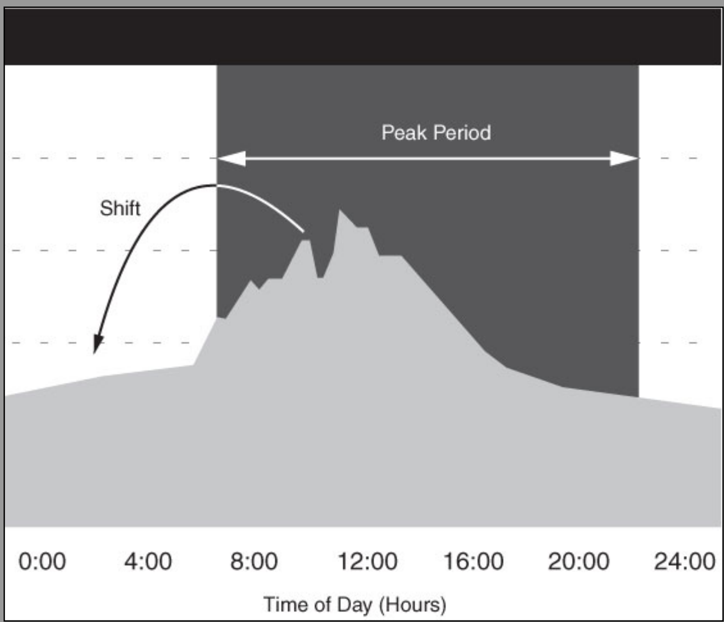
Electric Load Management in Industry

Leonardo ENERGY



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Energy Efficiency

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THIS BROCHURE IS AN INTERNATIONAL UIE REPORT

WHAT IS UIE?

Stemming from the International Union for Electroheat, the abbreviation of which has been retained, the UIE enlarged its scope in 1994 to cover all issues related to the promotion and development of electricity applications. Its efforts are focused on studying electrical technologies and their applications, communicating the relevant information and liaising with the organisations concerned with the subject.

Most UIE Members are represented by a National Committee but in countries without National Committees, the UIE is open to individual or corporate Members. Member countries include: Argentina, Austria, Belgium, Brazil, Canada, Czech Republic, Finland, France, Germany, Italy, Japan, Netherlands, New Zealand, Poland, Portugal, Rumania, Spain, Sweden, Switzerland, United Kingdom and the United States.

The UIE Presidents are elected in rotation; traditionally, the job is taken over by a person from the country hosting the forthcoming quadrennial Congress. The representatives of the National Committees get together in a Directing Committee, which defines the policy and strategy of the Union. In particular, the Committee manages three study organs :

- The "Techniques and Applications" Committee is the Union's technical Committee; it organises the choice of working topics and monitors the technical work.
- The "Education and Research" Committee manages training and communication actions aimed at teachers and students.
- The "Information and Communication" Committee organises the Union's exchange of information and communication, with special emphasis on the quadrennial Congresses.

WORKING GROUPS

The choice of working topics is made by using an original method. The field of investigation is selected and adapted following a quadrennial enquiry with the National Committees. The proposals are assessed according to the criteria of usefulness and feasibility:

- Usefulness is measured on the basis of the topicality and sustainability of the issue, the number of "taker" countries and the nature of the project (the need to "let know" is better valorised than a technical watch or a synthesis);
- Feasibility is measured on the basis of the availability of ad-hoc experts, the state of development (research, development, industrialisation) and the investment the members are willing to put in.

The topics studied by the UIE Working Groups and the 14 technical themes selected for discussion at the Birmingham Congress result mostly from the enquiry conducted in 1992 to outline the field of investigations for the period 1992-1996. For example, the "Techniques and Applications" Committee set up six Working Groups in 1993, which produced reports on:

- Waste Treatment and Clean Processes
- Electric Load Management in Industry
- Guide to Quality of Electrical Supply for Industrial Installations
- Electricity in the Food and Drinks Industry
- Energy Savings in Buildings by Efficient Use of Electricity
- Energy Savings in Industry by Efficient Use of Electricity.

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Foreword

Energy is a fundamental possession, essential to the functioning of our economies. Even though the European Union's energy dependency has decreased, energy is still a rare commodity.

The energy policy plays a determining role in attaining goals of competitiveness, security of supplies, and environmental protection. It is an essential element in the economic and social cohesion of the Community's interior market.

The choice of the type of energy to use for a given application is relatively limited (there are what are called "captive uses": electricity for lighting or motor power, gasoline for automobile transport, etc.) and often depends on a given country's resources. That is why actions that promote better use of each type of energy remain most effective in increasing "economic efficiency", guided by the principle of using energy at the most appropriate times.

Where electrical energy is concerned, it is important to reach consumers and in particular smaller industries and businesses to inform them and help them make intelligent and constructive use of their "load curve". This is one of the keys to productivity gains.

This report's outline of the specificities of electrical energy use shows that investments and production costs are directly dependent on simultaneity of needs. Thus a regular curve at the national or local level, one whose direct or indirect costs are reflected in rates, is essential for the consumer.

The authors show that today, industrial users have the technical means to regulate and manage their electrical needs at a reasonable cost. This is a natural consequence of automated management of industrial production.

Finally, the most interesting aspect of this study, in our opinion, is that it gives a variety of examples both of industries concerned and of nations they are based in. This is how the UIE's international specialists want to go about convincing us: pragmatically. We should be grateful to them for doing so.

Fabrizio CACCIA DOMINIONI

Director for the Directorate XVII IC:

Industries and markets II

Non-fossil energy

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Chapter 1 - Overview of Load Management

In all industrial sectors, the continuous struggle for increasing competitiveness calls for the ongoing improvement of the quality/cost ratio of the products offered to the market. This involves, among other factors, very close supervision of the production costs. However, factory managers often pay little attention to energy costs in general, and electricity costs in particular, either because of their relatively minor impact on total costs, or because they are simply regarded as "non-manageable", unless some loss of flexibility is accepted.

Closer examination of how these costs arise shows that it can be possible to take advantage of incentives and favourable pricing offered by utilities in order to encourage consumers to use energy in such a way and at such times that it enables the utility to manage load patterns. By making the best use of these incentives, it is possible to achieve significant savings in production costs, with no adverse effect on product quality or productivity.

1.1. Electricity, the Special Product

Electricity is a public good, which is available at any time, in almost every place and is used for a very broad range of applications.

As electricity cannot be economically stored on a large scale, it has to be produced at the same moment and in the same quantity that is actually requested and has to be transmitted instantaneously from the power generator to the user via transmission lines. Because of these special features, the electricity supply system has to be designed for the maximum expected demand.

Moreover, depending on the generating plants in operation at the various times of the day and season, the efficiency of the production and the cost of the fuel burnt in the thermal plants may change significantly. Therefore, unlike other industrial branches where "inventory policies" are possible and the facilities are sized and operated according to the average demand, in the case of electricity, it is the maximum demand that is the main driver of fixed operating costs, while the time of consumption impacts on the variable costs.

On the other hand, the demand of electricity is defined as a derived demand: consumers do not use electricity "per se", but require the energy services made available by it. This means that if it is possible to modify timing and the amount of the electricity consumed, and still provide the same useful effect (i.e: equal comfort and productivity), the value to the customer of the energy service itself remains unchanged and, in most cases, users do not notice the difference.

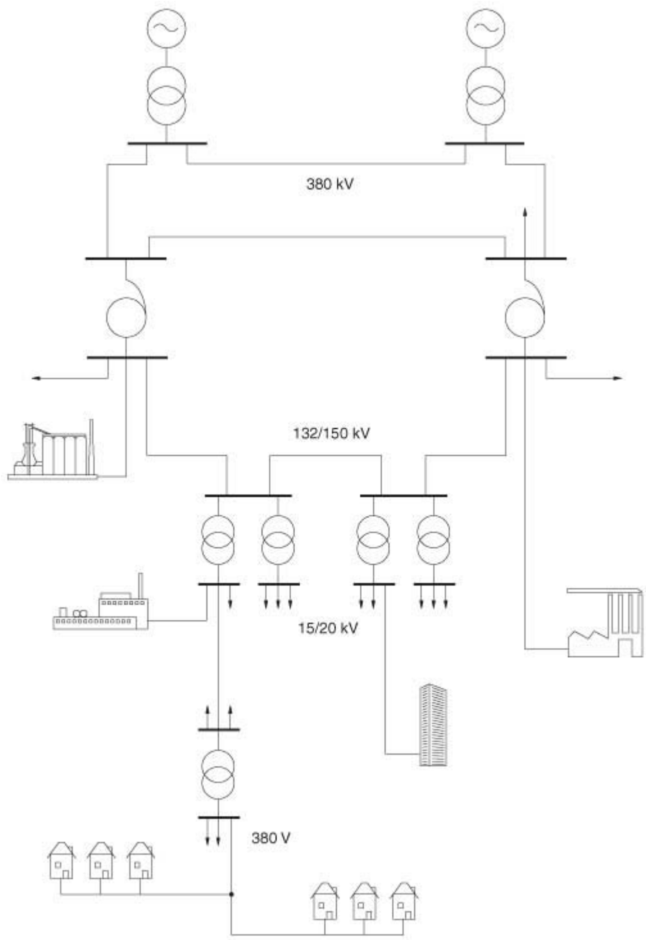

Figure 1.1 - Electricity supply system: production, transportation and distribution to customers

Based on this principle, Demand Side Management techniques have been developed by utilities to influence the electricity demand and increase the utilisation and operating efficiency of existing supply facilities, thus delaying the need for new capacity and reducing the operating costs.

Electric Load Management is a specific method of controlling the peak load in the network in order to produce a constant demand. It represents an important measure in the set of options used in the Demand Side Management (DSM) framework (see Appendix A.2 for additional details).

1.2. Electric Load Management

Electric Load Management, from now on simply called Load Management (LM), can be defined as any action taken by the customer and/or the electricity supplier to change the load profile in order to gain from reduced total system peak load, increased load factor and improved utilisation of valuable resources like fuels or generation, transmission and distribution capacity.

Load management initiatives are usually instigated by the utilities' need to smooth the system load curve (see example in Figure 1.2) and, in this way, delay (or avoid) the installation of extra capacity. Typically, customers are made aware of this need either by means of a general price signal (e.g. time-of-use rates), or through the offer of specific agreements with selected users who agree, in exchange for a bill discount or other financial incentives, to reduce the load at short notice from the utility.

In some cases, the utility can exert direct control over the customer's loads, that is the agreement entitles the dispatching centre to remotely switch on and off electrical equipment according to the network and generation requirements, thus using load management for a spinning reserve service. Whatever is the trigger chosen by the utility, electricity users are stimulated to lower demand in periods of critical supply, and increase it when cheap and abundant capacity is available. Successful load management allows all participants - customers and utility to benefit from the efficient use of the network and generation without adversely affecting the energy service.

The set of options available for load management in industry includes process rescheduling, machinery interruption/restart cycles, thermal energy storage, use of backup generation, automation, etc. As it will be better explained later, the choice of every option is to be weighed against the rate system or financial agreement in effect and the technological constraints posed by the production process.

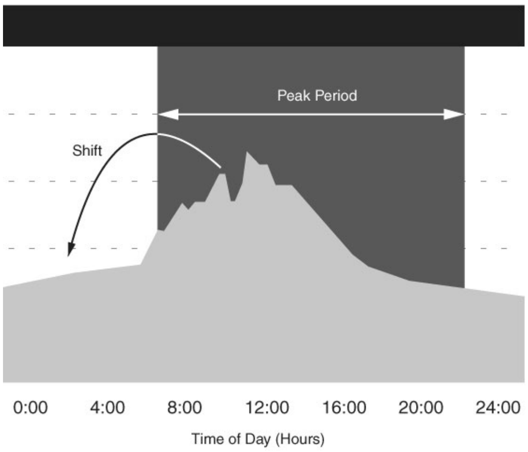

Figure 1.2 - Peak shifting

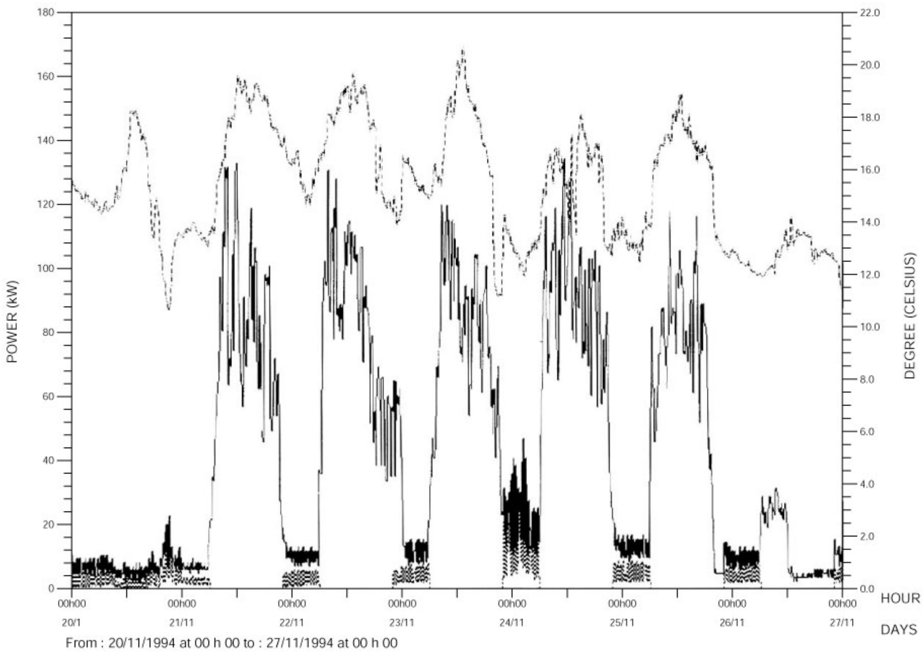

Figure 1.3 Example of a load curve recorded in a printing company
Upper curve: Outside temperature
Middle curve: Electricity consumed by the workshop
Lower curve: Electricity consumed for space heating

For example, process rescheduling is almost impossible with direct load control measures when the control periods come at random time, while it performs well with time-of-use rates; the interruption practice is effective with any form of financial incentive. However, care should be taken to avoid too frequent shutdown/start-up cycles of motors.

Besides the technical analysis, load management measures have to pass an end cost/benefit test, where it is crucial that the rate system and/or of the mechanism of the various agreements made with the utility are clearly understood. In this perspective, the assistance of utility marketing departments can provide useful support.

1.3. Presentation of this Brochure

The aim of this brochure is to give the readers an overview on how Load Management can be best implemented by industrial electricity users, where necessary with the help of the consultancy services and expertise provided by the electricity utility.

Large industries usually have sufficient expertise on load management in-house. Small and medium size companies often lack the necessary technical skills and information. For this reason, the content of this brochure is specially focused on typical applications in the small and medium sectors of industry. However, the brochure will also be of interest to utility marketing and distribution personnel, energy consultants and process and equipment manufacturers.

Given the primary target, there is a general concern about keeping the content as simple as possible, thus avoiding too many technical details. However, some advanced load management systems, tariffs and services are dealt with.

The brochure is divided into eight parts.

The **first chapter** deals with the special features of electricity and describes some basic concepts of Electric Load Management.

In **Chapter 2**, the main factors influencing the cost of the electrical energy are explained.

Chapter 3 points out the importance of load management for the efficient use of the electrical generation, transmission and distribution system. The impact of load management on the electricity system and the advantages that can result for the customer are also discussed.

The interaction between the customer and the utility is stressed in **Chapter 4**, in a marketing approach.

Chapter 5 explains how the different industrial processes affect the load in the electrical network. It also explains what organisational and technical measures can be undertaken to control the load. Some examples of load management in selected industries are also presented.

Chapter 6 deals with case studies, a collection of actual examples of implementation of load management techniques at several industrial facilities across the countries represented in the working group. Each example is explained in terms of cost, benefits, implementation and reaction of those concerned.

The brochure ends with **Conclusions** and with **Appendices** containing details of the rate structures in the countries involved, and other points related to load management.

In writing this brochure, the authors have intentionally focused on the general conditions that make electric load management a viable practice in industrial facilities. Less time is devoted to specific equipment, devices and installations, that may become obsolete in time and may not be readily available everywhere. Up-to-date information of this nature can usually be obtained from local manufacturers, producers and distributors.

Chapter 2 - Cost and Price of Electricity

2.1 The Cost of Electricity Supply

The total cost of supplying electric energy is made up of the cost of producing, transporting, distributing and delivering electricity to customers. These charges include in particular: salaries, cost of the fuels, maintenance, depreciation, capital costs, taxes and return on equity.

The above cost items can be classified into three categories:

1. Costs independent of the energy and power required. These costs usually include the customer's supply connection and administration (connection to the grid, meter reading, billing, technical assistance, etc.)
2. Costs related to the customer's power demand as a consequence of the required investments and work force (depreciation, interests, salaries, maintenance, etc,)
3. Costs that depend on the amount of energy supplied (fuel, maintenance, etc.).

Based on this classification, the total annual cost of electricity supply can be represented by the following expression:

Ct = a + bP + cE

where **P** is the maximum power demand, **E** the annual energy supply, and **a, b,** and **c** are cost coefficients. This formula is a good approximation of the actual structure of the costs and is very useful in understanding the following analysis of the factors influencing the costs themselves.

First of all, it must be considered that the electricity industry is characterised by a number of peculiarities that are not usually found in any other industry. These factors constrain the operation of the utilities and significantly affect the supply costs. Factors involved include:

1. the impossibility to defer the supply with respect to demand
2. the impossibility to economically store the product on a large scale, and to implement "inventory policies"
3. the need to allow for a suitable reserve margin, in order to cope with unexpected losses of capacity or increases in demand
4. very capital intensive facilities, with long construction times and operation lives.

In particular, points 1. and 2. mean that at every instant, the production must exactly equal the demand, and therefore the power system has to be planned according to the maximum expected demand. In most industries, production facilities are usually dimensioned with respect to the average demand, as it is possible to face irregularities in demand by resorting to the inventory store.

Additionally, the reserve margin (item 3.) requires an increase of the sizing power over the maximum demand. In Figure 2.1, given the same seasonal trend in demand, the different criteria are shown for planning the production capacity both in an electric utility and in an industrial enterprise.

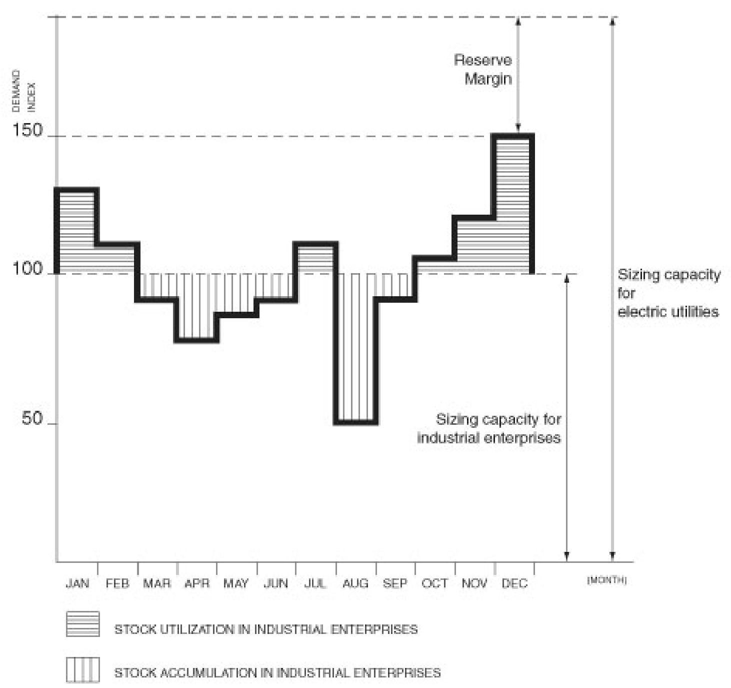

Figure 2.1 - Different sizing capacities in an electric utility and an industrial company, given the same seasonal trend of demand.

If one relates the requirement in sizing capacity to the unit capital cost of electric plants (rather expensive by their nature, see item 4.), it is possible to have a clear idea of the impact of the peak load on the investments of a utility and thus on the supply costs[1]. To be able to meet continuously changing demands, generation systems are usually composed by power stations with different dynamic performances. Three broad categories of generation units can be defined:

- **Base load plants**, such as nuclear, run-of-river hydro and large fossil fuel fired thermal plants. These units have low marginal costs and high energy efficiencies, but do not have the flexibility needed to follow fast changes in demand. For this reason, they are normally operated at a fixed level of output close to their rated maximum.
- **Intermediate plants**, such as hydro and more flexible thermal plants that are used for regulated production. Their level of output can vary inside specified technical limits.
- **Peak load plants**, such as gas turbines, turbo jets and daily hydro storage (with or without pumping). These sites are able to rapidly change their production level, but for various reasons (limited available energy for the hydro, and high marginal cost for gas turbines), they have to be operated for limited periods.

Figure 2.2 provides an example of a typical 24-hour electric system load profile with the field of action of the different generation units. It should be noted that the production schedule of the generators is (roughly speaking) optimised when the units are sequentially loaded according to increasing marginal costs. This means that during peak time, almost all of the available power stations will be running (including the less efficient ones), while at off-peak time, just the plants with the lowest marginal costs will be in service. The result is a cost of the energy produced (essentially fuel cost, for systems where thermal plants predominate) that is higher during peak time than at off-peak hours.

As an example, Figure 2.3 shows per-unit marginal costs on a typical working day.

Through load management, it is possible to flatten the load curve by limiting the consumption during peak time. This allows the postponement of the need for additional capacity, while at the same time increasing the operating efficiency of the energy system. The reduction in supply costs that results has positive impacts on tariff levels and therefore, on customers' accounts.

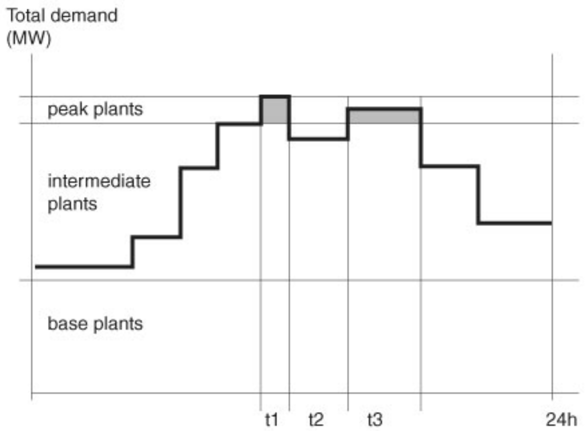

Figure 2.2 - Typical 24-hour electric system load profile

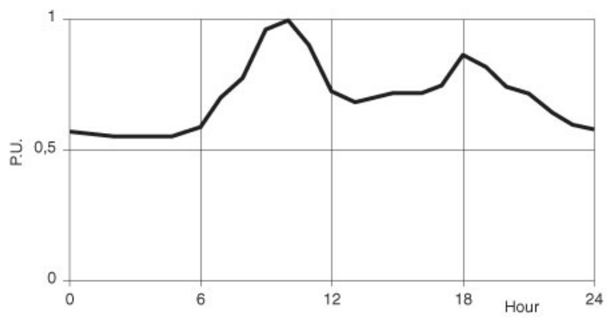

Figure 2.3 - Marginal fuel costs on a winter working day

[1] Electricity costs are also influenced by the location of supply and by the voltage level at which it is delivered. Particular locations may require the use of very long distribution lines (in rural areas, for example) or of submarine cables (for the electrification of small islands close to the mainland) that involve investment costs well above the average. Similarly, costs are also sensitive to the voltage level: the lower the voltage is the higher the distribution investments and Joule losses suffered by the utility are.

2.2 Electricity Rates

The basic philosophy that guides the rate-making process is a constant effort to link, as closely as possible, the price of the electric service to the costs incurred by the utility to deliver it. Therefore, it is essential that the structure of rates approaches the structure of costs, and that every price component reflects its original cost.

With a few exceptions, tariff systems are based on **binomial** rates, with a unit demand charge related to the maximum power demand (either contractual/subscribed demand or metered peak demand) and a unit energy component that is linked to the kWhs consumed. In systems where thermal generation is relevant, the energy price includes a term, named fuel cost adjustment, that is linked to the cost of the fuel, and is exposed to the variations of the international price of oil and coal.

Sometimes the demand charge is split into two components, one allowing the utility to recover the capacity cost of the local network, and the other one expressing the unit capacity cost of the rest of the system. Typically, the first component is linked to the customer's peak, whenever it arises, while the second one is connected to the customer's demand at the time of the system peak.

Moreover, at the time of application for the supply, the new customer is often required to pay a one off charge related to the cost incurred by the utility for the electrical connection to the grid.

Usually industrial customers are billed according to **time-of-use** rates. This means that the cost of the energy consumed depends on the hour of the day and the season[2]. According to the "cost theory" introduced in the previous section, kW and kWh prices are higher during peak time and lower at off-peak, so that customers are provided with "price signals" that stimulate them to modulate their consumption in order to minimise the cost of the service, thus minimising the money they pay for it.

In fact, if a customer can organise his activity in such a way so as to keep the consumption low during peak time, he contributes to defer investments and to improve the efficiency of the supply system, thus benefiting himself from reduced costs. In this way, the Utility and its customers can be considered partners working together to achieve the maximum benefit from electric usage at minimum cost. The typical customer reaction to these price signals involves not only peak shaving, but also encourages load shifting from peak to off-peak time, sometimes producing load profiles peaking at night.

These rates can be considered an approximation of marginal-cost-based rates, as they represent just an "estimate" of the true cost of the service. In fact, as the price levels and the periods of variation are determined long before they are actually used to bill the customer, they cannot reflect critical conditions for the system on a particular day and at a particular time. Outages in the generation, transmission, and distribution equipment, unforeseen changes in the generation mix, and unexpected demand variations, all mean there is no guarantee that customers receive correct information about the current costs associated with marginal consumption and concentrate the demand in periods of abundant supply, avoiding additional consumption when the electric system is getting overloaded.

According to the **marginal** cost theory instead, rates are determined little in advance (here comes the alternate definition of spot prices) and based on the actual variation, both in capital and operation costs, involved by each additional unit of electricity demanded. The cost adjustment mechanisms developed under spot pricing incorporates the causal link between the load growth and planned future investments (long-term, or capacity component): when demand approaches the system capacity limits, this automatically triggers a sharp increase in price, thus providing a strong incentive for customers to wisely modulate their load curve in order to effectively improve the operation efficiency of the utility's assets. Although preferable, from the point of view of the economic efficiency (at critical times, only the most valuable end-uses will compete for limited supply resources), the diffusion of tariffs based on actual marginal costs, where the price varies every few minutes according to supply conditions, has long been inhibited by the complexity of the telecommunication, metering, and control systems required.

On the utility side, the administration costs for updating spot prices, communicating them to customers, and metering consumption are higher than under current pricing. On the customers' side, energy management computers are needed to control and schedule processes using spot price forecasts and information on machinery energy requirements.

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[2] For their simple implementation, in some countries, "flat" rates are still used for the smallest customers, with supply at low/medium voltage and a maximum demand up to a few hundred kWs, depending on the tariff system. These rates are based on average costs and, as the name implies, the unit price of both demand and energy is constant and not subject to variations according to the time of consumption.

Sometimes, for supply with a subscribed demand of the order of a few tens kWs, the metering equipment includes a demand limiter that switches the supply off when the load exceeds the subscribed power. Alternatively, for higher demands or where the customers are charged for the actual demand, a kW-recording equipment is installed. In this case, if there is any violation of the contractual limit, the excess demand is charged at an overprice, without interrupting the supply.

Today, technology progress in microelectronics has however considerably reduced these costs and further reductions are expected in future. In this context, industrial energy users who know how to respond to fast varying energy costs and have flexibility in relocating their electricity consumption will gain the biggest benefits.

Presently, this innovative concept is still in the initial phase of development and experiments are under way in several countries. However, an important move towards its full deployment is represented, for example, by the pricing mechanisms in effect in the UK and Norway, where daily prices on a 1/2-hour schedule are set the day ahead.

It is also important to mention the contracts with an **interruption clause**. This type of contract is historically associated with very big industrial customers (with a demand of the order of some MWs), but today, they are being implemented for smaller and smaller customers. With interruptible rates, the subscriber agrees, upon request of the system dispatcher and in exchange for a favourable rate structure, to reduce his load in terms of a fixed level of demand, or to a pre-specified level of demand.

