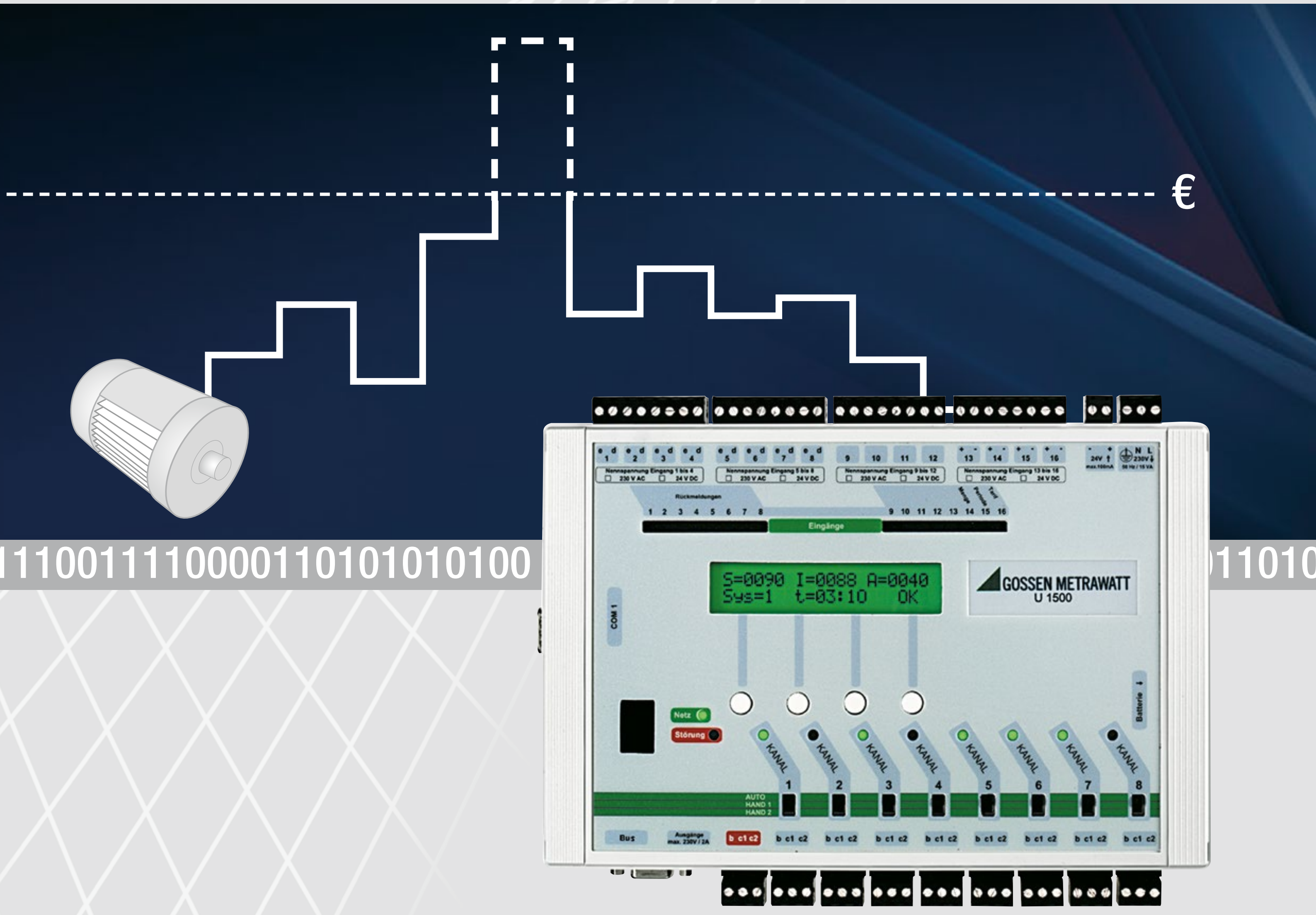
GOSSEN METRAWATT

Safety through Competence



Manual for the Use of
Peak Load Optimizing Systems U1500

Energy Management

Preface

Consumption costs for energy sources such as electrical power, gas and district heating, which are billed as a rule based upon measured power values, can frequently be reduced significantly with only minimal technical efforts. It is precisely for this reason that in-house energy management should include an assessment for determining whether or not the use of modern load optimizing systems is practical and efficient.

Detailed knowledge regarding the power supply contract conditions offered by various utility companies, utilized process sequences and how they can be influenced, and existing equipment and how it is controlled, is necessary for the preparation of an optimization concept.

This manual is intended to provide decision makers and system technicians with a tool for discovering potential savings, and for evaluating the efficiency of an optimizing system.

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1 Basics

1.1 *Tariffs for Special Contracts Customers*

As a rule, the billing price invoiced to electrical utility customers with special contracts differentiates between kilowatt-hour rates for energy consumption (in cents per kWh), and demand rates for maximum power demand (in € per kW).
There are thus two different ways to reduce overall costs: by reducing energy costs and power costs:

1. Reduced energy costs can only be achieved by permanently diminishing superfluous energy consumption, or by shifting energy import from high tariff periods to the less expensive low tariff periods. Savings can also be realized through the use of more economical production equipment. Potential savings of this type have already been taken advantage of to a great extent in many cases, or are economically impractical due to the large investments which would be required. Any further reduction of energy costs would influence the production process and the product, which cannot be tolerated as a rule.
2. Reduced power costs can be achieved by leveling off energy import by controlling production equipment such that pronounced “chargeable demand peaks” are avoided. This short-term redistribution of imported energy is executed automatically by means of so-called energy management systems. Due to the fact that energy import is generally only postponed for a few minutes by the load optimizing process (i.e. energy is not reduced), the effects on the production process are usually imperceptibly minimal. However, the customer must have a suitable import profile to achieve savings of this sort, and the concept and the utilized system must be ideally matched to one another. In this case, power costs can be significantly reduced by means of just a few short, targeted interventions at the right point in time, i.e. considerable savings can be achieved.

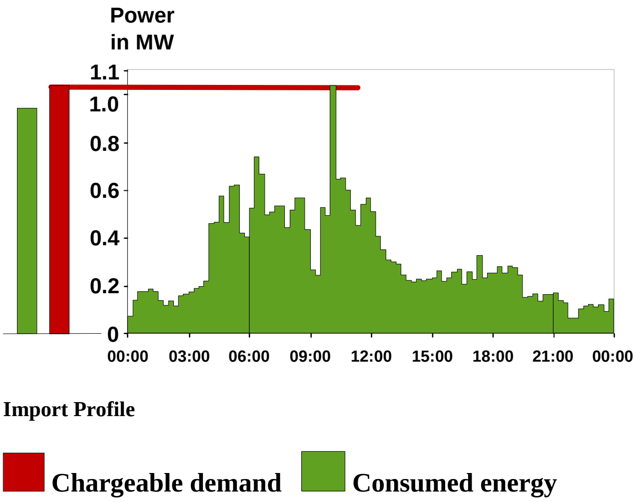
Individual customer import profiles determine kilowatt-hour and demand rates.

In order to better understand the various factors which play a role in load optimization, we must first take a closer look at several physical relationships, as well as the billing practices of the power utilities.
Active energy E (usually measured in kWh) and active power P (usually measured in kW) demonstrate the following relationships:

$$P = E / \Delta T \quad \text{or} \quad E = P * \Delta T$$

Power is thus consumed energy per specified time period ΔT.

The following figure depicts the so-called “import profile” (daily load curve) of a special contract customer.
Power costs (symbolized by the red bar) are determined based upon the highest demand peak (usually measured as a 15 minute mean value) which occurs during the billing period.
Energy costs (symbolized by the green bar) are proportional to the green surface area: The larger the surface area, the more energy has been consumed, i.e. the more energy has been used in the manufacturing process.

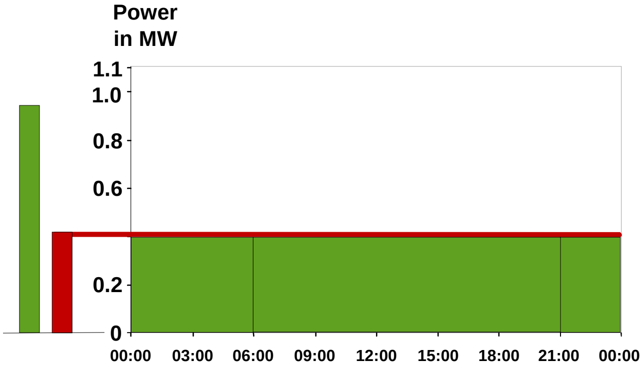


Import Profile

The power utility must be able to cover the customer’s maximum power demands at all times, and must therefore provide capacity (i.e. cables, transformers and power plants) according to the customer’s greatest intermittent power requirement, in order to prevent short-term machine stoppages or blackouts at the customer’s facility. As the above depicted profile shows, capacity made available for the customer (which is associated with great expense) goes to waste most of the time.
The customer is required to order standby energy so that the power utility is able to determine how much capacity it will have to place at the disposal of the special customer, and must make a proportionate capital contribution to network costs for this service.

