TARIFFS AND LOAD MANAGEMENT : THE FRENCH EXPERIENCE

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ABSTRACT

The aim of an electric public utility is the optimum control of the electrical energy generating and consumption system. Consistency is required between the means of control at level of supply and the means of control at level of demand. On the demand side, marginal cost pricing is an efficient tool to achieve a good management. This paper presents the french experience in this field.

INTRODUCTION

Load management can be dealt with by combining tariff incentives, physical controls, and marketing programs . It is a well known fact that marginal cost pricing has governed the tariff (and commercial) policy of ELECTRICITE DE FRANCE for almost 30 years. However, to increase the efficiency of the tariff signal, EDF has implemented tariffs based on marginal cost through various techniques of large scale load control, especially for Low Voltage (LV) customers.

The paper sketches out the main aspects of this experience and the recent developments and changes made to this load management policy with respect to the present french electricity supply-demand system.

I. THE EDF APPROACH

The constant adaptation between electricity supply and demand can be achieved in two ways : on the supply side, through the construction of additional facilities, and on the demand side, by implementing tariffs, load management schemes and a commercial policy. Changes in demand clearly imply changes in the supply system in terms of both installed capacity and of the operating conditions of the system, which need to be taken into account.

Like many other utilities, EDF has always considered that the problem was to control the total system to reach an overall optimum for the community as a whole, and to define the most appropriate tariffs and load management schemes by comparing costs (including implementation costs) and benefits for both the supplier -reflected by marginal generation and distribution costs- and the consumers.

According to economic theory, in order to contribute to the collective optimum, a public utility in a monopoly situation must follow the three pricing rules : meeting the demand, minimising its production costs, and selling at marginal cost. This last principle consists of informing the customer on the cost engendered in the supply system by changes in his electricity consumption pattern through the tariff. Therefore, by selecting the alternative which minimizes his cost, the customer will choose the least cost alternative for the community as a whole.

EDF's pioneering efforts for implementing tariffs based on marginal cost in the electricity sector are well known (see [1] and [2]). The favourable conditions of France have contributed to the success of this implementation. Institutionnaly, EDF has had the possibility to define its pricing policy with the approval and support of the French Regulatory Authorities. In addition, through tariffs based on long run marginal cost, EDF has been able to meet its financial requirements, and only minor financial adjustments have been necessary. Indeed EDF has always been characterised by a rather high rate of growth of electricity consumption (see [3] and [4]on this point of compatibility between marginal cost pricing and financial constraints).

Tariffs cannot reflect all the differences in costs, or the cost of all the various kinds of supply. Equalizations are therefore necessary to avoid excessive complexity of the tariffs and to limit metering and installation costs. The optimal complexity of a tariff will result in balancing higher costs of metering and implementation by the advantage for the community as a whole obtained by the change in the consumption pattern that a more precise and efficient tariff signal brings about. The electricity producer must consequently study the most important customers energy requirements for whom electrical solutions may be possible. On the basis of the overall cost for the community, when an electrical solution is competitive and has a large development potential, it is then appropriate to draw up a tariff which reflects its cost most accurately.

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EDF has adopted the method of analysing electricity uses for defining its marketing and pricing policy. This is an attempt for taking into account the long term price elasticity of the electricity demand. For instance, when it appeared in France, that hot water production by electricity using storage water heater was very competitive and less costly than other alternatives, EDF created an optional two periods time-of-day tariff for residential customers : normal hours and low-load hours ; 7 million customers have taken this option since 1965.

Another example is given by the many studies relating to direct space heating which have led to defining the optimum degree of insulation, and have made it possible to check that a two-part tariff system with one price for subscribed demand and one or two prices for energy could give an accurate indication of the cost of this application. EDF has been applying this kind of two-part tariff to every residential customer over the last two decades.

To limit metering and implementation costs, has been led extensively to propose optional ffs, instead of a single but more complex iff. All the options are incitative, i.e., they are designed for each customer to select the option which best reflects the cost of his supply. EDF considers the use of this method of optional tariff as the best approach for decentralizing the cost-benefit analysis of a more complex metering system. For instance, the demand charge in the LV low-load hours tariff is higher than for the basic tariff -in order to cover higher metering costs- so that the customer chooses this option if and only if the advantage of this system is greater than the additional metering cost.

