecasting are less than those in the long-term, the operating plant margin is not as large as the planning plant margin; say just over two-thirds of the latter.

Savings due to remote meter reading and administration: Such savings would be made in item like the (a) elimination of (i) meter readers for all services; (ii) meter testing departments; (iii) meter repair departments; (b) increased cash flow due to more frequent billing quicker payment of bills; (c) savings in bad debts and theft. A figure of £200m/annum for England and Wales would not seem unreasonable in 1981 price levels.

Table 1: *Possible savings under variable pricing*

8. References

[1] U.G. Knight, "Power Systems Engineering and Mathematics", Pergamon Press, 1972.

[2] L.D. Taylor, "The demand for electricity: a survey", The Bell Journal of Economics, Vol. 6, No. 1 (Spring 1975).

[3] "Glossary of terms related to load management", IEEE Trans. on PAS, Vol. 104, No. 9, Sept. 1985, pp. 2381-2392.

[4] "Spot pricing of electricity", Electrical Review, Vol. 208, No. 24, 26 June 1981.

[5] B.J. Cory, "Load management - a review", Symposium papers, Energy Sector Strategy And Management, London, March 1985.

[6] "Demand planning in the 1980's", IEEE Power Engineering Review, April 1985.

[7] J.R. Stitt, "Implementation of a large-scale direct load control system - some critical factors", IEEE Trans. on PAS, Vol. 104, No. 7, July 1985, pp. 1663-1669.

[8] H.S. Houthakker, "Some calculations of electricity consumption in Great Britain", Journal of the Royal Statistical Society (A), Vol. 114, Part III (1951), pp. 351-371.

[9] F.M. Fisher and C. Kaysen, "A study in econometrics: the demand for electricity in the United States", Amsterdam: North Holland Publishing Co., 1962.

[10] K.P. Anderson, "Residential demand for electricity: econometric estimates for California and the United States" The Rand Corporation (R-905-NSF), Jan. 1972.

[11] T.D. Mount, L.D. Chapman and T.J. Tyrrel, "Electricity demand in the United States: an econometric analysis", Oak Ridge national Laboratory (ORNL-NSF-49), Oak Ridge, Tenn., June 1973.

[12] D.F. Crawley, "Load management - physical systems", Symposium papers, Energy Sector Strategy And Management, London, March 1985.

[13] T.W. Berrie, "Power system economics", Peter Peregrinus Ltd. 1983.

[14] M. Munasinghe, "Energy policy and integrated pricing framework", Symposium papers, Energy Sector Strategy And Management, London, March 1985.

[15] S.V. Berg, "Innovatives electric rates", Lexington Books, 1983.

[16] R. Turvey and D. Anderson, "Electricity economics", John Hopkins University Press, 1977.

[17] G.F.K. Herrmann, "Marginal cost pricing of electricity", Electronics and Power, Oct. 1976, pp.682-685.

[18] F.C. Schweppe, "Power system 2000", IEEE Spectrum, July 1978.

[19] T.W. Berrie, "Interactive load control: part 1 - basic concepts indicate £1,000m plus savings", Electrical Review, 11th Sept. 1981.

[20] T.W. Berrie, "Interactive load control: part 2 - load pricing and investment", Electrical Review, 9th Oct. 1981.

[21] M.C. Caramanis, R.E. Bohn and F.C. Schweppe, "Optimal spot pricing: practice and theory", IEEE Trans. on PAS, Vol. 101, No. 9, Sept. 1982, pp. 3234-3245.