Special customers are thus not all equal where the power utility is concerned. Customers with high power demands and low energy consumption cause higher costs in making power available than customers who demonstrate uniform energy import.

The import profile of the “ideal customer” is shown in the figure below:



Ideal Customer

The "ideal customer" demonstrates constant power demand and thus takes full advantage of the energy which has been placed at his disposal. Although energy consumption (size of the green surface area) is identical in both of the above examples, power demand (red bar) is significantly lower for the ideal customer.

The pricing policies of the electrical power utilities place great importance on the homogeneity of power import for the above cited reasons. The "hours of full utilization" are an important measure for the power utilities in this respect. In order to determine this quantity, the customer's total annual energy is divided by the highest peak power value which occurred during the billing year (total annual energy / peak demand). The costs for the energy supplier decrease as the number of hours calculated in this way for the customer increases.
Hours of full utilization for "bad" customers amount to less than 2500 hours, and for "good" customers more than 3500 hours.

Customers with many hours of full utilization are rewarded by the power utilities with low kilowatt-hour and demand rates, or with a "high hours of use rebate". The reduction of chargeable peak demand with the help of an optimizing system thus not only results in reduced running costs, it also increases the hours of full utilization and, under certain circumstances, leads to better tariffs.

Planning Security for Power Import

Since liberalization of the electrical power markets, the power utilities are offering more and more new tariff models which place ever increasing significance on power demand.
So-called "scheduled deliveries" based upon power forecasts for individual customers provide the power utilities with planning security. If these forecasts are adhered to precisely, the customer is rewarded with very favorable tariffs. Deviations from forecasted power demands are penalized with high costs for required compensating energy.

The All-Important Mean Value

How is chargeable peak demand determined by the power utility?
The measuring equipment utilized by the power utilities (peak demand meters) records energy consumed during the so-called "measuring period" and divides the resulting value by the duration of the measuring period. From a mathematical standpoint, the arithmetic mean value for instantaneous power during the measuring period is calculated in this way. The measuring period for electrical power usually has a duration of 15 minutes (30 minutes in rare cases). Measuring periods of 1 hour are common for gas and district heating. The peak demand meter starts generation of the next mean value as soon as each given measuring period has ended.
Mean power values are thus generated continuously. If the measuring period has a 15 minute duration, 96 15-minute mean power values are generated each day, and 2880 are generated per month (if the given month has 30 days). The meter flags the highest mean power value between any two meter readings.
Monthly maximum demand is used in most cases for power billing purposes (monthly chargeable demand). Sometimes, although less frequently, so-called "annual chargeable demand" is used, in which case the average value of 2 or 3-month peak values is usually billed.

What are the consequences of the measuring method used by the power utilities (chargeable demand = 15 or 30-minute mean value) for automated demand control?

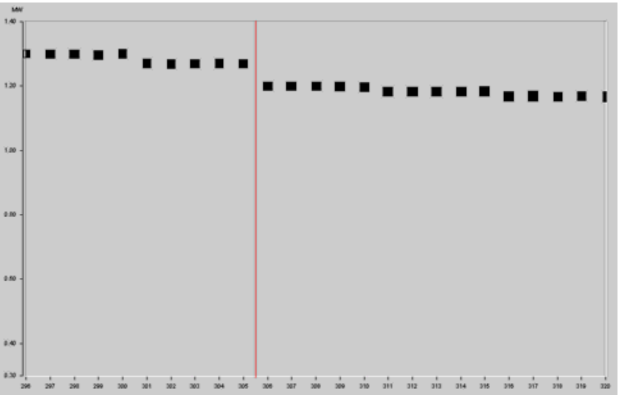
1. Optimizing systems must be fully synchronized to the power utility's measuring period, and must thus be capable of analyzing the measuring period signal generated by the utility. In our opinion, systems by means of which optimization is accomplished with a "floating mean value window" are far from ideal where switching frequency is concerned.
2. The redistribution of energy during any single measuring period does not result in any savings where power costs are concerned, because overall energy import during the measuring period is the decisive factor with regard to chargeable demand, and not instantaneous demand peaks. In order to reduce monthly peak power by, for example, 20%, energy must be reduced by 20% – at least during the measuring period with the highest monthly energy import.

It also becomes apparent that, under certain circumstances, 15 minutes of unusually high energy import resulting from coincidental, concurrent start-up of specific pieces of equipment may drastically increase power costs for an entire month, or have a negative effect on hours of full utilization for the entire year. Just a few interventions executed by an energy management system may thus be enough to reduce power costs in a lasting fashion.

Just a few switching operations may generate significant results.

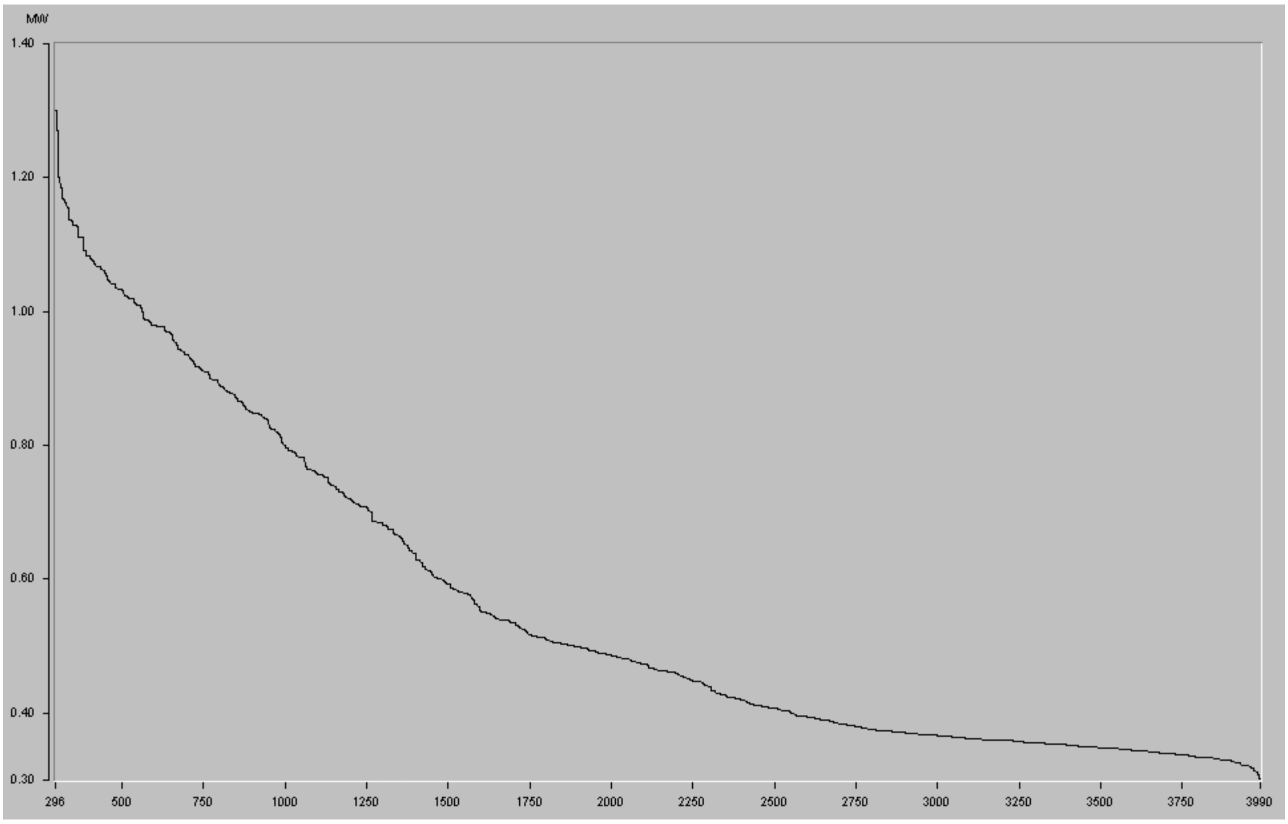
The figure at the bottom of the page depicts a "continuous curve" measured at a customer facility. As opposed to the usual representation of measured values, the 15-minute mean power values are not arranged according to their sequence in time, but rather magnitude. The value associated with the greatest power demand is at the left-hand side of the chart (approx. 1.3 MW in the example), and the value associated with the smallest power demand is at the right-hand side (approx. 0.3 MW).
The curve is made up of approximately 3700 measured values, which corresponds to a measuring duration of roughly 38 days.

