Multi-Channel Load Analysis: From Visualisation to Automation

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ABSTRACT

Multi-channel power monitoring forms a basis to establish reliable energy concepts with well-targeted measures. Carrying out monitoring measurements, one has to pay attention to the following principles:

1. The total load characteristic of a company and the individual load curves of consumers have to be measured. This gives a break-down of total consumption into individual consumers (= power balance), allowing exact cost allocation.
2. Measurements have to be done in at least in a one-minute resolution (rather than 15 minutes) to identify the operating characteristics and the exact time pattern of each consumer to derive organisational economy measures.
3. The measuring program has to run continuously for a fortnight (rather than being confined to a few hours or days); various factors (e.g. fluctuating utilisation levels of machine capacity, breakdowns, temperature effects, ...) become obvious.

Being specialists in the work processes taking place in their companies, the customers can now see in a common discussion of the measured data (load curves) how their activities act on energy and power demands. Thus it is possible to work together to seek possible solutions, as these normally become obvious from the clear representation of measured data analysing the efficiency of the envisaged measures, individually or as a whole.

Often quite simple automation technology can help to encourage employees in various branches to realise energy efficiency measures, after they have seen where energy is needed, used and abused:

- Air pressure systems can be closed down for the night and weekend and can be started up automatically half an hour before the start of the working day.
- Machines causing peak demands can be blocked against each other to avoid load peaks and disturbances of function (e.g. in air pressure systems).
- Instead of continuous operation, sensors can detect the filling level in a storage volume and can start exhaust ventilation systems and other appliances only when needed.
- Pneumatic transportation systems can be automatically stopped after all the material is gone.
- Artificial light can be switched off automatically when nobody is present or natural light is bright enough.

Introduction

Situation

To understand a companys process and its relevant energy procedures, besides a rough examination of the company and observation of the production methods, it is necessary to analyse and check the energy bills. Sometimes simple negotiations about tariffs lead to noticeable results in cost savings. Because there is often confusion on the customer side about single notions and entries in the energy bill, the work of an energy consultant and energy consciousness formation begins at this point. Furthermore, the comparison with branch reference numbers allows one to see if the production and the energy consumption conform or if they differ.

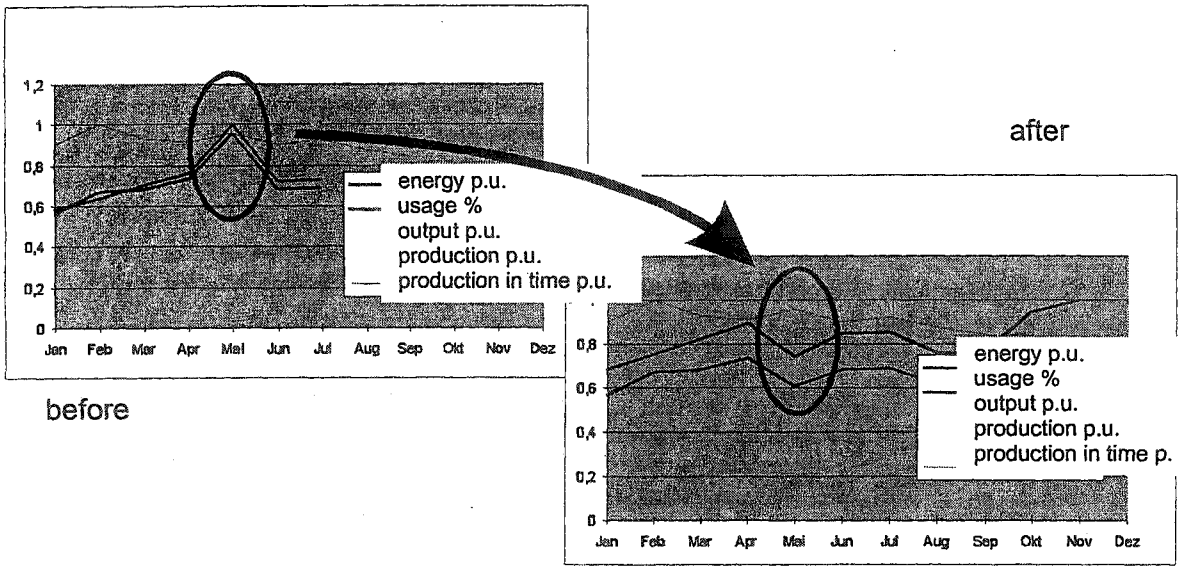

Figure 1. Specific Energy Consumption to the Production: A Mistake in the Bill Could Be Seen

The example in Figure 1 shows how a wrong meter reading could be seen by the specific value energy per unit. After correcting the bill, the specific energy demand course followed the production course.