The recent revision of EDF's tariffs aims at improving the efficiency of the control techniques of the French electrical system on the demand side and illustrates the application and the possible development of the principles laying the foundations of EDF's pricing and load management policies.

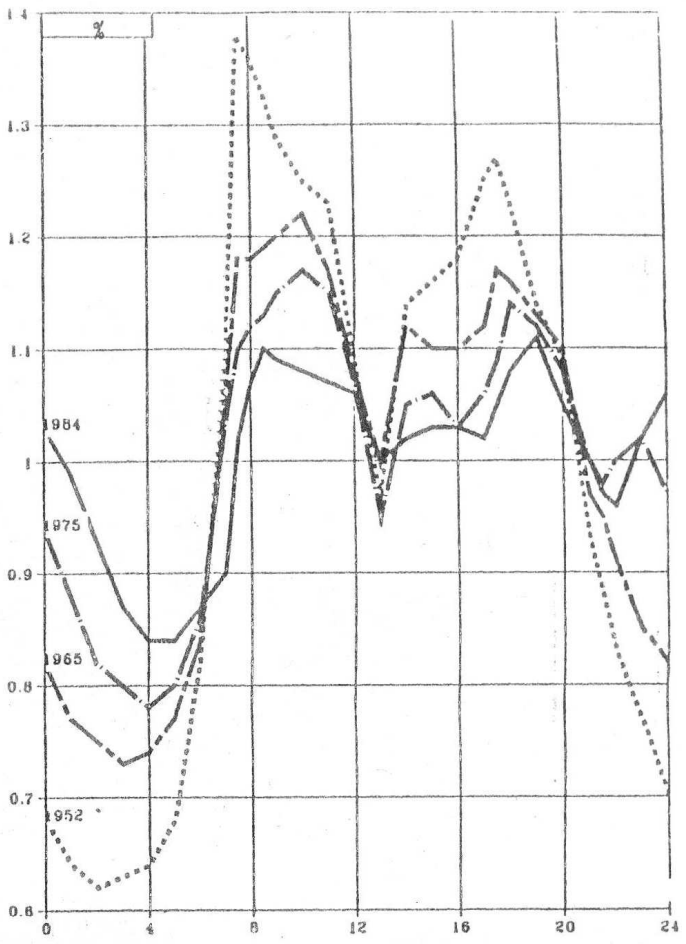
I. RECENT DEVELOPMENT IN THE FRENCH ELECTRICITY SUPPLY-DEMAND SYSTEM

The characteristics of modulation of tricity demand in France have changed co iderably over the last decades.

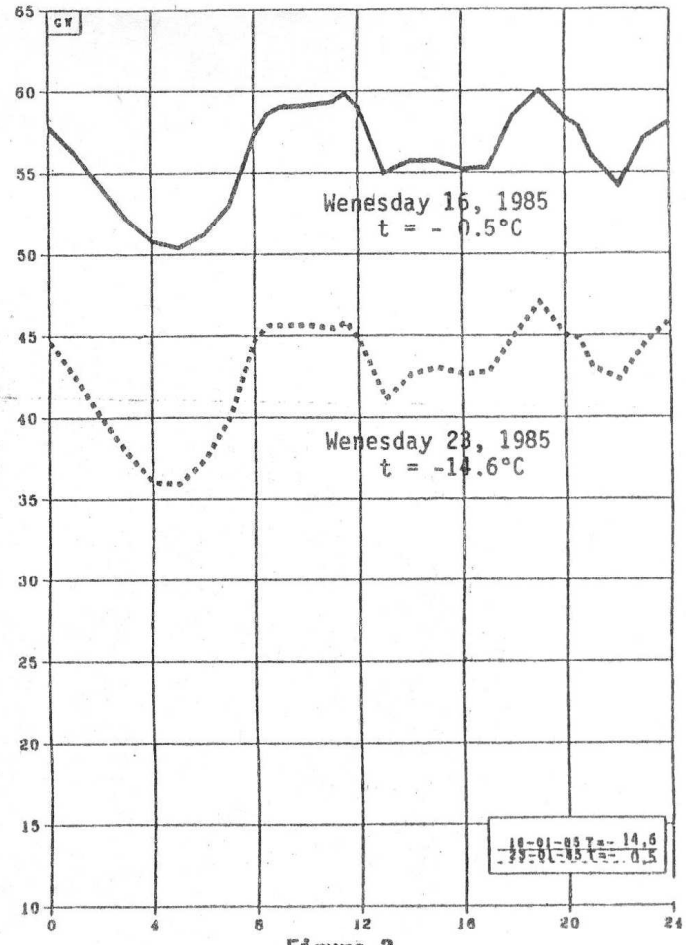
The daily load curve at system level has flattened out considerably, particularly under the effect of the tariff policy and the development of electricity uses (direct space heating and water storage heating) deriving from it. The daily load factor of the busiest day is now 90 % in comparison to 85 % ten years ago. Figure 1 indicates the past change in the profile of the daily load curve.