The 25 highest measured values for power demand, i.e. the first 25 values, have been enlarged in the figure below. In order to reduce chargeable demand by about 100 kW, the optimization system only needs to intervene in 10 of the 3700 measuring periods (to the left of the red line), i.e. 99.7% of all measuring periods remain unaffected.



Thus the management system only needs to influence selected pieces of equipment on just a few days for just a few minutes in order to generate significant savings. Reducing peak power by 100 kW with a demand rate of approximately € 80.00 per kW per year * would result in power cost savings of approximately € 8000.00 per year.

* Revision level: 2002



2 Optimizing Systems

2.1 Range of Applications

Cost Reduction

As a result of the tariffs used by the electrical power utilities with validity for special contract customers, there are three decisive reasons to make use of optimizing systems:

1. Reduce power costs by leveling off energy import
2. Assignment to more favorable tariffs by increasing hours of full utilization
3. Avoidance or postponement of the procurement of standby energy

Instantaneous Power Limiting

An additional fourth aspect is the result of technical factors: In particular in older facilities, the electrical hook-up does not always grow along with the installation of electrical power consumers, resulting in problems with overloaded transformers and cables.
Systems which are only designed to reduce power costs, and which thus only evaluate the so-called "quantity pulse" when measuring imported power and energy, are incapable of acquiring or influencing instantaneous power. On the other hand, systems which are only laid out to limit instantaneous power do not generate any savings where import costs are concerned. They only prevent intermittent peak loads with durations ranging from several milliseconds to several seconds, in order to avoid having to upgrade the electrical hook-up to protect in-house, stand-alone power generators from overloading.
Systems which are intended for instantaneous power limiting without strict interactive disabling of power consumers must thus be equipped with its own, high-speed instantaneous power measurement. Current is continuously acquired in each phase conductor to this end via individual measurement inputs, in order to be able to reliably prevent overloading, even at individual phase conductors with imbalanced load.
Due to the fact that a significantly different control strategy is called for in this case – as opposed to limiting the 15-minute mean value – GOSSEN METRAWATT offers systems with special software and expanded hardware (analog inputs), which are custom tailored to meet the needs of the individual customer.

2.2 Technology

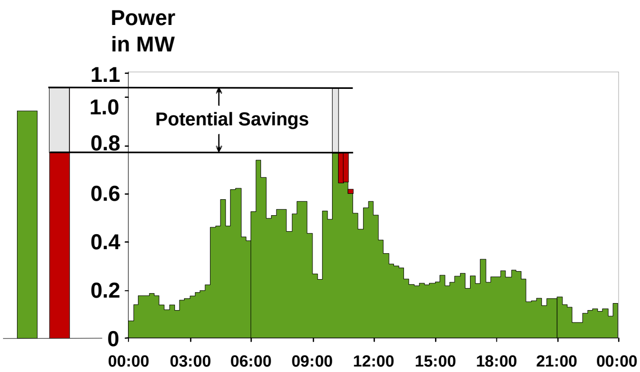
The most important application for optimizing systems is cost reduction, and we will thus limit ourselves to this type of system in our technical discussion.
The system to be utilized must be capable of limiting average power to a specified setpoint for each individual measuring period (we'll use the 15 minute measurement as an example) during the entire billing period. If the setpoint value is exceeded only once, a 15-minute mean value could be generated which would result in drastically increased power costs.
15-minute mean value peaks occur where optimization has not been implemented, if numerous pieces of equipment coincidentally demand power concurrently during any given 15-minute measuring period.
What can be done to prevent this situation?

Manual Demand Management

One could attempt to prevent concurrent power demands by means of organizational measures, i.e. "manual demand management". This procedure also includes simple disabling circuits which prevent concurrent operation of several large power consumers. Nevertheless, the inflexibility of this type of system quickly becomes apparent if an important order suddenly needs to be processed quickly.
A strategy for leveling off energy import could also be incorporated as an organizational aspect of the production environment. However, in order to be effective, measures of this sort must be implemented continuously and consistently without exception, which is usually very difficult in actual practice.
Simple maximum demand monitors are frequently installed which generate acoustic and/or optical signals, if a high demand situation arises. An "energy manager" is appointed in this case, who executes manually implemented measures in order to defuse the high demand situation. Unfortunately, the labors of an entire month can be negated at once if the responsible person is not in the facility when a single demand peak occurs, or if other duties prevent him from responding quickly enough, so that in the end no cost savings can be realized at all.
It is thus relatively unlikely that manual demand management will result in reduced costs: On the one hand, it's impossible to be continuously aware of the objective demand situation which leads to much fumbling in the dark. And, on the other hand, implemented measures often disrupt the production process and are not necessary 24 hours a day anyway, because high demand situations occur only infrequently.

Optimized Energy Import with Automated Demand Management

How do modern, automated peak load optimizing systems and energy control systems tackle this problem?
Due to the fact that they are continuously kept up-to-date regarding the demand and cost situations of the special contract customer by means of the so-called “quantity pulse”, the “measuring period signal” and the “tariff switching signal” in addition to power measurements performed by the electrical power utility, they are capable of monitoring each individual measuring period and maintaining specified limit values for each respective tariff period.
When short-term high demand situations arise, these systems push energy out into the next measuring period, thus leveling out of energy import. Only as much energy as necessary is “redistributed” in order to avoid exceeding the limit value.



Leveling Off Energy Import

The above figure shows how energy (red surface area) is automatically redistributed from high demand periods to subsequent periods. Total energy consumption is not reduced, it is only pushed out by a few minutes from just a few high demand measuring periods. Chargeable demand is thus considerable reduced, and unnecessary knee-jerk reactions are avoided at the same time.
If peak loads are very pronounced and short (one to three measuring periods in duration), and if suitable equipment is used (this factor will be discussed in detail later), there’s no need to fear any discernible influence on the production process.

Decisive Functional Features of the Optimizing Computer

Simple maximum demand monitors are frequently utilized, which function in a highly undifferentiated fashion, and impede the production process more than is necessary without fully exploiting potential savings. In many cases they are bypassed after a very short period of time.

We do not intend to address all the technical details of a modern optimizing computer in the following pages. However, due to the fact that the systems which are currently available from the market differ to a great extent, one should at least be able to separate the chaff from the wheat.

Modern optimizing systems should:

- Be able to process information from the piece of equipment to be controlled via binary inputs, in order to be able to take the degree of utilization of the interconnected power consumer, and in turn the production process, into consideration in a flexible, differentiated fashion
- Be capable of suitable extrapolation within the measuring period in order to reduce switching frequency
- Be equipped with differentiated setpoint management in order to do justice to various tariff aspects for power billing
- Provide the user with good value for the money, so that amortization is economically advantageous

Blind Optimization Doesn’t Pay

It is by no means adequate for the optimizing system to be informed solely regarding currently required power and the demand situation by means of measuring signals from the power utility.
It is just important, if not more so, for the system to be informed by means of so-called “operating feedback signals” as to whether or not a connected piece of equipment is contributing to current power demand.
The system is not only provided with information regarding currently available “controllable load” to this end, it is also capable of adhering to specified minimum make times and maximum break times. The following examples are intended to illustrate these issues:

1. A piece of equipment is switched on, for example by a thermostat. A system which does not register this event because it is incapable of evaluating operating feedback signals coincidentally switches the same piece of equipment back off again a millisecond later. Due to the fact that this practice may damage the device in the long-term under certain circumstances, many manufacturers design their equipment such that shutdown signals are ignored until a certain amount of time has elapsed after power-up. According to internal optimization calculations, the power consumer is theoretically switched off, but in actuality it continues incessantly to drive up the mean value. Valuable time elapses before the system finally recognizes, by means of a sluggish pulse measurement, that its shutdown signals are not having the desired effect. The setpoint may be exceeded as a result, because there might not be enough “compensating energy” (sheddable load * remaining time) in the event of a

delayed reaction. On the other hand, a system which recognizes the fact that the piece of equipment has been switched on by a thermostat allows it to run uninfluenced for the specified minimum make time, and immediately looks for other sheddable load based upon current recorded run times of other equipment.

2. A piece of equipment has not consumed power for 3 minutes because the thermostat has not closed. The optimizing system, which is unaware of this status because it does not evaluate operating feedback, switches it off for an additional period of 5 minutes which corresponds to the maximum break time. The piece of equipment is thus switched off for a total of 8 minutes. A system which is capable of evaluating operating feedback would only switch it off for an additional 2 minutes, in order to avoid exceeding the maximum break time of 5 minutes. Due to the fact that the intelligent system was already aware of what would happen 3 minutes earlier, it might shut down additional equipment under certain circumstances in order to avoid exceeding the setpoint.