Multi-Channel Load Analysis - Principle

After first visiting the company and checking of their energy bills, the next step is to carry out a more detailed analysis and to evaluate different energy and cost saving measures. It is therefore necessary to make detailed measurements, which can be used to see where energy is consumed - when, by whom, how much and why - and to see if energy was used or abused. Such energy analyses can also be helpful to clarify the company's internal procedures and energy consumption. To show unfavourable operating conditions, problems in the control system and more, a tool to meet these requirements was developed. Therefore a concept is needed which can measure not only voltages and currents, but also other important

physical values providing important information for a long time in various time resolutions and which can store, organise and visualise the data. The use of separate data loggers for each measuring point would be, for temporary measurements, too material and work intensive and not economical.

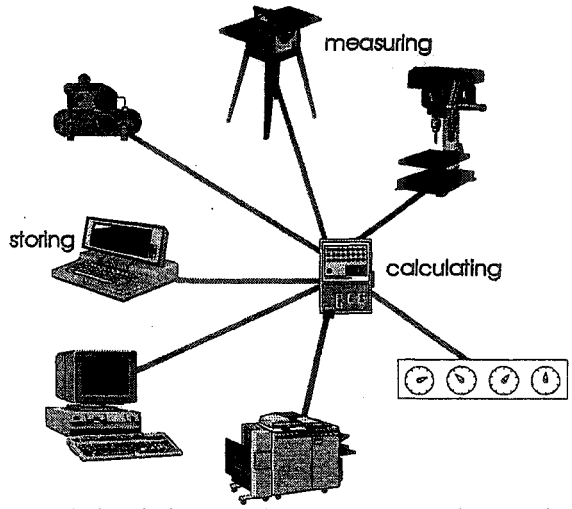

Figure 2. Multi-Channel Load Analysis – Principle

Multi-Channel Load Analysis – Technical Description

In order to reduce measurement costs, a multi-channel measuring instrument was developed by the Department of Electric Power Systems. The tasks this instrument has to fulfill, are the "measurement on all channels", the "integration at every time" and the possibility to "download the data of the measurement". These data will be stored centrally on a laptop, which will be able to load down data from several instruments. Clamps will be used as sensors for the electric currents. Electric voltages can be measured directly or with voltage transformers. All other important electric facts (P, Q, S, load factor) will be calculated on the basis of the measured voltages and currents. Sensors for other physical quantities can be used if their signal voltage corresponds to –1...0...1 V (for example a PT 100 temperature sensor with bridge connection and amplifier).

The number of channels is 21 (3 independent voltage channels and 7 current channels for each voltage channel). So a system of three phases with up to seven channels or a system of one phase with up to 21 currents can be measured - mixed circuits (2 phases, 1 neutral conductor) are also possible. Other systems such as an impulse counter, can also be integrated in the system. Such systems are mainly used to check metering of kWh's information gathered by userowned monitoring systems. For large companies, load curve measuring systems are used and the data can be obtained from the supplier.

The following features are particularly important for a multi-channel load analysis:

- The possibility to measure the sum and all relevant partial load curves: this shows the distribution of energy and efficiency on the users and makes an energy balance.
- The possibility to measure for at least two weeks: different influences, for example various production loads, production break downs but also environmental influences like temperature and humidity, influence the results and make representative statements possible

- The possibility to measure 24 hours, around the clock: not only during the day (during production), but also during night: thus, stand by losses (for instance leakages) can be detected
- seven days a week: weekend- and holiday consumption are also of interest for energy efficiency
- The possibility to measure in a 1-minute-time resolution or less: In that way, one can see the flow of production and this can be the basis for administrative measures

With the results of these measurements, machines and devices and their energy consumption can be analysed and, based on these analyses the whole production and energy flow can be optimised.