By contrast, changes in the working pace and the development of electrical heating have enhanced the seasonal aspect of the demand, which on a winter day is almost twice that of a summer day.

In addition, the sensitivity of the load to random conditions, particularly temperature, -which has less of an effect on the shape of the daily load curve than on its level- has increased to a considerable degree. Demand at low load hours (nigth-time) on a cold winter day is now greater than at the peak hours on a mild winter day (see figure 2) :



- Figure 1 -
Change in the profile of the daily load curve



- Figure 2 -
sensitivity of daily load curve to temperature

Whereas in the past, the periods of high demand were concentrated on a few hours per day but over a large number of days, they are now concentrated on a large number of hours on the same day, but just a few days during the winter at unpredictable dates.

As regards supply side, the economic advantages of nuclear derived electricity as a base or semi-base load has become quite clear over the last decade in France. The break even plant factor in terms of hours of plant use when substituting nuclear for coal is equivalent to less than 3000 hours. An other modification is the relative reduction in hydro electric storage facilities. The hydro-electric plants available to EDF, including pump storage facilities are appropriate for the regulation of the daily load curve so that the use of thermal facilities is almost constant for 15 to 18 hours of the busiest days, but are inadequate to transfer energy from a mild to a cold day. Specific peak thermal (oil-fired) units are required and operate for a very short period of time in a year. Table 1 lists the mix of plants of the French system :

	1985		1990	
	GW	TWh	GW	TWh
fuel oil + m	15	13	13	11
coal	14	79	12	16
hydro-electric	21	64	24	71
nuclear	37	213	57	302
Total	84	329	106	400

- Table 1 -
Mix of plants

The main consequence of these modifications, is a very substantial difference in marginal costs between low-load periods in which the marginal cost is equal to the fuel cost of nuclear power stations (these plants alone are then sufficient to meet demand) and periods in which peak units with a very high running cost must enter into service, as well as when meeting an additional demand requires the development of new equipment. The marginal cost may therefore vary by a ratio of 20 to 1 between two extreme situations.

Because of the change in the structure of the world energy market since 1973 and the economic advantage of nuclear electricity in France, and despite the marked widening of the range of marginal costs, electricity has had to play an increasingly substantial role on the french energy market and is rapidly replacing other more expensive energy sources in all sectors, using technologies which have already proven appropriate, as well as new technologies (bi-energy systems, thermal plasma, etc...)

Greater possibilities of load management emerge from the increasing recourse to electricity on the energy market.

IV. EDF'S TARIFF SYSTEM

III.1 High Voltage customers

The former green tariff, created in 1957 was applied to the 150 000 EDF customers connected at medium, high and very high voltage. 5 periods were taken with different prices : 3 periods per day in winter (October to March) and 2 in summer. The impact of this time-of-day tariff has often been described ([5], [6], [7]). As an illustration, the typology into 8 categories of load curves of all industrial High Voltage (HV) and Very High Voltage (VHV) customers in 1983, shown in figure 3, reveals two types of reactions to the tariff signal :

- some customers reduce their demand for two hours twice a day during the peak period. Many different industries respond to this signal, the most typical sectors of these categories are cement works with a reduction of about 170 MW (- 40 %) and iron and steel industries with a reduction of approximately 120 MW , by production rescheduling and capacity expansion.

- other customers take advantage of the lowest price level during low-load hours to increase their demand during this period (10 : 00 pm to 6 : 00 am). This response is mainly due to industries using combined generation or self-production except during low-load hours.

It should be recalled that this impact is not only due to the differentiation of the time of use of the energy price but also to the differentiation of the demand charge over to the same periods.