In some cases, the utility is given direct control on customers' loads, that is to turn off customer appliances when the system capacity limit is approaching. The contract is regulated by a series of terms of reference (minimum warning time, maximum duration of the reduction/interruption of load, maximum number of requests, etc.) that vary from case to case[3].

When the value of the power factor drops below a minimum level (generally 0.9), the network has to supply more electricity than what is actually converted into useful power; for this reason, a charge for reactive energy is also to be paid. This is an incentive to install correctly sized capacitors, in order to minimise the reactive energy requirements.

Finally, in almost all countries, customers are also required to pay taxes on their electricity consumption. The reasons are usually due to the governments' wish to limit energy consumption, because of its environmental impact.

Tariff Parameters

The allocation of the cost of the service among different categories of customers may depend on specific parameters that characterise the consumption. Not all of such parameters are actually taken into account in the various rate systems. For industrial customers, the most common ones are the voltage level and the utilisation factor[4].

The Voltage Level

Depending on the value of the customer's demand, the delivery of the energy can be made at low, medium, or high voltage. The rate is inversely correlated to the voltage level, as the higher is the voltage, the lower are the utility's investments and Joule losses, but of course the customer has to sustain the transformation and distribution costs beyond the delivery points[5].

The Utilisation Factor

The utilisation factor corresponds to the degree of exploitation of the power demand made available to the customer and is usually represented either by a dimensionless quantity or by a number of hours per year. In the first case, it is evaluated as the ratio between the actual energy consumption and the potential consumption obtained by multiplying the available capacity by the number of hours of the year (8760). In the second case, it equals the ratio between the energy consumption and the subscribed demand/or metered demand depending on the rate system). For a given energy consumption, the higher the utilisation factor of a customer, the more efficient is the sizing capacity of the supply system, at the same time the higher the probability of the customer's participation to the system peak. The cost of energy and demand charges vary inversely with the utilisation factor, i.e. the higher the utilisation factor, the higher is the cost of the power and the cheaper the energy.

Overview of Electricity Rates Across Countries

This section is situated in Appendix A.1.

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[3] It should be noted however that in some countries, the present over-capacity situation of several utilities is leading to a revision of the contracts with interruptible loads.

[4] A third parameter, seldom taken in account, is the contribution to the system peak, that allows to differentiate the price of electricity according to the customer class.

[5] It is worth noting that at high voltage the quality of supply is better than at medium and low voltage.

Chapter 3 - Importance of Load Management

3.1 Impact of Load Management on the Total Electricity System

In the previous chapter, the cost and price of electricity was considered. Now that we know what factors contribute to the cost and how the selling price is arrived at, it is time to consider how effective load management can reduce costs and therefore price, and what this means to the producer, the distributor and the end user.

First of all, it is important to be aware of the following facts:

- Short duration production of electrical energy to meet peak demand is expensive, as it requires a plant which can react rapidly to changing demand patterns.
- A plant operated to meet peak demand contributes to a high marginal cost of power consumed at peak periods, which is necessarily passed on via suppliers tariff rates to the customer.

Customer demand coincident with system peak demand is therefore more expensive.

In addition, customer demand coincident with peak demand at various levels of the network determines the capacity requirements of the distributor and therefore determines the element of electricity charges related to transmission and distribution.

If a customer can reduce his demand coincident with system peak demand and reduce the requirement for network capacity (rated demand), then the customer reduces the total electricity charges by saving costs to the supplier, distributor and producer.

An individual customer's demand is aggregated with others to create demand patterns at various levels in the network. Ultimately, the customer's demand contributes towards the total system demand seen by producers. Control of demand coincident with the peak demand at various levels in the electricity supply chain can yield savings to the supplier and the customer. Savings achieved by the customer must offset the cost of achieving load control, such as production scheduling, advanced control and use of energy storage mediums. From the customers' point of view, savings are realised through the major elements of the bill:

- Production costs are reflected in the maximum demand (kW) or the energy (kWh) cost element of the bill, i.e. the contribution that the customers' demand makes towards the generating capacity at various times of the day.
- Transmission costs (high voltage, system-wide network costs) are reflected in the Transmission Use of System element of the bill, often expressed in terms of maximum demand coincident with system peak demand, i.e. the contribution that the customers' demand makes towards the required capacity of the Transmission System.
- Distribution costs (lower voltage, local network costs) are reflected in the Distribution Use of System element of the bill, either as a kWh rate or as maximum demand charge expressed in kVA or kW i.e. the contribution that the customers' demand makes towards the required capacity of the local distribution network.
- In addition to the above costs, customers who demand a new connection or an expansion of existing capacity may be asked to contribute towards the direct costs of the distribution system reinforcement at the local level.

It is important to note that whereas costs associated with energy demand are charged at the time-of-use (i.e. contribution towards demand at a particular time of day), maximum demand and demand coincident with transmission peak demand relates to fixed electricity distribution assets which must be sized to meet that demand. Costs are always minimised by seeking the greatest utilisation of fixed assets, i.e. by spreading the total demand as evenly as possible to reduce the peak capacity requirement.

Electricity suppliers and producers generate cost messages for their customers in the form of tariffs or contracts for energy supply which reflect their desire to maximise the utilisation of assets. Conversely, one can view the charge structures as the need to recover sufficient revenues to cover the costs of supplying customers' demand. Most tariffs contain incentives and penalties to persuade the customer to use energy in a way which optimises the use of generation, transmission and distribution assets.

Naturally, as one considers the demand at higher levels of the network, diversification due to aggregated demand resulting from many customers tends to reduce the impact that an individual customer has on costs. In many instances, the aggregated demand can take advantage of patterns of life. For example, industrial and commercial demand tends to occur at different times to that resulting from domestic customers as the domestic customers are by definition out at work or shopping. Likewise, demand varies with the time of day due to life-styles, solar gain, workdays and weekends, and similar factors. It may also vary with time of year, particularly in northern climates where heating is required during winter and cooling is required in summer.

Night-time demand is naturally low, so many electricity companies promote off-peak sales of electricity through advantageous tariffs with the aim of optimising the utilisation of network and generation assets. A major element of load control is the utilisation of energy storage devices to take advantage of off-peak supplies and reduce on-peak demand. Depending on the climate and work patterns of the country concerned, other off-peak periods (mid-day, for example) may also be promoted through advantageous tariffs.

3.2. The Total Demand System Compared with the Customer Load Profile

In order to identify load management possibilities at the customers' installations so as to reduce the peak load in the electric system, the total system demand must be compared with the customers' load profile. As can be seen in Figure 3.1, the total system has one peak load at times t_1, and another one at time t_3. In the example, both peaks are met by peak plant production. The customers' demand profile has been chosen flat during the daytime period to simply the comparison between the two demand profiles.

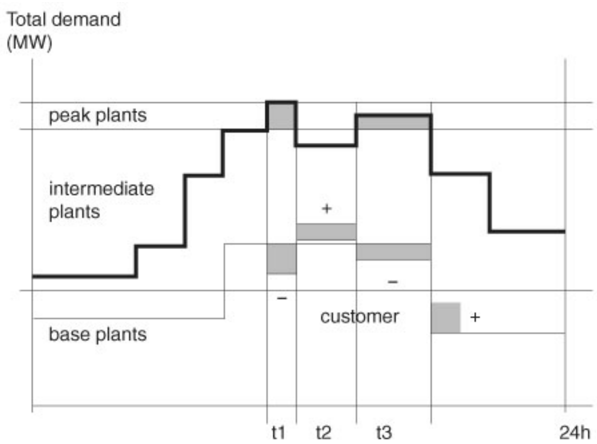


Figure 3.1 – Total system demand compared with the customer's load profile (also refer to Figure 2.2)

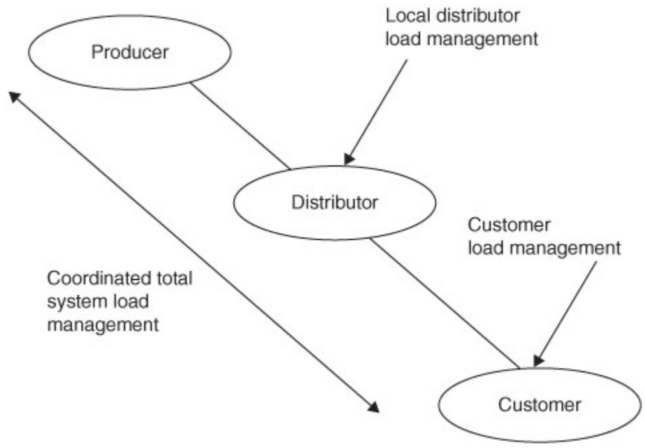


Figure 3.2 – Co-ordinated total system load management

The goal is to reduce the need for gas turbine production or other peak-time expensive production capacity by decreasing the demand at the customers' installations during t_1 and t_3. One way of doing so is to increase the load during t_2 or postpone the energy use until the low period in the evening.

What types of demand changes can then be performed at the customer's installation without sacrificing the performance of the customer?

Some of the most common techniques are:

- Energy storage units charged during off-peak periods and used during peak hours
- Load priority systems to avoid large loads interacting simultaneously
- Rescheduling of processes
- Use of own power production.

These techniques are presented in Chapter 5.

3.3. Co-ordinating Load Management for Maximum Benefit

The benefits of load management are many. It serves the efficient use of investments related to production and distribution of electricity. These benefits can be achieved by the producer and distributor as well as by the customer. The focus of the action taken and the reasons for load management are however somewhat different among the participants.

Through co-ordinated load management – activities made with respect to the total system -, it is possible to avoid the start of unnecessary production plant. This gives at the same time environmental benefits. If load control is not co-ordinated between the producer, distributor and customer, action taken by the customer in order to reduce the cost for power demand may lead to a sub-optimisation for the total system. In this case, the revenue for the customer who has taken this action could be much higher than the reduced costs for the distributor and the producer. This is the case if the customer's peak reduction occurs during hours when capacity is available at the production plant and in the distribution network.

If load control among customers increases widely, without co-ordination with the producer and distributor (that is in the presence of incorrect price signals or unsuited incentives), the small or non-existent systems effect that results may unbalance the supplier's cost/revenue equilibrium. This will lead to an adjustment (increase) in the present tariffs to compensate for the lost margin, thus raising a problem of equity, as customers without load management will be cross-subsidising those who have improperly modulated their load curve.

This happens, for example, when the rate systems or the specific agreements allow for an excessive premium on demand reduction, but less incentive is given to the energy consumption shifted to off-peak time. In this framework, customers react mainly when clipping only the sharpest or narrowest peaks of their load curves, with small energy content; in fact, this involves important gains with small effort, as short duration loads are easier to control.

This short duration makes it almost impossible to have a good coincidence among the individual load reductions, particularly if the declared peak period lasts several hours. The result is a system effect much lower than the sum of the single-customer load reductions, with minimal impact on supply costs.

3.4. Advantages of Practising Load Management

The producer, distributor and customer all have many advantages to achieve by practising load management. These advantages are summarised in the following:

- ❑ Load management avoids the requirement to increase transformer, cable sizes and generator capacity
- ❑ Load profile is generally more efficient, controlling peaks
- ❑ As peaks are likely to coincide with periods of most expensive electricity prices, either individual industries will become more competitive or prices will be forced downwards
- ❑ It is environmentally more acceptable due to an effective use of resources.

3.5. Example of Industrial Load Management

In the example that follows, the aggregate demand for one large industrial customer and two classes of domestic customer are considered. The example relates to a large dairy process, in a rural location, in a northern climate, with two seasonal peak demands corresponding to a winter heating demand and a summer cooling demand. The domestic demand consists of two major classes of customers; those with off-peak storage heating, and those without storage heating. As the total peak demand occurs during the winter, the analysis relating to capacity requirements has been conducted for the expected winter peak demand, corresponding to the coldest days. Summer peak demand is not a concern as the domestic demand is low in this season.

In the example, the winter peak demand for the industrial and domestic customer groups are shown on Figure 3.3. After taking account of power factor and other loads (such as street lighting), the aggregate demand of all the customers at the primary substation is also shown.

As can be seen in Figure 3.3, the total demand curve at the primary substation shows three peak demands; an early morning peak relating to domestic storage heating, and two later peaks relating to coincident domestic and industrial demand during the transition from home to work in the morning and from work back to home in the evening. In this particular example, the distributor has reached the maximum available safe capacity of the primary substation and is faced with reinforcement if the early evening peak cannot be reduced. Failure to take account of the reinforcement requirements would have implications for the security of supply to all of the customers connected to the primary substation.

In addition to the demand curves, Figure 3.4 shows the costs of electricity production which are passed on to the customer by the supplier during the peak seasonal demand. The costs shown are based on energy costs from the UK Pool trading system averaged over a month, and indicate the actual system demand for energy and to a lesser extent, the predictability of demand.

The industrial customer pays for energy at these prices plus a small premium, whereas the domestic customers pay for a flat rate or at two rates depending whether they have standard or off-peak heating tariffs. As can be seen, the peaks correspond to relatively expensive energy purchase periods reflecting the total system demand at those times. Note also that a relatively cheap period exists prior to the early evening peak.

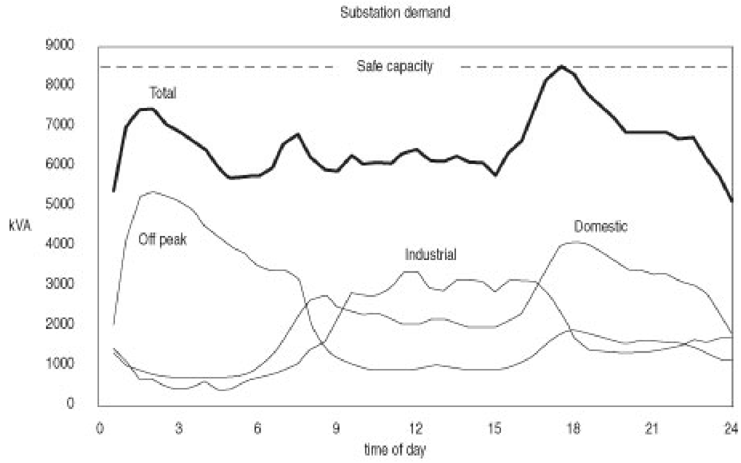


Figure 3.3 – Components and total demand

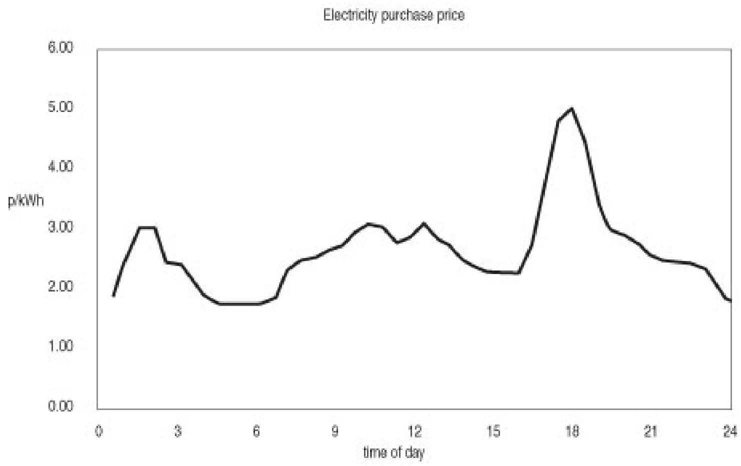


Figure 3.4 – Costs of energy purchase at the peak day

If the industrial customers practise load management, they can avoid higher energy purchase costs and may also benefit from avoided reinforcement costs associated with the network. This can be achieved either through a contract arrangement with the distributor or through avoided maximum demand charges. Two load management options are open to the customer in this example:

- ❑ Install storage devices to shift some load from periods coincident with both the peak energy purchase costs and the local network peak demand (which is creating a need for reinforcement). In this example, the dairy may consider ice storage or management of bulk cold storage (thermal mass). In the example, 600 kW of demand is shifted by 1.5 hours, requiring 900 kWh (equivalent) of storage capacity.
- ❑ Reschedule production so that the working day starts and ends earlier. This may be possible in some cases, but is difficult to achieve in practice as there is likely to be an effect on the domestic profiles which include the contributions of many of the dairy’s employees and production is tied to farming schedules. In the example, a one-hour shift of total production is considered without taking account of effects on local employee domestic profiles.

In addition to these load-shifting options, the customer may also be able to reduce either overall demand through energy efficiency measures or reduce kVA demand through power factor correction. In the example given, much of the load relates to electric motors, giving an overall industrial power factor of less than 0.9, such that transformer loading (rated in kVA) is more than 10% greater than kW demand. Although power factor correction may be beneficial, it would not in itself solve the problem illustrated. Overall energy efficiency measures save consumption throughout the entire demand period and may be effective in reducing bills, but are less likely to achieve the relatively large demand reductions desired at the peak period.

In practice, various combinations of load management and conservation measures may be possible, including targeted energy efficiency, power factor correction, partial rescheduling and combinations of energy storage.

In Figure 3.5, the effects of these options are shown on the industrial demand curve.

Figure 3.6 shows the effects of these changes on the primary substation demand curve, illustrating the contribution that the two options could make towards alleviating the reinforcement requirements at the transformer.

The customer would have to cover the costs of each of the measures and the financing of the capital investments over a number of years, offset by the savings in energy purchase costs. In addition to the customer costs, it can be assumed that the supplier will also save costs relating to network reinforcement, with potential benefits to higher levels of network. In some circumstances, these savings may be shared with the customer through supply contracts.

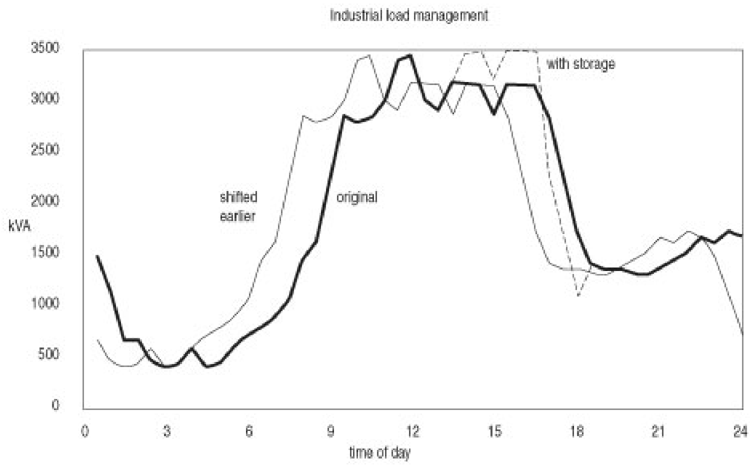


Figure 3.5 – Effects of load management on the industrial profile

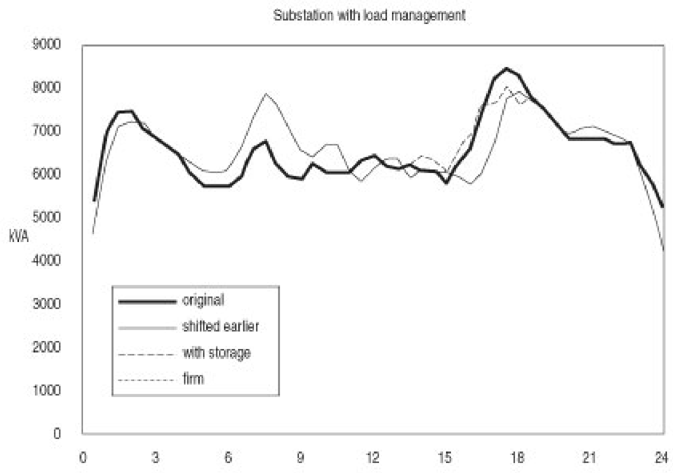


Figure 3.6 – Aggregate effects on the primary demand profile

Chapter 4 - Market Aspects of Load Management

The technical aspects of load management (LM) are covered in the previous chapters. Aspects which will be discussed in this chapter are globally referred to as the interaction between customers and distributor/producer.

Items discussed in the following paragraphs are:

- market activities: what activities are developed for the market by the distributor/producer
- the different load management contracts
- the treatment of risk.

4.1 Market Activities

There is a general trend towards development of LM contracts. The reasons are diverse, sometimes the trigger is set by a need for extra (technical) capacity. On other occasions, a financial system between producers and distributors gives opportunities for the successful introduction of LM.

In most cases, LM is a service provided by the distributor/producer. The long-term goal of LM is to ensure the cost efficient use of production and/or distribution facilities.

The following procedure is often used by utility marketers in order to encourage LM agreements. Also, producers and/or distributors provide general information (such as this brochure) to customers. Customers who feel they have a potential for LM should contact their distributor; in practice, they start with step 4 (see below):

1. If a distributor/producer wants to introduce LM, the starting point is set by knowing his market. This can be achieved by building a database, containing customer data. This data should cover fields like maximum load, annual energy consumption, global description of the types of load (interruptible or not) and the energy costs in respect to the total costs.
2. Starting with this data and some global indications of the benefits of LM, the distributor/producer should select the customers who have a potential for LM.
3. The next step is to visit these customers and introduce LM as an opportunity for energy cost reduction.
4. If this initial stage is successfully completed, the next step is an investigation, in which the customers play an active role. This examination should result in an overview of interruptible loads (volumes and duration of interruptibility) at the sites of the customers. This data is collected by means of interviews and/or measurements.
5. Based upon this short list and the global benefits of LM for the distributor/producer, a formal offer is made to the customers. This offer will not only include the tariff aspects of load management, but can also deal with the equipment used with LM. The customers will then take a decision based upon the financial benefits versus any production losses.

The above described procedure (5 steps) will be more or less the same for each potential LM contract. The process described above should be constantly evaluated.

4.2. The Different Load Management Contracts

Due to the great variety in financial and/or technical systems on the distribution/production side, there are several possibilities for setting up a LM contract.

For instance, the producer/distributor can either pinpoint a specific load to be interrupted or leave the choice of load to be interrupted up to the customer. In the latter case, there is greater freedom for the customer.

There are also several ways of treating volumes. Some customers will try to achieve maximum load reduction, but the utility does not know how much load will actually be controlled. In other cases, there is an agreement on how many kW will be controlled.

Another aspect is the maximum duration of the load control, varying from 30 minutes to several hours a day. On the response time to a load control command, variations are seen from instantaneous to a scheduled load control, especially for loads with long reaction times (several hours).

All these aspects influence the type of LM contracts and are coupled to the maximum benefits which can be achieved by customer and/or distributor/producer. Although many forms of LM agreements exist throughout Europe, as described above, most fall into two broad categories:

- ❑ utilities incorporate load management into their general tariff structures
- ❑ specific arrangements are made between utility and individual customers.

The general tariff structures (see Chapter 2 and the Appendix A.1) differ from more simplified structures (the Netherlands, Sweden, Switzerland...) to a great variety of rates, with changing demand and energy charges (Belgium, France, Italy...). These changes reflect annual, seasonal, or daily scarcity or abundance of supply. Whether the structure is complex or more simplified, the utility can assist its customers in selecting the most suitable tariff option and/or installing the optimal measuring equipment accompanied with the best suited load management system.

The last item of interest lies in the way the load is controlled. In systems where the customer has freedom in reacting to load reduction commands, the customer is normally warned by means of a tone ripple signal (signal carried by the distribution network), or by radio transmission signals. But in the case of a direct control by the utility, some way of direct communication by phone or telecommunication lines must be provided.

If the load management has to meet the tariff structures as mentioned before (tariffs with changing charges, as a function of time), some local intelligence can be installed on the customer's site. This local equipment directly controls the load by switching off/on specific loads.

The local utility can inform the customer in the most appropriate way concerning the different tariff structures and possibilities in the field of load management equipment.

4.3 Treatment of Risk

Load management tries to optimise and fit capacity with a varying demand or, in the long run, ensure the most cost-effective use of production/distribution facilities.

The risks can roughly be divided into technical and financial.

Technical Risks

If LM has to meet capacity restrictions in production or distribution systems in a potential overload situation, then the LM contract should incorporate very clear agreements between customer and distributor in order to ensure the correct behaviour by the customer. For example, given the situation that the demand in an area at peak times has reached the safe available capacity, if a customer with LM possibilities is located in this area, the distributor can postpone the investment necessary for upgrading the safe capacity if this customer is willing to reduce his load at peak time.

In this kind of situation, the distributor must make sure that this customer really does control his load; otherwise, a state of overload will still result ending in disconnection in order to prevent serious damage from occurring.

Financial Risks

The financial risks are connected to investment decisions. A LM contract with greater freedom for the customer implies an uncertainty for the distribution/production companies. This leads to slightly higher (future) investments resulting of course in lower benefits.

In respect to a financial accounting system between production and distribution, based upon maximum demand, the risks are normally postulated in penalties to be paid if the actual demand exceeds the contracted value.

These risks occur specially in those cases where a LM contract is based on maximum freedom for the customer. These risks are normally translated to the maximum financial benefits for the customer, as negotiated in the LM contract.

4.4 General Remarks on the Interaction between Utilities and Customers

Throughout Europe, there are many different forms of LM incentives, either in a way of general tariffs or in the way of curtailable contracts.

Normally, there is a trade-off between maximum benefits for the customers and their freedom in responding to load reduction requests.

In setting up LM agreements, it should be kept in mind that customer and provider need to play an active role, in determining and understanding the actual load curve of the customer. This is necessary to achieve an insight of the load reduction possibilities.

Distributor/producers can provide an additional service by installing measurement and/or control equipment on the site of customer, to give a better understanding of the customer load curve(s) or means to alter its shape.

In spite of the great variation in the LM contracts in Europe, as a general rule, a good interaction between customer and distributor is necessary for a successful implementation of a LM agreement resulting in maximum benefits for both parties.

Chapter 5 - Industrial Loads and their Control

We have described in the previous chapter the financial mechanisms (rates and incentives) through which utilities encourage their customers to lower their demand in periods of difficult or critical supply, and to increase it when cheap and abundant capacity is available.

It is now time to show what users can do to modulate their load curve and therefore take advantage of the most favourable price of electricity.

To do this, it is important to:

1. understand how an industrialist's load curve, measured at the connecting point to the distribution grid, is built up by the addition of the power demand of each appliance at any time of the day
2. identify the most suited endusers for Load Management practices
3. determine what arrangements can be made so as to limit the maximum draw of power from the grid and also how to delay electricity consumption until the most economically favourable periods. This will also involve anticipating periods of high demand.

5.1 Load Curve Analysis

The examination of the daily load curves is the first step towards the implementation of Load Management. Such analysis can include the following activities:

1. Definition of the load curve objectives, depending on the pricing mechanisms in effect. From the customer's point of view, a "flat" curve is not necessarily the best solution: most often industrial customers may want to reduce the load during the utility peak time and to increase off-peak consumption. Under particular rate systems however, there may be a primary interest in reducing the factory's peak, whatever the coincidence is with the utility's; anyway, a credit is given for load reductions at peak time.
2. Checking monthly electricity bills to determine if Load Management opportunities exist, and if so during which time periods (refer to classification further on).
3. Recording of the total load curves on days when the facility is to be controlled. To take into account contingencies that can occasionally affect the total power demand, it is advisable to take recordings over several weeks. In this way, it will be possible to identify time, magnitude, and duration of the load to be shed. This gives an early indication of the probability of success of an intervention of Load Management. For example, shorter peaks are generally easier to remove.
4. Technical analysis of the feasibility of Load Management. That is, to make sure that constraints do not exist to interrupting/rescheduling loads, with respect to: safety of operations, impacts on quality and quantity of production, preservation of the integrity of the equipment, and mutual interactions with other facilities in the factory. In this way, interruptible operations can be identified and, in case, also appliances to step up off-peak (see section 5.2 below).
5. Analysis of the controllable operations that, for the value and timing of their consumption, can be retained as the major contributors to the load to control. To this aim and whenever possible, it is useful to record the load curves of the main operations coincidentally with the measure of the total load curve. This will allow the amount of load reduction, that can be achieved by means of interruption or deferment of every single operation, to be determined.
6. Definition of the Load Management strategy that results in a load curve as close as possible to the desired objective without compromising performance and duty.
7. Consulting manufacturers about availability of LM systems compatible with the preceding points (technical description, economical analysis and benefits anticipated).

