Methodology for energy efficiency on process level

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Abstract

Today, energy efficiency issues are becoming more and more important within organizations. Many problems arise when these organizations take the challenge of producing with fewer resources, like materials and energy. There is no general procedure to integrate these aspects in everyday organizational practices. The international standard ISO 50001 defines general requirements for the operational and organizational structure for companies but the standard gives no information about how to realize energy-efficient processes on productive or non-productive level. The energy consumption of processes is rarely known because of an insufficient existing infrastructure and missing measuring devices. Furthermore, often there is a lack of manpower and knowledge about new and innovative technologies. If any expertise exists, it is linked to individual positions and not systematically integrated in projects or structures for the improvement of production processes. The integration of know-how in energy performance such as energy efficiency, energy use and consumption in organizations needs a knowledge management system and a procedure for the consideration of energy aspects. The new approach is to link a systematic methodology for the identification of energy saving potential to the proposal of measures for their improvement. This approach requires a detailed analysis of the technical and structural facts in production processes. The outcomes of this analysis combined with a database of common measures are generating company-specific measures. The measures are going to be evaluated by defined criteria. The results will be provided for the different roles in an organization. Examples are user-specific checklists or processes for individual tasks. With this approach it is possible for organizations to recognize and to document their knowledge about energy efficiency and to build up a base for a continuous improvement process.

Keywords: energy-efficient processes; energy management; ISO 50001; continuous improvement; measure of energy consumption

1. Energy efficiency in industrial surroundings

Maybe one of the most difficult challenges of manufacturing companies is to ensure sustainable business development. One aspect of sustainable business development is a responsible usage of resources like energy. Measures to reduce energy consumption and emissions are top topics for German and European companies. Driven by customer requirements, nongovernmental organizations but also by legislature and increasing costs for energy, manufacturing companies feel more and more pressure to use less energy.

Energy management systems were identified to reach energy savings potential in the industrial sector. [1,4] The implementation of energy management systems will enable companies to identify their potential for energy savings and to reduce their energy consumption. [2]

Various studies estimate the energy saving potential from 25 to 30 percent in the industrial sector. [3] Nevertheless, until now there are still enterprises who have not implemented an energy management system or a continuous improvement of energy efficiency. [4] Several studies ascribe this to various barriers [5,6,7,8] and lacks between industrial needs and scientific literature. [9]

Additionally, the costs for the implementation of an energy management system, the process implementation, resource distribution for employees, measuring devices and additional ICT structures often discourage potential users. [5] But also the general and abstract description of energy management systems in the standard ISO 50001 leaves much room for interpretation. This often leads to disorientation and sometimes is the cause for the failure of the entire system.
To overcome these barriers and hurdles this paper will introduce a cost-effective and easy to handle approach to implement energy-efficient processes in enterprises.

1.1. ISO 50001

Energy management systems (EMS) are internationally standardized within the ISO 50001 and already in industrial use. The structure of the standard includes organizational aspects, systematical and technical aspects. The organizational aspects consist of the organization and the representatives and define the responsibilities and duties of the different roles. Systematical and technical aspects describe the conception, planning, realization and check-up as well as the adaption and adjustment of the management system. Furthermore, a continuous improvement is required. [10,11]

While the ISO 50001 gives only a framework and defines general requirements, the conversion and compliance is in the enterprise’s responsibility. [11,12] The experience shows that companies have difficulties in following steps:

• Assessment of initial situation due to the lack of data and information
• Missing focus on key energy consumer and deriving improvement measures
• Implementation of a continuous improvement process through a lack of employees’ interaction

In general, an energy management system should consist of: [1,10,11]

• energy policy with strategic and operational energy goals
• legal and the energetic initial position
• organizational structure, processes and the personnel responsibilities
• a system for training, documentation, communication and reporting
• a catalogue of methods for a continuous improvement process
• a planning system with defined planning processes.

These single components must be integrated with the plan-do-check-act-cycle (PDCA). [10,11] Figure 1 summarizes the components of this holistic approach.