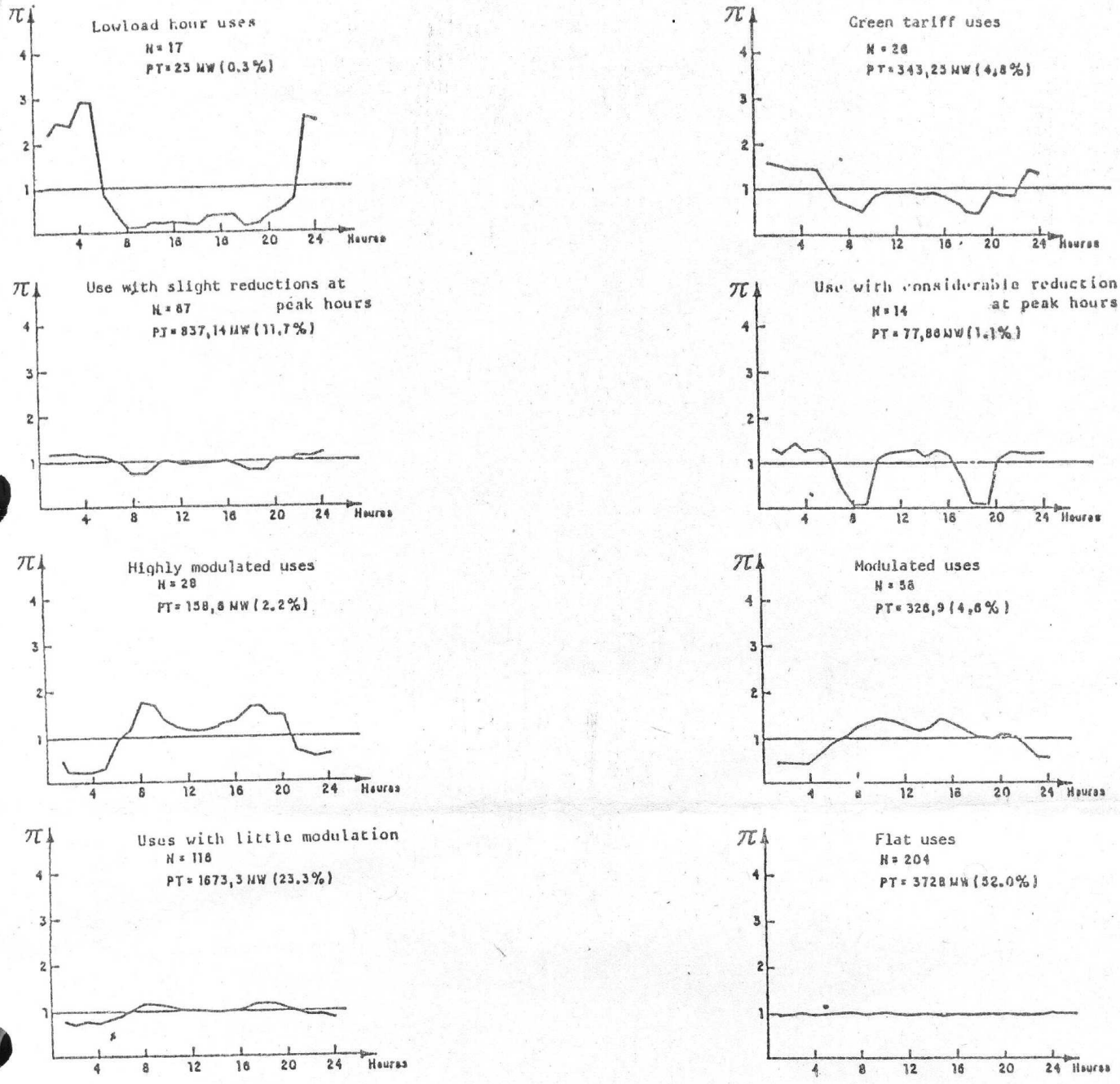
For these customers the aim of the revision of the tariff (see [8]) was to adapt the prices to the change in marginal costs and especially to reflect the increasing seasonality of the costs. In summer, prices are much lower, and the winter period now only covers 5 months. In addition, for the 500 largest customers (subscribed demand higher than roughly 10 MW) the tariff signal is more detailled and now offers [8] different price periods, distributed over the 4 seasons and according to the time-of-day.