Visualisation

In order to be able to explain the measured data in a simple but efficient way, an efficient visualisation is necessary. It is not enough to show only some curves and numbers, it is necessary to discuss the results with those persons responsible for energy efficiency and the managers in order to find useful measures. Due to the high amount of data (measurements with 50 sensors during two weeks in minute-time resolution create about 3 million data sets) the development of powerful software is necessary. The development of a fast and simple data-base architecture was necessary to evaluate and handle the collected data. In addition to the visualisation of the load curves $P_i(t)$ for the total demand and the partial loads, presentations are required to allow proposals and discussions about improvements in the energy situation or about the reasons for disturbances.

The following examples demonstrate the effectiveness of the developed multi-channel load analysis.

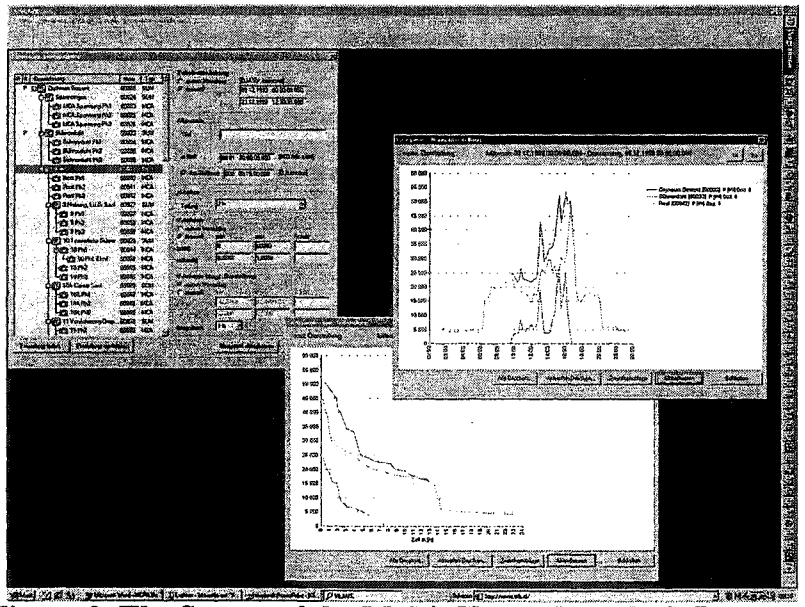

Figure 3. The Screen of the Multi-Channel Analysis Program

a) data structure, b) load curves, and c) sorted load curves

Use of Sensors for Filling Level

The following example shows the load curves of a wood chopper and an exhaust ventilation system before measures were set. Both the wood chopper as well as the exhaust ventilation system were permanently on power during the whole 8-hour working period. In Figure 4 this continuous operation of the two systems can be seen.