Fig. 1 components of an energy management system, based on [11]

The requirements of the standard can be divided into organizational and technical aspects, and an organizational framework and a technical operative system could be deduced. The organizational framework is the basis for actions and defines the system adjustment, the organization, structures and processes. This is where the energy management system is located and acts as instrument for rough planning. The technical operative system is the system for actions, measures and realization. This system includes the observation object (product, process or facility). Here, the operating energy management system is located. Between the framework and the operating system a technical control system acts as interface where the detailed planning is carried out and the general / top level requirements are translated / broken down in specific operational goals for the observation object. [11,13] This correlation is summarized in figure 2.

Fig. 2 concept of an energy management system, based on [13]

1.2. Organizational framework

The organizational framework needs to be constructed as decentralized and self-reinforcing structure and has to have a clear concept. Therefore, a holistic system must be anchored at the top level
management. It is responsible for integrating energy efficiency aspects in the corporate policy and in the corporate culture. Integrating energy efficiency aspects in the corporate mission, vision and philosophy are measures for employees’ awareness and improves the outside publicity against the stakeholders. Also a very important duty is the definition of energy efficiency goals on corporate level. [10,13] Besides strategic thinking, monetary and non-monetary incentives for energy saving measures can motivate employees and should be created. [1,12]

There is a long organizational distance between the top management, where enterprise decisions are made, and the operative level, where measures are realized. To support and unburden the top level management a permanent representative is on the top of a hierarchic, linear energy management structure. This structure breaks down the responsibilities, targets, goals and resources top down until the operative level, advantageously down to the process level. And on the other hand, it serves as communication path where information such as reports, feedback or assessment is processed bottom-up. It is very important to create interdisciplinary energy efficiency teams on operative level to ensure that all aspects of energy efficiency are considered. The team members are representatives of their departments and are responsible for the exchange on this level. A plant or a division energy manager coordinates the teamwork and is responsible for the communication. [11,13]

1.3. Technical operative system

The technical operative system provides the prerequisite for the improvement of energy efficiency. Here, the observation objects like processes, devices and machines are located. Energy efficiency projects on the observation objects are performed within this system. [14] These projects follow a general procedure: Determining the actual situation – assess the actual situation – deriving improvement measures – implementation of important measures – determining the new actual situation – evaluate the new actual situation and so on. The data generation creates knowledge on energy consumption and allows a determination of process indicators. Then, the energy consumption is assessed and process-specific measures are identified and realized. Finally, the realized measures are evaluated regarding costs and savings.

Today, for the measurement of energy data several options are available from the manual measurement as a snapshot or a continuous log to fully automated measuring systems. There are approaches for the integration of energy data in manufacturing execution systems (MES) [9,21] and for the automatic monitoring of machine tools [22]. On the standardization level the development of data models and transfer protocols for the gathering and transfer of energy data in the automation industry is carried out [17,18]. Furthermore tools for the simulation of energy consumption in production processes are developed to predict the consumption of the system in different production conditions [19,20]. The measuring equipment, the sensor and actors and finally the equipment for transmission, communication and evaluation of data needs to be installed in new devices and machines. For existing devices and machines without any installations a retro-fit solution would be too costly and not realizable.

The essential prerequisite to support the action system is the generation of transparent, valid and process-based know-how on energy consumption [9].

1.4. Technical control system

The overlap between the organizational framework and the technical operative system is small and their specific work fields differ fundamentally. To implement an integrative solution for the cooperation a technical control system is necessary. This control system provides functions of a knowledge management system, acts as a collaborative work space and is a reporting tool. Together with the organizational framework a detailed planning of the energy efficiency goals is realized within the system. Furthermore, it provides the necessary information on energy efficiency on the needed aggregation levels.

