Implementing Load Management in Manufacturing Companies: A Feasible Approach

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***Abstract*—In order to introduce load management in the manufacturing industry, some obstacles need to be pointed out. This paper presents a feasible approach on how to implement load management measures in companies. To do so, load management and energy management are explained and distinguished in a first step. Subsequently, the implementation method is introduced. Therefore, by using this paper, companies will be enabled to use load management measure and reduce their energy costs significantly.**

Keywords - Load management; Energy management; Energy Monitoring; Manufacturing industry; Renewable energies.

I. INTRODUCTION

In a continuously changing production environment, the ability to stay competitive depends for the majority of companies on the production price of a product [1]–[3]. The ability to produce a product at lower costs can lead to a significant market advantage. Therefore, the ideal adjustments of essential target values like occupancy, timelines, or process costs are crucial for a company's success [2]. However, the costs for resource, energy and production utility raised in the last decades dramatically [4].

In particular, the price for electrical energy in Germany has risen severely over recent years. This development refers to the increasing expansion of renewable energy [1]. Within the implementation of the priority access of renewable energy the prices for electrical energy raised [5]. This development refers to the fact, that the EEG-allocation (EEG: German Renewable Energy Sources Act, legislation to foster the use and invest in renewable energies) in Germany increases in the amount of expanding renewable energies [6]. As a result of the expansion of renewable energy the grid stability is endangered [7]. The priority access of volatile renewable energy leads to an unsecure supply reliability, which is one of the most important location factors for the German manufacturing industry [8].

Raising energy prices promotes a significant competitive disadvantage for the manufacturing industry shown in Figure 1 [5]. Moreover, growing scarcity of resources pushes energy prices [1]. Especially the scarcity of resources in the past increased environmental awareness in society and industry [2][9].

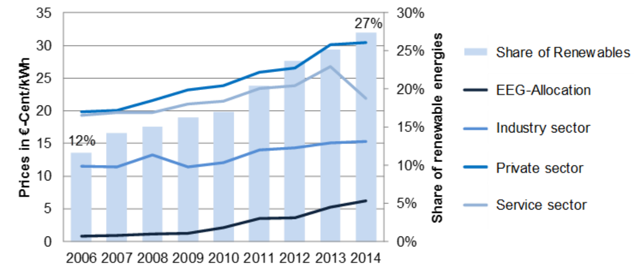

Figure 1. Development of energy prices [10]

In order to guarantee the grid security and create a greater environmental compatibility, Germany published a target to develop the most energy efficient and environmental friendliest economy in the world [11]. The focus of this program is the expansion of renewable energy. To compensate the incoming side effects like increasing energy prices flexibility mechanisms are even more relevant. The management of loads in the electrical grid can be realised by using flexibility potentials in manufacturing industry. The identification of those potentials is very important. Hence the survey of process-specific energy data in the manufacturing industry is necessary to point out any potential [12]–[14]. In this context, information gathering can be done by continuous energy monitoring of manufacturing companies [2]. Many companies are struggling to identify which information is necessary for load management and how the information can be collected. Consequently, there is a lack of a structured approach on how to create the information base to archive the energy transparency as a first step to load management. The presented approach focusses on the manufacturing industry, as literature research confirms, that this area has the greatest potential for load management. However, the concept can easily be adopted to other application areas (e.g. Office buildings).

In Section 2, this paper describes fundamentals of load management concepts. In Section 3 it then focusses on the implement of load management in the manufacturing industry. Considering, among other things, organisational requirements as well as the necessary transparency of the energy system, this paper develops a general approach to introduce load management in manufacturing companies.

II. Definitions and Fundamentals

Describing basic concepts and distinguishing several terms within the field of energy management, load management and energy efficiency is essential to get a common understanding of the presented work. In contrast to base loads that is covered by conventional power plants like lignite-fired power plants or nuclear power plants, the sustainable generation in renewable energy plants usually cannot be controlled. These circumstances lead to a discrepancy between feed-in time and amount of fed-in power of some renewable energy technologies like wind and solar systems [7][15][16]. To get deeper understanding of this, Figure 2 visualises a comparison of installed and given power of renewable energy technologies. The figure displays the discrepancy of installed and given power of renewable energy technologies in January, May and June. Biomass and hydropower are not volatile. Therefore, the loads are nearly constant or were reduced by demand management. The behaviors of Solar and Wind plants are quite different. The strong volatility of solar can be seen in the difference between January and May. Wind, on the other hand, covers 70% of the installed load in January, but drops the production close to zero in June.