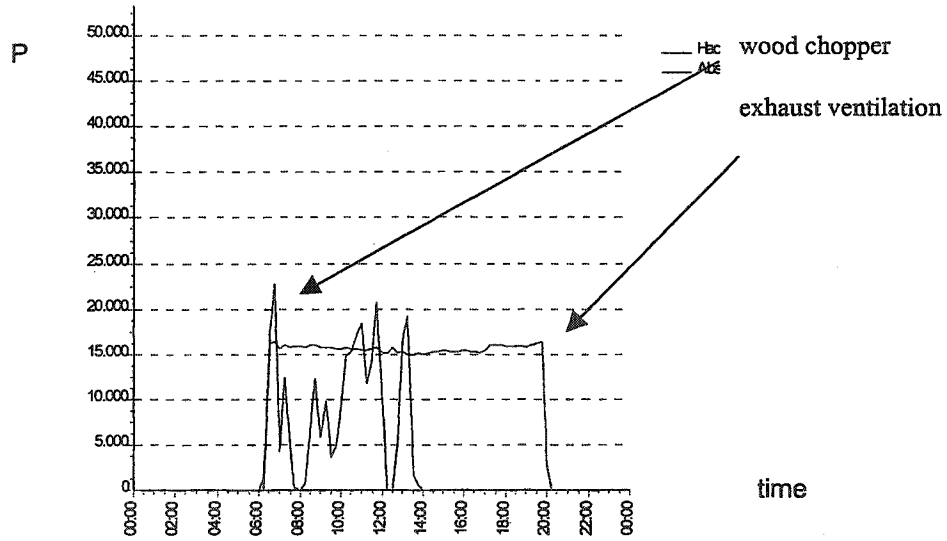

Figure 4. Load Curve of a Wood Chopper and an Exhaust Ventilation System Without Energy Efficiency Measures

The wood chopper's power fluctuates between peaks or part load, when material has to be processed, and no load. The exhaust ventilation system runs with full power independently of the process demand characteristic. The wood chopper was fitted with a filling level monitor which stops the chopper if the container is full. The energy-saving proposal in that case was to combine the operation of the exhaust ventilation system with the operation of the wood chopper. The wood chopper was also combined with an automatic time switch and can be blocked in the peak time. Thus, in principle the wood chopper has the same energy demand as before but without causing expensive peaks. The main saving is that the exhaust ventilation system requires about 70 % less energy than before.

In another examples it was found that the switch for the exhaust ventilation system was mounted on a place the worker could not reach. Remounting the switch in a proper way led to about 50 % energy saving without high investment cost.

Operation of Air Compressors

The electric energy used to produce compressed air is an important field for energy efficiency improvements. Compressors very often are running the whole time with unnecessarily high pressure. The following two graphs show the energy consumption of two different compressors in two different companies. The first graph shows the change of pressure in the air pipe system. A decrease in pressure from 10 bar to 8 bar, a pressure which

is still enough for the tools using air, reduces energy demand in stand-by time (which accounts for 95% of energy consumption) by a half.

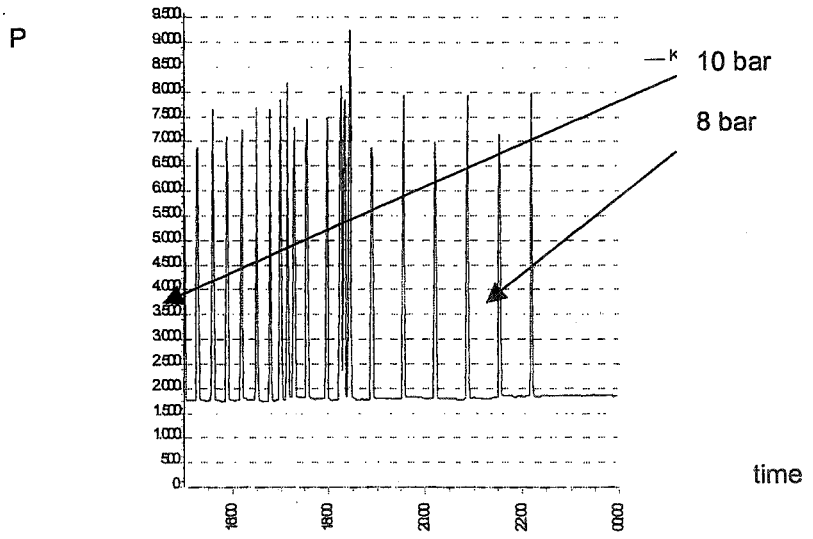

Figure 5. Load Curve of a Compressor, With Pressure Setting Changing from 10 to 8 Bar

The next example shows a compressor which is working even on weekends. It shows the energy consumption over a whole week. It can be seen that the stand-by losses are very high and in sum more than twice the energy demand during the working time. Very simple measures like switching off the equipment can cause a big effect and cost nearly nothing. Graphs like these can help to bring energy efficiency problems into the minds of people.