Beyond this, the fact that certain pieces of equipment must continue running until a given process is completed before they can be “disabled” for a specifiable period of time (which is often the case), can be managed very easily by the optimizing computer’s software with the help of appropriate operating feedback signals. If this is not possible, the desired control strategy must be purchased from the manufacturer in the form of accordingly differentiated, and expensive retrofitting. And to top it all, this approach results in the same problems as described in example 1.

In addition to these simple and plausible reasons for processing operating feedback, there are a number of other less obvious aspects which make is advisable to take information into consideration which originates from production equipment (including thermostat switching statuses und warnings such as “coolant temperature too high”): The system is thus aware of various operating states, for example whether electro-thermal power consumers are currently in a warm-up phase or a holding phase, and is thus able to flexibly adapt load shedding priorities and break times to production conditions.

Beyond this, so-called “trend calculations” or “extrapolations” are much more accurate with the help of operating feedback, and switching frequency can thus be reduced. The same rule applies in this case: The more information is available, the easier it is to achieve one’s goal. Compare this situation with trying to find your destination without a map. The trial and error approach results in many unnecessary failed attempts before you reach your goal. However, if you’re in possession of the required information, as provided, for example, by a navigation system, you’re able to reach your destination easily without any detours.

It is thus important to make sure that the optimizing system is equipped with binary inputs for information from the equipment to be controlled in addition to the relays required for intermittently switching power consumers off, i.e. optimization may not be carried out blindly. In particular the demand optimizing modules which are integrated into building management systems are frequently blind to equipment operating states.

Trend calculations are not necessarily the ideal solution.

As has already been mentioned repeatedly, the objective of peak load optimization is to avoid exceeding one or more specified chargeable demand setpoints. This means that energy made available during any of the power utility’s measuring periods must be limited to a fixed value. For example, if the setpoint value is 1000 kW, the system may not permit the consumption of more than 250 kWh of energy during any give 15 minute measuring period. In this way, the optimizing system actually limits the amount of imported energy during high demand measuring periods, which is then “made up for” in the subsequent period.

The easiest way to assure that this is the case is to limit the amount of permissible energy per measuring period to a specific amount: Control takes place along a so-called “setpoint line”, as is also the case, for example, with temperature control. These processes often have very fancy names like time integration and PI/PID control. However, processes which function quite well for temperature have proven themselves inadequate for demand optimization for a very simple reason: Only a portion of the control variable can be influenced, namely controllable load. If control is carried out along a setpoint line for the entire duration of the measuring period, an unexpected load which is not connected to the system may cause the setpoint to be significantly exceeded at the end of the period.

For this reason, many systems make use of the so-called “trend calculating process”, by means of which current overall energy import (instantaneous power) is extrapolated to the end of the period in consideration of past overall energy import. Even if appropriate cushioning is integrated into the process, a “bad trend” could result in excessive load shedding, and a “good trend” could result in inadequate optimizing.

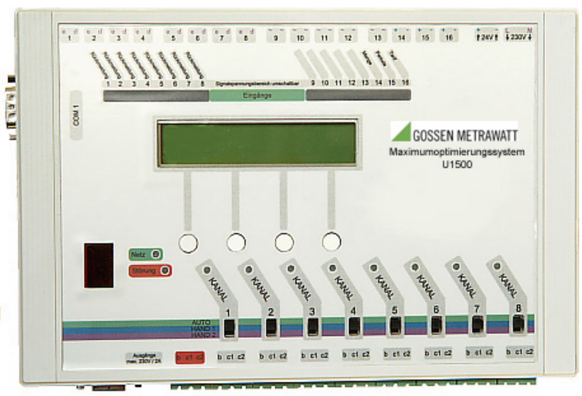
On the other hand, systems which perform true extrapolations of energy import based upon controllable load using a wealth if information as described above (e.g. past performance of equipment during the current measuring period), and only combine this with the trend process for the load to be influenced, are very likely to eliminate the above described negative effects.

Differentiated tariffs in liberalized energy markets necessitate differentiated setpoint management.

In the meantime, a standard has been established for most optimizing systems by means of which switching amongst up to four limit values (setpoints or upper power limits) is accomplished with a maximum of two binary tariff signals.

Due to the fact that energy management systems have an average service life of approximately 20 years, they should be designed today for use with tomorrow's tariff models (e.g. scheduled deliveries), so that new tariffs can be accommodated by means of simple reconfiguration. This means that time specific specification of 24 or 96 limit values per day must be feasible.

"Automatic setpoint adjustment" represents an additional aspect of "setpoint management". If a low value prevails at the beginning of the billing period, this system is thus able to automatically increase the limit value to the highest demand peak occurring during the billing period: It doesn't make any sense to maintain a low setpoint for the rest of the period. In particular with greatly fluctuating monthly power requirements, this strategy significantly increases average annual potential savings without having to manually select a suitable setpoint each month.



GOSSEN METRAWATT's U1500 peak load optimizing system is equipped with binary inputs for up to two signals (operating feedback and demand requirement) for each piece of interconnected equipment. It is capable of managing 365 x 96 limit values and adapts itself dynamically to the production process with flexible control strategies and setpoint management. It's the ideal solution for industry, commercial kitchens, the commercial trades and administration buildings.

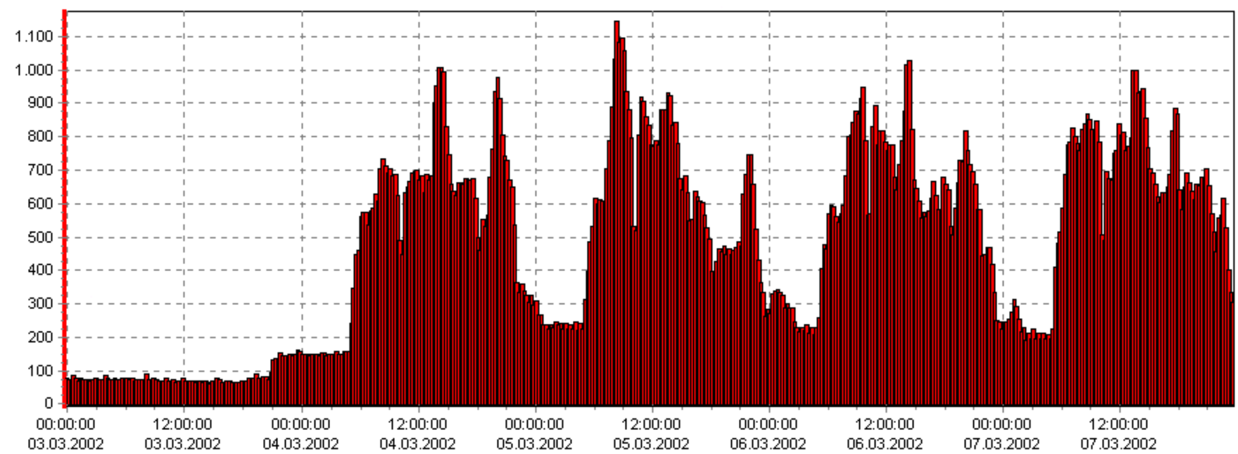
Transparent Operations and Flexible, Individualized Parameters Configuration

By making energy import and system data available at the integrated LCD (e.g. monthly maximum values with time of occurrence, import situation and output switching statuses during the current measuring period, and plain text messages for system errors), the responsible party is provided with accurate information regarding the facility's demand situation.

The energy situation becomes clear-cut and transparent thanks to the read-out of differentiated load profiles, energy consumption, graphics depicting switching operations and utilization of production equipment (based upon operating feedback signals) at a PC or a notebook. This not only motivates personnel to save energy, it also opens up new potential savings and further opportunities for optimizing energy consumption.