As a simplified example, Figure 5.1.a shows details of the day load curve of a small factory whose main operations are indicated. Their ratings are:

- oven: 30 kW
- permanent processes: 75 kW
- space heaters: 55 kW
- ventilation: 2 kW
- lights: 24 kW
- hot water storage: 18 kW

Figure 5.1 - After programming the operations, the effect on the load curve

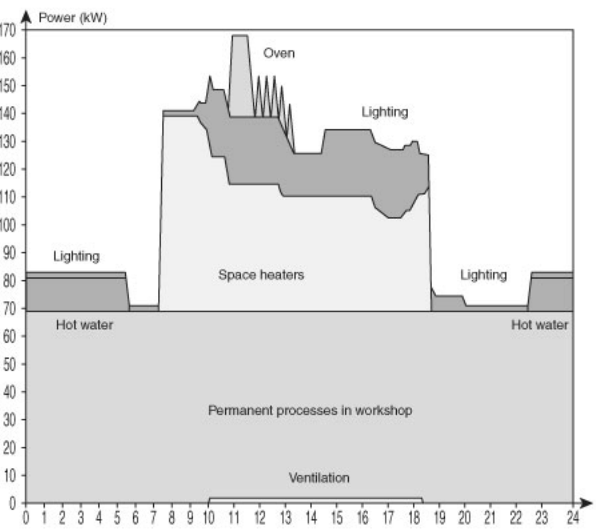


Figure 5.1.a - Load curve with programmer but without disconnection

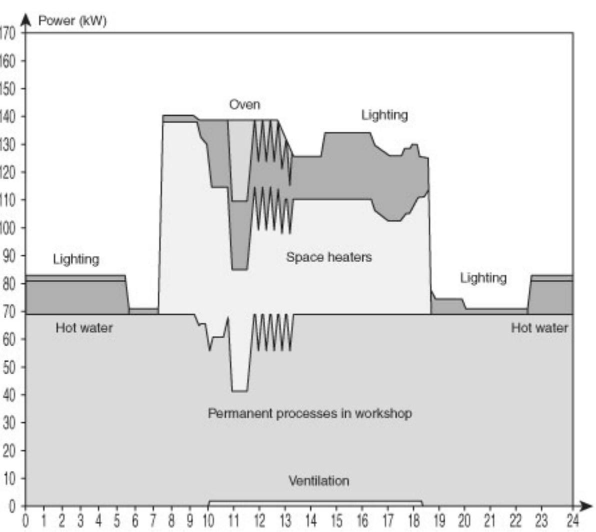


Figure 5.1.b - Load curve with programmer and disconnection

Note that with the exception of the permanent processes and hot water storage, all equipment is normally operated according to a modulated load curve and at less than their ratings. The natural diversity in power consumption makes the resulting peak load of the factory 170 kW at 11 am, i.e. less than the sum of the ratings of the single appliances (204 kW).

In our example, hot water produced at night is already a major contributor to diversity and helps to contain the maximum demand in the global load curve.

Looking more carefully at the load curve and at its components, it can be noticed that the peak load has a short duration and is mainly driven by the coincident operation of the oven and the floor heating. The thermal inertia that is typical of storage utilisation like floor heating, allows the interruption of the supply for a period without causing any discomfort to the user. The peak demand and its relevant cost can therefore be reduced by using an automatic system to disconnect the floor heating (temporarily and zone by zone) when the oven is operating.

Figure 5.1.b shows the resulting load curve: the max, power has been reduced from 170 to 140 kW, thus decreasing the annual electricity bill by 6%.

Figure 5.2 shows an actual example of the action of a load management system installed in a smelting plant. Figure 5.2.a shows the disconnecter action which allows the subscribed power to be reduced from 3500 kW (installed power) to 2400 kW. Figure 5.2.b is an example of two short over-powers which have not been penalised. The resulting profit can be estimated between 180 000 and 250 000 FRF per year. The payback period is around one year.

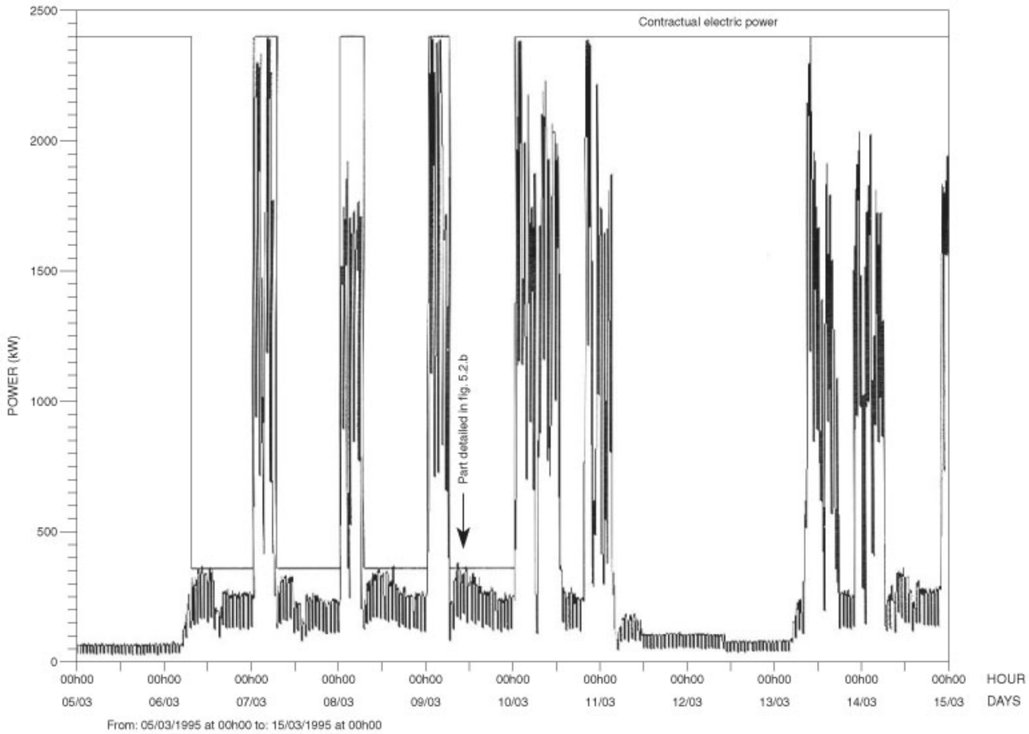


Figure 5.2.a - Contractual and instantaneous electric power of a smelting plant equipped with load management

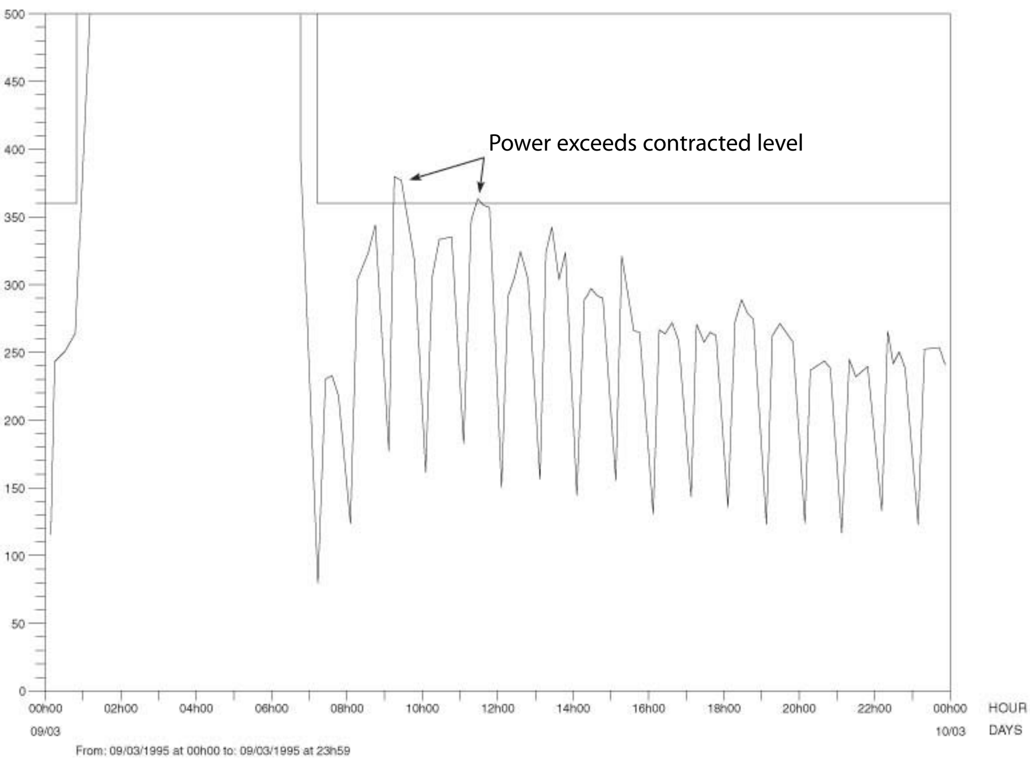


Figure 5.2.b - Detail of Figure 5.2.a showing two short over powers

Load Curve Classification

As a general point, different statistical studies on daily load curves in France have lead to a classification of the consumers connected to 20 kV lines in seven classes (see Figure 5.3):

- class 1: permanent uses
- class 2: modulated uses, seven days a week
- class 3: lightly modulated uses
- class 4: sharply modulated uses
- class 5: uses in two times four hours
- class 6: uses with peak-hour disconnection
- class 7: off-peak uses.

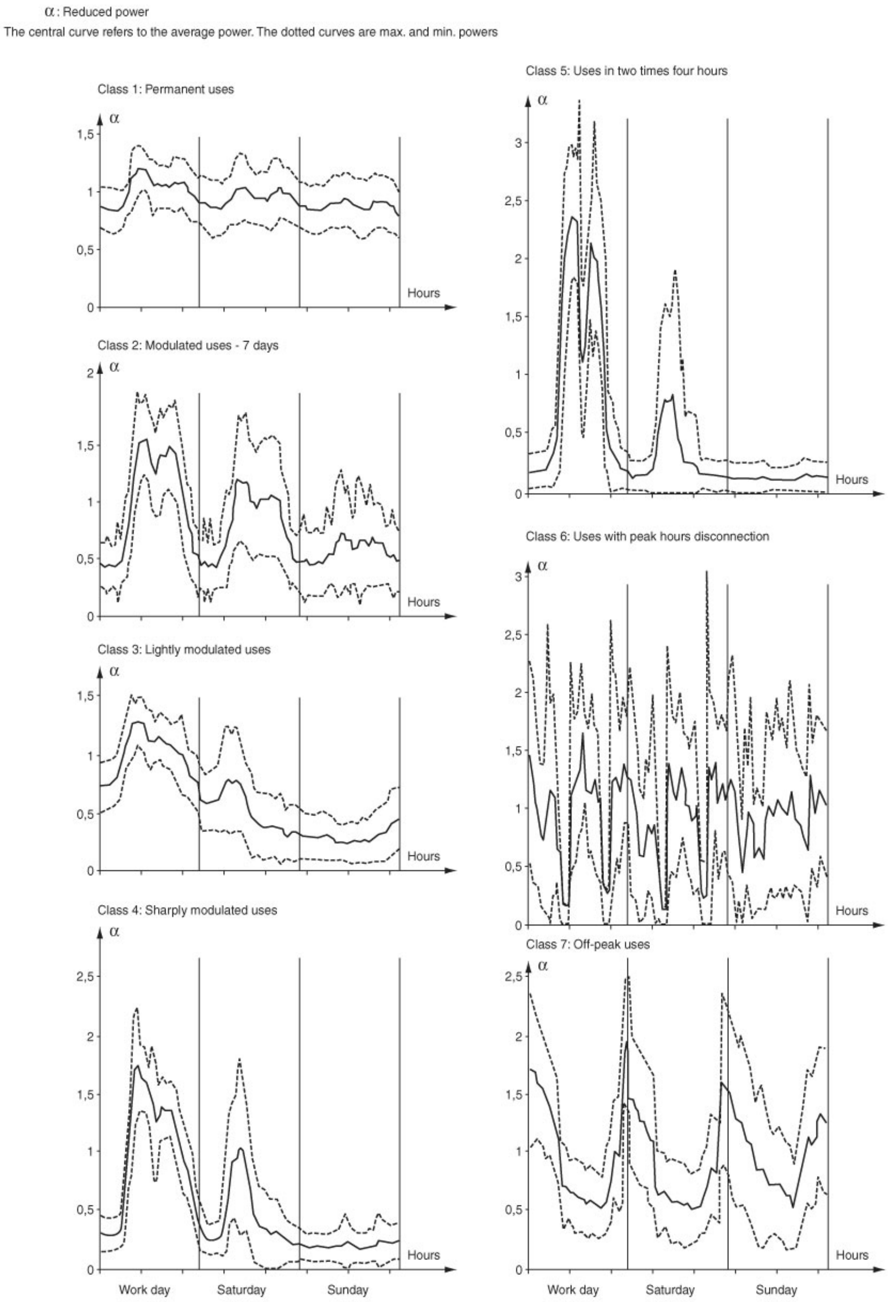


Figure 5.3 - Load curve classification

Most industrialists belong to classes 3, 6 and 7. Classes 6 and 7 group the consumers sensitive to the tariff structure and who have chosen to adapt their consumption consequently. Load curves of the other classes are more or less modulated during working days and weekends.

Independently from the shape of their load curve, each consumer has a different average power. For simplicity, all the curves of Figure 5.3 have been reduced to the average power during working days.

These seven categories can be situated on a plane (as shown in Figure 5.4) using two criteria: PR (peak ratio) and NR (night ratio) where:

- PR is the ratio of the mean power absorbed during peak hours in one month, to the mean power absorbed during off-peak day hours in one month
- NR is the ratio of the mean power absorbed during night hours in one month, to the mean power absorbed during off-peak day hours in one month.

Load management consists in decreasing the PR value (towards left part of the figure) and increasing the NR value (towards upper part of the figure).

This figure can be used for the analysis detailed in the previous paragraph; at first, calculate your own present PR and NR values and place the corresponding point on the figure. In this way, you identify which class of users you belong to. Then study different LM systems as explained in this chapter and place the consequent points on the figure. This should help to determine which is the best Load Management strategy or solution for you.

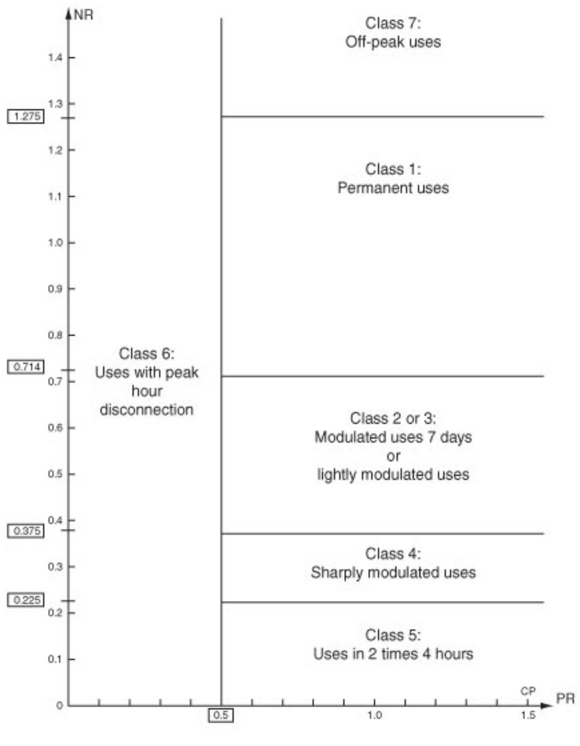


Figure 5.4 - Load curves situation using PR and NR ratio

5.2 Controllable Electric Loads

The effectiveness of load management measures depends on the degree to which it is possible to increase, decrease, or reschedule loads. The identification of which loads can be managed, and to what extent (how often and for how long), is a fundamental operation to be performed prior to the implementation of any load management programme. To this aim, it is useful to identify industrial loads possessing similar operational characteristics and therefore exhibiting the same level of controllability.

Thermal and Refrigeration Loads

Examples of electric thermal uses include furnaces (arc, induction, resistance, etc.), boilers and water heaters, space heaters, chillers and air conditioners. A characteristic of such applications is that the equipment can usually operate within a band around the set performance temperature, and is in a position to tolerate some deviation from the optimal value. This makes it possible to interrupt or to boost the supply when needed with a limited impact on performance. Another feature of thermal and refrigeration end-uses is their storage capability (refer to paragraph 5.4), which allows a further flexibility in varying the duty cycle, without adversely affecting the customer.

In case of electrical load interruption, dual-energy systems can also be used.

Fixed-cycle Loads

Fixed-cycle loads work according to a constant, pre-set sequence of operations. Examples are found in metal heat treatments and in the food industry for cooking, baking, sterilisation, etc. If these loads are interrupted, they may or may not restart the cycle from the interruption point. This will depend on the duration of the interruption and on the type of process involved. Heat treatments, for example, are not likely to produce metals with the required characteristics if they do not proceed according to the scheduled sequence of heating and cooling. Similarly, cooking may result in a useless production or, in particular cases, even in damage to equipment if the process is interrupted. Other processes, like drying, are less sensitive to interruptions.

Customer acceptance of control over this kind of end-uses will therefore depend on the impact that interruptions may have on quality and quantity of the production (refer to paragraph 5.3: "programming" and "disconnecting").

Other Loads

Loads included into this category are operated on an as-required basis. Typical examples are: lighting, elevators, cranes and motors for operating machines in general. Many of these loads are directly operated by the user, other ones depend on a particular time or conditions.

With regards to interruption, these are the most critical end-uses. In some cases, their control may involve endangering the safety of operations in the factory. Lights, for example, must be on at night, and elevators cannot be stopped while carrying people. The operation of some of these loads can be deferred; however, customers may be strongly averse to control policies that do not result in significant benefits (refer to paragraph 5.3: "change in behaviour").

After a French study, load management systems are mostly installed in the metallurgical and mechanical industries (37% of the systems examined) and in agrifood industries (32%); the operations most often disconnected for LM purposes are:

- ❑ Convectors (wall resistors for space heating): 44%
- ❑ Ovens: 39%
- ❑ Air conditioning: 32%
- ❑ Compressors for refrigeration: 29%
- ❑ Resistors in heat trays, tanks, sterilising equipment, etc.: 28%
- ❑ Resistors with fans for space heating: 27%
- ❑ Fans: 22%

Static loads (resistance, induction) are more easily disconnected than dynamic loads (such as electric motors) because their operation raises little constraints and frequent starts and stops do not reduce their life duration. Static loads are generally involved in processes (heating, drying, cooking, melting, etc.) where rival processes exist, which use another energy. Therefore, LM systems present an argument favouring the installation of electrical processes.

Electric motors can also be managed if sufficient precautions are taken. Too frequent starts can cause overheating thus shortening life duration of insulating parts. However, motors equipped with efficient starters which reduce current intensity, can be interrupted more often.

Precautions must also be taken when considering the machines connected to the motors and the automatic systems piloting the processes involved. Generally, three periods should be considered for each machine managed: maximum duration out of operation, minimum duration in operation, minimum duration out of operation.

LM projects should be discussed with company representatives so as to ensure that no injury to personnel or damage to machines can occur. At any time, LM should not hamper the operation of processes, as labour costs or reject costs could become much higher than earnings brought by LM.

5.3 Control Methods

Control methods for good load management can be divided into three options:

- ❑ **A change in behaviour** is easy and requires low investment. The employees are trained and made aware of the tariff rates so that they behave in a thrifty way with lights, fans and all electrical devices they can operate manually. Machines are used only when necessary (allowing for reasonable time for starting up and limiting the number of start/stop operations).
- ❑ **The programming** of electricity consumption is more efficient but demands more investment. The goal is to reduce any "undue" consumption (for example, ventilation when personnel are not present) and also the moving of electricity consumption from periods when it is more expensive to periods when it is less expensive (for example, hot water production at night in a storage tank, or scheduling heavy operations during off-peak hours).

This is normally performed by reorganising the work activities. To this purpose, process rescheduling is more appropriate for facilities which operate on two or three shifts. If two or more production lines are involved, the operation cycles can be modified to avoid their coincidence at peak time. Depending on the thermal inertia of buildings, electric heating and air conditioning should be used in the early morning (during the night rate period) to pre-heat or pre-cool premises. In this way, the temperature level is reached before the day rate period. Similarly, heating systems can be switched off before employees are due to leave the premises. In industry, lighting usually contributes very little to the electricity bill (typically around 5-8%), and its programming could prove uneconomical.

- **Disconnecting** electrical appliances (or extensively limiting their use) during peak hours to maintain maximum power under a pre-fixed threshold. For example, figure 5.5 shows extra-heating disconnection during peak hours.

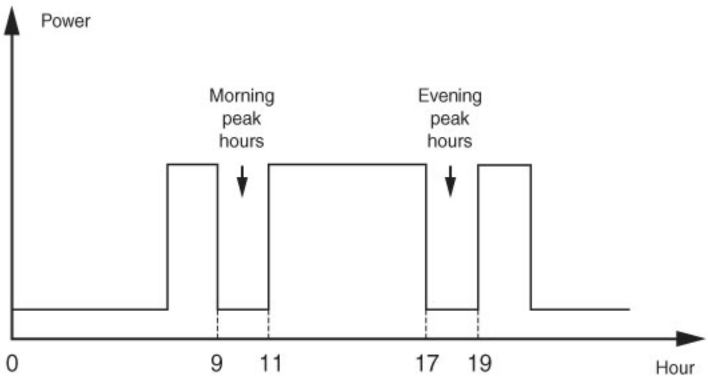


Figure 5.5 - Example of extra-heating disconnection during peak hours

The measured electrical power absorbed by large consumers is frequently averaged over a 10, 15 or 30 minute period. During this period, it is often possible to postpone some low-priority uses so as not to exceed the contractual threshold (see section 5.7) over the period. This practice is generally feasible for industries that can step up and down their production for a certain time, without heavy impacts on the production levels and without damaging both equipment and products.

These possibilities occur particularly for processes where half-finished products and materials can be stored during one or more phases of the production activity. Where this is possible, this can enable other parts of the factory to work in periods of demand reduction.

Industries with excess production capacity can use this excess to modulate the load (that is to reduce the production during peak hours and to step it up during off-peak time) without operational or financial problems, and without reducing the total production. Instead, for industries running at their capacity limits, the reduction of electricity demand for a given time can result in a reduction in production. Where this occurs, some process restructuring is required in order to benefit from the economic advantages of load management.

5.4. Storage Systems

Energy storage enables a shift of consumption to off-peak periods without impacting on the operation of the productive process; it is therefore particularly suited to programming/disconnecting practices. Although electricity to a large extent cannot be stored (see point 1.1), it is possible to partly anticipate its consumption. This can be achieved by means of systems involving batteries or, if thermal energy is required, by heating a medium such as water, air or oil, in a storage tank.

The customer who installs a storage device usually draws power from the grid during the off-peak period to charge the equipment, which is subsequently discharged during the period of peak demand. In this way, the peak is cut back or shaved depending on the maximum power and energy characteristics of the equipment. Even if some stand-by losses occur, decrease in tariff rates (from peak hours to day hours, or from day to night hours) provides a good return on investment.

The most common applications are concerned with thermal energy storage (both heat and cool). The direct storage of electricity through batteries is less popular because of the cost and the difficulties in optimising the charge/discharge cycle.

Here are some examples of thermal energy storage systems:

- hot water for personnel or process is easily stored in a tank and warmed up at night using electrical resistance. Large volumes prove economical, and tanks as large as 100 to 200 m^3 are in operation in many different industrial sectors, in particular in the agri-food industries which use a large amount of hot water for rinsing, cleaning, cooking, etc.
- water storage in a tower or a pressure vessel reduces pump consumption during peak hours (and results in a better safety in case of fire)
- chilled water or ice for process purposes or air conditioning can also be stored in tanks to reduce costs, increase safety in operation and ease maintenance
- high pressure air or oil tanks are installed for the same reasons. Compressed air and oil under pressure are used in many different industries for valves, moulding tools, etc
- floor heating by means of resistance included in the concrete when making the building floor allows for storing thermal energy at night and heating during working hours. Because of its inertia, floor heating is generally installed when other thermal supplies are low or quite constant (storage rooms, small workshops)
- batteries loaded at night supply low rate electricity to forklift trucks used at day
- the installation of capacitors to improve power factor can be understood as load management, as both Joule losses and costs are reduced. A set of automatically controlled capacitors is recommended.

5.5 Stand-by Electricity Generation

Because of the high cost of electricity during peak periods, local electricity generation can prove economical. The project should be studied deeply, as investment and operating constraints are often very heavy. All ancillaries have to be taken into account: location and amount of space required, motor preheating and cooling, discharge of burnt gases, sound and vibration insulation, etc.

When the economic feasibility is proven, most of the installations use diesel motors dimensioned to supply the total power needed by the factory; electric capacities generally range from approximately one megawatt. Electric generators are connected to the factory using control/interface devices in order to prevent any malfunction with the distributor's supply. Maintenance teams should be specially trained as several cases of "not starting when needed" have been listed, and this is far from economical.

In case of co-generation (or CHP, combined heat and power), the operation of the plant involves technical constraints that can only be solved by means of a balance between the utilisation of the heat and the electricity produced. Instead, if these facilities are connected to the utility's grid, they can be designed and managed according to the demand of technological heat, thus resorting to the possibility to exchange energy with the utility when electrical problems arise at customers' premises (surplus or deficit of electricity generation, frequency and voltage stability, emergency and reserve services, etc.).

5.6 Change in Technology

A change in technology can produce a reduction in both consumption and demand (rational use of electricity), or be specifically targeted towards load management.

For example, the first approach corresponds to:

- substituting inefficient lights with modern energy efficient ones
- replacing reciprocating compressors by screw compressors
- substituting:
  - resistor ovens with induction ovens in iron smelting
  - global heat treatment (by conduction) with local heat treatment (by induction)
  - convection air heating with electric infrared emitters in paint drying
- using variable speed motor drives
- installing heat pumps on dryers exhaust gases to preheat air or water.

A second approach involves selecting processes or machinery that allow for independent sequential operations, instead of coincident ones. In this case, intermediate storage of materials is often used.

5.7. Demand Controllers

The control of loads is performed by means of devices that optimise power reduction or disconnection from the grid on the basis of a pre-established limit regarding the maximum load. The operation of a demand controller can either be triggered by a "peak load" signal transmitted by the utility (through radio frequency, line carrier, telephone lines, etc.), or in response to variable-on-peak/-off-peak electricity rates. In this second case, a load limit is set for each rate period.

When the conditions exist for approaching the setpoint, the device sequentially switches off interruptible loads according to a priority list (the less important ones first). Disconnected loads will be automatically resupplied according to a programmed logic, as soon as the risk of exceeding the limit recedes. Typical load controllers have the following major parts (see Figure 5.6):

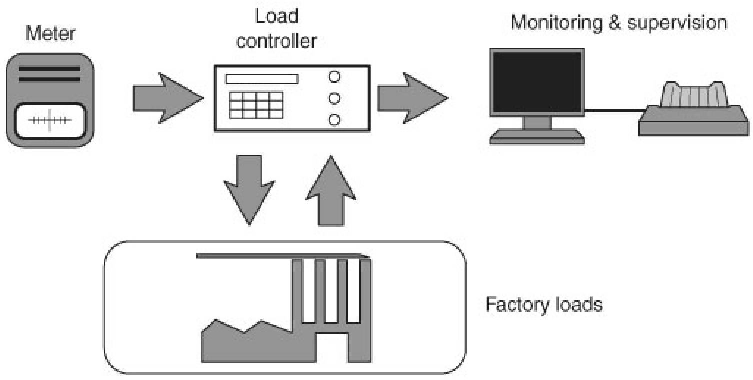


Figure 5.6 - Principle of load controller system

1. a keyboard for programming the equipment, establishing load setpoint(s) and priority levels among end uses
2. a visual display of the programmed parameters (load setpoints, rate periods, on/off status of loads) and self-diagnosis
3. a logic unit (microprocessor) that compares demand levels with setpoints and decides the control actions
4. input channels from the meter for kW/kvar values and for receiving either the peak signal from the utility or the rate period signal from the meter itself
5. input/output channels for ON/OFF commands and status detection of loads
6. serial interfaces with a personal computer and printer (for the most sophisticated controllers).

The control is usually performed through a forecasting algorithm; in the most common (and simplest) case, the difference is calculated between the total available energy in a given period of time (obtained by multiplying the maximum contractual power by the time period itself) and the energy consumed from the beginning of the period. The ratio between this difference and the remaining time to the end of the period represents the maximum power that can be absorbed without exceeding the contractual limits.

Figure 5.7.a shows a simplified example of such a power programme. Figure 5.7.b is an actual recording of the disconnecter action shown in Figure 5.2 (a power reduction can be seen during the fifth minute).

If customer-side generation is available (gensets, cogeneration, etc.), this can be handled like a load, provided that the ON/OFF load status controls are reversed. In this way, what is normally called "load disconnection" will actually mean "generator startup", and viceversa "load activation" will consist in "generator shutdown".