In 1985, this revision has been completed and the customers'response regarding their seasonal consumption is already substantial : the 300 largest customers'subscribed demand during normal hours in summer is roughly 1 500 MW higher than the subscribed demand during normal winter hours which corresponds to a total of approximately 8 000 MW.

Customers respond by scheduling maintenance in winter, or by using the production capacity more in summer than in winter (iron alloys, chlorine or zinc electrolysis). But the main impact of the new seasonal price differentiation is to promote the substitution of electricity for fossil fuel in steam production in the summer, using bi-energy system. The fact that electricity is now cheaper in summer than fuel oil or gas even for steam production using an electric boiler is reflected in table 2 which presents the increase of electricity sales for bi-energy applications in the summer observed in 1984 and forecast for 1985 :

	1984 observed	1985 forecast
Electricity sales for summer in the bi-energy uses in the industrial sector	4.5 TWh/ year	5 TWh/year

-Table 2 -



for each category :
N = Number of customers
PT = Total demand MW

- Figure 3 -
Typology of all HV and VHV industrial customers (530) into 8 categories of shapes of the daily load curve

III.2 Low Voltage customers

Since 1965, the "Universal tariff", applied to Low Voltage (LV) customers, is a two-part tariff with a demand charge relating to the subscribed demand, which is scaled in 3 or 6 kVA steps. After selecting a level of subscribed demand, the customer is held to respect the contract which is controlled by a circuit-breaker. As indicated in table 3, this simple type of local controller is now very common in France.

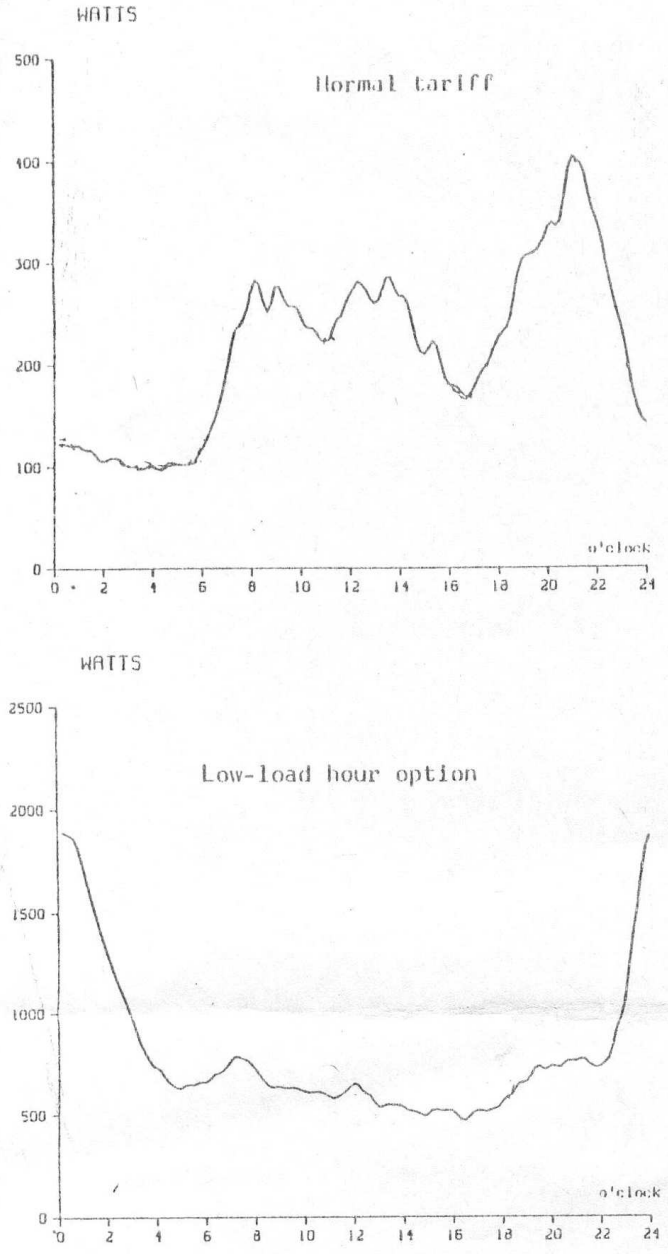
Total number of LV customers	25 000 000
LV customers with circuit-breaker	24 000 000

- Table 3 -

The universal tariff also offers a tariff by time-of-use with two period as an option : normal hours and low-load hours. This option is implemented with the help of a two-dial meter.