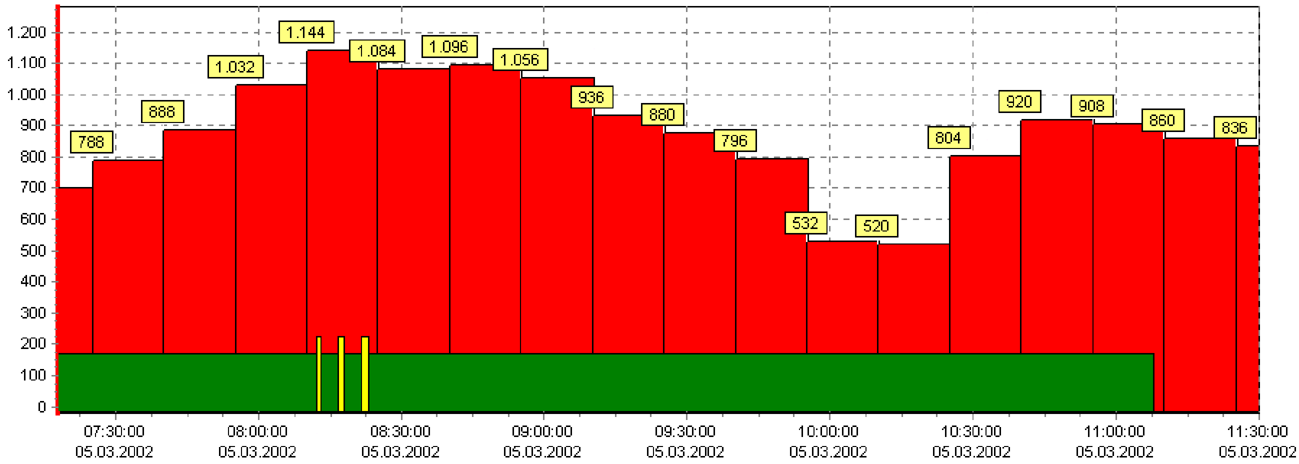
With the help of menu-driven parameters configuration using the system's integrated LCD and function keys, or by means of Windows software at a PC, company and user-specific control strategies (load, time or event dependent) can be conveniently selected and limit values, load shedding priorities, minimum make times and maximum break times can be specified and modified during operation.

The graphic below shows the load profile for overall import over a period of 5 days. Peak power demand occurred on the 5th of March, 2002.



The figure below shows a read-out of 15-minute mean values for the day on which peak power demand occurred during the month of March. The system's setpoint was set to 1145 kW. Operating feedback from the heater of a given piece of equipment (autoclave) is shown in green (approx. 140 kW). The time periods during which the optimizing system shut the heater down in order to avoid exceeding the limit value are shown in yellow.

The heater was shut down for a period of approximately 4 minutes during this high demand measuring period. If the heater had not been influenced by the optimizing system, power demand would have been roughly 38 kW greater. By briefly taking control of a single large power consumer, savings of approximately € 2400 were realized extrapolated over the entire year (based on an annual demand rate of € 65.00).



3 Facility Analysis

System Efficiency

As a rule, there is no single answer to the question as to whether or not an optimizing system is efficient. High power requirements do not alone provide any indication as to how great potential savings might be, and how much it will cost to realize such savings.
Frequently, potential savings are calculated very superficially using quantities which are purely hypothetical. For example, so-called "concurrence estimates" are sometimes utilized, which we discourage emphatically.
Just how sensible the use of an optimizing system might be depends to a great extent upon 3 factors:

1. It must first be determined which type of tariff schedule is being utilized.
2. Then it must be determined whether or not distinctly pronounced, singular mean peak power values occur. This can only be accomplished by analyzing the load profile.
3. An equipment analysis must then be conducted in order to determine which power consumers can be shut down intermittently, allowing for integration into an optimizing concept. In particular within this context one often hears the statement, "you can't shut anything down at our plant". However, if one considers the fact that a GOSSEN METRAWATT system can operate efficiently with potential savings of as little as 30 kW, it pays to go looking for controllable load.

The appendix includes checklists which help provide you with basic information regarding point 1 (tariff schedules) and point 3 (equipment). In combination with load profiles, potential savings can be estimated as an initial step.

Load optimization can only function satisfactorily if an individualized optimization concepts is prepared for each location!

If these data indicate that significant potential savings might be realized, you should ask one of our experts to prepare an individualized optimization concept with a system proposal. After conducting a facility tour, detailed documentation can be prepared providing operations engineering or your electrical installation service provider with a basis for quoting the installation of a system.

Within the framework of an appraisal of economic efficiency, amortization time for a suitable system is calculated on the basis of potential savings, component costs, initial start-up services and installation costs.

3.1 Analyzing the Tariff Schedule and Consumption Billing

Essential prerequisites for determining potential savings include knowledge regarding tariff schedules and your current monthly power requirements. An appropriate checklist has been provided in appendix A.
Data required to this end can be taken from your power supply contract and your monthly or annual invoices.
Several of the checklist entries are explained in detail below.
You power utility keeps standby power on hand for you. Just how much standby energy is maintained depends to a great extent upon the available technical infrastructure (transformers, cables etc.). You can place an order for estimated peak demand (subscribed demand), which is covered by standby power. The power utility plans capacity based upon subscribed demand. You are billed for a certain portion of subscribed demand in any case (e.g. 70%), even if monthly or annual peak demand is less than this amount. Thus from a financial standpoint, it doesn't make any sense to reduce power requirements with the help of an optimizing system to a level which is below this minimum chargeable demand.
The entry of demand rates and kilowatt-hour rates to the checklist is necessary for two reasons, Firstly, this makes it possible to determine actual savings based upon potential savings for the specified power costs. Secondly, it is possible to determine whether or not potential savings can be further increased through the use of a different tariff schedule after load optimizing has been implemented (higher demand rate and lower kilowatt-hour rate). Most power utilities offer two different tariff schedules for special contact customers: steep tariff, i.e. high demand rate and low kilowatt-hour rate, and flat tariff, i.e. low demand rate and high kilowatt-hour rate. Overall annual energy must be entered for the same reason, from which hours of full utilization are calculated in order to incorporate possible usage rebates into achieved financial savings, if they apply. It is advisable to include the name of a contact person from your power utility in the checklist so that you can make any necessary enquiries regarding alternative tariffs after optimization has been implemented.
Another very important aspect of load optimization is the power billing mode. For example, if the utility only measures power during special peak load periods (perhaps for only one hour each day), it may be possible, under certain circumstances, to achieve even greater potential savings with an optimizing system than would be possible with continuous 24 hour power measurement.
Entries to the checklist indicating whether power is billed on a monthly or annual basis are primarily important for the setpoint management strategy. This strategy must be taken into account in advance in order to determine mean annual potential savings. Monthly peak power demands are required for the entire billing year to this end, which are included in the invoices from your power utility.

3.2 Analyzing the Import Profile and the Load Curve

Monthly peak power demands taken from the power utility's invoices don't at first tell us anything about when and for how long peak monthly power import took place. A statement indicating whether or not pronounced short-term peaks occurred can only be made after analyzing the load profiles. Obtaining the required load profiles is of course easiest after an optimizing system or a data logging system has already been installed, which is capable of acquiring and printing out load profiles.
If you do not have such a system at your disposal, start by contacting your electrical power utility. The utilities use meters with load profile memories for many customers, and are often able to provide you with load profiles for the days on which the highest monthly demand peaks occurred.
In order to obtain representative data, monthly load profiles should be requested for months during which high power demands occurred: Vacation months are not suitable for analysis.
As a rule, an uninterrupted measuring period of two to four weeks from a representative month is enough to gain an insight into the duration and degree of peak loads.

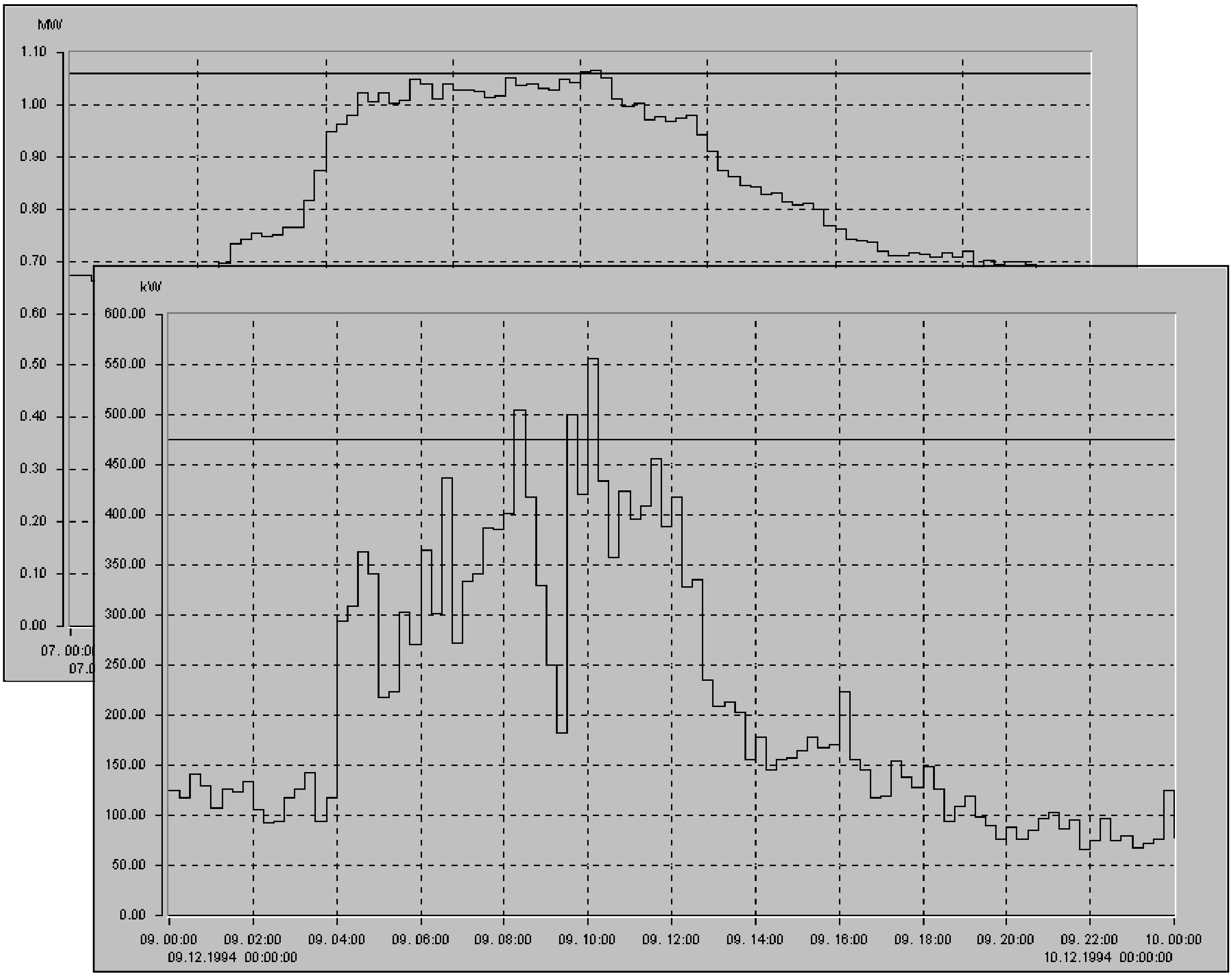
GOSSEN METRAWATT's Measuring and Analysis Service