These systems can control both manned and automatic loads. Manned loads are appliances or machines for which an operator is required; in this case, connection and disconnection signals are sent to the operator and the consequent control measure is subject to the operator's approval.

Moreover, the most sophisticated systems not only switch loads on and off according to their priority, but can also be programmed to take into account, both of the power absorbed by the loads and the particular requirements of the loads themselves. For example, maximum and minimum disconnection time can be set for every load, and it is also possible to establish a minimum operation time between two consecutive disconnections.

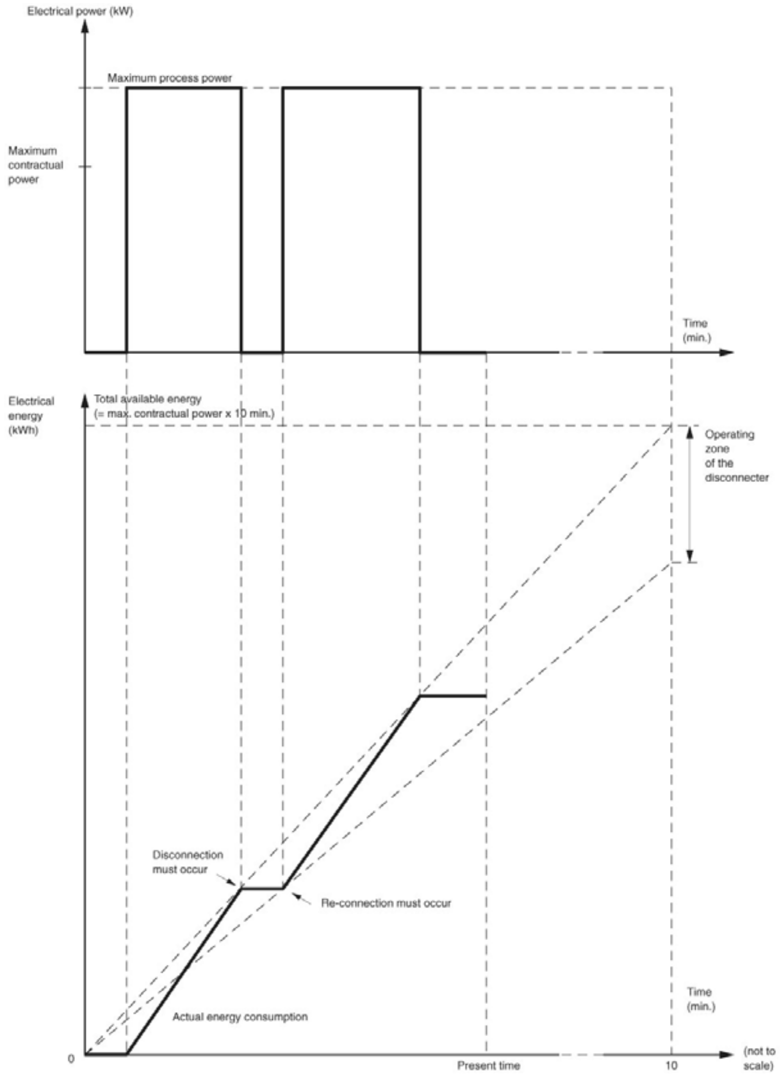
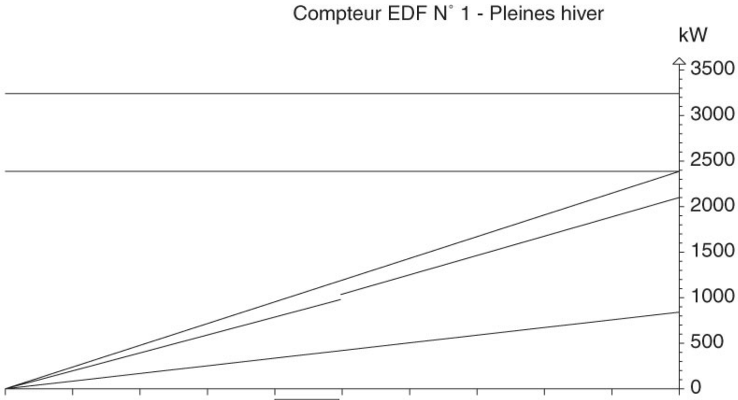


Figure 5.7.a - Example of power programmed for a 10 min. kWh meter.

G. Pontouvre M.L.	Concentrateur

Pente de délestage du Lundi 6 Novembre 1995 à 14:06:08 - Semaine 45

Compteur EDF N° 1 - Pleines hiver



Mn 1	Mn 2	Mn 3	Mn 4	Mn 5	Mn 6	Mn 7	Mn 8	Mn 9	Mn 10	Niv. délestage : 0
240	480	720	960	1200	1440	1680	1920	2160	2400	Pente théorique
206	417	614	806	984	1262	1454	1665	1876	2088	ACTIF TOTAL
81	168	254	345	422	508	590	676	758	835	REACTIF TOTAL
0.92	0.92	0.92	0.91	0.91	0.92	0.92	0.92	0.92	0.92	Cosinus phi

Figure 5.7.b - Actual recording of a disconnecter action

Today, demand controllers are installed in all kind of industrial facilities, allowing the initial investment cost to be recovered in a very short time from the savings on the electricity bill.

Furthermore, plant energy monitors are commercially available to oversee and control all the energy operations in a factory through the connection to meters located in the production departments or close to the main operations. These devices are usually interfaced with a personal computer that, at periodic intervals (day, week, month), produces a spreadsheet detailing electricity consumption subdivided per rate period and cost centre. A database can also be organised giving the relevant information regarding electricity consumption.

The most advanced plant energy monitors also incorporate a load controller. As this seems to be the trend, one can foresee that more and more equipment will perform both tasks, while just the lowest cost devices will only be used for demand control.

5.8 Load Management in Selected Industries

As a complement to the general concepts explained previously, what follows is a collection of examples showing how load management is implemented in particular industrial sectors, taking into account the constraints posed by the various production processes. Of course, the list is anything but complete; however it includes processes where the cost of electricity is an important fraction of total production costs.

Detailed examples are given in Chapter 6.

Metal Works Industries

In small industries, melting of iron scraps is performed by means of induction furnaces usually operated at off-peak periods. All non-energy intensive activities (loading and unloading the furnace, sand blasting, etc.) are concentrated during peak time. When required, the temperature set-point of the molten metal in the furnace is maintained with low power consumption, either by operating the furnace at minimum load or by resorting to auxiliary resistors.

In surface treatment facilities, the duty cycles must be carefully studied in order to schedule the operations so as to limit the number of furnaces that are on at the same time.

Electrolysis Industries

In the zinc, chlorine and soda industries, it is estimated that electrolysis cells account for about 75-90% of the total load of the facility. When needed, the cells can operate at 60% of rated capacity, with little plant modifications and without big operating problems. In addition in most plants, it is possible to store intermediate and finished products, both upstream and downstream of the production line.

Technology Gas Industries

Technology gases, such as nitrogen and oxygen, are currently employed in many industrial processes and can be obtained by the liquefaction and fractional distillation of air. After gasification, a part of the production is compressed to be stored in cylinders or distributed through pipeline networks.

A load management strategy can be based on process interruption and rescheduling. Liquefaction, for example, can be quickly started up from idle. It is therefore possible to stop and restart the liquefaction plant when needed, or to concentrate all liquefaction during off-peak hours. Moreover, all plants are equipped, downstream of the process, with tanks for the storage of the gases; this allows the modulation of the compressors according to the available storage capacity and the shipment rate. It is worth noting that smaller facilities utilising mainly reciprocating compressors show less startup problems in comparison to a system based on turbocompressors.

Cement Industries

In the cement industry (adopting either dry or wet processes), most of the installed electric power is concentrated both upstream of the rotating kiln (raw material transportation, crushing, screening, homogenising, ensilage) or downstream (in particular, the clinker grinding mill usually represents the biggest user of electricity).

The preparation and homogenising facilities can be halted for longer or shorter periods of time depending on the storage capacity of the downstream silos that continuously supply the rotating kiln. These interruptions are however difficult for dry process plants that are equipped with heat recovery devices for predrying the raw materials.

The clinker grinding mill may also be stopped for a time without affecting the operations of the kiln, as there is usually a storage capacity available for the clinker upstream of the grinding mill.

Concrete Mixing Equipment, Processing of Marble, Stones, Gravel and other Building and Public Works Materials

Industries devoted to these activities show a high degree of operating flexibility with a broad recourse to electricity. They also have vast storage capacities for the finished products (mixed components for concrete, graded gravel and sands, structural marbles and stones). Moreover, quarrying is often regulated by environmental laws that limit the amount of material that can be excavated daily. For this reason, the operation of the dredge and of the crushing plant can be easily interrupted at peak time or scheduled to off-peak, without impacting on the production. These features allow the modulation of the electric demand without particular difficulties.

Refrigeration Plants

Refrigeration facilities are particularly suited to thermal energy storage applications that allow the shift of electricity consumption to off-peak periods. In some cases, the thermal inertia and insulation of refrigeration buildings allow the implementation of thermal storage by simply changing the temperature of the final or intermediate product, without needing the installation of a storage device.

Some frozen products, for example, can be cooled to a below-normal temperature during off-peak periods and then subjected to a mild temperature increase during on-peak periods. This can help minimise compressor operation during peak time, without endangering the quality of products.

Moreover, a proper programming of the industrial operations can also lead to significant load shifting at practically no investment cost. It is known, for example, that in a well insulated refrigerating warehouse, the cooling needs are concentrated during the storing operations. If these operations are scheduled at off-peak time, most of the refrigerated load is automatically shifted to off-peak, while during the rest of the day, just a few compressor switch-ons are required to compensate the stand-by losses.

Plastics Fabrication Industries

In these industries, energy demand is due to motor drives, fine-tuned heating and cooling processes, and control equipment. Possible options for load management are thermal energy storage and process rescheduling.

Thermal energy storage allows the shift of the electricity consumption to off-peak periods for the production of refrigerated water needed for cooling the moulding equipment or the finished plastics. Process rescheduling may also involve polymers blending and the regrinding of scrap material.

Chapter 6 - Examples of Installations

To complete this survey, we have included in this part 19 examples of industrial installations which have been chosen to cover a wide range of applications of electric load management in many industrial sectors and countries.

The table below lists these examples.

Case Nr.	Type of Industry	Name of Company	Country	Main Products
13	Agriculture, Agrifood	Greenhouses, North Brabant	Netherlands	Vegetables
19	Agrifood	Allied Mills Ltd., Liverpool	United Kingdom	Flour and by-products
1	Agrifood	Abattoir de Verdun	France	Beef and sheep meat
2	Agrifood	Sieras, Saint Julien du Sault	France	Ready-to-use dishes for planes and trains catering
10	Chemicals	Takeda Chemical Industries Ltd., Shimizu City	Japan	Industrial chemical products
6	Chemicals and pharmaceuticals	Confidential	Italy	Synthetic resins and insulating enamels
11	Electrical and electronics equipment	Takaoka Electric Manufacturing Co Ltd., Nagoya	Japan	Electric machines and appliances
12	Metal works	Tokyo Kinzoku Co Ltd., Tokyo	Japan	Non-ferrous metal products
3	Metal works	Fonderie de Saint-Dizier	France	Cast iron products
7	Metal works	Fonderie Roz S.p.A. Torino	Italy	Cast iron products
14	Metal works	Gunnebo Fastening AB, Gunnebo	Sweden	Nails and other iron products
15	Metal works	Lundgrens Gjuteri AB, Halmstad	Sweden	Cast iron products
4	Plastics	General Electric Plastics, Oise	France	ABS plastic granules
16	Paper and wood	Ansgarius Svensson, Södra Vi	Sweden	High quality timber
17	Paper and wood	Widmer-Walty AG, Oftringen	Switzerland	Recycling paper and corrugated paper
18	Quarrying	Steinbruch Mellikon AG, Mellikon	Switzerland	Limestone
8	Quarrying	Cava Francesca S.r.l., Pontirolo Nuovo	Italy	Inert materials
5	Quarrying and building Materials	Ciments Lafarge, Martres	France	Cement
9	Waste treatment	CO.BE.A. S.p.A., Levate	Italy	Recycling ferrous and non-ferrous metals

6.1. EXAMPLES IN FRANCE

Structure of the French Electricity Industry

The French state-owned company Electricité de France (EDF) is the main producer and distributor of electricity. The production of electricity can therefore be easily adapted to the French demand (about 400 TWh/year) and foreign sales (about 70 TWh/year).

General Tariff Structure

Tariff rates for industry include two cost components:

- ❑ one for the peak power used [kW]
- ❑ one for the energy consumed [kWh].

Several rate structures divide the year into two to eight periods of time according to the customer needs (see details in Appendix A.1).

Policies on Load Management

As a public company, EDF curbs all undue electricity consumption or cost.

EDF recently launched a set of seven services to small and medium size industry in order to help its customers reduce their electricity bill by better economical management, improved quality of electricity and knowledge of electrical processes. Load management is part of this service.

EDF promotes load management implementation which, in particular, allows for subscribed power to be reduced in order to decrease the customer's energy bill. These actions have to be set up carefully by analysing and controlling the load curve (which has to stay beneath the subscribed power to avoid penalties).

EDF proposes to invoice the "reached power" during the first operational year of new customers or appliances. The reached powers recorded, thanks to electronic meters, help customers to fix their needs. They can hence fit their "subscribed power" accurately.

Case Nr. 1	Industry - Agrifood	Country - France
ABATTOIR DE VERDUN (MEUSE) Beef and Sheep Meat		

Summary

The Abattoir operates an energy management system mainly for the production of heating and cooling. The control of electricity demand is based on a 10-minute cycle. The pay back period of the investment is 2.2 years.

1. Company Profile

The Abattoir de Verdun produces 9500 tons of beef and sheep meat per year. It employs 66 persons and has an annual turnover of 7 million French Francs.

Electricity is the only energy supplied to the company. The subscribed power of electricity is 350 kW during peak hours and normal day hours, and 630 kW during night hours. The annual electricity consumption is 1.9 GWh.

Hot water is produced at night by a heater of 480 kW power rating and stored in large tanks of 100 m^3 capacity.

2. Description of Load Management Measures

2.1 Before Investing in Load Management Installations

The energy consumption was not under tight control. Electricity bills were thought to be higher than necessary.

2.2 Load Management Installations

A programmable system (with 90 inputs and 104 outputs) for the total control of heating and cooling as well as compressed air was installed in 1989. It features:

- remote measurements of electricity consumption for each process
- monitoring of the subscribed power and disconnection of selected electric loads based on a 10 minute cycle
- alarm handling, in particular for temperature and humidity of the cold chambers.

3. Economical Analysis

The total investment in load management equipment was 0.32 million French Francs. The subscribed power was lowered from 660 kW to 630 kW. The estimated reduction of electricity consumption is 10%. The pay back period is 2.2 years, which does not take into account the non-quantified savings in operation and maintenance.

4. User's Acceptance and Satisfaction

Because of more accurate temperature control in the premises, the product quality has increased.

Further optimisation of the process and of the load management would require detailed analysis by specialists.

Data collected by EDF Industrie.

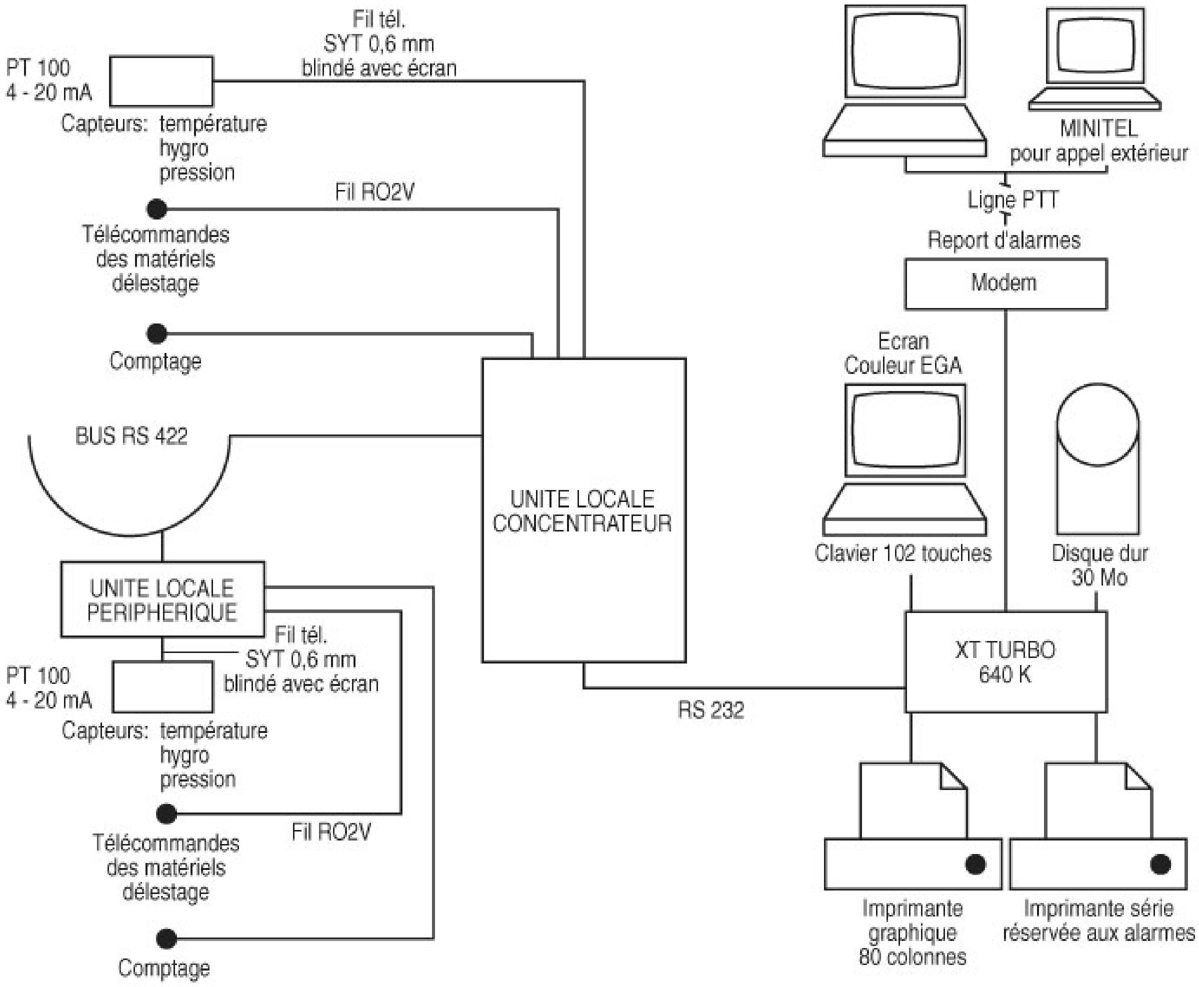


Figure 6.1 - Control system

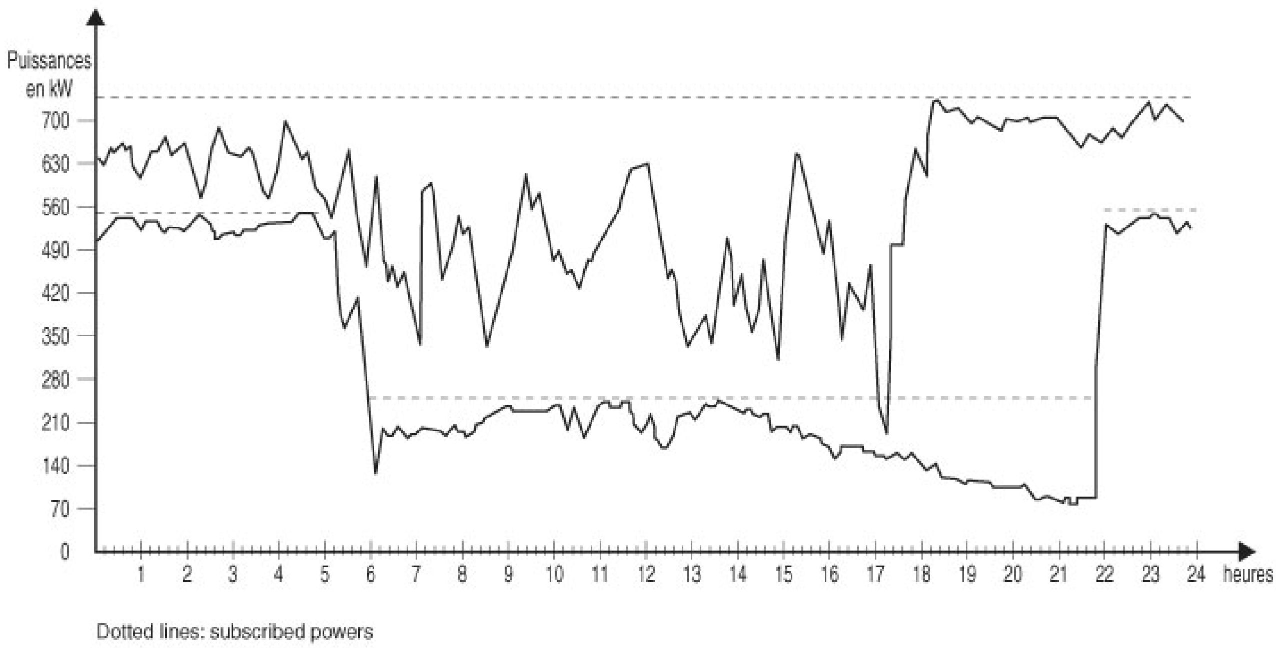


Figure 6.2 - Load profiles

Case Nr. 2	Industry - Agrifood	Country - France
SIERAS, SAINT JULIEN DU SAULT Ready-to-use Dishes for Planes and Trains Catering		

Summary

SIERAS operates a computerised energy management system mainly for the production of hot water and temperature control of ovens and cold chambers. The reduction in subscribed demand is 60 kW. The pay back period of the investment is 4.5 years.

1. Company Profile

SIERAS is a major producer of ready-to-use dishes for lunch and dinner served in planes and trains. It employs 60 persons and has an annual production of 1.4 million dishes (4500 per day).

Electricity is the only energy supplied to the company. A "green" tariff for very long time utilisation with a subscribed power of 325 kW is applied. The annual electricity consumption is 1.25 GWh.

2. Description of Load Management measures

2.1 Before Investing in Load Management Installations

The electrical energy is mainly consumed by the process for cold production (40% of total consumption), for heat production (30%), and for transport by conveyor-belts (20%). Heating and lighting of premises use another 10% of the energy supplied.

The energy consumption was not under tight control. The time of peak demand was randomly distributed.

2.2 Load Management Installations

A programmable system Merlin Gerin ISIS 48 G with two substations connected to a personal computer with more than 200 inputs and 48 outputs was installed in 1990 for:

- ❑ the optimised control of hot water production (cascade heating of tanks at night)
- ❑ tighter temperature control of cookers, ovens and smoking chambers
- ❑ improved temperature control of cold chambers for freezing and storage
- ❑ demand-oriented heating of premises according to personnel attendance, internal/external temperatures and tariff periods
- ❑ control of peak demand
- ❑ remote measurements and recordings of electricity consumption for each process.

The control installation is equipped with remote control via telephone (Minitel).

3. Economical Analysis

The total investment in load management equipment was 0.13 million French Francs. No investment was necessary in the process infrastructure. The subscribed power was lowered from 385 kW to 325 kW. The reduction of electricity consumption is 30% in winter and 15% or 20 000 French Francs over the whole year. The pay back period is 4.5 years, which does not take into account the non-quantified savings in operation and maintenance.

4. User's Acceptance and Satisfaction

The customer is delighted with the result of the installation. The operational reliability of the cold production and of compressors has increased thanks to preventive maintenance. Because of more accurate temperature control in the cold process chain, the product quality has increased.

However, the customer would prefer analog plots of the main output signals over digital data.

Data collected by EDF Industrie.

Case Nr. 3	Industry - Metal Works	Country - France
FONDERIE DE SAINT DIZIER (HAUTE MARNE) **Cast Iron Products**		

Summary

This foundry was totally refurbished in 1992, replacing two old existing cupolas with two automated induction ovens. From that date, the electricity contract has included 22 peak days total disconnection of the factory.

The new process together with change in tariff rates lead to large savings, easier operation and improved quality of the product.

1. Company Profile

The Fonderie de Saint Dizier is situated in the centre of the town. It produces cast iron items, 60% lamellar and 40% spheroidal graphite, and employs 68 persons. The annual production is 5,000 tons and annual turnover is 40 million French Francs.

2. Description of Load Management Measures

2.1 Before Taking Load Management Measures

The foundry used two cupolas. Due to the introduction of strict regulations, the output of fumes and dust had to be reduced. The company was also looking for enhanced flexibility and reduced operating costs.

2.2 Load Management Measures Taken

Two induction ovens replaced the cupolas. They are used alternatively with a single 250 Hz - 4 MW medium frequency (MF) converter. Iron is melted at 1530°C. The unit capacity is 5000 kg and fusion capacity is 7000 kg/h, for a specific consumption of 600 kWh/t. Twice during the oven emptying (40 min. cycle), the oven temperature is manually reset by reconnecting the MF-converter and controlling the power according to the amount of liquid iron still in the oven.

The fusion workshop operates two shifts (3 am to 6 pm), 3 to 5 days a week. It is totally shut down during peak periods, i.e. 18 hours for 22 days a year (coldest days). Peak demand is 4720 kW and annual consumption is 6.8 GWh, i.e. 1.9 million French Francs.

3. Economical Analysis

The total investment in process infrastructure and buildings was 8.5 million French Francs. There was no specific investment required for load management equipment. The new, automated process only requires four people instead of 11 before.

Although the electricity bill was increased due to simultaneous substitution of coke by electricity, the annual net benefit is 2 million French Francs and the pay back period is 4 years.

4. User's Acceptance and Satisfaction

The introduction of the new process has resulted in the following benefits:

- ❑ more flexible operation thanks to the reduction in fusion duration
- ❑ chemical analysis and temperature more accurately controlled
- ❑ all types of cast iron can now be melted
- ❑ reduced labour costs
- ❑ reduction in pollution and improved working conditions
- ❑ improved reliability of equipment
- ❑ good personnel acceptance.

The new equipment enabled the factory to comply with the ISO 9002 standard. This opened new and "harder to please" markets.

Data collected by EDF Industrie.

Case Nr. 4	Industry - Plastic	Country - France
GENERAL ELECTRIC PLASTICS (OISE) ABS Plastic Granules		

Summary

The electricity network of this company has been entirely renewed. A telesupervision system has been installed to improve the management of the electricity consumption and the operating conditions, and to make the production personnel more aware of energy management. An automated reactive energy compensation system was then installed. These modifications led to a decrease in the electricity bill and operation and maintenance costs, and improved production continuity and safety.

1. Company Profile

Situated on a 30 hectares site, the GE Plastics ABS Company produces 50,000 tons/year of ABS plastic granules in approximately 2,000 different colours. Its gas consumption is 430 TJ/year.

The peak demand of electricity is 7,300 kW, for an installed power of 20 MW. The annual consumption is of 40 GWh/year, i.e. 14.4 million French Francs. The electricity tariff includes 8 time-of-use periods.

2. Description of Load Management Measures

2.1 Before Investing in Load Management Installations

The factory electricity network was very diverse and difficult and costly to maintain. The factory managers wanted to closely control the energy consumption.

2.2 Load Management Installations

The electricity network in the factory was progressively renewed during 1992 and 1993. Electricity is now distributed by 20 kV through two halfloops (each approximately 12 km long) and nine transformer stations.

A telesupervision system was then installed, an investment of 0.7 million FRF, with the following objectives:

1) to improve the management of the electricity consumption, by assigning power limits to the various production units

2) to make the production personnel more aware of energy management

3) to improve the operating conditions.

The communication network is of the Modbus-RS485 type at 19 200 bauds. The system includes:

- 18 distributed modules with 600 inputs/outputs each
- one PC micro computer and one printer
- specially developed software whose main functions are:
  - synopsis of the transformation station and the electrical network
  - power, energy and cost management (global and per production unit)
  - remote control and network supervision
  - plotting of active and reactive power curves
  - printing of all results.

This supervision system has shown that reactive energy consumption was too high (yearly average power factor tan phi = 0.7, cos phi = 0.82 - which led to approximate additional costs of 0.45 million FRF/year). A compensation system has therefore been installed including:

- high voltage capacitors, 1200 kvar (constant power)
- low voltage capacitors 1050 kvar (variable power)
- low voltage capacitors 550 kvar (constant power).