This optional time-of-day tariff -chosen by 7 000 000 customers today- has encouraged the use of water storage heaters which now correspond to approximately 12 000 MW of diversified demand under EDF control, and promote the development of around-the-clock uses of electricity such as direct electric heating, which, in the case of France, is an economical solution for substituting electricity for more expensive (and imported) fuels.

The customer's average daily load curves with and without the low-load hours options has been drawn up by taking a sample of approximately 1 000 customers in an extensive permanent load research program [9].



- Figure 4 -

Average load curve for the average LV customers

The success of this optional tariff explains the remarkable increase in the daily load factor of the total load curve for France (approximatly 90 % today).

Two different techniques have been used for implementing this time-of-day tariff : time-switches, or ripple control relays. These devices change the dial of the meter, and may also be used by the customer for controlling part of his load (often a water heater). Table 4 indicates the proportional use of the two techniques :

LV customers	25 000 000
Low-load hours option	7 000 000
with time-switches	3 700 000
with ripple control	3 300 000

- Table 4 -

No new time-switches are installed today, since more than 85 % of all LV customers supplied by EDF may now be under ripple control, the reliability and cost-effectiveness ratio of the 175 Hz ripple control system is better. This is the effect of the economies of scale : 400 000 new relays are installed per year in France.

The current tariff revision does not change the main lines of the LV tariff structure. A new tariff has been created for customers whose subscribed demand exceeds 36 kVA. This new "Yellow Tariff" offers 4 price periods : winter and summer, normal and low-load hours. For the smaller customers, prices have been adjusted to the new conditions of marginal costs, and the definition of low-load hours has been made more flexible. Because of the success of this optional tariff, differences in marginal costs within the day are now smaller ; further, it is essential to prevent the development of electricity uses during low-load hours from causing a local peak on the distribution network, so that the benefit at generation level is offset by a higher cost of strengthening the network . The differentiation of tariff periods by category of customer solves the problem. There are still 8 low-load hours per days for low voltage consumers, but the timing may vary from one customer to the next, and may not necessarily be continuous. For instance there may be two hours in the middle of the day and 6 hours in the night. This diversity in timing amongst the customers is now substantial with the increasing adequacy of the ripple control system : by super-imposing a second frequency of 188 Hz, the system will offer 900 different additional commands in comparison to the 40 commands of the 175 Hz system.

The low-load hours option is a good example of the use of a time-of-day tariff as an effective load management scheme. And the creation of the "peak day withdrawal option" illustrates the possible extension of this approach.

IV. The peak day withdrawal option

This new optional tariff has been introduced to reflect the evolving nature of the time of the peak. As indicated above, the peak period now covers a large number of hours per day distributed over a small number of days of the year. However the date of these peak days is unpredictable. This new phenomenon calls for a specific response.

The peak day withdrawal option -offered to small as well as large customers- includes a flexible peak period, consisting of twenty two 18 hour days which EDF chooses in real time. Their choice allows them to select periods in which, with a high degree of probability, the load is such that specific peak production units have to be installed and commissioned. The energy prices vary much more widely than in the standard tariffs. For Low Voltage tariffs, table 5 shows that the price of energy may vary from the ordinary period to the peak day period by a ratio of 10 to 1.

	Demand charge F/year	Energy cF/kWh	
Standard tariff	1148.40		50.70
Low-load hours option	1583.04	Normal hours : Low load hours :	50.70 29.00
Peak day withdrawal option	694.80	Peak days : Off peak :	295.00 32.45

- Table 5 -

The different options offered to a customer subscribing 12 kVA (effective july 1985)

The signal is given with very short notice (half an hour) to the LV customer using the ripple control system .

For the green tariff applied to large supplies, the differences in prices are even more acute. For HV and VHV customers, the signal is given through the switched network (they are also informed by phone the day before).

The peak day withdrawal tariffs are particularly suitable for reflecting the cost of electricity supplies for bi-energy systems, and give the customer enough information to operate his equipment in the most economical way. These tariffs are a strong incentive for the installation of a heat pump or an electric boiler combined with an oil boiler as a back up system. In this way EDF expects a large substitution of electricity for fossil fuels on the market for space heating appliances.