The knowledge management includes technical components, like measurement instructions, a general and process specific catalogue of measures for energy efficiency, the definition of criteria for the observation object and learning from experience where project know-how is documented and integrated for following projects. For the realization of a collaborative work space an ICT-support is indispensable. [9] Regarding the requirements of this supporting system, the use of intra- or internet-based collaborative work systems is recommended. Ideally, the energy management supporting system can be integrated in existing corporate collaborative work space systems. [13]

2. Integration of action and control system

The prerequisite for an energy management system which enables a continuous improvement of energy efficiency is the implementation of the organizational framework. The organizational structure itself is inoperable without the implementation of a technical operative system in which the action system is located.
The interface between organization and technique is the technical control system. This interface allows for a continuous process improvement on technical level by providing required information and knowledge. Figure 3 relates a standard energy efficiency project to the necessary extensions in the technical control system. The goal of this approach is to create the technical baseline for a continuous improvement of energy efficiency on process level. The single components of figure 3 will be explained in the following subchapters.

2.1. Data generation and measuring instructions

In industrial environments the prerequisite for an automated gathering of process-based energy consumption is rarely found. Often, measuring devices are missing or they do not support an automated transmission of measuring data. Furthermore, no infrastructure for transferring the data is installed. For existing production equipment, the installation of the needed measuring devices would require a major investment effort. [4]

Still there are numerous enterprises that measure their energy consumption on plant level with one single electricity and gas meter. A simple recording of the energy consumption, however, is not sufficient. Rather, it is necessary to record the energy consumption of significant consumers together with those production and peripheral data which do affect energy consumption. This is one way to detect weak spots in the production process as well as energy wasters with high specific energy consumption. This can be achieved by the combination of continuously measured energy data (energy data acquisition) with the production planning and execution system.

To avoid major invest and to enable energy efficiency potential, a methodology for the manual As-Is process analysis is necessary. Therefore, process relevant energy consumers (electric, thermal, compressed air, water) need to be identified and described. By providing a detailed measurement instruction the repeatability and transparency of the gathered data is ensured. The instructions clarify for each consumer questions, like:
- Which data is used?
- Which measurement is necessary?
- With which measurement instrument, where and how it is to be done?
- In which operating conditions is to be measured? (Stand-By, starting, warming-up, …)
- Which calculation formula is used?

Moreover, in case of missing measuring possibilities and devices, formulas for the estimation or calculation of the energy consumption are documented in the instruction. For example, in case of thermic installations without a separate gas meter calculation, formulas for the estimation of the energy consumption by billing thermal losses are used.

2.2. Process-based indicators

The generation of energy consumption data on process level creates transparency and links the energy consumption to single consumers. By relating the energy consumption to production data specific process based indicators (e.g. kwh/piece or kwh/kg) are created. These indicators are suitable for a benchmarking. For the determination of the indicators a detailed documentation of the data used and the indicators calculation is necessary to ensure comparability and transparency.
Consequently, this calculation instruction allows an assessment of comparable processes within the enterprise regarding their energy consumption and the identification of best practices. [15]

For communication and decision making on different hierarchic levels the aggregation level of the indicators for energy consumption and energy efficiency needs to be adjusted. The organizational system uses key performance indicators on an aggregated level for goal definition, for decision making and evaluation of energy performance. These indicators are gathered on corporate, plant or product level in regular intervals monthly, quarterly or yearly. They are mostly easy to determine for example by relating the total energy consumption of a plant to the total number of produced products. For management proposes these indicators are sufficient to detect abnormalities or undesirable developments, but for the operational level these indicators have no real benefit. [9, 16]

2.3. Catalogue of process-based measures

The key success factor for energy efficiency improvement is knowledge about possible measures to reduce energy consumption on process level. It is often the case that this knowledge is missing, that it is just partly available or that it is linked to individuals in the enterprise. To create and document the knowledge on process level a catalogue of possible, general measures and their detailed description (costs, savings, amortization, potential savings, process and quality risks ...) is necessary. Ideally, this catalogue is a database solution which is integrated in the ICT-structure of the technical control system. By linking each general measure to recognition criteria on process level a possibility for their specific identification and selection is created. Furthermore, by identifying responsible departments and responsible roles in the enterprise the catalogue serves as central knowledge management system that realizes a role-based information distribution as a push system. On plant level departments which have a direct or indirect influence on energy efficiency aspects need to nominate a representative.