This includes a power margin to take account of any potential production increase. It replaced existing capacitors. The operation of the new compensation system is fully automated.

The investment was 1.6 million FRF. The compensation system performance has been pre-guaranteed by the engineering company. The average power factor has been improved to tan phi = 0.3, i.e. cos phi = 0.96.

3. Economical Analysis

The total investment in load management equipment was 2.3 million French Francs.

The electricity bill has been decreased by 0.45 million French Francs and the annual cost savings in operation and maintenance amounts approximately to 0.4 million French Francs.

The pay back times are 2 years for the supervisor and 3.5 years for the compensation system.

4. User's Acceptance and Satisfaction

The electricity network renewal and the supervisor improve production continuity and safety together with network operating conditions.

Reprogramming of the supervisor can be easily carried out in the event of process modification.

Data collected by EDF Industrie.

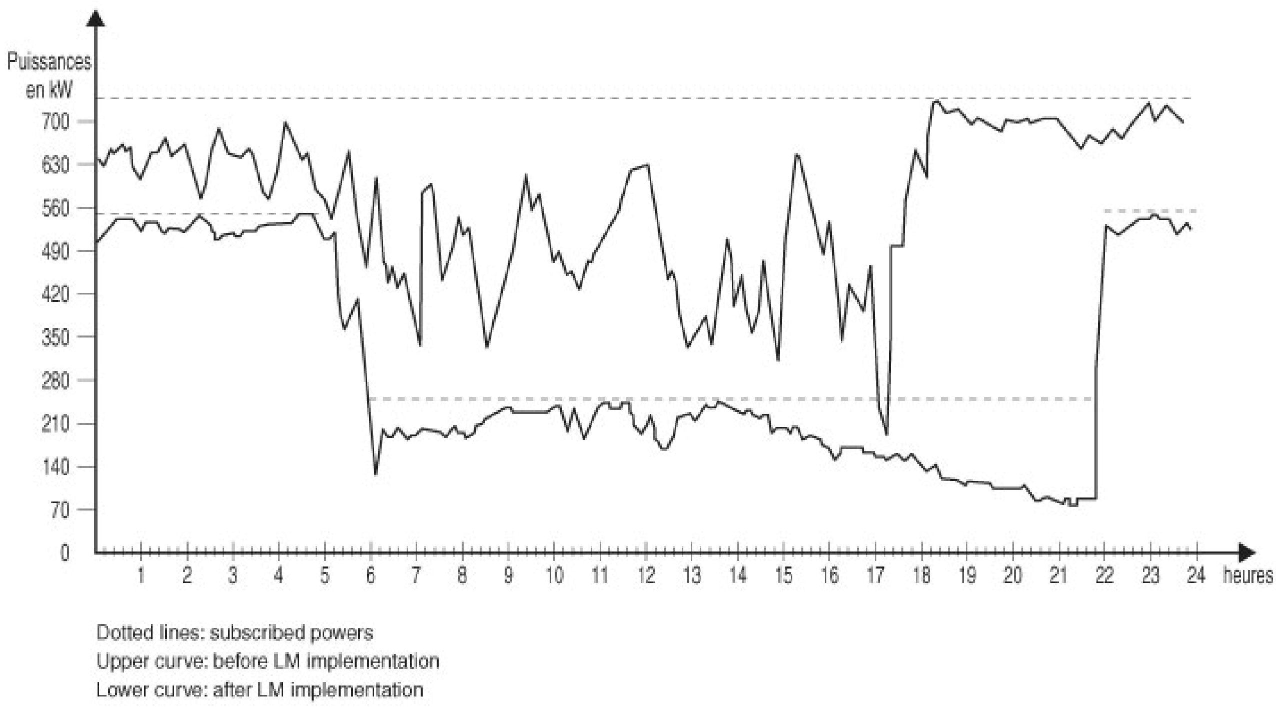


Figure 6.3 - Active power (kW) and tan phi after condensators are in operation

Case Nr. 5	Industry - Quarrying and Building Materials	Country - France
CIMENTS LAFARGE, MARTRES (TOULOUSE) **Cement**		

Summary

The Cement works of the Lafarge group at Martres near Toulouse make extensive use of variable speed drives. More than 80 converters are installed with a power range from 500 W to 400 kW. The pay back period of the investment is less than 3 years.

1. Company Profile

The Cement works of Ciments Lafarge at Martres next to Toulouse were built in 1956, modernised in 1966 and totally refurbished in 1991/92. The Cement works employs 110 persons and has an annual production capacity of 825 000 tons of cement.

2. Description of Load Management Measures

2.1 Before Investing in Load Management Installations

The Cement works consist of two production lines. A total of 1200 electrical motors in the power range from 0.1 to 1850 kW are used in the process.

In the cement works, the ventilation equipment was designed to manage also exceptional conditions. Therefore, under normal operating conditions, the throughput of air was far higher than necessary. During 1991 and 1992, the production lines were totally refurbished. Variable speed drives are now used extensively. In addition, dust extraction systems were installed to comply with new regulations.

2.2 Load Management Installations

The new installation is based on an industrial control system. The process is controlled and monitored from a control room. It was a company policy to apply variable speed drives wherever suitable. Most of the new motors are of the asynchronous type. A total of 80 converters from ABB Industrie in the power range of 0.5 to 400 kW were installed. They allow variation of the speed over a wide range e.g. factor 1:1000. They also give more torque at start and the starting and stopping sequences are “soft”, resulting in negligible impact on the supply system. The number of wearing parts is reduced considerably.

The ventilation installation is now controlled according to the actual needs by the process. The new installation uses only about 70% of the energy of the former installation. And servicing is much easier due to the variable speed.

The rotation oven, the longest in Europe with a length of 161 m and a diameter of 3.75 m, was refurbished with an electronic variable speed drive of 250 kW. The standard speed of the oven is 1.5 revolutions per minute. During warm-up, the speed is only one revolution in 6 minutes. The electronic speed and torque controls guarantee smoother operation.

3. Economical Analysis

The extensive use of variable speed drives has reduced energy consumption for ventilation, transport of material, and the electrical drive of the ovens.

For example, the blower ventilating the cement-shredding unit had its motor power reduced from 400 to 315 kW, together with installing its variable speed drive.

The annual energy costs are reduced by more than 0.15 million French Francs. The pay back period is 3 years, which does not take into account the non quantified savings in operation and maintenance.

4. User’s Acceptance and Satisfaction

The customer is delighted with the result of the installation. Variable speed drives are now used in all cement works of the Lafarge group. The customer is convinced that not all the advantages of the new technology have yet been exploited.

The installation involved rewiring of the total electricity distribution system. Special attention was given to the separation of control signals and power rails, and to the design of the ground plane.

Data collected by EDF Industrie.

6.2. EXAMPLES IN ITALY

Structure of the Italian Electricity Industry

Today, the Italian electric industry includes:

- ENEL, the state-owned company, delivering almost 80% of domestic electricity generation
- other industrial producers, providing 16% of overall generation
- some municipal-owned utilities, producing more than 4% of the total
- minor utilities contributing around 0.5% of the total energy produced.

General Tariff Structure

Time-of-use rates in Italy are based on four rate periods. These are (from the most expensive to the cheapest): Peak, High Load, Medium Load, and Off-Peak. For each period, customers subscribe (declare) the amount of power they require. Their bill is then based on this declared power.

Under certain conditions, loads in excess of the subscribed values are tolerated. In this case however, the excess demand is charged at a penalty rate. When large violations of the subscribed demand limit become common, the customer is required to review his contract in order to avoid further penalties and network problems. This mechanism calls for the choice of the subscribed demand through the optimisation (compatible with the facility operations) of the consumption during the various rate periods.

Policies on Load Management

Load Management practices are aimed at carefully controlling the load profile in order to stay as close as possible to the subscribed demand without exceeding it. To help customers subscribe the correct demand, ENEL has a commercial policy called "start up-contract" which is available for new contracts and for old contracts requiring a load adaptation. This consists of a one-year trial period during which the load is monitored. The subscribed demand is considered provisional, that is, no penalties are charged for violations of the demand limit. After this period, the load recordings allow customers to tailor the final contract according to their load requirements. ENEL's commercial offices are at customer's disposal to assist them in selecting the cheapest option.

Case Nr. 6	Industry - Chemicals and Pharmaceuticals	Country - Italy
SYNTHETIC RESINS AND INSULATING ENAMELS		

Summary

The chemical company involved is a world leader in the production of synthetic resins. The production process consumes the major proportion of the electric energy. Load management has been successfully used for many years. By stricter control, the subscribed demand has further been reduced giving a yearly benefit of an estimated 18 million Lire.

1. Company Profile

The chemical company considered in this example is a world leader in the development and production of synthetic resins and insulating enamels. The production capacity is more than 10 000 tons per year. The company employs a staff of about 60 people. It uses electricity and fuel oil for space heating and diesel oil for back-up generation. The annual consumption is about 3.1 GWh of electricity and 1300 tons of fuel oil.

2. Description of Load Management Measures

2.1 Energy Profile before Taking Load Management Measures

The company is supplied at high voltage (22 kV). A time-of-use contract for high utilisation with subscribed demands of 525/625/625/625 kW for peak, high, medium and off-peak periods, is in force. The analysis of electricity consumption shows that the process is the main load (85%), with lighting 10% and cooling 5%.

2.2 Load Management Installations

Load Management has been successfully in use for many years. The process is controlled by a DUOMAX electronic controller manufactured by Landis & Gyr. On receipt of tariff signals provided by the meter, an electronic device disconnects some loads when the expected load is likely to exceed the subscribed demand.

In 1994, however, an investigation revealed that a stricter control was possible. The subscribed demand was further reduced from the previous values (525/625/625/625 kW) to 450/500/500/500 kW for peak, high, medium and off-peak load periods.

The decrease of 75 kW during peak hours and 125 kW during the other periods was made possible by disconnecting some low priority loads (such as depuration blowers, dryers, cooling fans and pumps). Due to the short duration of the interruptions, the production process was not affected.

3. Economical Analysis

The new load management policy has required the reprogramming of the load controller by an external contractor.

The yearly savings on the electricity bill due to the reduction in subscribed demand is estimated at 18 MLire.

4. User's Acceptance and Satisfaction

The load management measures have been well received from all points of view. No negative impact has been reported with regards to operation and maintenance or on the quality of the products.

The equipment has proven very reliable.

Data collected by ENEL S.p.A. / DSR-CRE

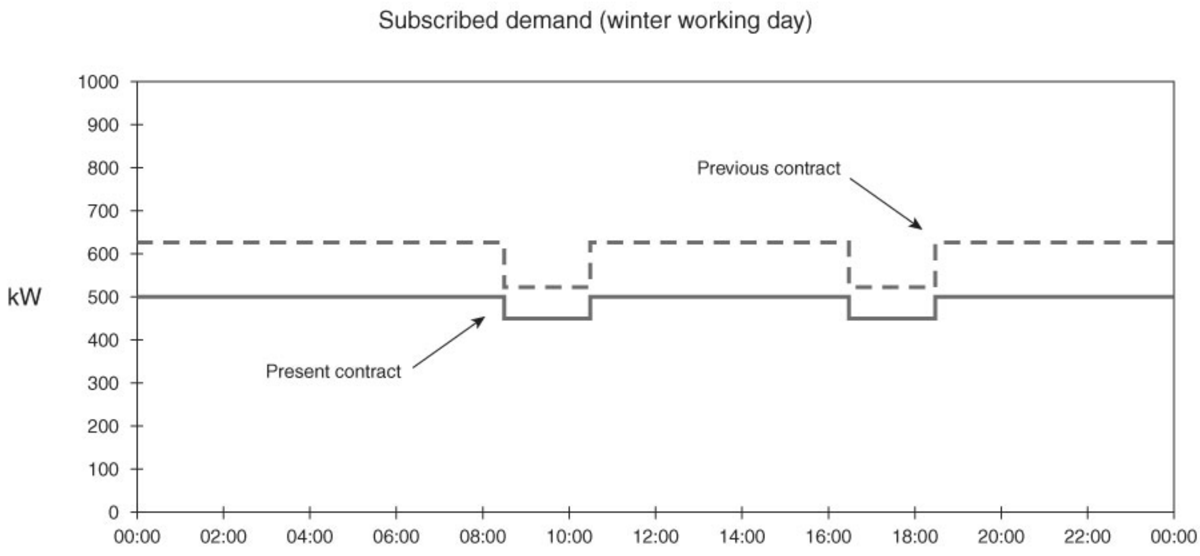


Figure 6.4 - Subscribed demand (winter working day)

Case Nr. 7	Industry - Metal Works	Country - Italy
FONDERIE ROZ S.P.A. TORINO Cast Iron Products		

Summary

FONDERIE ROZ S.p.A. manufactures cast-iron products. The company has a long history of load management. The first implementation dates back to 1986. By rescheduling their production process and by installing a load controller, the subscribed demand was reduced during all periods, but mainly during peak time. The cost of the load management installation and process refurbishment was 45 million Lire. The pay back period for the investment was about three to four months.

1. Company Profile

FONDERIE ROZ S.p.A. manufactures cast-iron products by melting various metal scraps. The company is based in Torino and employs a staff of 50 people. It uses electricity and natural gas. In particular, the induction furnace has very high power consumption and therefore, its operation has to be planned very carefully.

2. Description of Load Management Measures

2.1. Energy Profile before Taking Load Management Measures

FONDERIE ROZ S.p.A. is supplied at high voltage (22 kV). A time-of-use contract for medium utilisation with subscribed demands of 850/2200/2200/2200 kW for peak load, high load, medium load and off-peak periods is in force. The main electric loads are the induction furnace (2500 kW), equipment for sand-blasting and furnace loading (500 kW) and other facilities (170 kW).

2.2. Load Management Installations

Load Management was first implemented in 1986 and is performed by the careful scheduling of energy intensive activities. In particular, the production is organised in such a way to avoid the use of the induction furnace during peak hours. Only activities involving relatively low electric loads are carried out during peak hours, e.g. sand-blasting, furnace loading, holding the molten metal at temperature by means of auxiliary resistors. As a result of this scheduling of operation, the subscribed demand has been reduced by 1670 kW during peak hours. A DOT electronic load controller (manufactured by TXT) was installed to prevent the total load exceeding the subscribed demand in the various rate periods by eliminating the coincident operation of various items of plant. This resulted in a further reduction in the subscribed demand of 150 kW at peak hours and 470 kW during the other periods.

When necessary, the load controller disconnects low priority appliances for short periods of time in order to keep the average load during the integration time interval of the meter (15 minutes) below the subscribed value. In particular, the operation of the induction furnace is interrupted to avoid exceeding the subscribed demand.

3. Economical Analysis

The implementation of load management measures has required an extra investment of 20 million Lire (20 ML) in the process infrastructure and an additional 25 ML for the installation of the load controller. The process modification was mainly concerned with the auxiliary heating equipment which is used to keep the molten metal in the furnace at a set temperature during the periods when the furnace is disconnected.

The total annual savings on the electricity bill are estimated to 165 ML, of which 130 ML are due to the process rescheduling. The remaining 35 ML is due to the use of the load controller. The resulting pay back period is therefore about 3 to 4 months.

4. User's Acceptance and Satisfaction

No negative aspects have been reported regarding operation and maintenance or on the quality of the products.

The load controller is easily re-programmable. The installation has proven very reliable.

Data collected by ENEL S.p.A. / DSR-CRE

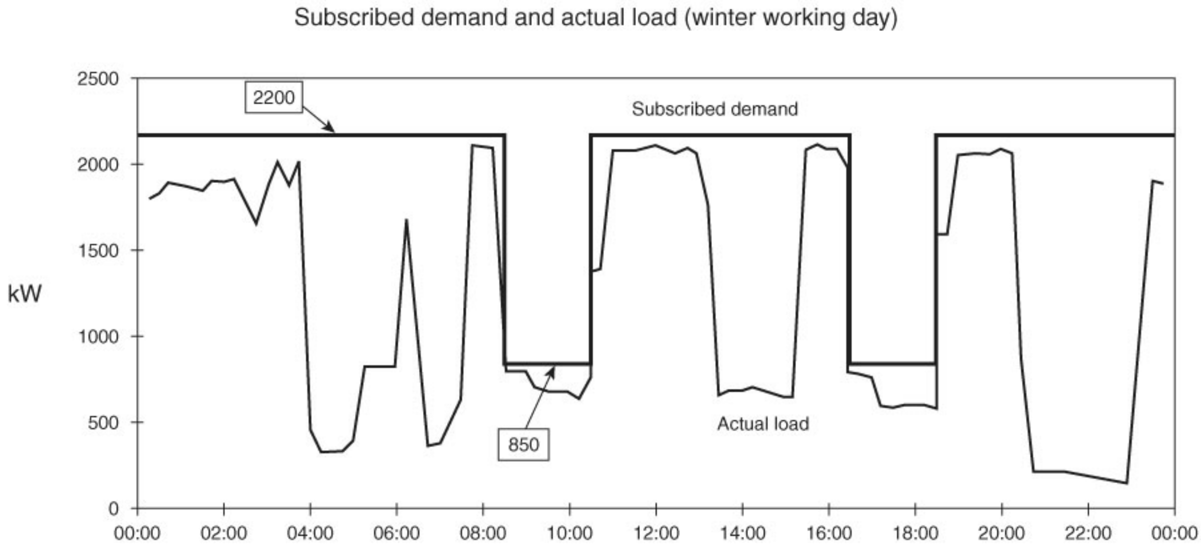


Figure 6.5 - Subscribed demand and actual load (winter working day)

Case Nr. 8	Industry - Quarrying	Country - Italy
CAVA FRANCESCA S.R.L. – PONTIROLO NUOVO (BG) Inert Materials		

Summary

The annual production schedule and adapted inventory policy allow the company to minimise the load requirements during the winter peak hours. The process is eased by the seasonal drop in inerts demand during the winter and by the fact that long term storage does not damage product quality.

Electricity costs have been reduced by 30%.

1. Company Profile

CAVA FRANCESCA S.r.l. employs 10 people. It extracts and processes some 200 000 m^3 of inert materials per year. The electricity consumption is about 900 MWh/year with costs of 200 MLire/year, corresponding to 13% of total operating costs.

2. Description of Load Management Measures

The company is supplied at high voltage (15 kV). A time-of-use contract for medium utilisation with subscribed demands of 150/850/850/850 kW for peak, high, medium and off-peak periods is in force. The recorded maximum demand is 786 kW. The ratings of the main electric loads are:

dredge	300 kW
crushing mills	300 kW
conveyor belts	150 - 200 kW
lighting	10 kW
compressed air	20 kW

Load Management Measures

The measures implemented consist of rescheduling the production in order to allow for the complete interruption of everything except the general services during winter peak time. A suited annual inventory policy that takes into account the limits imposed by local authorities to the quarrying activity satisfies the market requirements with a reduced production time. During winter, market demand for building materials (inerts) is lower than in other periods. Exceptional requests are met by delivering from stock and by weekend production.

Only minor maintenance work is carried out during winter peak time. More important maintenance work is scheduled for the beginning of the working week with additional work on Saturdays when necessary. No additional control equipment is installed. The resulting load reduction is about 700 kW with a consumption of 250 000 kWh shifted to off-peak periods.

3. Economical Analysis

No investment was needed. Additional cost for extra work on Saturdays are small because the whole facility can be operated by three people. Moreover the quality of the product is not affected by long term storage. The electricity bill reduction is in the order of 60 MLire/year.

4. User's Acceptance and Satisfaction

Production scheduling has now been carried out for some years. No negative impacts on quality or quantity of production are reported. The impacts on operation and maintenance are minimal.

The Management of the company is fully satisfied with the implemented measures.

Data collected by ENEL S.p.A. / DSR-CRE

Case Nr. 9	Industry - Waste Treatment	Country - Italy
CO.BE.A. S.P.A. LEVATE (BG) Recycling Ferrous and Non-Ferrous Metals		

Summary

CO.BE.A. S.p.a. recycles large amounts of ferrous and non-ferrous metals. The shredding plant has a high power rating, well above the maximum available demand. By rescheduling the production process and the installation of a load controller, the subscribed demand was lowered during peak time. The additional cost for the installation of load management equipment was 12 million Lire. The pay back period of the investment is about one month.

1. Company Profile

CO.BE.A. S.p.a. is one of the major Italian companies engaged in the recycling of ferrous and non-ferrous metals. It employs a staff of 46 people at its Levate works. Its activities cover collection, shredding and separation of metal scrap. The shredding plant in particular has a very high power consumption, therefore its operation has to be planned and co-ordinated very carefully.

2. Description of Load Management Measures

2.1 Energy Profile before Taking Load Management Measures

CO.BE.A. S.p.a. is supplied at high voltage (15 kV). A time-of-use contract for medium utilisation with subscribed demands of 1800/1800/1800/1800 kW for peak, high, medium and off-peak periods is in force. The annual consumption is about 1 GWh. The main electric loads are the shredding plant with 2800 kW, the shears with 600 kW, the press with 200 kW and other facilities with 130 kW.

ENEL's local marketing office contacted CO.BE.A. S.p.a. because of the unusually high subscribed demand component of 1800 kW in all rate periods. This value was needed because the process often required, although only for short periods, the coincident operation of energy intensive equipment. CO.BE.A. management considered the substitution of the existing main machinery with new, more productive equipment. They also examined the opportunities to reschedule the production processes.

2.2 Load Management Installations

With the new equipment, the production philosophy was switched from parallel to serial operation with intermediate storage of partly finished goods. This meant that the shredding plant and shears were not used at peak times. Routine maintenance was programmed on workdays to allow production on Saturday mornings in order to take advantage of the off-peak rate. The new subscribed demand is now of 350/1800/1800/1800 kW for peak, high, medium and off-peak periods.

A DUOMAX (Landis & Gyr) electronic controller was installed to monitor the shredding plant and shears so as to ensure they are never operated coincidentally.

The rating of the shredding facility (2800 kW) is well above the maximum available demand at any time. This means its operation has to be carefully controlled to avoid penalties due to excess demand. Automatic load disconnection is not practicable in this case because inappropriate power interruption might result in damage to the equipment. Therefore, whenever the demand threshold is likely to be violated, the load controller sends a warning signal to the operator who decides on the optimal shut down measures.

3. Economical Analysis

The decision to install new more productive equipment was taken independently of the implementation of load management measures. The additional cost of the load management installation was 12 million Lire (12 ML). The yearly savings on the electricity bill from the load management measures are estimated to be 134 ML. The pay back period is therefore about one month.

4. User's acceptance and satisfaction

After a period of training, no major impact is reported on quality or quantity of production. The operation of the shredding plant is in manual mode as it is crucial to protect the shredding equipment from unscheduled supply disconnections.

The customer has particularly appreciated the technical assistance offered by the Utility.

Data collected by ENEL S.p.A. / DSR-CRE

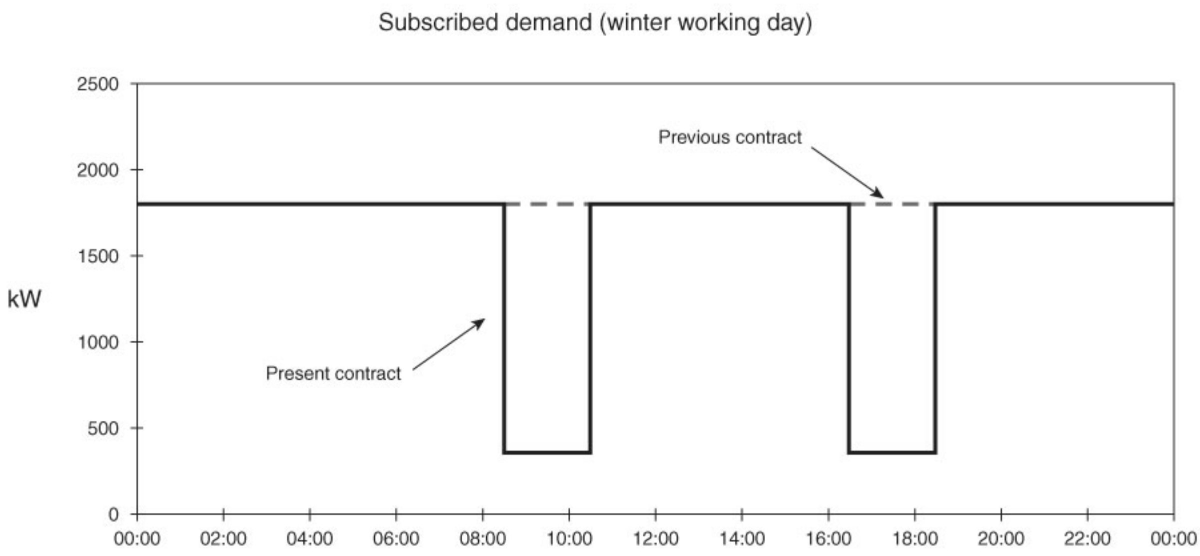


Figure 6.6 - Subscribed demand (winter working day)

6.3. EXAMPLES IN JAPAN

Three cases are presented hereafter

- Takeda Chemical Industries, Ltd., Shimizu City
- Takaoka Electric Manufacturing Co., Ltd, Nagoya
- Tokyo Kinzoku Co., Ltd., Tokyo

Case Nr. 10	Industry - Chemicals	Country - Japan
TAKEDA CHEMICAL INDUSTRIES, LTD., SHIMIZU CITY Industrial Chemical Products		

Summary

Takeda Chemical Industries produce industrial chemical products in their Shimizu plant. The process requires large amounts of nitrogen. The modification of the nitrogen generator led to a reduction in annual energy costs of 4.1 million Yen.

1. Company Profile

The Shimizu Plant of Takeda Chemical Industries employs 273 people and produces over 90 000 tons of industrial chemical products per year. The annual turnover is 18.6 billion Yen.

2. Description of Load Management Measures

2.1 Before taking Load Management Measures

The chemical process uses large amounts of nitrogen. To increase production, the nitrogen generator had to be modified to give more output. Instead of increasing the power rating of the compressor, air (instead of nitrogen) is used, and a pressure booster and buffer tank were added to the existing facility in 1993.

2.2 Load Management Measures taken

The additional nitrogen is produced by an additional booster compressor - increasing the pressure from 5.0 to 6.8 kg/cm^2 - and the use of a buffer tank with increased storage capacity. See the schematic diagram of the nitrogen generator in Figure 6.7.

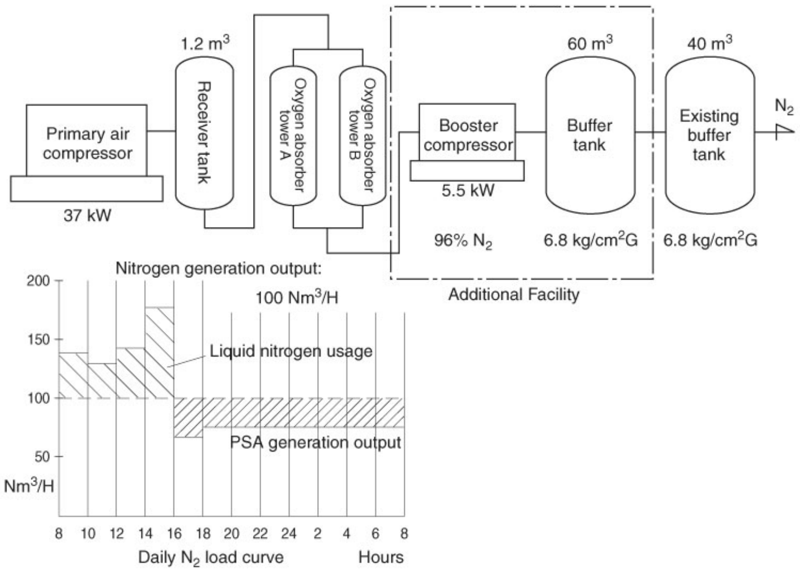


Figure 6.7 - Nitrogen Generator

3. Economical Analysis

As a result of the modification of the nitrogen generator, the demand was reduced by 20 kW. The annual reduction in energy consumption is 68 MWh, and also 23 MWh are shifted to off-peak periods thanks to the buffer tank.

The investment cost totalled 25 million Yen. The annual benefit is 3.2 million Yen. The technical life of the equipment is estimated to 15 years. The payback period of the equipment is 6 years.

4. User's Acceptance and Satisfaction

This change in process gave the following benefits:

- production and maintenance costs are lower
- although the purity of the produced nitrogen is inferior to that of liquid nitrogen, product quality is maintained by adequate control of the appropriate nitrogen purity
- operation of the nitrogen production is easier due to the use of fully automated equipment
- further increase in nitrogen production is possible
- liquid nitrogen is used as a backup during maintenance operations of the compressor
- production cost have been reduced considerably.