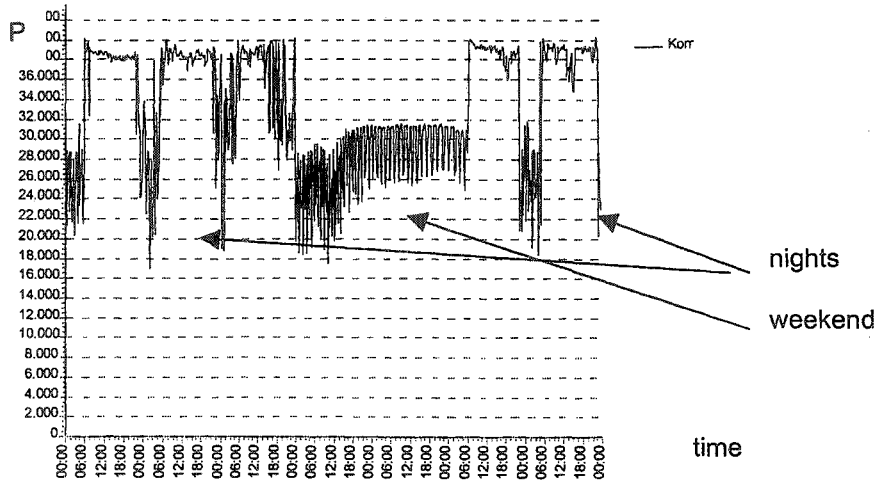

Figure 6. Energy Consumption of a Compressor During a Week without Switching Off during Weekend and Nights

Lighting

This example shows how the main consumer in a company can be detected by a measurement. The following graph originates from the steel industry – and as can be seen, the main consumption was caused by the hall lighting.

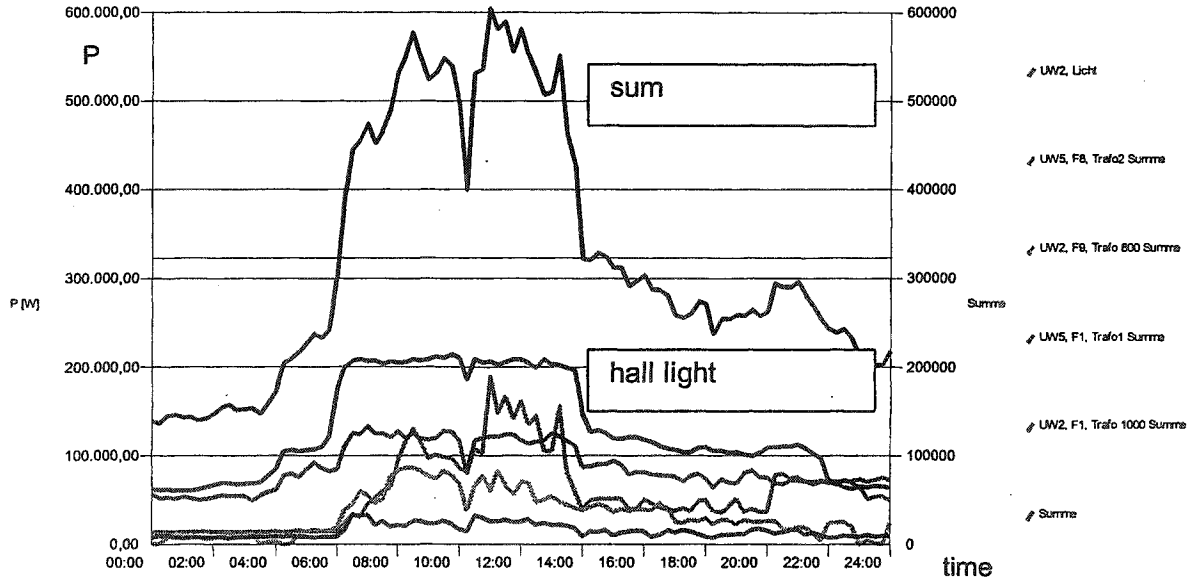

Figure 7. Load Profile of the Total Demand, the Hall Lighting And other Partial Loads of a Company

In general, it can be said that the share of lighting on electric energy consumption, for instance in industry, is mostly undervalued – measurement experience shows that it reaches 10% minimum, sometimes substantially more. The chosen example in Figure 7 shows a share of nearly 40% for the hall lighting. In the afternoon, half of the hall was lighted, but only a few machines were used in production. A local inspection showed that there had been a system installed for switching off individual sectors, but usually it was not used. There had also been a load management, which had only been used for a few other tasks, but not for controlling the lighting.