German electricity transmission system operators compensate the incoming volatility by using control energy. Within this concept manageable power plants like gas turbine plants or pumped-storage power plants are usually used [17]. The control energy concept leads to dealing with peak loads or loss loads properly [18]. In Summary it can be said, that through expanding renewable energy in the electrical grids the supply reliability cannot be guaranteed. Dealing with the volatility of renewables refers to the priority access of those ones legitimated by EEG-allocation. Control energy uses load flexibilities to secure supply reliability. This is necessary to ensure the critical success factor like low energy prices for a society with a manufacturing industry as leading edge. However, energy prices are rising. Therefore, load management is one possible opportunity to compensate increasing energy prices.

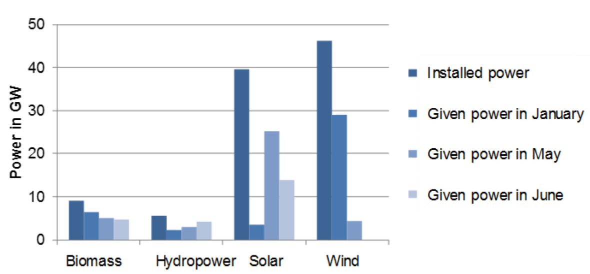

Figure 2. Renewable energy volatility [19]

A. Definition of Energy

Energy is a fundamental factor. Several types of energy can be transformed into each other, but neither be created nor exterminated [7][14][20]. Energy is used to heat buildings or to warm up process fluids to a high temperature (space or process heat). Besides that, energy is used to drive engines within machines or vehicles. In this context, energy is called mechanical energy or electrical energy.

B. Definition of Energy efficiency

The term “efficiency” follows its Latin origin “efficientia” which means efficacy [21]. Energy efficiency is the relation between benefit and initial energy input [22]. Energy efficiency also describes an intelligent usage of the initial input aiming to use the available energy as efficient as possible [13]. Following this definition, energy efficiency is increased by reducing energy consumption while (simultaneously) keeping the energy benefit constant [23].

C. Definition of energy management

The introduction of energy management in the manufacturing industry will have an impact on increasing sustainability, receiving environment and lowering energy costs [9][24]–[26]. Energy management is defined as an instrument of coordination aiming an ecological and economical satisfaction of energy requirements in companies. This goal is realized by a predictive, organised and systematic approach of energy production, procurement, storage, distribution and usage [27][28].

Energy management can be considered from two perspectives. There is a technical perspective dealing with energy monitoring, analysing the energy data and deriving plans of action to achieve defined goals. Furthermore, there is an organisational perspective which follows a holistic view of energy consumption and usage in processes, proceedings and procedures in the manufacturing industry [9]. To achieve goals, such as raising energy efficiency or reducing energy costs, energy management uses approaches like investing in new technologies, changing behaviours and identifying energy saving opportunities [29]. Referring to the identified approaches and goals of energy management, load management describes one aspect of energy management.

D. Definition of load management

First, load management must be distinguished from demand side management (DSM), since both terms are easily mixed up. Demand Side Management is a generic term for different approaches of systematically switching loads. It contains load management, energy saving approaches, fuel substitution and load optimisation [30]–[32]. Load management, however, describes the way to achieve the goal of changing the point of time and amount of load that is required [31]. Hence, load management describes the temporal relocation of energy consumption [12]. In addition to that definition load management is defined as switching loads on and off [13]. Therefore, load management focuses on internal processes, to reduce load peaks and thus reduce energy costs [33]. Examples of load management are described in the following chapter.

E. Measures of load management

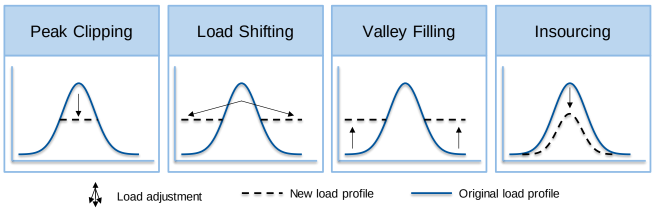

Figure 3. Load management measures

To avoid energy costs due to load peaks, load management focuses four different types of measures as shown in Figure 3 [30]–[32][34]. In the following, the different types are explained. “Peak Clipping” describes the immediate handling of peak loads. Thereby peak loads are reduced by a specific amount which reduces the energy costs significantly [30]–[32]. It is achieved by ejecting loads to prevent a significant peak load [35][36]. Using energy storage technologies are another opportunity to prevent peak loads by feeding-in energy at the point a peak load would occur [37].