Data collected by Chubu Electric Power Company.

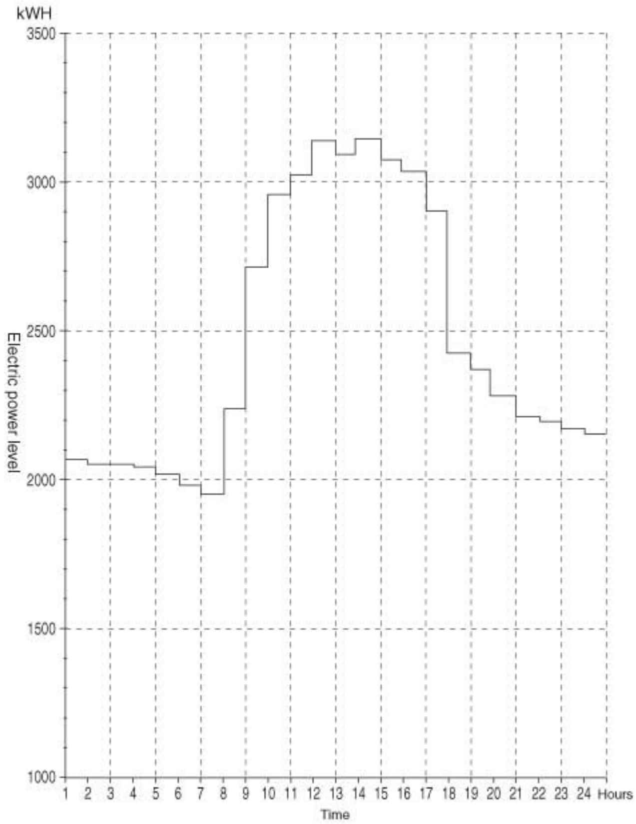


Figure 6.8 - Daily Load Curve after implementation (July 27, 1993)

Case Nr. 11	Industry - Electrical and Electronics Equipment	Country - Japan
TAKAOKA ELECTRIC MANUFACTURING CO., LTD., NAGOYA Electric Machines and Appliances		

Summary

The existing heat pump installation for air conditioning was replaced. Thanks to heat storage in a water tank and use of electricity at night rate, the annual energy costs have been decreased by 11.7 million Yen. Product quality has improved and operator errors reduced by 20% as a result of work environment improvement. The number of facility failures went down from ten to one a year.

1. Company Profile

The Takaoka Electric Manufacturing Co. in Nagoya produces electric machines and appliances with an annual turnover of 18 billion Yen. It employs 754 persons.

The electricity consumption is 8149 MWh/year. The peak demand is 3750 kW at the beginning of August.

2. Description of Load Management Installation

A heat pump system, a water storage tank and a building management system (developed by the user) were installed in 1988. Its installed power is 110 kVA, compared to 280 kVA for the old heat pump installation.

The cost of the equipment was 60 million Yen. The all-day electricity consumption has been transferred to night consumption except on the warmest days. To save more energy, the windows are shaded using a reflective film.

3. Economical Analysis

The total investment was 60 million Yen.

The annual electricity consumption was reduced from 800 MWh/year to 360 MWh/year (with a night time shift from zero to 25%). Saving in energy is 7.6 million Yen, savings in operation and maintenance are 4.8 million Yen/year.

4. User's Acceptance and Satisfaction

In comparison with the previous facility which required approximately ten repairs a year, the new equipment only required attention, on average, once a year. The maintenance costs therefore have been substantially reduced.

Introduction of a central monitoring and control system led to a reduction in the number of operators from two to one. Moreover, as a result of work environment improvement, operator errors were reduced by 20%, which in turn contributed to an improvement in product quality.

Data collected by Chubu Electric Power Company.

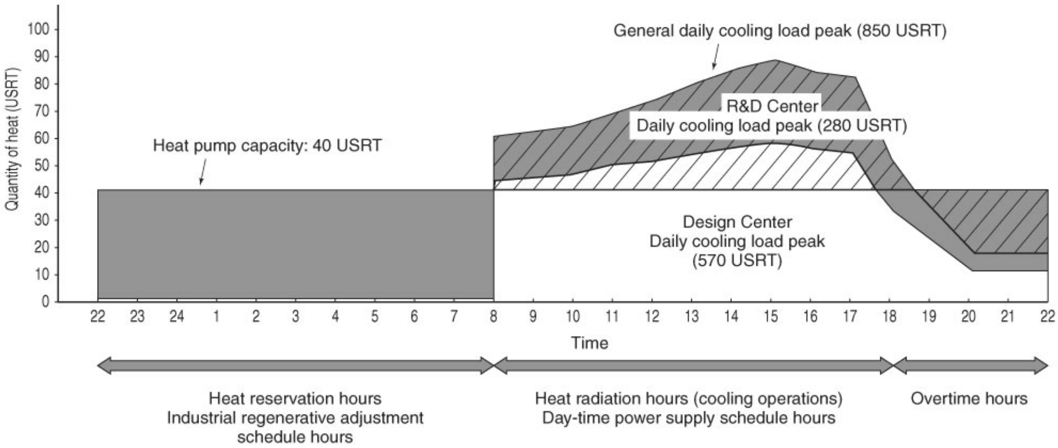


Figure 6.9 - Regenerative heat type air-conditioning system features

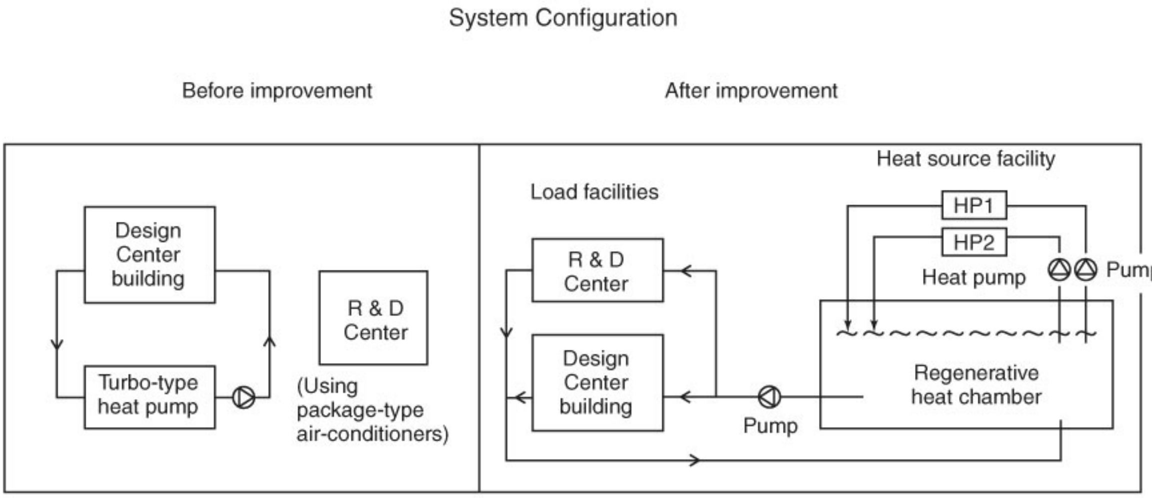


Figure 6.10 - System configuration

Case Nr. 12	Industry - Metal Works	Country - Japan
TOKYO KINZOKU CO. LTD., TOKYO Non-Ferrous Metal Products		

Summary

The investment comprises an intensive aluminium melting furnace (to permit unattended melting operations during the night and melt-holding operations during the day) plus a demand controller which temporarily shuts down specific equipment during periods of high demand. The heat treatment furnace has also been automated to shift daytime operations to night-time.

The annual benefit amounts to 11 million Yen. Other benefits include environmental improvement and reduced oxidation of the metal.

1. Company Profile

The Tokyo Kinzoku Co, produces 1210 tons of non-ferrous metal products per year with an annual turnover of 2.4 billion Yen. It employs 69 persons operating 10 die casting machines and 9 power presses.

The electricity consumption is 3289 MWh/year at a cost of 42 million Yen. The peak demand is 678 kW.

2. Description of Load Management Installation

An intensive aluminium melting furnace was introduced in 1991. This permitted unattended melting operations during the night and melt-holding operations in the daytime. In order to manage the load shape, the furnace was connected to a demand controller which gives an alarm based on the demand prediction and temporarily shuts down specific equipment.

The heat treatment furnace has been automated to shift daytime operations to night-time.

The electricity shifted to off-peak periods is 694 MWh/year.

3. Economical Analysis

The total investment was 92.8 million Yen, of which load management equipment was only 0.8 million Yen.

The total annual benefits are 11 million Yen, This is made up of 3.7 million Yen/year for electricity bill savings, 6.5 million Yen/year for cost savings in operation and maintenance, and 0.8 million Yen/year from increased production quality.

4. User's Acceptance and Satisfaction

Melting operations are carried out during non-production hours so that production interruptions due to a shortage of melt have been avoided. In addition, a consistent melt temperature is secured. However, consecutive holidays are required for maintenance and repair operations.

The aluminium alloy is not heated to an excessively high temperature at the time of melting, so that oxidation has been decreased down to one tenth. This improved the yield rate and corrected a wide range of internal product defects.

Experience shows that it is crucial to make careful and thorough preparation during the afternoon shift in order to ensure that melting operations are carried out successfully during the night, when no operators are present. Another key to the successful implementation of the load management initiatives has been due to the full support given by senior management and cooperation from the entire work force.

Data collected by Chubu Electric Power Company.

Hours	KW
1	248
2	246
3	236
4	214
5	213
6	233
7	281
8	392
9	470
10	541
11	566
12	568
13	510
14	543
15	538
16	569
17	560
18	542
19	562
20	521
21	540
22	511
23	356
24	237
Maximum	569
Night-time rate	26.0%

Before "Management" Implementation July 4, 1990

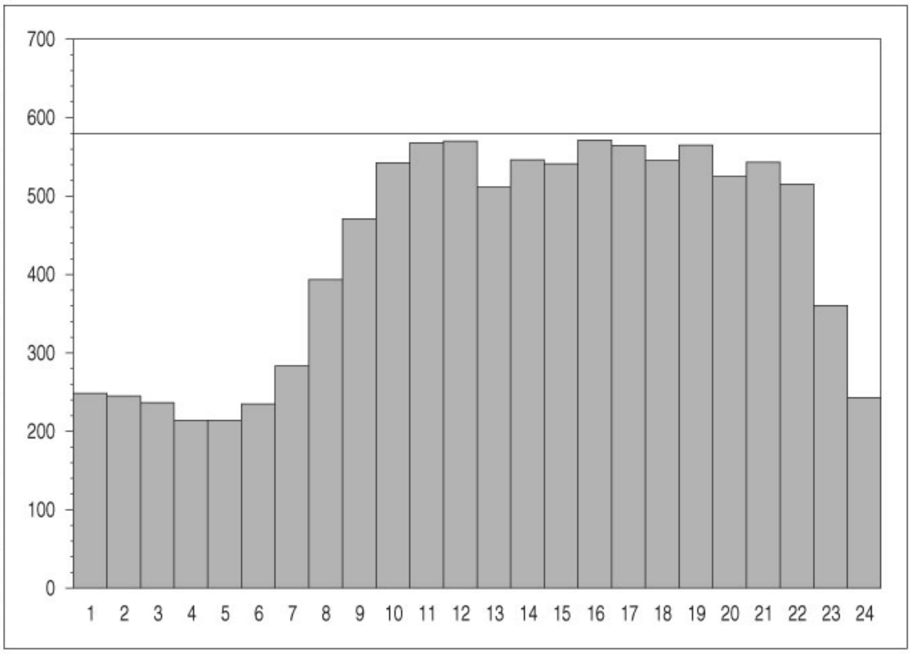


Figure 6.11 - Before “Management” Implementation (July 4, 1990)

Hours	KW
1	573
2	565
3	576
4	573
5	576
6	556
7	575
8	428
9	463
10	536
11	573
12	555
13	511
14	595
15	561
16	599
17	605
18	548
19	568
20	557
21	530
22	511
23	461
24	582
Maximum	572
Night-time rate	42.1%

After "Management" Implementation January 17, 1992

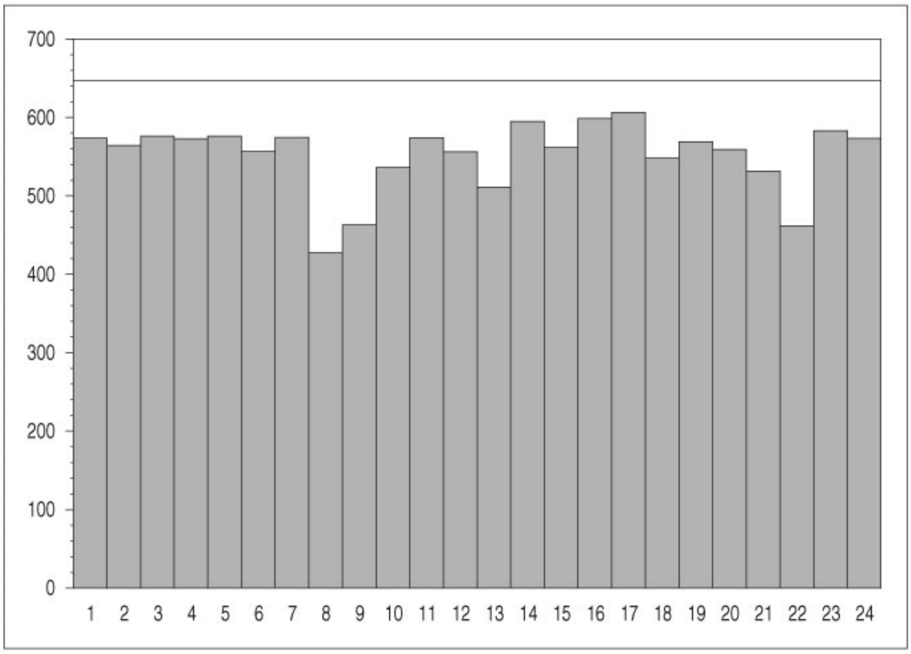


Figure 6.12 - After “Management” Implementation (January 17, 1992)

6.4. EXAMPLE IN THE NETHERLANDS

Structure of the Dutch Electricity Industry

In the Netherlands, various companies make up the electricity supply industry. Four major production companies sell their produced electricity to a pool. Several distribution companies buy energy from the pool and sell it on to their customers and end-users. Due to the fact that electricity demand varies considerably during the day, over weeks, months and years, there is a need for system planning and optimisation. This duty is fulfilled by a national institution called SEP.

The Main Functions of SEP are:

- ❑ planning of the daily production, based on forecasts
- ❑ providing economical optimisation; achieving the best use of primary fuel sources
- ❑ long-term planning of the need for capacity
- ❑ providing a system for billing the distribution companies according to their demand.

Components in the Tariff Structure

Throughout the Netherlands, many different tariff structures exist. Each utility has its own policy in setting up its tariff structure. Nevertheless, most tariff structures provide strong incentives to customers for Load Management (see the Appendix A.1 for actual information on tariffs).

EZN

The tariff structure was set up to reduce the extreme growth in the peak power of the system. A tariff system with three major cost components for industrial customers is used:

- ❑ fuel costs during day hours (charged per kWh)
- ❑ fuel costs during night hours (charged per kWh)
- ❑ fixed operating costs (charged per kW during the peak power period of the network).

As a rule of thumb, for an industrial customer, the electricity bill will comprise 50% unit costs and 50% fixed costs.

Policies on Load Management

The reduction of the fixed operating costs is a big incentive in Load Management, because each distribution company can influence its share on the fixed operating costs of production. The sum of the fixed operating costs of the four production companies is split between the distribution companies according to their actual share in power during the peak power in the system.

The moment of maximum load is not at a fixed date during the year; it can occur at any time. As a result of this billing strategy, every Dutch distribution company tries to make the best use of its potential for Load Management. As a result after a few years of operation, the load curve during daytime has flattened considerably throughout the year.

Case Nr. 13	Industry - Agriculture, Agrifood	Country - Netherlands
GREENHOUSES (NORTH BRABANT) Vegetables		

Summary

The local utility in the Southern parts of the Netherlands has developed a tariff option for customers operating greenhouses. The participating customers receive a discount on their electricity bill dependent on them reducing their demand during periods of high load on the electrical network.

1. User's Profile

In North Brabant (southern region of the Netherlands), greenhouses are numerous. They use light to grow plants faster, cooling equipment and pumps to fill water tanks for irrigation.

About 100 operators of greenhouses participate in an adapted form of load management where they reduce their actual load during high load conditions on the electric network. This is communicated by a "high load" signal to which they are free to respond. Their financial benefit is proportional to the power reduction.

2. Description of Load Management Installations

The customers taking part in the load management programme are connected to an information network. The Electricity distribution companies send messages to their customers indicating when they should reduce their loads. These times can either be at variable time instants or on a regular basis.

These customers are provided with two potential free contacts, which are incorporated in the tone ripple device. These contacts have different functions: The first signal is a warning signal by which the customer knows that the control period starts within 5 minutes. The second signal indicates the beginning of the control period. Some customers use the signals in a manual way. They connect the warning signal to a bell or flashing device. When a warning is received they manually shut down some energy consuming processes. Most customers connect the signals to process computers or any other system to automatically shut down processes. A relatively small group of customers reschedule their processes in such a way that their maximum demand occurs during night hours. During day hours (the normal period where the utility controls the load) they succeed in having almost no demand at all. In this way they automatically fulfil the load management requirements.

Customers who can control their loads get a special tariff option which is applied on top of the normal tariff. By means of tone ripple control the utility can send a message to every participating customer, when the customer should control his load. His actual demand during these periods is monitored by a special two-register demand measuring device. This device records the maximum demand during the utility control period and the overall maximum demand. For the difference between these two demands, the customer receives a credit of HFl 22,50 per kW per half year. This system gives maximum freedom to the customers; they can choose whether they want to control their load or not. But when a participating customer does not reduce his load once during the utility control periods, he cannot achieve a high credit any more.

3. Economical Analysis

The utility calculated how the yearly bill of the total group of participating customers is influenced by the load management agreement.

4. User's Acceptance and Satisfaction

The above mentioned figures are collected over the year 1993. The number of participants is still increasing, partly because the distribution company actively promotes this form of load management, and also because the savings can be significant and in some cases can add up to a quarter of the annual costs.

Data collected by n.v. PNEM, s'Hertogenbosch.

6.5. EXAMPLES IN SWEDEN

Structure of the Swedish Electricity Industry

The Swedish electricity market was deregulated on January 1st 1996. Politicians believe that deregulation will lead to a more competitive market and therefore to the more efficient use of electricity. Customers now have a choice of different suppliers.

General Tariff Structure

In the deregulated market, the tariffs for electricity supply have one component for consumed energy and another for the peak demand. There is, therefore, a strong incentive for the customer to reduce his peak load. This will reduce his costs for the peak load, and also the cost for maintenance and additional installations associated with the peak load.

Policies on Load Management

Before deregulation, Load Management was regarded from an engineering approach in order to make better use of the electric network and therefore reduce the electricity supply company's operational costs. In a deregulated market, the focus of an electricity supply company shifts from the above approach to one where the response to customers needs has top priority in order to maintain and increase sales. The aim is to find out the most optimum terms and conditions for supply, in order to decrease the customer's energy bill. In addition, products and services that reduce customers overall costs, are offered.

The Swedish government has a programme, the aim of which is to decrease the need for electricity and to ensure its efficient use. This programme is administered by Nutek. Nutek sponsors local industry activities on load management.

Case Nr. 14	Industry - Metal Works	Country - Sweden
GUNNEBO FASTENING AB, GUNNEBO Nails and other Iron Products		

Summary

Gunnebo Fastening AB is the main manufacturer of nails in Sweden. The peak load was high compared to the total power consumption.

Therefore the company planned to redesign the process. With improved process control and the installation of load management equipment, the peak load was substantially reduced. As a result, the electricity bill was reduced by about 5%.

1. Company Profile

Gunnebo Fastening AB manufactures nails and other iron products. The company has a turnover of 223 Million SEK a year and employs a staff of 197 people. The primary energy used is electricity, except for heating boilers, where oil is used in periods of high load on the electric system.

Gunnebo Fastening AB decided to improve the process and to control the use of energy. New load management equipment was installed in 1994.

2. Description of Load Management Measures

2.1 Energy Profile before Taking Load Management Measures

Gunnebo Fastening AB is supplied at high voltage (10 kV). Tariff N2 with 6 price periods is applied. The peak demand was 6300 kW and energy consumption 28 GWh a year. Peak demand was measured on a Monday morning in January.

The process analysis shows that installations for heat treatment and surface treatment use about 50% of peak demand, electric motors and welding equipment make up about 30%, fans and cooling equipment another 10%, lighting load amounts to about 10% of the peak demand.

2.2 Load Management Installation

The load management equipment installed measures all actual consumption and process temperatures. The material flow and the start up sequence of the heating furnaces were redesigned and stabilised. The main production units were refurbished with tighter temperature control.

As a result, the new installation has reduced production lead times and also production cycle time. Additional energy savings have been made with the installation of a new space heating system for the premises, replacing the old hot water system.

3. Economical Analysis

The company objective was to achieve a pay back period on their investment in approx. one year. The redesign of the process infrastructure required an investment of 150 000 SEK. The cost of the new load management equipment was 250 000 SEK.

The combination of load management measures resulted in a reduction of the subscribed demand from 7300 kW to 6300 kW. Improved planning methods and shorter production times resulted in a reduction in energy consumption of over 1%. This meant that the pay back period for the complete project was one year.

4. User's Acceptance and Satisfaction

The process redesign improved the production quality substantially, because of tighter control and shorter lead times. The installed equipment is easily adaptable. Additional benefits result from the better supervision of the production and the reduced time to identify malfunctions.

The company is very satisfied with the attained improvements.

Data collected by SYDKRAFT AB, Malmö.

Case Nr. 15	Industry - Metal Works	Country - Sweden
LUNDGRENS GJUTERI AB, HALMSTAD **Cast Iron Products**		

Summary

Lundgrens Gjuteri AB is a manufacturer of cast iron items. The peak load was high compared to the total power consumption. The company therefore took part in a government sponsored energy savings programme. This involved the installation of load management equipment and the redesign of the process. As a result, the peak load was substantially reduced. Also the electricity bill was reduced by more than 10%.

1. Company Profile

Lundgrens Gjuteri AB is situated in Halmstad and manufactures cast iron items. The company produces 3600 tons a year with a staff of 67 people. The primary energy used for production is electricity. Space heating is provided by a district heating scheme.

Lundgrens Gjuteri AB decided to improve the process and to control the use of energy. New Load Management equipment was installed in 1994.

2. Description of Load Management Measures

2.1 Energy Profile before Taking Load Management Measures

Lundgrens Gjuteri AB is supplied at high voltage (10 kV). Tariff N3 with 6 price periods is applied. The peak power was reached anytime during production hours. The peak power used in the process chain was 3850 kW. The main electrical loads are the two ovens for melting the iron and the casting equipment with a capacity of 6 tons per hour. Other loads are the grinding robotics and surface finishing machines.

Compressors, fans and cooling equipment use an additional 100 kW.

2.2 Load Management Installation

The load management equipment installed measures all actual consumptions. Meters are installed on different production units in order to acquire information regarding load and to increase staff awareness regarding power consumption. The two induction ovens of 1500 kW each can be controlled separately. When the overall load reaches a pre-set limit, the power is reduced. The first stage is a "soft" reduction, when only building ventilation and some compressors are controlled. If the load is still too high then further power reduction is activated.

3. Economical Analysis

The company objective was an investment with a pay back period of one year maximum. The redesign of the process infrastructure required an investment of 40 000 SEK. The cost of the new load management equipment was 80 000 SEK.

With the new load management equipment and the training of staff, the peak load was reduced from 4000 kW to 3200 kW. The energy consumption was marginally reduced to 5800 MWh per year mainly due to shortened lead times in production. The resultant savings on the electricity bill meant that the pay back period for the complete project was less than one year.

4. User's Acceptance and Satisfaction

The process redesign improved the product mainly because of tighter temperature control and shorter lead times. The installed equipment is easily re-programmable and has shown a high degree of reliability. The company is highly satisfied with the outcome of the new installation.

Data collected by SYDKRAFT AB, Malmö.

Case Nr. 16	Industry - Paper and Wood	Country - Sweden
ANSGARIUS SVENSSON, SÖDRA VI High Quality Timber		

Summary

Ansgarius Svensson processes timber. Electricity is used for sawing and drying. The company implemented a load management system with strictly automatic load control in 1993/94 in order to reduce the peak demand. As a result, the electricity bill was reduced by approx. 5%. The cost of the load management installations was 100 000 SEK. The pay back period is estimated to 2 years.

1. Company Profile

Ansgarius Svensson is a local producer of high quality timber. The company has a turnover of 50 Million SEK a year and employs a staff of 20 people. The primary energy used is electricity. The peak demand is set up in winter time.

Timber drying requires various profiles of temperature and air humidity during the drying sequence. Ansgarius Svensson decided to improve the drying process and to control the use of energy. New load management equipment was installed in 1993/94.

2. Description of Load Management Measures

2.1 Energy Profile before Taking Load Management Measures

Ansgarius Svensson is supplied at high voltage (10 kV). Tariff N3 with 6 price periods is applied. The peak demand was 690 kW and energy consumption 3.2 GWh a year. Peak demand arose at any time during the winter months.

Analysis of the process revealed that load control could only be implemented for the drying part of the production process. Load control on saws would result in too many problems with the production flow.

Drying was carried out using electric boilers, compressors and fans. The drying operation accounted for about 50% of peak demand, saws 45% with lighting and heating making up the remainder.

2.2 Load Management Installation

The load management equipment installed measures the consumption of the drying equipment. Boilers, compressors and fans are controlled individually. Load control is fully automatic. The parameters (temperature, air, humidity and time) are all controlled.

3. Economical Analysis

The objective of the company was that any investment should be recouped in approx. two years. The cost of the new load management equipment was 100 000 SEK. No other change in the process infrastructure was necessary.

After optimisation of load management measures a reduction of the subscribed demand from 690 kW to now 570 kW was attained. Due to the resulting savings on the electricity bill, the estimated pay back period of two years for the whole installation was met.

4. User's Acceptance and Satisfaction

The installed equipment has proven to be reliable. The load control is fully automatic. The quality of the produced goods has improved. During the drying process, both temperature and humidity are recorded. On demand, graphs can be shown to interested customers. The company is very satisfied with the attained improvements.

Data collected by SYDKRAFT AB, Malmö.

6.6. EXAMPLES IN SWITZERLAND

General Remarks on Electricity in Switzerland

Electrical energy amounts to 20% of the total Swiss energy consumption. The production is mainly hydro (61%, of which 35% by storage facilities and 26% by power stations on rivers) and nuclear (37%). There are considerable daily and seasonal variations in power generation because of the water level in the rivers and seasonal storage and pump-storage hydro power stations.

Structure of the Swiss Electricity Industry

The structure of the Swiss electric industry has grown historically and encompasses more than 1200 companies. Some are privately owned and operated, but the majority belongs to the public sector. Each company is autonomous in setting tariffs (structure and price level).

General Tariff Structure

The majority of the Swiss utilities use a tariff structure with two cost components for industrial customers:

- a cost element for the peak power used (kW; demand rate for bulk consumers)
- a cost element for the consumed energy (kWh).

Many companies charge time-of-use rates with two periods on working days and flat rates at weekends with different levels during summer and winter seasons. The maximum power is recorded and defines the cost component for power demand. As a rule of thumb, for an industrial customer, the rate element related to power makes up approximately a third of the electricity bill.

Policies on Load Management

Load Management practices are encouraged in order to control the load profile. The maximum power component on the electricity bill may be reduced by close collaboration with the local utility. By shifting its maximum power demand to off-peak hours, the customer is charged a lower rate for his use of the electrical network.

The individual utilities are autonomous in setting up their Load Management measures. Load management programmes are mainly used by the largest electricity companies, in close co-operation with their customers. Load Management is treated as a bilateral collaboration between supplier and customer and less as a “technical act”.

Utilities generally provide an information gathering service with regards to consumptions of individual customers and will also provide basic analysis of possible improvements. Local suppliers are pleased to answer questions.

Case Nr. 17	Industry - Paper and Wood	Country - Switzerland
WIDMER-WALTY AG, OFTRINGEN **Recycling paper and corrugated paper**		

Summary

Widmer-Walty AG manufactures packing material using waste paper. A new power plant - designed as a combined cycle gas turbine set - produces the necessary process steam and electricity. During the local electricity supplier's peak load conditions, the power plant is utilised to feed energy to the electric network. An agreement between Widmer-Walty AG and the electricity supplier covers power consumption and power generation.