In the event that no load profiles are available, GOSSEN METRAWATT offers a measuring and analysis service for acquiring energy data on-site at your facility.
Load profiles can be recorded by simply mounting an optical probe to the billing meter. The probe converts rotor disc revolutions into pulses, which are stored to a portable data logger.
As a rule, we ship the required measuring equipment to you. After the measuring period has ended, you return the measuring system to us. Data are then prepared for graphic representation with high-performance software, and you receive comprehensive measurement documentation with a complete analysis of your load profile in consideration of optimization opportunities.
GOSSEN METRAWATT is also capable of performing complex measuring tasks with portable systems, which are equipped with up to 5 recording channels. Current and voltage is acquired in this way by means of clip-on meters. By using several systems of this type at the same time, outgoing feeders in primary and sub-distribution cabinets can be measured simultaneously and, for example, equipment which causes peak loads can thus be identified. Beyond this, additional electrical quantities can be recorded as well, such as power factor cos φ and harmonics.

Potential Savings based upon Magnitude and Duration of Demand Peaks

In order to conveniently determine potential savings with the help of the load profiles, they must be available as graphic representations. As a rule, examining the load profiles from the days during which the five to seven highest mean power values of the measuring period occurred is enough.
In order to estimate potential savings, an attempt is made to push "demand peaks" out into neighboring "demand valleys".
The two figures included below show the load profiles of two different facilities for the days during which the highest power requirements occurred. The profiles were generated with the GOSSEN METRAWATT measuring system.

It is only possible to shift a very small amount of energy (= surface area, i.e. power * time) into the first or second measuring periods which follow the demand peak with the profile shown in the background (electrical equipment manufacturing facility). With a chargeable demand of approximately 1070 kW, potential savings are less than 10 kW. The limit value which would have to be selected for the optimizing system in this case (black horizontal line) would be roughly 1060 kW. If a significantly lower limit value were selected, the optimizing system would intervene continuously over a period of several hours, which would result in a reduction of overall energy and would significantly impair the production process. An optimizing system would neither be sensible nor economical in this case.
The situation is entirely different with the load profile shown in the foreground (food processing facility). Due to the fact that short, highly pronounced peak demands occur for the duration of only one measuring period, energy can easily be pushed out by a few minutes into the demand valleys. Initial chargeable demand of roughly 560 kW was reduced to approximately 475 kW (black horizontal line). Thus savings of 85 kW were realized by controlling food storage and deep freezing units, as well as equipment in the cafeteria.

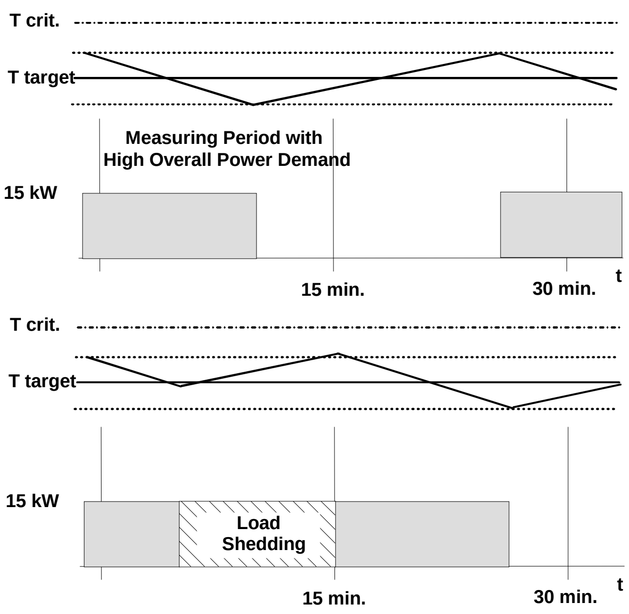


3.3 Equipment Analysis

High potential savings based upon pronounced peak demands in the load profile cannot be realized if there are not an adequate number of devices which can be shut down intermittently, or switched to a low energy operating mode.

What does "shut down" actually mean within this context?

The term "shut down" is naturally associated with "standstill". If we want to reduce power consumption only slightly at a downstream unit (e.g. a conveyor belt) which runs 24 hours a day at a specific, although unforeseeable point in time, it must, as a rule, be shut down abruptly. Measures of this sort negatively effect the production process to such a great extent that the costs for the stoppage would far outweigh the energy savings. In this case, the term "shut down" means more than just a standstill with reference to the production process, it can indeed be equated with "regression".
In the following example we'll consider the compressor of a food storage or deep freezing unit. Mean power consumption is roughly 15 kW. As a rule, the unit is controlled by a thermostat and switches itself on and off within specified temperature ranges. If operated without load optimizing (top half of the following figure), it contributes roughly 15 kW * 10 min. / 15 min. = 10 kW to chargeable demand when run for 10 minutes during a measuring period with high overall power demand.



If operated with load optimizing (bottom half of the above figure), the optimizing computer runs the unit for the predefined minimum make time of 5 minutes, and then shuts it down for the maximum break time of 10 minutes as required by the prevailing demand situation. This is referred to a "cycling" the power consumer. In this case, the unit's contribution to chargeable demand is 15 kW * 5 min. / 15 min. = 5 kW. This short-term "shutdown" has thus resulted in savings of approximately 5 kW. If we observe the temperature curve, we discover that it remains nearly within its normal range: The critical temperature limit is not violated. The energy reduction in the high demand measuring period is made up for automatically in the subsequent period, and there is absolutely no negative influence on the production process.
In this case as well, the term "shutdown" cannot be equated with "standstill", but rather with "savings".
The prerequisite is, of course, that the demand peaks are short, because if refrigeration were cycled uninterruptedly by the optimizing system for a period of 60 minutes, a so-called "pump-down effect" might result and the critical temperature limit could be exceeded. This once again illustrates how important the analysis of the load profile is in achieving ideal results.