“Load Shifting” also describes the immediate handling of peak loads. However, in this case, technologies are introduced to reduce peak loads. Energy storage technologies enable companies to temporary switch production processes. The change of organisational or production processes leads to a reduction of peak loads. Although energy is not saved, energy costs are significantly reduced. The energy consumption of several production procedures is not saved but switched to a point of time in there is no risk of peak load [30]–[32].

“Valley Filling” describes a load management measure, which lifts the base load of a company to cut the average electricity price. This measure accompanies with a change of energy contract of the energy supplier. Because the total energy consumption is increased, the load profile is polished. Any energy supplier prefers a polished load profile and will remunerate those profiles. Another use case is a loading of electric cars in the night. The raised load in off-peak times polishes the whole load profile.

The last measure of load management is named “Insourcing”. It describes the reduction of energy purchase. Unlike “peak clipping”, “insourcing” reduces the load profile holistically. There is no need for a specific peak load analysis. Companies reduce the energy purchase by producing a specific energy amount themselves. Achieving this goal, companies need new energy production technologies like cogeneration units or PV-plants in combination with an energy storage.

In order to summarise and classify these findings, the following Figure 4 explains in several layers how terms like energy and load management relate. The top layer represents the concept layer. As described earlier, operational energy management is the primary term. Energy management comprises several goals and measures.

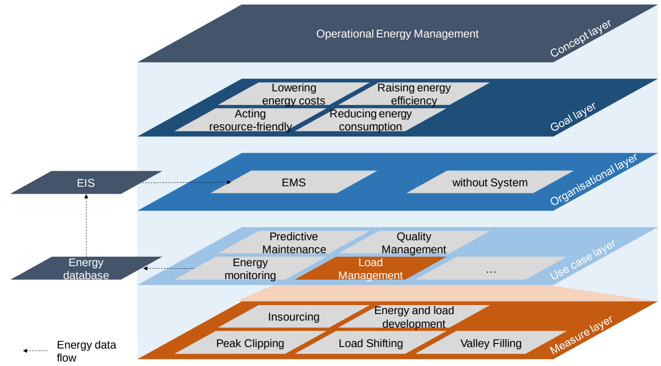

Figure 4. Content of operational energy management

Hereafter follows the goal layer. In this layer, all goals of energy management are summed up. It starts with lowering energy costs, raising energy efficiency, acting resource-friendly and finishes with reducing energy consumption. These goals which have their origin in the operational energy management, can be achieved be various actions. The organisational layer describes two typical types how energy management topics can be addressed. On the one hand, companies can implement a holistic energy management system (EMS) that is standardized by a German, European or international institutions. On the other hand, a not standardized solution to achieve the formulated goals can be realised without using such a system. In this case, the organisation of the individual solution falls in the responsibility of the company. For an appropriate usage of an energy management system, the information flow must be organised properly. Therefore, an energy database for continuous memorizing energy data would be crucial. Thus, the measured data is always ready for a delivery on demand. For a company, it is important to receive data and information to the exact right point of time, spot and quality. Therefore, the introduction of an energy information system (EIS) is necessary. The combination of an energy management system, energy information system and energy database is the best way to deliver information and data to the type of quality as further up explained. The use caser layer describes different applications within the energy management context. The focus of this paper is on the field of load management, but it is worth mentioning, that use cases like predictive maintenance, quality management and energy monitoring can also achieve energy management goals. All aspects have in common that they collect data which must be memorized for later using.

The last layer is the measure layer. This layer contains all load management approaches. In principle, all terms of the layer above have their own measures on the layer below. Hence, this figure represents one expression from a concept to certain measure in energy management context and load management application.

III. Implementation of Load Management in the Manufacturing Industry

Companies should be supported by the following approach to introduce load management. It should give answers to questions such as: how can load management implemented holistically? Where are the benefits?

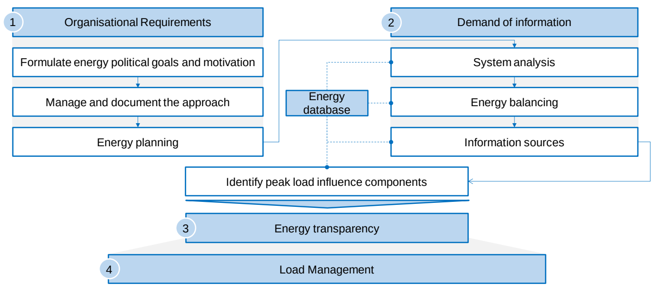

Figure 5. Load management introducing approach

The approach in Figure 5 contains four essential steps. First, companies must meet the organisational requirements. Second, companies must fulfil the demand of information. Third, when the demand of information is accomplished, the required energy generation/consumption transparency can be achieved. Fourth, once all required foundations are provided the load management can be introduced by implementing load management measures.