1. Company Profile

The 300 staff of Widmer-Walty AG manufacture recycled paper for office use and for packaging as well as corrugated paper. The company processes 67 000 tons of waste paper a year, 10% of the Swiss volume. A wide range of packaging products used for transport, storage and exhibition is produced.

2. Description of Load Management Measures

2.1 Energy Profile before Taking Load Management Measures

Manufacturing paper and corrugated cardboard demand a huge amount of process steam to dry the paper and to glue the corrugated cardboard. Till 1993, process steam was produced in two oil fired boilers. Due to new regulations on air pollution, a new solution had to be implemented.

Following various studies, the answer was felt to be a combined cycle gas turbine plant.

Major criteria were the long term requirement for process steam and electricity and the optimum use of the available primary energy. See the schematic diagram in Figure 6.13.

The power plant consists of a gas turbine and a steam turbine. It produces 45 tons of process steam per hour and 9 MW electricity.

The production runs in three shifts from Monday morning to Saturday night. The power plant is started automatically on Monday morning.

2.2 Load Management Measures Taken

The power rating of the combined cycle power plant is designed to produce the power demand for in house process requirements and a surplus of several 100 kW. This surplus energy is delivered to the local network. Actual measured values of the energy supply - consumption or generation - are available to the load management operators at AEW.

The objective of the load management initiative is to increase generation at peak load conditions on the network. The local electricity supplier transmits a "high load" control signal to Widmer-Walty AG when the load on the network is high - usually in the morning of workdays from November to February. The combined cycle plant is then set to a different mode of operation in order to produce more electricity. In addition, parts of the internal manufacturing process are suspended. With these measures, up to 3 MW can be delivered to the network for a period of time. Figure 6.14 shows an example of an increased delivery.

3. Economical Analysis

The agreement between the customer, Widmer-Walty AG and the local electricity supplier, AEW, especially rewards the customer for the load generated during the peak load conditions of the network. During the first year of operation, the system has shown its worth. Widmer-Walty was rewarded for their power supplied during the networks peak loads.

4. User's Acceptance and Satisfaction

The customer adapted the driving of the power generation equipment to maximise the generated power during the "high load" signal. The new regime was introduced without major difficulties.

Data collected by Aargauisches Elektrizitätswerk.

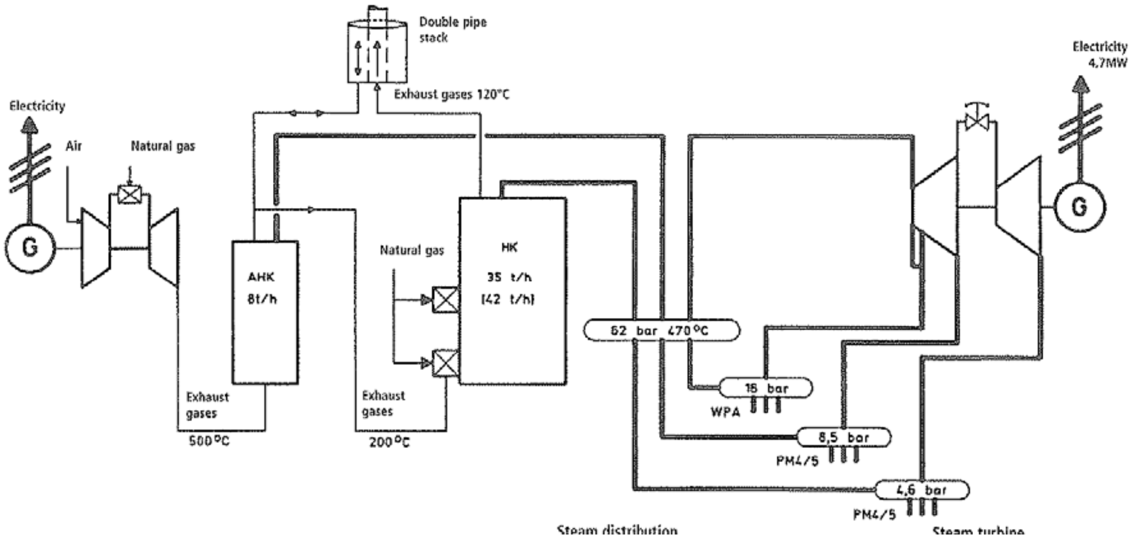


Figure 6.13 - Widmer-Walty combined cycle power plant

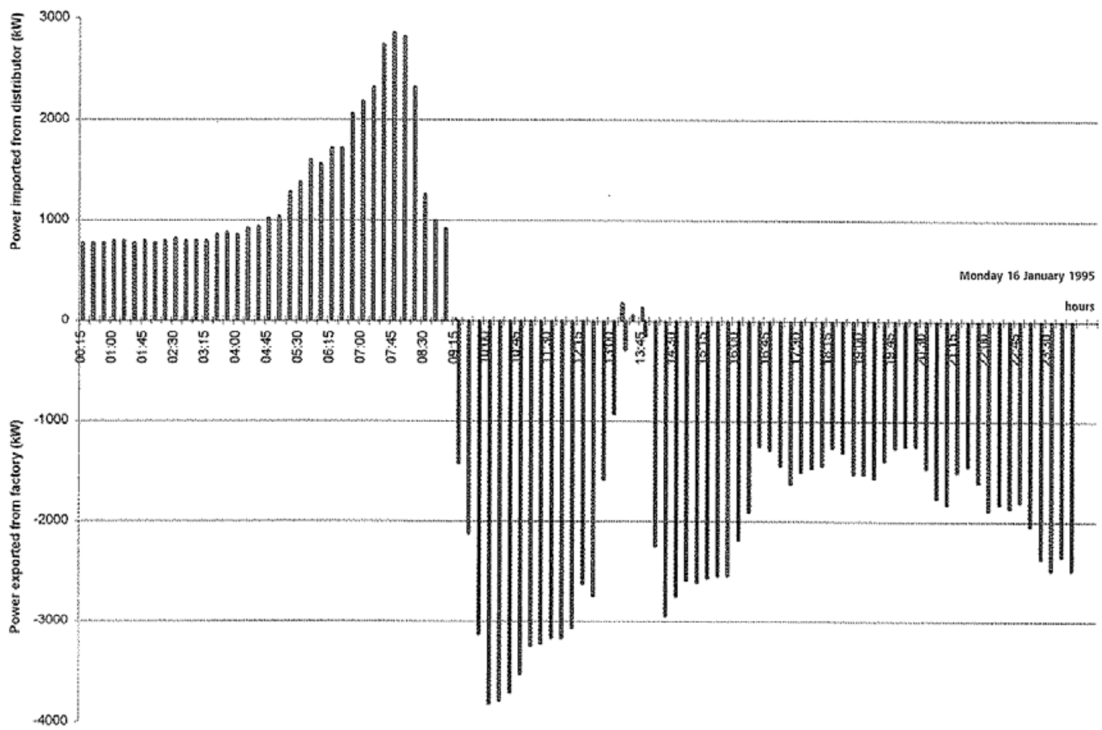


Figure 6.14 - Increased electricity delivery to the electricity supplier

Case Nr. 18	Industry - Quarrying	Country - Switzerland
STEINBRUCH MELLIKON AG, MELLIKON Limestone		

Summary

Steinbruch Mellikon AG operates a limestone quarry. In order to provide a nearby cement works with crushed limestone for cement production, Steinbruch Mellikon AG installed a new stone crusher. This case history describes the agreement made between the company and AEW regarding reduction of power demand during peak load situations on the AEW network.

1. Company Profile

Steinbruch Mellikon AG has a staff of 20 people. It originally removed approximately 100 000 tons of limestone per year from the quarry at Mellikon. The limestone was mainly processed in shaped blocks for use in parks and gardens and for the building of natural walls. A small part of the production was crushed for use in road making.

A nearby cement works has developed a need for 200 000 tons of crushed limestone for use in cement production.

2. Description of Load Management Measures

2.1 Energy Profile before Taking Load Management Measures

Steinbruch Mellikon AG's existing stone crusher has a power rating of 90 kW. Its use was not restricted. For the extension of capacity, the biggest dredge operating in Switzerland was put to use to extract 300 000 tons or 120 000 cubic metres of limestone per year. The existing stone crusher was supplemented with a more powerful type with a power rating of 230 kW.

2.2 Load Management Measures Taken

The stone crusher and storage facilities for the crushed material were designed in close co-operation with the electricity supplier so that the crusher machines do not operate permanently. The aim of the load management measures taken was to either disable or at least drastically reduce power consumption during peak load situations on the network.

3. Economical Analysis

The agreement between the customer and the local electricity supplier defines an attractive bonus related to the level and cost of peak power used. It allows the interruption of the operation of the crushers for several hours during peak load conditions on the network. As these conditions normally arise on working days in winter, this interference on the production process is manageable because sales of limestone are reduced during winter.

4. User's Acceptance and Satisfaction

The customers accepted the new regime without difficulties.

Data collected by Aargauisches Elektrizitätswerk.

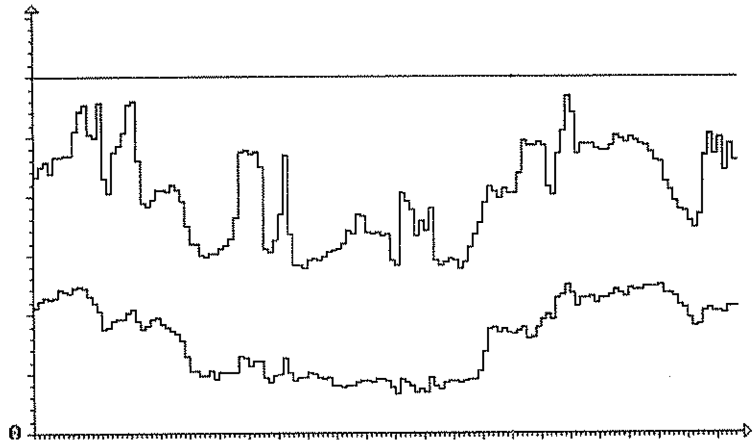


Figure 6.15 - Effect of Load Management measures

6.7 EXAMPLE IN THE UNITED KINGDOM

Structure of the British Electricity Power Industry

The UK electricity supply industry has been privatised for over five years and comprises a number of generating companies, twelve Regional Electricity Companies (RECs) and three integrated generating and distribution companies. There is also a National Grid Company which until recently was owned by the 12 RECs.

General Tariff Structure

All customers with a load capacity exceeding 100 MW are free to negotiate supplies of electricity from any supplier or generator with appropriate fees paid to the transmission and distribution company. The Electricity Regulations require companies to encourage efficient use of electricity and specifically refer to DSM as a means of achieving this objective. Electricity companies have encouraged DSM through tariff arrangements and, in some cases, providing load management services for customers including gas and electricity where relevant. There are some companies independent of electricity suppliers also providing load management services to industry.

The effect of privatisation on primary energies has encouraged the adoption of natural gas turbines, CHP (or co-generation) and the burning of waste for generation of electricity. A government subsidy encourages the development of renewable sources of electricity (wind power, small hydro, etc.). These all have a contribution to load management according to the costs and size of the relevant load.

Policies on Load Management

Competition is the thrust for load management applications in the UK. Now that differences in price for the supply of electricity are reducing, services, such as load management, are becoming increasingly important for customers and electricity suppliers. Consequently, there is no national policy on such matters as DSM, SSM or IRP (see Appendix A.2), although European legislation could have an influence in the future.

Case Nr. 19	Industry - Agrifood	Country - UK
ALLIED MILLS LTD., LIVERPOOL Flour and Flour By-Products		

Summary

Allied Mills Ltd. produces flour and flour by-products. By introducing variable speed drives for the main motors, the peak energy consumption was reduced and the noise level on the premises significantly lowered. The cost of the load management installations was £ 4,500. The pay back period is estimated to be 1.3 years.

1. Company Profile

Allied Mills Ltd. processes, in its Seaforth Mill in Liverpool, about 100 000 tons of wheat into flour and flour by-products. The plant runs approx. 160 hours a week on average. It employs a staff of 30 people. The primary energy used is electricity for the various motors and lighting, as well as gas for central heating.

2. Description of Load Management Measures

2.1 Energy Profile before taking Load Management Measures

Seaforth Flour Mill is supplied at high voltage. A tariff with day/night units is applied. The maximum demand was 1200 kW and measured on an afternoon in November.

The mill has 230 motors in the range of 0.75 to 110 kW. The compressors and air fans are equipped with 18 kW motors. For lighting, 429 x 1.5 m twin light fittings are used.

The original return air system overpressurised the flour mill. It was energy intensive and generated unacceptable noise levels.

2.2 Load Management Installations

For the return air system, a Danfoss VLT inverter was installed, which measures pressure with a sensor and controls blower speeds accordingly. Since the installation of the inverter, environmental conditions have improved and running costs are down by approximately 50%. Prescribed demand has also been reduced by 100 kW and process rescheduling has resulted in a 25% shift of unit consumption to off-peak periods.

3. Economical Analysis

The investment for the load management equipment was £4500. Besides a reduction in electricity costs, a range of other benefits has resulted including easier and more reliable operation, and reduction in the demand on filters mean they last longer. These benefits plus the saving in electricity costs mean the whole installation has a payback period of 1.3 years.

4. User's Acceptance and Satisfaction

The installed equipment was very well received by the staff, mainly because of the noise reduction. Operation is easy. The system uses a stepped menu for altering parameters. It has shown very good reliability.

The company is very pleased with the outcome of the project. Other mills in the group have shown a great deal of interest in the results.

Data collected by MANWEB plc, Chester.

CONCLUSION

In recent years, the European energy policy has been mainly devoted to the development of Demand Side Management. The electricity distribution companies, directly concerned by this fact, have initiated different programmes in order to improve demand management in relation with rational use of energy.

The electricity tariff structures in Europe generally have a dual base (power delivered and energy consumed), with any differences between countries due to the types of power plants and primary energies. Hence, the principles of load management are very similar throughout Europe.

With regards to small and medium size companies, electricity management means taking account of the tariff signals given by distributors together with local constraints (production process, electrical safety, etc.).

This brochure provides an overview of the most common practices presently implemented to control electric loads in small and medium industries. It shows that load management is a viable operational concept at most facilities, as it can provide for significant economic benefits to energy consumers.

Among the various Load Management techniques available, the collection of case histories reported here indicates as the most popular those based on process rescheduling and load interruption/restart using a dedicated microcomputer.

The transformations under way in the Electricity Supply Industry of several countries, with the resulting unavoidable impacts on the commercial relationships between Utility and Customers, will possibly involve a change of philosophy regarding the Load Management measures implemented.

Electricity spot pricing, for example, which is being introduced as an experiment in some countries, will involve a fast and continuous variation in the level of electricity rates that will motivate industrialists to select flexible processes whose operation can quickly be adapted to changes in the cost of supply and to invest in energy management and storage systems.

In such a context, the Utility staff will continue to play an important role in guiding customers to make correct choices. Energy users are invited to apply to their local Utility offices for assistance with any technical or commercial problem that may arise.

APPENDIX A.1 - Rate Structures Across Countries

In this section, a qualitative description of the rates applicable to small and medium industrial customers is outlined. What follows can be considered as a natural complement to Chapters 2 and 6, as it helps to explain the rate structures of the various Utilities by referring specifically to the tariffs for the applications described in the case studies. Though the overview is inevitably restricted to the countries where the Case Studies take place, the rate structures described can be regarded as representative of the most frequent cases.

Belgium

Electricity prices are unified all over the country, with regard to both structure and price levels. The rates are binomial, with a charge related to the maximum monthly demand metered in a 15-minute period and a charge for the energy consumed. All tariff components are indexed monthly: a part of the energy charge is linked to a parameter reflecting the changing cost of fuels used in power stations, while the demand charge and the remaining part of the energy cost depend on a parameter which is intended to reflect the changes in other generation and distribution costs.

Customers supplied at medium voltage (15 kV) and with a maximum demand up to 4000 kW are billed according to time-of-use rates, with prices of both demand and energy depending on the different time of the day and the season. The seasons are defined as follows:

- ❑ Winter: November to February
- ❑ Mid-season: March, April, September, October
- ❑ Summer: May to August.

The daily periods are defined as follows:

1. normal load hours: 15 h/day (7:00 to 22:00), Monday to Friday, excluding holidays
2. low load hours: remaining hours
3. winter peak hours: a period of 4 hours inside the 15 h/day of normal load hours; this period is defined by the local Utility.

The demand charge is constant throughout the day in summer and mid-season, while winter charges show a sharp increase at peak time. The energy charge is differentiated in all seasons between normal rate and low-load rate.

With regard to reactive energy, the kvarhs (inductive and capacitive) consumed beyond 50% of the kWhs consumed are billed separately, at a price of 20% of the average price of kWh.

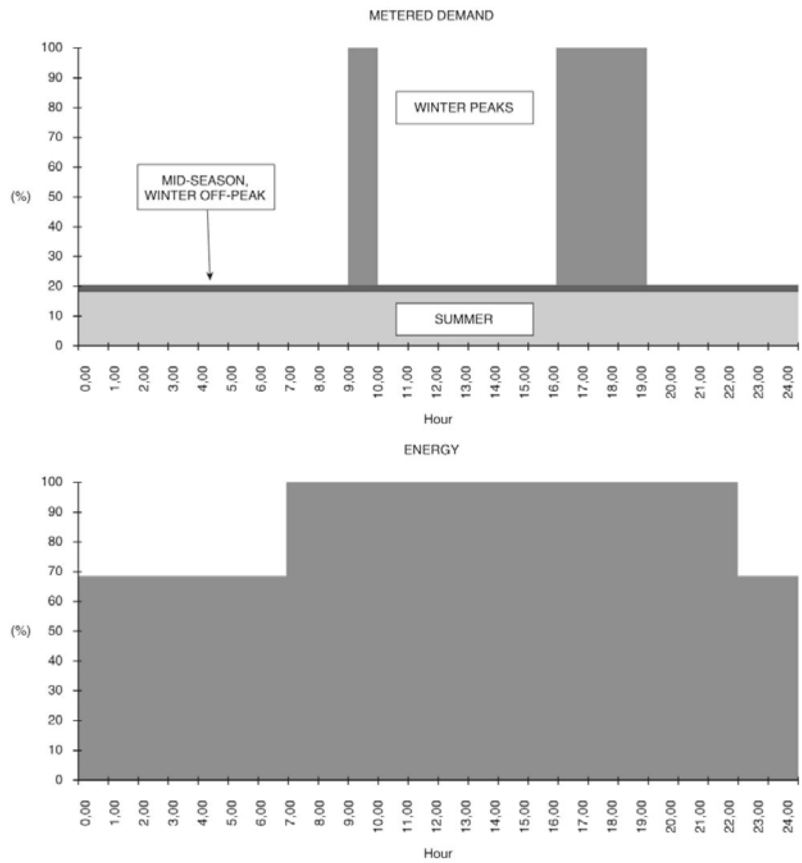


Figure A.1 - Structure of Belgian electricity rates http://www.leonardo-energy.org

France

Most of the electricity is produced, transported and distributed by a state-owned company named Electricité de France (EDF). 471 TWh (76% nuclear, 16% hydro) were produced in France in 1995, of which 73 were sold abroad.

Since 1981, the company has significantly enlarged its tariff range, based on a customer's subscribed demand:

- the "blue" tariff, from 3 to 36 kVA (230400 V)
- the "yellow" tariff, from 36 to 250 kVA (230 400 V)
- the "green" tariff, divided in "green A" from 250 kW to 10 MW (20 kV), "green B" from 10 to 40 MW (63 or 90 kV) and "green C" beyond 40 MW (225 kV).

Each tariff is based on time-of-use rates, and referred to the marginal cost of development. Different options are available: base load, off-peak (blue tariff), peak-day demand reduction (all tariffs), modulatable (green tariff); the choice is optimised according to a customer's load curve and the possibility of modulation during the day and the year. The commercial offices of the utility provide consultancy services and expertise in helping customers select the most suited option.

Electricity rates are unified all over the country, with regard to both structure and price levels. The rates are binomial, with an annual standing charge for the subscribed demand and a charge for the kWhs consumed depending on season and time of day (with the "green" tariff, reactive energy is billed for the amount of kvarh exceeding 40% of kWh consumption during peak and high load winter hours).

For example, the "green A5" tariff is particularly suited for small and medium size industrial customers; it includes five rate periods defined as follows:

- seasonal periods:

  Winter: November to March

  Summer: April to October

- time of day periods:

  peak: 4 hours per day (9:00 - 11:00 and 18:00 - 20:00), Monday to Saturday in December, January and February,

  high load hours: 6:00 - 22:00, Monday to Saturday (except for the peak hours mentioned above), in winter and summer,

  low load hours: 22:00 - 6:00, Monday to Saturday and all the hours of Sunday, in winter and summer.

Moreover, the "green A5" tariff offers four rate versions that combine different costs of power and energy, depending on the yearly utilisation of the subscribed demand: short time utilisation, medium time utilisation, long time utilisation and very long time utilisation (the standing charge increases and the kWh rate decreases when the annual duration increases). Figure A.2 shows the rate variations through time for the "green A5" tariff, medium time utilisation. Note that the demand charge is incremental. With reference to the above ranking order, this means that in every rate period, it is applied to the subscribed kWs exceeding the contractual demand of the previous period.

For larger powers and consumptions, EDF offers an eight rate period tariff **("green A8", "green B"** and **"green C"**), considering a mid-season (November and March) and separating July and August from summer. The **peak day demand reduction option** includes 22 days of 18 hours (7:00 - 1:00 the day after) chosen by EDF during winter (November 1" to March 31") in "real time" conditions when electricity costs are the highest (coldest outside temperature, problems occurring in power plants or networks). Electricity rates are high during these peak days, but they are much lower during the 3 or 5 other periods of the year.

The consumer who is able to reduce or even stop his electrical consumption during peak days can therefore reduce significantly his annual electricity bill.

The **modulatable option** includes four periods with decreasing rates:

- the same 22 days of 18 hours as for the peak day demand reduction option
- 9 mobile "Winter" weeks
- 19 mobile "mid-season" weeks
- 24 mobile "low load" weeks.

The 22 peak days can occur during "winter" and "mid-season" weeks. Each week starts at 7:00 on Tuesdays, in a completely random way (the highest rates corresponding to the highest production costs). Only a very long time utilisation version and a medium time utilisation version are offered with the peak day demand reduction and the modulatable options.

A new type of contract has been recently introduced, modifying "green" tariffs in "emerald" tariffs, when taking into account the quality of electricity. It specifies maximum voltage variations, annual numbers of short and long power cuts, and disturbed operating conditions. EDF refunds its customers in case of disturbances exceeding the agreed thresholds.

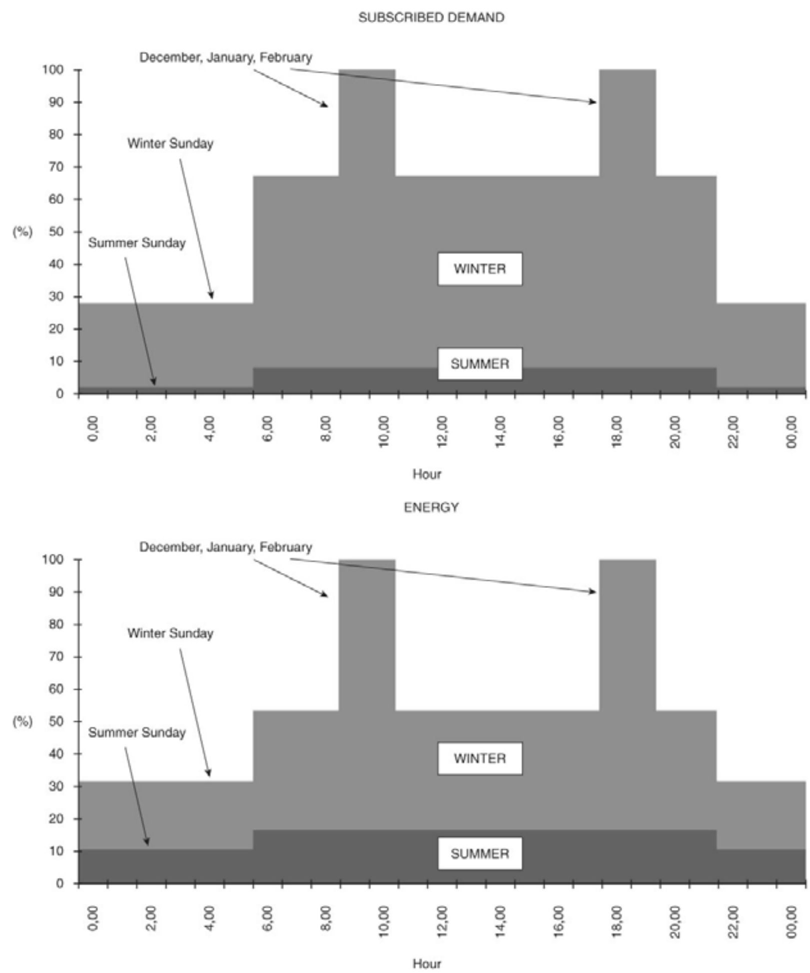


Figure A.2.a - Structure of French electricity rates ("Green A5" tariff)

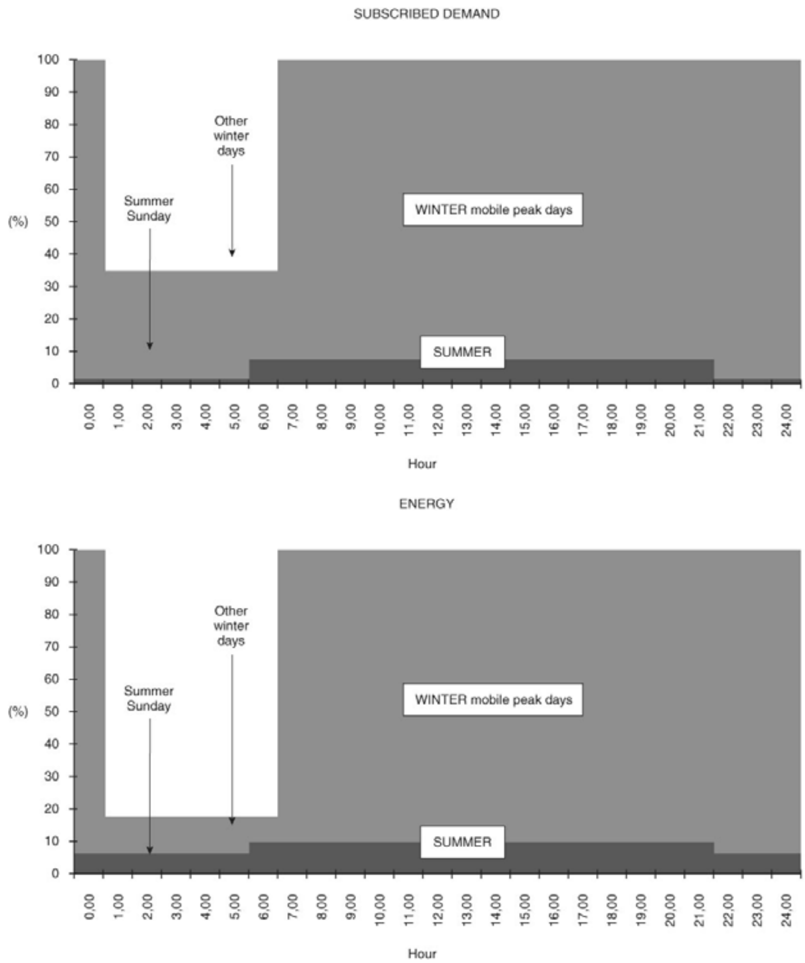


Figure A.2.b - Structure of French electricity rates (peak day demand reduction option)

Italy

Electricity rates are unified all over the country, with regard to both structure and price levels and, for industrial customers, vary according to the voltage level and utilisation factor.

The rates are binomial with an annual charge for the subscribed demand and a charge for the kWh consumed. As the generation system is mainly based on thermal plants, the energy charge includes a fuel cost adjustment. When the power factor falls below 0.9, customers also pay for the additional cost of delivering reactive energy.

Customer supplied at medium (up to 50 kV) and high (over 50 kV) voltage and with a subscribed demand exceeding 400 kW and 500 kW respectively are billed according to time-of-use rates, with prices for both demand and energy depending on the different times of the day and the season.