2.4. Process assessment

With the generation of energy consumption data and process specific indicators and with the implementation of the described knowledge management the baseline for process assessment is set. But still the challenge of identifying appropriate measures for the observation object is present. Therefore, a process-specific checklist that links the identification and selection criteria of the catalogue of process-based measures to the measured energy consumption and the process-based indicators is necessary. By adding measured or calculated values, energy indicators or answering closed questions in the checklist the observation object is assessed. Besides the energy consuming components, the process periphery, waste water, waste heat, resource aspects and questions for the purchase of new equipment are considered in the checklist. To be usable for different similar processes in an enterprise and to enable a continuous process improvement the checklist needs to be applicable independently from already realized energy efficiency measures. The checklist approach is user-friendly and a quick assessment of the observation object is possible. The outcome of the assessment is the generation of process-specific information that is matching the identification and selection criteria defined in the catalogue of general measures.

2.5. Process-specific measures

The information generated in the process assessment is logically linked with the identification and selection criteria of the catalogue of process-based measures. This logic database query is based on the checklist information and allows the identification of suitable measures for the observation object out of the general catalogue. For the example of a constantly working electric drive, the information gathered with the checklist could be the proportion of actual, measured power consumption to his nominal power, the year of construction and / or the efficiency class of the drive. The definition of reference values and efficiency curves in the catalogue together with the logic evaluation of the information enables a safe statement regarding an energy efficient exchange of the drive.

The linking of measures to departments and responsible roles is part of the catalogue. This definition of departments and responsible roles allows an automated transfer of the identified measure directly to the responsible role. Besides the detailed information on the identified measure, these representatives receive an invitation to the next energy efficiency team meeting. In this meeting the identified measures in total are aligned with the plants and corporate energy efficiency goals. According to the goals the measures are prioritized and selected. Finally, resources and schedules are fixed for the selected measures.

2.6. Post-project process assessment

After the realization of the selected measures its success and energetic effects are assessed by a new data generation and a new calculation of the process-based indicators. Due to this determination the progress and energy savings are transparently documented and best practices can be adapted. Furthermore, this assessment
creates the baseline for the next energy efficiency project and supports the continuous improvement on process level.

2.7. Integration of project know-how

The realization of energy efficiency measures creates actual know-how, e.g. energy savings, costs, payback time, duration, impacts on productivity or quality, barriers and problems. By documenting this knowledge and implementing it in the catalogue of measures a continuous improvement of the catalogue’s quality is reached while costs and time for similar measures are reduced due to existing experiences.

2.8. Discussion

Following this technical approach requires precise and in depth process knowledge. The generation of the checklist and the catalogue are process specific and enterprise-based. To develop and adapt the tools preferably a pilot project should be performed by energy efficiency experts together with an interdisciplinary project team. To justify those efforts and to maximize the benefit this method is suited for big enterprises that run similar or standardized processes in different plants. For SMEs the approach could be adapted, for example the role-based evaluation of the measures is not mandatory. Furthermore, the database structure and the automatic generation of measures could be discussed. Here, the process assessment will still be carried out with the checklist. The evaluation will not be based on logic linking but on the generation of criteria that will be assessed manually.

3. Conclusions

For the implementation of energy-efficient processes a combination of organizational and technical aspects is necessary. While for the organizational aspects the ISO 50001 standard provides a framework, for technical aspects, a cost-effective and easy to handle approach for the continuous improvement of energy efficiency does not exist. Therefore, a methodology for the technical support of energy efficiency together with the needed interface to the organizational structure was developed in order to enable enterprises to implement continuous energy efficiency processes for existing production equipment. The interface is a technical control system which provides measuring instructions, a catalogue of common measures on process level and the integration of energy efficiency knowledge created by the realization of projects. The realization as database allows for an automatic identification of specific measures for energy efficiency with a checklist on process level, a role-based evaluation of the measures and a continuous improvement of the processes’ energy efficiency.

References