A. Organisational requirements

The reduction of energy consumption is a long term process. Therefore, it is recommended that the introduction of load management must be well organised and controlled. The organisational requirements are basically described by the DIN EN ISO 50001:2011. But not all requirements to introduce load management are addressed in this standard. First, it is important that companies create an energy policy. A policy in this context must contain energy long-term goals. Furthermore, it must contain a motivation that is communicated within the company, because the employees shall live and realise those policies. The policy must be formulated close to reality, comprehensible and goal-orientated. Moreover, a company must implement a process of documentation. Besides that, a company must develop an energy plan to summarise all goals, approaches and review processes. Within an energy plan, a company decides which energy data must be collected, how data can be collected, how does a data working process looks like and how a company would work with the information flows. Those steps are important to build a fundament for the introduction of load management.

B. Demand of information

Every measure within the context of load management works with real time data. Collecting those data is therefore a necessary requirement. To acquire the required information in a continuously changing environment, data must be collected in various dimensions of the company, e.g., company's location, buildings, rooms, production processes and energy sources. This kind of consideration is called system analysis. The objective is to create a holistic flow sheet of all forms of energy and its use locations. Assuming an overall system, to achieve a holistic flow sheet, it has to be broken down to its source elements.

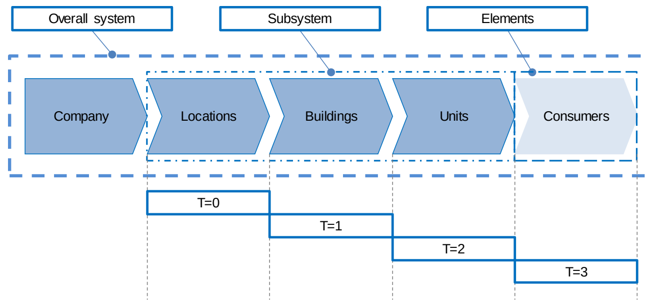

Figure 6. System analysis [22]

Figure 6 represents a typical construct of a company in the manufacturing industry. Dividing this construct in three types of system elements, it is shown that there are different degrees of depth. Starting with the overall system, which contains all given components, a company has its locations (T=0). The location level is the first layer. Diving in the subsystem, a location contains at least one building (T=1). The building level is the second layer. Each building contains at least one unit of its company for example production, supply, quality management or services (T=2). The unit level is the third layer. The deepest layer are the energy consumers (T=3). For example, there are machine tools, cooling energy generation or printers. The consumer level is the last layer. In order to achieve energy transparency in a company, a system analysis is fundamental. Close to a system analysis is the balancing. The goal of both concepts is to disperse the areal boundaries of energy consumers in a company for transparent visible consumer structure.

Once all energy consumers in a company have been identified, the next step would be to determine where they are located, what form of energy they are using and when they are consuming how much energy. Consequently, an energy monitoring system must be implemented to collect the real-time consumption data. The collected real-time data must be memorized in a database. But there are circumstances, for example financial barriers, which inhibit a company to implement an energy monitoring system. In this case, there are different options to collect data. Literature has shown that there are just few energy consumers in the manufacturing industry with high impact on peak loads. By comparing the main energy consumers and the main energy conserve potentials in the manufacturing industry, a measurement priority listing can be determined:

1. Compressed air generation
2. Energy generation for cooling purposes
3. Ventilation system
4. Machine tools
5. Electrical system
6. Pumps

Influences to peak loads due to illumination or information and communication technologies are usually neither significant nor manageable. The list above shows, which consumers in the manufacturing industry must be prioritised when collecting real-time data.

C. Energy transparency

Collecting real-time data is a fundamental component to achieve energy transparency in a company. Real-time data is required to implement an autonomous load management in the future. The needed data acquisition is a separate challenge, which is discussed in other publications. In addition, the issue of IT security must be considered. The acquired data is now used to identify specific components of the maximum load peak of a company's load profile. Figure 7 presents an activity diagram which contains an approach to identify specifics peak load components.