This tariff is also interesting for a large number of industrial sectors : for example arc furnaces and zinc or chlorine electrolysis can withstand a partial or total shutdown during the peak days. The use of self-generation is also another means of response to this tariff signal.

In 1985, after four years of different experiments, these options are offered to all categories of customers. The impact of these options at the beginning of 1985 is indicated in Table 6 ; results are encouraging, considering the short period of application : less than a year for LV customers, and two years for MV and HV customers.

	LV customers	HV customers
Number of customers	24 000	72
Reduction in diversified peak demand	80 MW	800 MW
% of total system peak (59 987 MW 16.1.85)	- 1.5 %	

- Table 6 -

The reduction in peak demand is expected to increase to 5 000 MW in 1995, which will represent approximatly 6 % of peak-demand of the system.

V. THE "MODULATABLE" OPTION

In low-load periods, electricity is generated at particular low cost, especially when nuclear capacities are only partly used. However, a strict definition of tariff periods does not represent accurately this type of phenomenon, since prices are necessarily the mathematical expectation of costs which are largely of random character, particularly with respect to the availability of equipment or the level of demand.

The modulatable tariff is presently experimented by HV and VHV customers. This tariff is proposed as an option and is based on the same principle as the peak day withdrawal option. This option offers 4 tariff periods of fixed duration but with a flexible timing defined in real time by EDF. The different periods are :

- The peak day period : 22 18-hour days, with the same definition and prices as for the peak day withdrawal option,
- the flexible winter : 9 weeks (except the possible peak days) during which the marginal cost of generation corresponds to the fuel cost of the most expensive units but with almost no capacity cost,
- the flexible intermediate season : 19 weeks (except the possible peak days) ; marginal cost are mainly fuel cost of coal-fired stations,
- the flexible low-load season : the remaining 24 weeks in which it is highly probable that the marginal cost is limited to the nuclear fuel cost.

Table 7 presents the standard tariff and the modulatable option for customers whose power exceeds 10 MW, and indicates that with the latter option, prices are more differentiated and closer to the variations of marginal costs according to the state of nature.

1 - Standard tariff

Demand charge (F/kW/year)	251.16
Energy charge (cF/kWh)	
Winter :	
peak hours :	92.93
normal hours :	65.44
low load hours :	43.81
Intermediate season	
normal hours :	32.65
low-load hours :	24.28
Summer	
normal hours :	14.79
low-load hours :	9.63
July-August :	7.12

2 - "Modulatable" tariff

Demand charge (F/kW/year)	251.16
Energy charge (cF/kWh)	
Peak day :	196.88
Flexible winter :	46.80
Flexible intermediate season :	17.73
July-August :	8.29

- Table 7 -

Standard tariff and modulatable option for HV customer whose power exceeds 10 MW, and with an average load factor (general variant)

This modulatable tariff can be considered as a major step toward an effective implementation of "spot pricing", but the advantage is that the customer is aware of the specific duration of the price period, even if dates are random.

This tariff is very effective for bi-energy systems. Table 8 indicates the additional sales of electricity expected for 1985 associated with new bi-energy systems purchased by HV or VHV customers, on the grounds of the tariffs.

	Consumption per year
Summer bi-energy (Standard tariff)	2.3 TWh
Modulatable bi-energy (experimental option)	2.7 TWh
Total	5.0 TWh

- Table 8 -

Additional sales of electricity for 1985 with new bi-energy systems

After one year of testing, the results point clearly to the fact that this modulatable option really improves the tariff system.

CONCLUSION

Like the peak day withdrawal option, the modulatable option is a good illustration of the consistency of the marginal cost tariff system with a load management policy.

Some are proposing to confront load management techniques with marginal cost tariff systems to determine which system yields the best economic efficiency. In fact, as shown by the example of the peak day withdrawal option, this confrontation is not valid, since it is possible to define tariffs which can show the marginal cost of specific supplies which these techniques will be able to offer the customers. This correct indication of prices is vital, since this is the factor allowing for consistency between the means of control at the level of supply and the means of control at the level of demand, or in other words, decentralisation of an optimum which it is pointless to seek by any other method.

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