Energy Storage Capacity

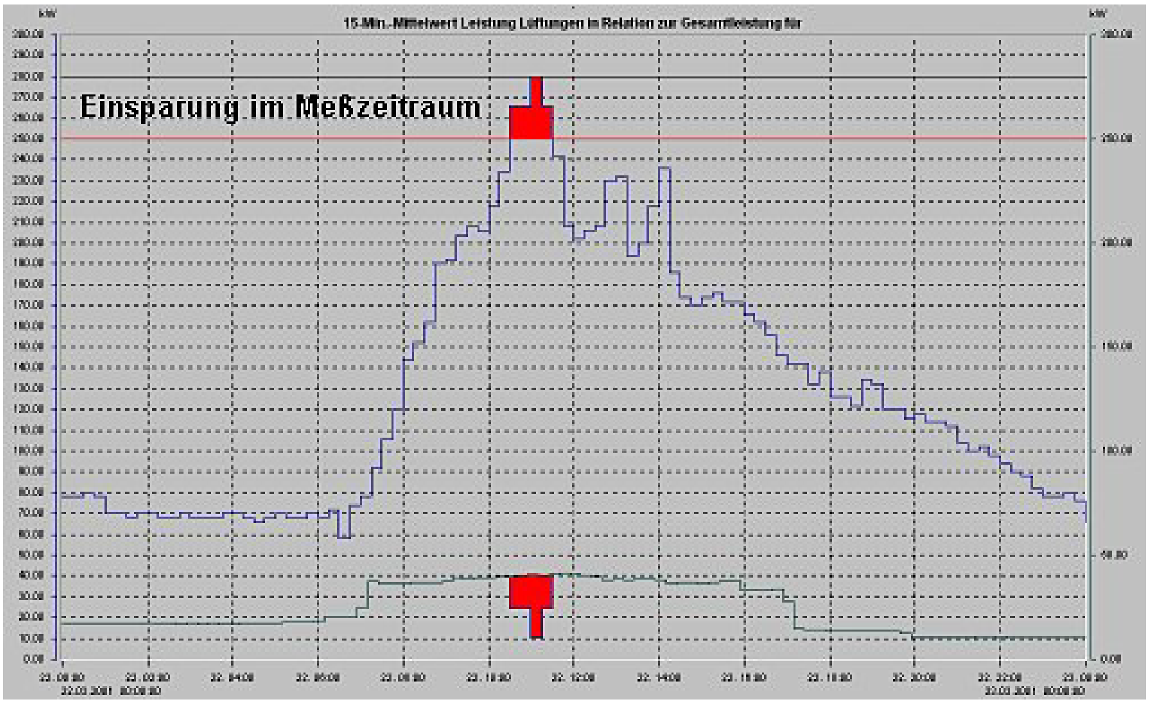
It has now surely become apparent which factors are crucial in deciding which power consumers will be controlled by the optimizing system: They should demonstrate a certain capacity for storing energy, as is often the case with equipment which is thermostatically controlled. All types of refrigerators and heaters (especially in large kitchens and industrial washers and dryers) are very well suited for load optimization. However, even if they have no energy storage capacity, consumers which demonstrate high power consumption can also be integrated into a load optimizing system if operation can be postponed for several minutes without impairing the production process (e.g. bottle molding presses, refuse presses etc.). Ventilators and air conditioning units can also frequently be linked to the optimizing concept in a trouble-free fashion. If the majority of utilized equipment is thermostatically controlled (for example in large kitchens), intelligent optimization systems assure that coincidental concurrences do not occur amongst the thermostats' individual cycles, and thus maintain homogenous power demand. In facilities with mostly non-controllable power consumers which are operated for short periods of time, and which nevertheless cause extreme demand peaks, high demand situations can frequently be compensated for by means of load-dependent control of basic power consumers without significantly impairing the production process.
The more intelligent the utilized system is, and the more equipment related information it is capable of processing, the less it influences the production process, and the more "critical" equipment can be integrated into the optimization concept.

3.4 Determining Realistic Potential Savings

Index B contains a checklist to which you can enter all of the equipment, along with the corresponding data, which you believe can be incorporated into an optimizing system.
The sum of all “adjusted potential savings” associated with the equipment included in the list results in “potential savings based upon equipment mix”.
We have already determined “potential savings based upon magnitude and duration of demand peaks” with the help of the load profiles.
Realistic potential savings generally amount to the lesser of these two figures.

In order to provide you with a feel for how demand peaks and controllable load interact with each other, we provide the following final example which demonstrates that shutdowns can also be tolerated for absolutely non-critical equipment, although energy is not pushed out into a new period, but rather minimally reduced.

The figure below shows the overall import load profile of an administration building, and the load profile of a selected ventilation and air conditioning system for the day on which the monthly chargeable demand peak occurred (approx. 280 kW). Power requirements are within a range of roughly 240 to 260 kW on all other days.
In this case, if we want to reduce monthly chargeable demand by 30 kW, the energy quantity highlighted in red must be either pushed out into other measuring periods, or eliminated by the optimizing system. Ventilators and air conditioning units are the easiest controllable loads to taken advantage of in administration buildings. Selected power consumers in the cafeteria’s kitchen take second priority as candidates for integration into the optimizing concept. If we want to compensate for demand peaks by means of load-dependent control of the ventilators, the ventilators’ energy requirements must be reduced by means of cycling by about 40% on one day of the month for the duration of three measuring periods, and by 75% for the duration of one measuring period. The ventilators’ energy requirements would also have to be reduced by roughly 25% on 10 additional days during the month for the duration of two measuring periods each. The system does not intervene on the remaining 19 days of the month. Where many ventilators and air conditioning units are used, experience has shown that cycling during 24 of a total of 2880 measuring periods per month is usually tolerable. In the example presented here, it results in realistic potential savings of approximately 11% of total power costs, alone by controlling the ventilation and air conditioning units with the optimizing system.



4 Technical Implementation

The expenses involved with installing a suitable optimizing system depend to a great extent upon individual construction conditions at the location in question. Generalized statements are not possible.
The following work must be performed during the course of installation:

1. Mechanical installation of system components (optimizing computer, decentralized substations if required)
2. Enabling of measuring signals from the electrical power utility
3. Laying of control cables to the individual pieces of equipment, and bus cables to the most important individual optimization areas
4. Equipment retrofitting, and securing cables to connector terminals at the equipment and the various components of the optimizing system
5. Initial start-up (generally executed by GOSSEN METRAWATT)

4.1 Installing the Components

GOSSEN METRAWATT optimizing components can be easily snap mounted to the customer's existing control cabinets and top-hat rails, or can be provided pre-installed to standard wall-mount cabinets upon request. The units are equipped with plug-in terminal strips which simplify installation and service.

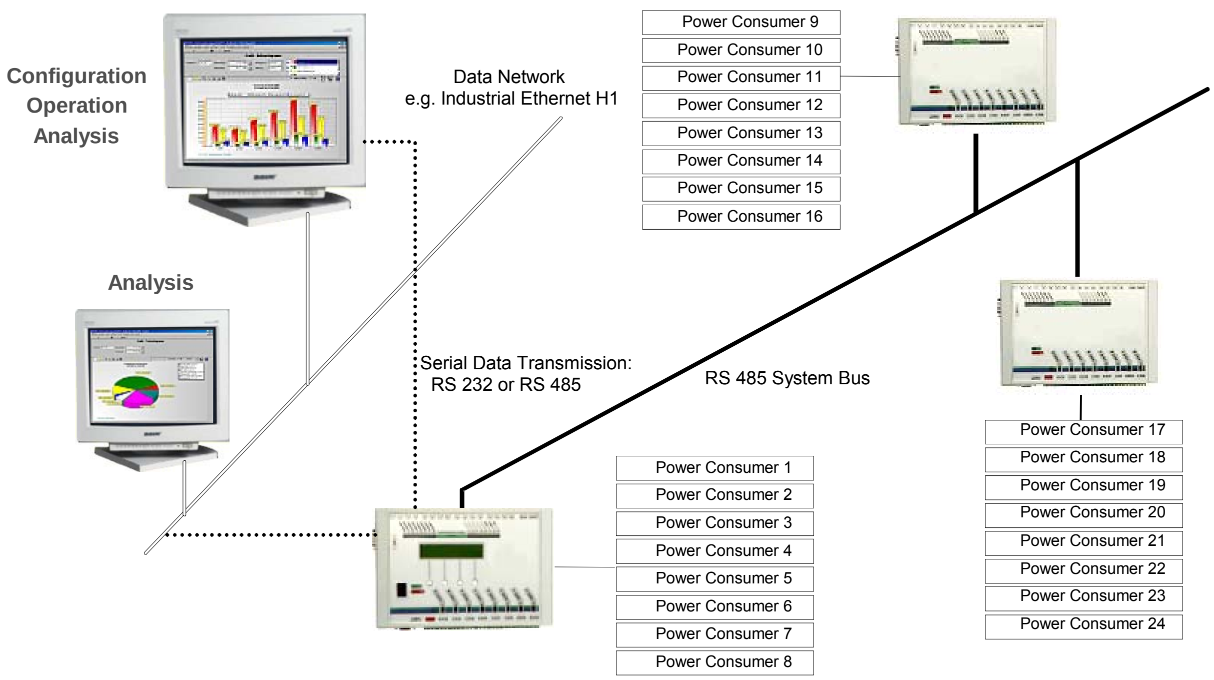
Visualization software can be run on a commercially available PC with MS Windows, which can be set up separately from the optimizing computer.

4.2 Signals Provided by the Electrical Power Utility

As a rule, the power utility enables the signals required for load optimization upon request, namely the kWh quantity pulse, the synchronizing pulse (measuring period signal) and the tariff switching signal (e.g. HT-LT). An isolating relay is installed to the power utility's measuring station to this end, and the required binary signals are transmitted to the optimizing system via a cable. Customer-specific configuration data from the power utility's measuring equipment (pulse value, e.g. 5000 pulses per kWh, transformation factor and measuring period duration) can be entered conveniently via menu-driven software to the optimizing system.