Deriving essential elements of the diagram, it is noted that load profiles of energy consumers and the main load profile of a company are required. Furthermore, the specific consumer load profiles must be inspected for load peaks to the point of time when the main peak load occurs. After this step, all specific loads are summarized and compared with the amount of the main peak load. If there is a difference (<<if(n)>>) it must be ensured, that the data set is complete as possible. If there is no difference (<<if(y)>>) a visualisation of the result should be created. The next question asked is whether the result is detailed enough or not. To answer this question, a company's layer must be determined. As explained before, a company has several layers. Load management requires information about the peak load components in sufficiently detailed depth. The ideal case would be at plant level (T=3). Including these last steps, energy transparency is guaranteed. The described steps enable companies to get a detailed view over their energy consumption and which kind of consumer has the highest impact on the total consumption. Another advantage of implementing the whole energy monitoring process is that the result can be used to identify energy wastage.

This procedure was validated at a company. The energy transparency was established and it was shown that the energy generation for cooling purposes had a peak load share of 20%. This transparency allowed counter-measures to be implemented.

IV. CONCLUSION AND OUTLOOK

Load management leads to lower energy costs in companies working in the manufacturing industry. This paper described the requirements that needs to be fulfilled to implement a load management. With the presented approach, companies are enabled to collect these data and information in a well-structured development. Starting with fundamentals like formulating a company's energy strategy and an energy plan. Furthermore, the company is advised to motivate their employees and document the whole introduction process.

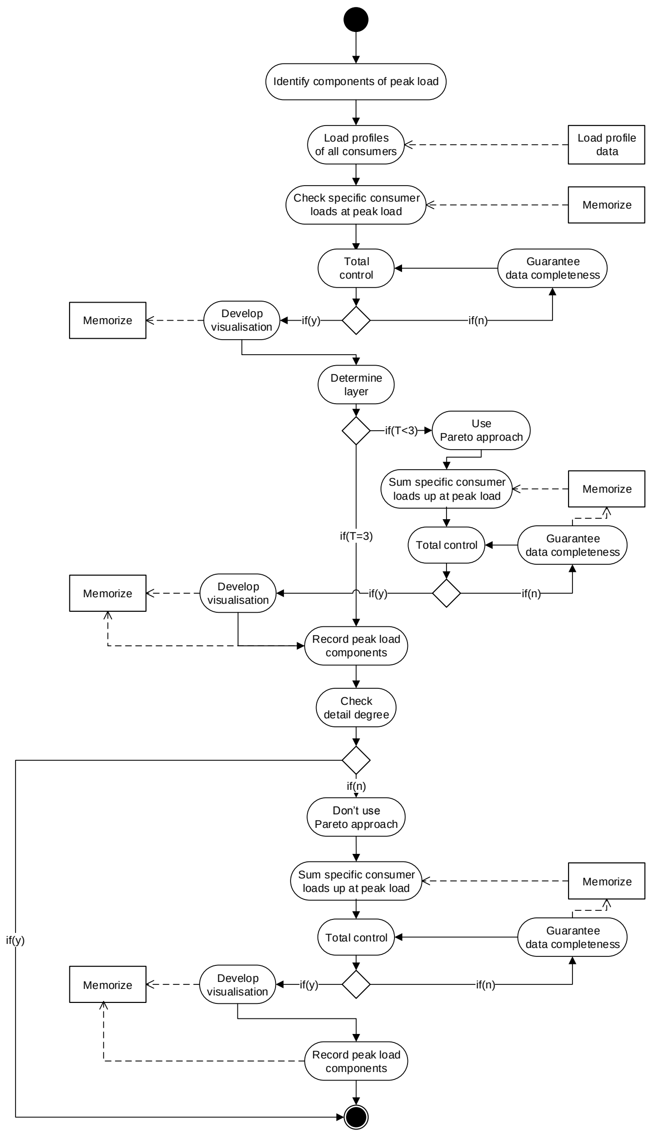

Figure 7. Identification of peak load components

Besides that, a company must start with a system analysis in order to create a transparent list of all energy consumers. Furthermore, a company must start with measurements in an early stage, to collect necessary data. Energy monitoring system assists companies in collecting important data and information regarding the energy consumption of machines, etc. Possible circumstances force companies to reject energy monitoring systems. In this case, the measurement of the energy consumption of prioritised consumers is recommended. This paper presented relevant consumers which have a high impact on the main peak load in the manufacturing industry. Using these fundamentals and the memorized data and information, energy transparency can be achieved by analysing collected and memorized data. Therefore, load profiles on all layers, such as buildings, units or consumers must be analysed following the presented approach. The result of this approach is detailed knowledge about every component of the main peak load. In the end, load management can be used to reduce energy cost in a company.

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