The solution of these problems was carried out in several steps: First, the sectored lighting was reactivated and connected to the load management. The second step was that only working places that had been registered at the beginning of work get light - all users have to announce a time schedule for their machines. The investment for this system was very low compared to the results in energy efficiency and cost savings. The pay-back time period was about half a year.

In various cases (daylight controlling and sectored lighting) it was found that the technical equipment for energy efficiency measures already existed, but was partly defect or simply not used. The reason very often is that this equipment is not mounted sufficiently ergonomically.

Washing Machine

The next example, a plant for washing wind-screen glasses with 400 kW, shows three conspicuous possible measures and estimates how far the energy consumption could be reduced:

1. Not starting the machine not before the beginning of work: allows an energy reduction of 10%, (immediately realised).
2. Mixing fresh water and used washing water: energy reduction of 25%, (in discussion, because a water recycling system has to be implemented).
3. Heat recovery by using waste heat from a nearby oven: further reduction potential of 25%,(in discussion, requires large investment and will be part of a future project).

In sum, over all possible measures, a 60% reduction of the total energy consumption will be possible.

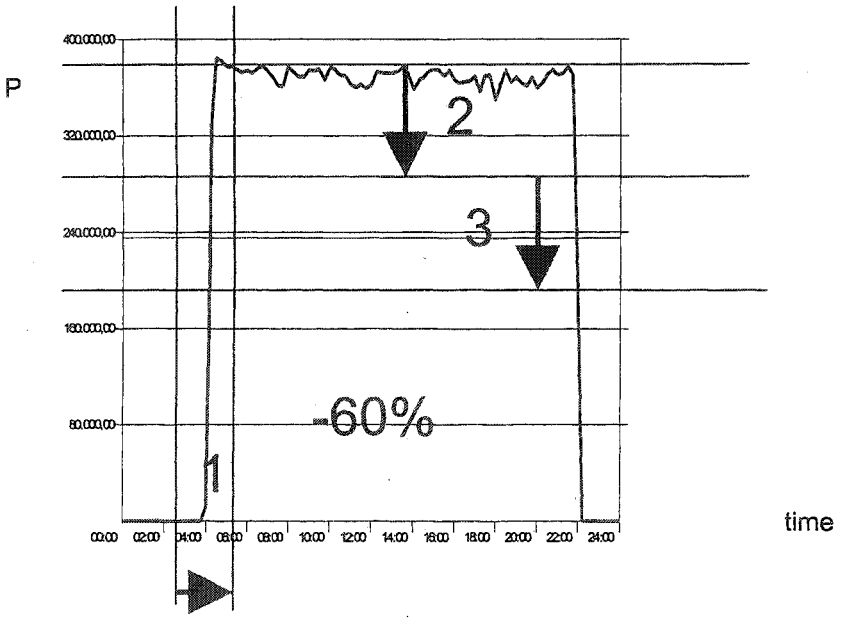

Figure 8. Load Curve of a Washing Machine and the Energy Saving Measures (1, 2, 3)

Conclusions

The above mentioned examples show very clearly how important detailed **multi-channel load analyses** can be for energy consultants to observe the real energy flows in companies. Using the described tool it is possible to observe the energy consumption and to present the energy situation in a clear way to the clients. Thus, possible advantages of measures can be demonstrated and the chance for measures getting realised can be increased, because of the efficient and impressive visualisation. Another advantage of the multi-channel load and process analysis is that consumers can see not only the energy consumption but can also get a additional information about their own process and energy efficiency. In that way the connection between power demand and production can be seen which leads to more consciousness about energy use related to their work. People also get trained to consider facts

about energy efficiency and will be enabled to see losses and abused energy by themselves. For the consumer, not only energy savings, but also energy cost savings are important. For that purpose this multi-channel load analysis is very useful and allows a company to detect possible approaches for the realisation of saving potentials.

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