The seasons are defined as follows:

- ❑ Winter: includes the months from January to March and from October to December (6 months);
- ❑ Summer: includes months from April to September (6 months).

The daily rate periods for supplies at medium voltage are:

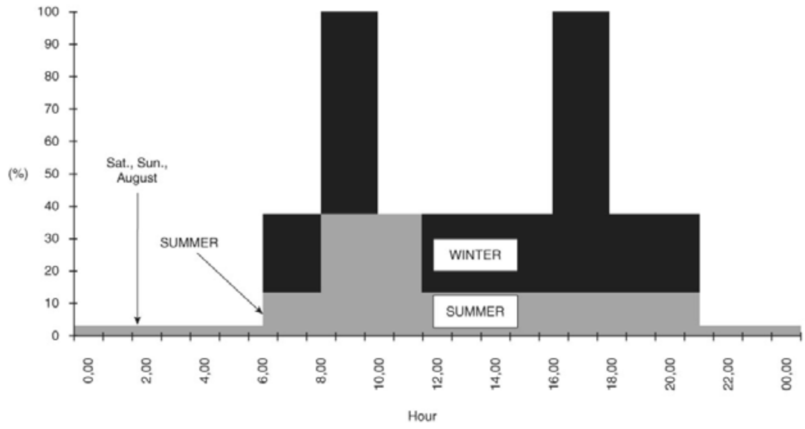
1. peak hours: 8:30 - 10:30 and 16:30 - 18:30, Monday to Friday in winter
2. high load hours: 6:30 - 8:30, 16:30 - 18:30, and 18:30 - 1:30 in winter, and 8:30 - 12:00 in summer (except August), Monday to Friday
3. medium load hours: 6:30 - 8:30 and 12:00 - 21:30, Monday to Friday in summer (except August)
4. off-peak hours: 0:00 - 6:30 and 21:30-24:00, Monday to Friday, all the weekend hours, and all the hours of August.

For high voltage contracts, the peak time periods are half an hour delayed.

In Figure A.3, the rate variations through time are shown for medium voltage customers with average utilisation contracts. Note that the demand charge is incremental. With reference to the above ranking order, this means that in every rate period, it is to be applied to the subscribed kW exceeding the contractual demand of the previous period.

Depending on the yearly utilisation of the subscribed demand, the customers are offered four rate options, that combine different costs of power and energy. The marketing offices of the utility provide consultancy services and expertise for helping customers select the most suitable option.

Cost of Subscribed Demand



Cost of Energy

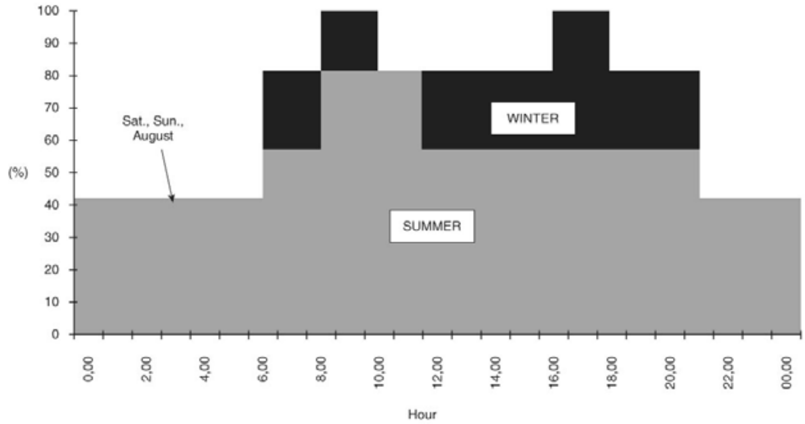


Figure A.3 - Structure of Italian electricity rates

Netherlands

Industrial customers are billed according to time-of-use rates, with the price of energy depending on the different time of the day. The rate periods are:

- normal load hours: 7:00 - 23:00, Monday to Friday
- low load hours: remaining hours.

The charge for energy consists of two components:

- fuel cost, related to the average fuel costs in the two periods
- capacity costs, covering a portion of production plus transmission and distribution costs.

The remaining part of production, transmission and distribution costs are charged on the maximum monthly demand. Other charges are related to the handling and rental of switchgear, transformers, etc. At the end of the year, the customer with a utilisation factor of more than 2000 hours/year can receive a bonus; this bonus is applied to the maximum yearly demand.

Load Management Options

The customer can participate in Load Management programmes.

To this aim, the distribution company introduces a variable peak period, which is controlled by the distribution company. The customer is forewarned about the period, during which his maximum demand is metered.

The difference between this peak demand and the customer's maximum demand is called the load managed demand; for each kW of load managed demand, the customer receives a yearly credit.

The variable periods have a maximum duration of two hours per day, a maximum of two periods per year may occur. During a year, the maximum overall duration of the load management periods is 250 hours.

In Figure A.4, the rate variations are shown for EZN industrial customers.

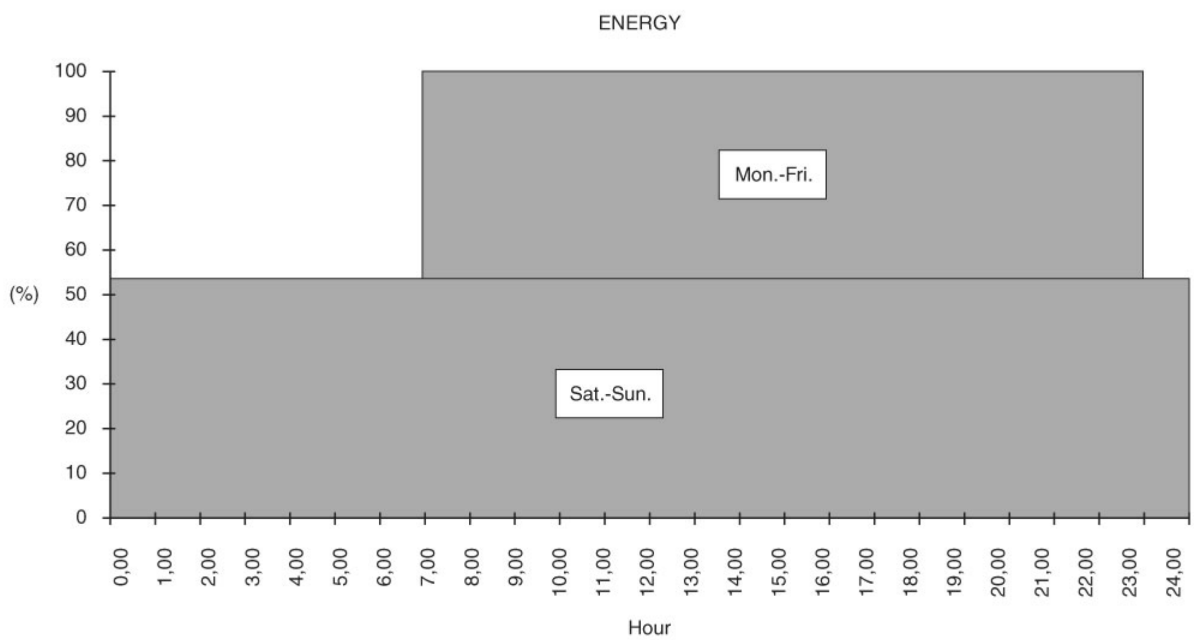


Figure A.4 - Structure of Dutch (EZN) electricity rates

Sweden

At present, the Swedish power companies have chosen to combine an energy charge reflecting the short-run marginal cost (SRMC) with fixed and power demand charges, combining costs for administration for the local and central networks, in order to recover the average costs of the company.

For the design of the electricity tariff, the distribution system is divided into a local and central network.

The **local network** consists of the parts which lie closest to the customer and where his demands determine the dimensioning of the network.

The **central network** consists of plants which are common to several consumers, and its dimensioning is determined by the maximum coincident demand of all customers. Analyses have shown that the peak load time embraces the period November-March, Monday-Friday, daytime.

The above principles are fully applied at the design of the high voltage tariffs (>10 kV), resulting in the following tariff structure with four charges.

Fixed charge (SEK/year)	Administration costs for measurement, reading and billing.
Contractual demand charge (SEK/kW, year)	Local network costs. A contractual demand charge based on the maximum demand during the year of account.
Power demand charge (SEK/kW, year)	Part of power demand dependent costs in the central network and bulk power costs. A peak demand charge based on the actual two highest one hour peak-load, different months January-March and November-December.
Energy charge	Production costs reflected by the short-run marginal cost with addition for transmission losses and the power dependent costs which are not included in the power demand charge.

Power and energy charges are differentiated according to six rate periods defined as follows:

1) Winter high load hours January - March, November - December 06:00 to 22:00 Monday-Friday.
2) Winter off-peak hours January - March, November - December all other hours.
3) Middle-season high load hours April, September - October 06.00 to 22.00 Monday-Friday.
4) Middle-season off-peak hours April, September - October all other hours.
5) Summer high load hours May - August 06:00 to 22:00 Monday-Friday.
6) Summer off-peak hours May - August all other hours.

Sydkraft rate structure is shown in Figure A.5.

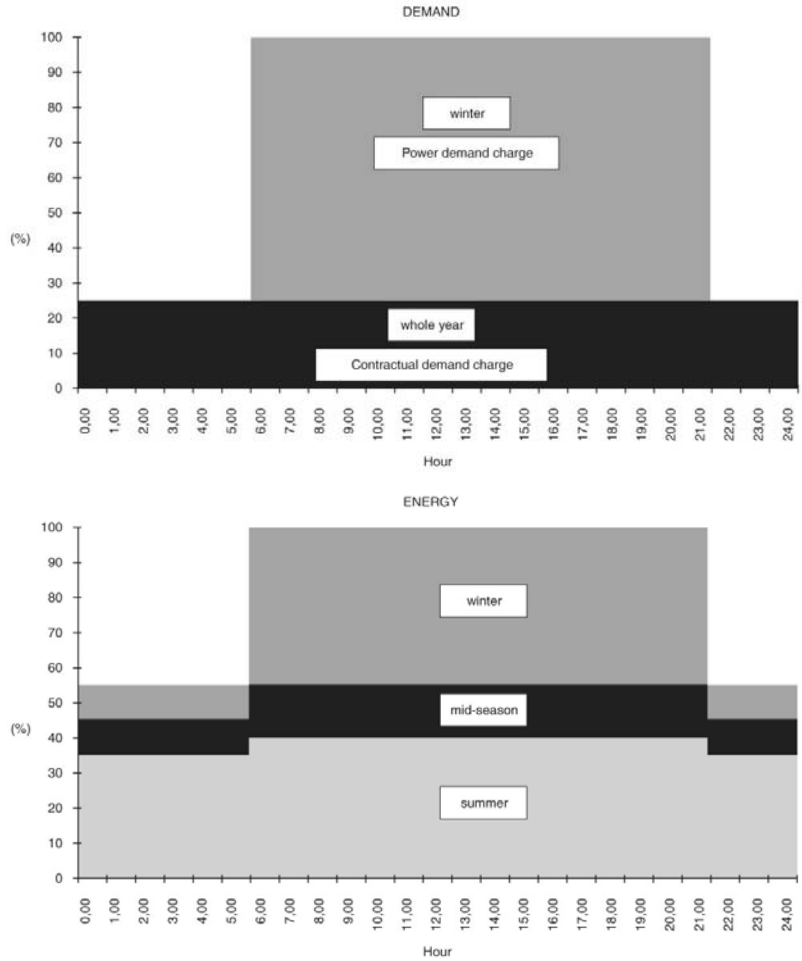


Figure A.5 - Structure of Swedish (Sydkraft) electricity rates

Switzerland

General Remarks on Electricity Rates in Switzerland

In Switzerland, every community has the right to operate its own utility or to issue a licence to an electricity supply company. The structure of the Swiss electricity industry has grown historically and now encompasses more than 1200 companies. Some are privately owned and operated, but the majority belongs to the public sector. Each company is autonomous in setting tariffs.

National Policy

National policy promotes the savings on energy and the efficient use of electricity. There are various laws and regulations on this subject at federal, regional and community levels. As a consequence for example, there are standards for thermal insulation values on buildings as well as limits on the use of electrical energy for direct room heating and air conditioning. A national programme "Energy 2000" strongly promotes renewable energies and supports pilot projects. Electricity as a product is in direct competition with other primary energies in various applications. A tax is charged on energy consumption and the taxation of CO_2 is under discussion.

Principles of Tariff Structure

The basic principle for the setting of tariffs is regulated. Tariffs have to be set:

- in accordance with the principle of laying the responsibility for special investments on the user
- to cover the direct costs
- identical for all users with the same characteristics in energy consumption
- to give incentives for the efficient use of energy.

The general tariff structure has three elementary cost components:

- a basic cost element for every customer (fixed standing charge for small consumers)
- a cost element for the available power (kW; demand rate for bulk consumers)
- a cost element for the consumed energy (kWh).

Many companies charge time-of-use rates with two periods on working days with different levels during the summer (April to September) and winter seasons. The maximum power is recorded and defines the cost component for power. As a rule of thumb, for an industrial customer, the rate element related to power makes up approximately one third of the electricity bill.

Aargauisches Electrizitätzwerk (AEW)

Electricity prices vary on a local basis, depending on the rates approved by the City Councils. AEW industrial customers supplied at medium voltage (16 kV) are billed according to time-of-use rates, with the prices of energy dependent on the time of day and season.

The rate periods are defined as follows:

1. Winter peak hours: 7:00-21:00 Monday to Friday, and 7:00-13:00 on Saturday, October to March.
2. Inter off-peak hours: 0:00-7:00 and 21:00-24:00, Monday to Friday; 0:00-7:00 and 13:00-24:00 on Saturday, and all the hours of Sunday, October to March.
3. Summer peak hours: 7:00-21:00 Monday to Friday, and 7:00-13:00 on Saturday, April to September.
4. Summer off-peak hours: 0:00-7:00 and 21:00-24:00 Monday to Friday; 0:00-7:00 and 13:00-24:00 on Saturday, and all the hours of Sunday, April to September.

Unlike energy, demand is billed at a constant (flat) rate on a yearly basis, considering the average of the three highest monthly peaks since the beginning of the year. The peak demand of a month is the recorded peak load during sixty subsequent minutes.

In Figure. A.6, the rate variations are shown for AEW industrial customers.

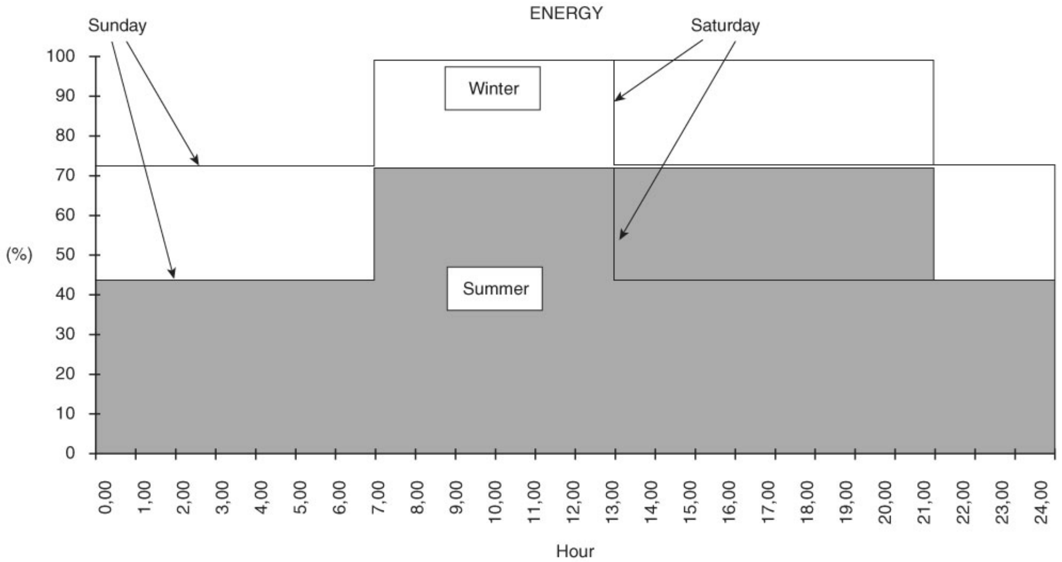


Figure A.6 - Structure of Swiss (AEW) electricity rates

United Kingdom

The electricity supply Industry in England and Wales was privatised in 1990 with the creation of a number of new companies and the introduction of competition for larger electricity consumers.

Three generating companies were formed: National Power, Powergen and Nuclear Electric. The national transmission system became the responsibility of the National Grid Co.

Electricity supply became the responsibility of the companies formed from the original electricity Boards plus National Power and Powergen.

Customers with a maximum demand in excess of 1000 kW were free to purchase electricity on the competitive market. In April 1994, this choice of supplier was extended to customers with a maximum demand in excess of 100 kW. From April 1998, freedom of choice will be available to all users of electricity.

Distribution is still the responsibility of the Regional Electricity Companies (RECs).

In Scotland, generation, distribution and supply remain the responsibility of two privatised companies, Scottish Hydro Electric in the North and Scottish Power in the South. These two companies are also able to compete for supply business in England and Wales.

Almost all electricity produced in England and Wales or imported from Scotland or France is bought and sold via The Electricity Trading Pool. Electricity is traded through The Pool on a half hourly basis, with prices varying from half hour to half hour throughout the day. These half-hour price variations are designed to reflect the cost of producing electricity in response to changes in anticipated demand and the type of generating station used.

Suppliers purchase electricity from The Pool assuming responsibility for all the costs associated with Pool membership and the formulation of contract terms for presentation to customers.

These terms may be fixed, in which case they will include a premium to eliminate the risk associated with purchasing from a variable pool. Alternatively, the terms may vary directly in relation to changes in pool prices. Customers who choose this option can vary their use of electricity to take advantage of low pool prices and to avoid high pool prices. The electricity supplier will also arrange for the delivery of electricity to the customer's site, the payment of Transmission Use of System Charges to National Grid Co and distribution Use of System Charges to the REC. The Supplier is also responsible for the collection of Fossil Fuel Levy and Value Added Tax.

Privatisation has resulted in a great deal of choice for customers. Suppliers have become innovative in the types of contract offered and competition between suppliers is extremely keen.

Typically, contracts will have a component based on the Maximum Demand over the Winter Period, a Supply Capacity Charge, a Fixed Charge to recover costs of Meter Reading, Billing, Administration, etc and a Unit Charge which may vary during the day and at weekends. They will also include a method of recovering the Use of System Charges discussed above.

Appendix A.2 - Demand-side Management, Supply-side Management and Integrated Resource Planning

The most important aspects of the different methods of controlling the supply and demand of electricity are characterised in bottom-up order:

Load Management (LM) is a method of controlling the peak load in the network in order to have constant demand and therefore use the investments to their optimum. LM is presented in Chapter 1. It is an important measure of the set of options used in the Demand Side Management (DSM) framework method applied by the utilities to influence the electricity demand.

Integrated Resource Planning (IRP) is a planning method used to minimise the use of primary energy (not only electricity). IRP makes use of potentials on the demand side (by DSM) and at the same time on the supply side (by Supply Side Management = SSM).

Every method has the objective of reducing costs. More details of the last three methods are described below.

Demand-Side Management

Demand-Side Management (DSM) influences the electricity demand. Methods traditionally used are Load Management combined with appropriate tariffs. Additional measures are in-depth information of customers regarding the most expedient use of electricity and energy services.

The infrastructure is best utilised at constant load. Because generating capacity and the network must be designed to the peak load, it is for the benefit of both customers and utilities to have an even demand. Tariffs are based on costs; the higher the cost of supplying the actual load, the higher the tariffs (refer to Chapter 2 for additional information). The utility sets price signals to control the use of electricity at a more or less constant level and therefore save power and costs by these measures.

DSM is also a means of improving the conversion efficiency. By supporting the applications, processes and installations with the best commercially available technologies saving potentials can be accessed. Market penetration of efficient equipment may be accelerated by promotion (or even subsidies) by the utilities. Some utilities are also involved in energy contracting.

Supply-Side Management

Intervention on the Supply-Side represents the traditional way implemented by Utilities to ensure the electricity service at all times with an acceptable reliability while complying with environmental standards and observing national and international legislation and agreements. The measures to be taken involve the planning of operations and capacity expansions of both power plants and transmission-distribution facilities.

New power plants with the most advanced technologies offer better conversion efficiency than older plants and at the same time produce less waste and pollutants. Retrofitting existing power plants also reduces fuel costs and improves emission standards. Co-operation among utilities reduces the need for reserve capacities.

The transmission network is built to connect power sources and centres of power consumption by a dense network of strong lines so as to reduce losses. Further minimisation is reached by new planning tools and adequate control of the grid.

Integrated Resource Planning

Integrated Resource Planning (IRP) is a planning method related to Supply-Side Management (SSM) and Demand-Side Management (DSM). In some countries, the term Least-Cost Planning (LCP) is used. IRP and LCP have virtually the same goals. Therefore LCP and IRP are seen as synonymous.

The goal of IRP is to minimise the use of fuels (primary energy). Based on IRP theory, the utilities planning comprises the whole energy flow from electricity generation, transmission and distribution and further to the transformation of end-energy to useable energy (heat, motion...) by means of installations and appliances.

The IRP method implies that utilities considering additional energy supply and energy savings on an equal basis may postpone or make redundant the construction of new power plants and therefore also reduce pollution of the environment.

IRP should stimulate competition between supply and savings. IRP depends on the framework conditions of the electricity sector in the different countries.

Appendix A.3 - Key Terms and Definitions

Base Load	The minimum load demanded over time on a power company's generation system.
Coincidence Factor	It measures the fraction of the customer's peak level that occurs at the utility's peak.
Coincident Demand	A customer or class demand, in kilowatts or megawatts, at the time of a utility's system peak demand. It is the demand that coincides with the system peak and is often used in cost allocation. For example, industrial customers' demands at the time of the industrial class peak demand could also be considered as coincident demands, even though they may not be coincident with the system peak.
Combined Heat and Power (CHP) or Co-generation	A generation facility in which both electricity and the waste heat are utilised.
Customer Classes	Groups of customers with similar characteristics (level of demand, usage, location and load pattern) which are classified together for setting electricity rates. Most utilities classify the majority of their customers as residential, commercial, industrial and agricultural.
Demand	The amount of electricity that a customer takes from the system at a certain time. Demand is often measured in kilowatts and is usually grouped in the following categories: ❒ average: the demand determined by dividing the total number of kilowatt-hours by the hours in the time interval ❒ coincident: a customer or class demand at the time of a utility system's peak demand ❒ maximum or peak : the greatest of all demands occurring during a specified time period.
Demand Charge	One component of a customer's electricity bill, along with the fixed charge and the energy charge. This charge recovers some of the capital and operating costs the utility incurs in providing sufficient operating capacity to meet that customer's maximum demand (kW) as needed.
Demand Side	Relating to the end use of electricity (consumers) rather than the production of electricity.
Demand Side Management (DSM)	Any utility's or government's activity designed to influence energy consumption. It includes Load Management.
Distribution Losses	See transmission and distribution losses.
Efficiency Improvement	Research in some technologies will result in lower energy use in future years. This parameter decreases the energy used by the technology each year, which may result in increased energy savings.
Energy Charge	One component of a customer's electricity bill, along with the fixed charge and the demand charge. This charge recovers operating costs, including the cost of fuel used to generate electricity. It depends on the number of kilowatt-hours consumed in each rate period.
Energy Conservation	An overall reduction in energy use.
Energy Efficiency	Improving the efficiency with which the energy is used while maintaining or improving the level of energy service.

Firm Capacity	The maximum available safe capacity of a distribution system, for example a primary substation.
Fixed Charge	One component of a customer's bill, along with the demand charge and the energy charge. This charge recovers some of the fixed costs that are directly attributable to serving an individual customer.
Fixed Costs	Operating costs that stay basically constant, regardless of the Utility's output. Such costs are incurred even when no electricity is used by customers. Fixed costs typically include wages, materials, property taxes, interest payments, depreciation and some maintenance costs.
Flat Rate	A rate structure in which the charge per energy unit is independent from the time-of-use.
Integrated ResourcePlanning (IRP)	A set of regulatory policies and utility planning practices to develop demand-side resources that are in the best economic and environmental interest of the Utility, its customers and society.
Kilowatt-hours (kWh)	A common and basic unit of electrical energy consumption, equal to 1000 watts steadily consumed for one hour.
Least Cost Planning (LCP)	Least Cost Planning and Integrated Resource Planning can be used interchangeably. IRP is preferred because "least cost" can be misleading.
Load	Electric power delivered to or required at any specified point of a system. Load originates primarily at customers' energy-consuming equipment.
Load Factor	The ratio of actual kilowatt-hours used during a certain period to the amount that would have been used, had the customer consumed energy uniformly during the same period at the rate of maximum demand. More generally, load factor measures the degree to which facilities such as a power plant or a transmission line are being utilised.
Load Management	Any action taken by the customer and/or the energy supplier to change the load profile in order to gain from reduced total system peak load, increased load factor and improved utilisation of valuable resources.
Load Shape	Demand curve related to time for a particular electrical technique.
Load Shifting	Shifting energy load from peak periods to off-peak periods.
Long Run Marginal Cost	The incremental cost of providing an additional unit of electricity over the long term planning horizon which may include a number of years. Typically, this includes fixed costs (i.e. the capital cost of new plants) as well as the variable costs of providing the additional electricity.
Marginal Cost	In the electricity industry, the total cost due to the production of one additional kilowatt-hour.
Megawatt (MW)	A unit of electrical power equal to 1000 kilowatts.
Non-coincident Demand	Maximum demand of a customer, or a customer class, regardless of when it occurs.
Payback Period	The amount of time required for an investment cost to be recovered, based on the benefit stream received (usually undiscounted).
Peak Clipping	Reduction in peak demand.
Peak Load	The maximum demand for electric power that determines the generating capacity required by a utility. More generally, it is the maximum load consumed or produced over a stated period of time.

Real Time Pricing	Setting energy prices to reflect the actual cost of providing energy at a given time and location. Applying this concept to electrical service results in customer rates that vary according to time- and site-specific, incremental Utility costs. Real-time rates offer customers an opportunity to control their electricity bills by adjusting their consumption to spot-price variations.
Rescheduling	Reviewing planning and organisation of industrial production in order to modify the load curve.
Reserve Margin	In a peak demand period, it is the difference between the production capacity of a Utility's system (including firm power purchases but excluding capacity on maintenance or forced outage) and the anticipated peak load.
Service Charge	See fixed charge.
Short Run Marginal Cost	The incremental cost of providing an additional unit of electricity in the short term (e.g. hourly, daily). Typically, this only includes the variable costs (i.e. fuel and operating and maintenance costs) of providing the additional electricity.
Supply Side	Relating to the production, transmission and distribution of electricity, as opposed to the end-use of electricity.
Supply Side Management (SSM)	Measures taken by the Utilities on power plants and transmission and distribution lines in order to minimise the cost of energy for a given level of reliability, and to reduce the impact on the environment.
Time-of-Use Tariff	A rate structure that prices electricity at different rates reflecting the changes in the utility's costs of providing electricity at different times of the day or year.
Transmission and Distribution Losses	The losses associated with providing electricity from generators to end-users.
Volt (V), Kilovolt (kV)	The unit of electrical voltage. One kilovolt equals 1000 volts.
Voltampere (VA) **Kilovolt-Ampere (kVA)**	The unit of apparent power. One kVA equals 1000 voltamperes.
Voltampere Reactive (var) **Kilovolt-Ampere Reactive (kVA)**	The unit of reactive power. Reactive power is the portion of apparent power (VA) that serves no useful purpose. One kvar equals 1000 voltampere reactive.
Voltage	The electric "pressure" of a circuit, measured in volts. It is generally a nominal rating based on the maximum normal effective difference of potential between any two conductors of the circuit.
Watt (W), Kilowatt (kW)	The unit of electric "useful" power. One kW equals 1000 watts. At many electricity companies, customer demand in the system at any time is measured in kilowatts.

Appendix A.4 - Bibliography

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Meeting Proceedings:

- *DA/DSM 94 Europe, September 27-29, 1994, Paris (France)*
- *DA/DSM 95, January 23-25, 1995, San Jose, California (USA)*
- *DA/DSM 95 Europe, November 21-23, 1995, Rome (Italy)*
- *DA/DSM Distributech Conference, January 15-18, 1996, Tampa Bay, Florida (USA).*

APPENDIX A.5 - LIST OF MANUFACTURERS AND CONSULTANTS

This part is handled as a separate document.

Please refer to your local utility if no separate document is appended.

Acknowledgements

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