Freely Configurable Binary Inputs

Each GOSSEN METRAWATT optimization component is equipped with a total of 16 binary signal inputs, which can be configured for operating feedback and measuring signals. Additional measuring instruments can be connected to unused inputs independent of the load optimizing system, for example reactive current meters and active current sub-meters, which are equipped with a so-called S0 data interface. In this way, data such as power factor cos φ, consumption at individual sub-distribution cabinets and the corresponding load profiles can be displayed and monitored in combination with PC visualization software.



4.3 Bus and Control Cables

GOSSEN METRAWATT is capable of providing an ideal optimizing system for facilities of any size – from centralized systems with 4 or 8 optimizing channels right on up to decentralized, expandable systems with an open-ended number of optimizing channels.
The figure on the previous page shows the basic layout of a decentralized system.
As a rule, the various pieces of equipment are connected to the optimizing components with control cables. The components communicate with the optimizing computer via a 2-wire bus cable.
Existing bus cables or building management systems can of course be utilized. The traditional, and most cost-effective procedure involves linking the systems via binary inputs and outputs: In light of the multitude of bus systems and building management systems available from the market today, the use of serial coupling modules is technically problematic.
In the case of unconventional solutions such as data transmission via the three-phase power grid, the advantages (inexpensive transmission over great distances) and disadvantages (increased susceptibility to interference) must be carefully weighed against one another.

4.4 Retrofitting Existing Equipment

The equipment must of course respond to the control commands transmitted by the optimizing system, and must also generate operating feedback signals. In many cases, this is easier to accomplish than one would think. Many equipment manufacturers, especially in the where large kitchen appliances are concerned, offer appropriate connection options fitted at the factory, or special retrofit kits so that control cables need only be connected to the corresponding terminals. When buying new equipment, we recommend asking the manufacturer about furnishing load optimizing connector terminals.
Within the framework of project engineering for optimizing systems, GOSSEN METRAWATT contacts the manufacturers of equipment which will be integrated into the optimizing concept in order to specify the required interfaces.

4.5 Demand Management as a First Step Towards Comprehensive Plant Optimization

In addition to pure load optimization, GOSSEN METRAWATT also offers numerous opportunities for expanding optimizing systems into comprehensive energy management and operations optimizing systems.
GOSSEN METRAWATT supplies you with everything from a single source – from electronic power meters for sub-measurements and systems for monitoring voltage quality, right on up to the implementation of automated cost-center billing systems.

5 Calculating Amortization Time

After potential energy savings have been calculated, a suitable optimizing system can be selected with an appropriate number of optimizing channels, and after clarification of the installation expenses, the system's amortization time can be determined based upon an objective appraisal of economic efficiency. In particular in the field of load optimization, amortization times of less than two years are not unusual.

Appendix C includes an additional checklist which allows you to perform a cost-benefits analysis.

6 Conclusion

Whether or not it makes sense or is economical to implement a load optimizing system must be clarified in detail for each individual facility. Potential savings in this area remain unexploited at many companies.
If there is sufficient reason to install such a system, success depends to a decisive extent upon several crucial criteria:
An individualized, detailed optimizing concept prepared in advance by experts assures excellent system reliability, and often reduces costs during the implementation phase. In addition to this, the system to be utilized should be intelligent and adaptable to changing future requirements, and should have adequate capacity in order to assure that potential savings can be taken advantage of for as long as possible.

After fulfilling these basic prerequisites, a suitable system is not only capable of reducing consumption costs and improving your tariff situation in liberalized energy markets, it contributes to a more conscientious approach with regard to energy consumption within your facility as well.

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Appendix A Tariff / Consumption Checklist

Tariff Schedule and Consumption Billing

Company: ____________________

Contact person / phone no. ____________________

Electrical Power Utility: ____________________

Contact person / phone no. ____________________

Optimizing system already installed? ☐ yes ☐ no

If yes: manufacturer ______________________________

Tariff Schedule: Measuring period: _______ min.

Subscribed max. demand: _____ kW Standby power: _______ kW

Minimum chargeable demand: ____________ kW

Annual demand rate: ____________ €/kW

Kilowatt-hour rate, HT: ____________ cents/kWh

Kilowatt-hour rate, LT: ____________ cents/kWh

Billing mode: ☐ HT only ☐ HT and LT ☐ High demand time only

☐ Monthly ☐ Annual / Mean from _______ highest months

Consumption Billing (demand component):

Monthly chargeable demand from previous year ______________:

Jan. ________ kW Feb. ________ kW March ________ kW

April ________ kW May ________ kW June ________ kW

July ________ kW Aug. ________ kW Sept. ________ kW

Oct. ________ kW Nov. ________ kW Dec. ________ kW

Total annual energy, HT: ____________________ kWh

Total annual energy, LT: ____________________ kWh

Peak annual demand: Month ______________ _______ kW

Hours of full utilization = total annual energy (HT + LT) / peak annual demand

Hours of full utilization: ____________________ hours

Monthly chargeable demand for current year:

Jan. ________ kW Feb. ________ kW March ________ kW

April ________ kW May ________ kW June ________ kW

July ________ kW Aug. ________ kW Sept. ________ kW

Oct. ________ kW Nov. ________ kW Dec. ________ kW

Example:

Customer: Sample Ltd.
Mr. John Doe
538-1234

Utility: Power Inc
Mr. Watt
835-4321

15 min.

1350 kW / 1500 kW

945 kW (70%)

70.00 €/kW

6.35 cents/kWh

5.45 cents /kWh

Does the utility measure power during the HT period only, during HT and LT periods or only briefly during periods of high demand?

... 3 highest months

2001

1132 / 1085 / 978

1067 / 1052 / 1025

1013 / 998 / 1124

1095 / 1168 / 1113

2,498,354 kWh

1,007,867 kWh

Nov. 1168 kW

3,506,221 kWh / 1168 kW

3001.9 hours

1056 / 1118 / 1025

1101 / 1078

Appendix B Equipment Checklist

Power Consumers to be Integrated in to the Optimizing Concept

Equipment designation (list large power consumers separately, e.g. units with several heating circuits)	Mean demand during normal operation	Shutdown sequence: 1 = this consumer will be shut down first	1 = power consumer is always in operation 0 = power consumer is never in operation	Minimum duration for which the power consumer must be run after shutdown	Maximum duration for which the power consumer may remain shut down	= mean power * max. break time / (min. make time + max. break time)	= potential savings. by means of cycling * likelihood of operation
Designation	**Mean Demand [kW]**	**Shed-ding Priority**	**Likelihood of Operation**	**Min. Make Time [min.]**	**Max. Break Time [min.]**	**Potential Savings by means of Cycling [kW]**	**Adjusted Potential Savings [kW]**
Example	9.0	5	0.6	7	3	9*3/(7+3)=2.7	2.7*0.6=1.62
Totals							

Designation	Mean Demand [kW]	Shed-ding Priority	Likelihood of Operation	Min. Make Time [min.]	Max. Break Time [min.]	Potential Savings by means of Cycling [kW]	Adjusted Potential Savings [kW]
Balance brought forward							
Totals							

Appendix C Economy Checklist

Cost Savings and Investment Expenses

Company

____

Contact person / phone no.

____

Example

Company: Sample Ltd.
Mr. John Doe
Phone: 538-1234

Cost Savings:

			Example
a.) Load profiles: cost savings based upon duration and magnitude of demand peaks:	____________	kW	135 kW
b.) Equipment list: cost savings based upon equipment mix:	____________	kW	75 kW
Realistic potential savings: the lesser of a.) and b.)	____________	kW	75 kW
Multiplied by annual demand rate:	____________	€/kW =	70.00 €/kW
Power cost savings	____________	**€ +**	**€ 5250.00**
Savings resulting from tariff optimization	____________	**€ =**	**€ 1100.00**
Total annual cost savings (A)	____________	**€**	**€ 6350.00**

Investment Expenses:

			Example
Optimizing system (____ optimizing channels) including services (project engineering & start-up)	____________	€	€ 4800.00
Signals furnished by the electrical power utility	____________	€	€ 300.00
Laying cables for controlling equipment, communications and signals from the power utility: Materials	____________	€	€ 350.00
Man-hours ________	____________	€	€ 950.00
Costs for retrofitting equipment: Materials	____________	€	€ 150.00
Man-hours ________	____________	€	€ 800.00
Other installation expenses: (e.g. installation of optimizing components, cable connection etc.) Man-hours ________	____________	€	€ 450.00
Total investment expenses (B)	____________	**€**	**7800.00**
Amortization time (B / A)	____________	**years**	**approx. 1¼ years**

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