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ADVANCED QUALITY APPROACH FOR ENERGY MANAGEMENT

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ABSTRACT

Quality, energy and environmental management are important success factors in the current competition. They are interrelated and cannot be considered in isolation but must be considered holistically and continually (on-line). This paper argues that quality improvement approaches can be applied in the energy management context. Companies need tools to achieve energy and environmental management goals by realizing energy efficiency targets and CO2 emission reductions. Such combinable tools available to support these actions are: regulations, quality management techniques, such as lean six sigma, benchmarking, FMEA Methodic, voluntary agreements, labeling and standardizations such as EN 16001 and ISO 50001. The new approach "Total Energy Management" covers all functions and areas of a company associated with energy purchase, consumption and management. It is argued that time proven techniques that have helped reduce quality costs and improve market share can also provide similar results when applied to energy management systems.

JEL CLASSIFICATION & KEYWORDS

■ L15 ■ O13 ■ O47 ■ QUALITY ■ ENERGY MANAGEMENT ■ EFFICIENCY TARGETS

INTRODUCTION

In industrialized societies, the effective energy supply and rational use of energy are primary conditions for economic development. Particularly since after the oil crisis of 1973, the world has been faced with the fact that energy raw materials are exhaustible and the amount of those kinds of raw materials is dwindling. In addition to the rapidly growing energy consumption, inconstant and mostly rising energy prices have been also a point of concern for the stakeholders. As a result of these facts, management of the energy has been subject of interest for all stakeholders since it is considered as a substantial way of improving energy intensity and lowering CO2 emission [1]. Energy Management (EM) is considered a combination of energy efficiency activities, techniques and management of related processes which result in lower energy cost, CO2 emission [2]. Managing energy consumption in a proper manner has been a substantial target for a sustainable development all over the world.

Linking of productive energy management to intelligent energy consumption

The experiences gained from various energy efficiency projects illustrate that not sustainable, one-time projects don't bring the desired outcomes after a period of time, if they are not monitored and adjusted in a continuous manner [3]. Therefore, these kinds of so-called stand-alone projects have been evolving to corporate energy management practices. Research by Caffal demonstrated that industries who adopt energy management practices may save up to 40% of their total energy consumption [4].

With the aim of securing the energy efficiency gained in the performed projects and offering the organizations basic tools and guidelines for proper energy management, various countries and regional organizations have introduced national or regional energy management standards.

Particularly, in the case of Energy Management, all parties are expecting concrete outputs rather than theoretical inferences. A key reason of thus poor result is that tools/techniques need to be placed in the continuous improvement management (CIM) context so that they are sustainable and also support the overall aims of the business. Within the context of energy management standardizations, such as EN 16001 and ISO 50001, there are two techniques defined: auditing and life cycle assessment (LCA). However, there are a growing number of tools and techniques, such as quality management techniques, that are outside the scope of the standards. For those in organizations tasked with implementing energy management, identifying appropriate tools and techniques and achieve the energy management goals can be a daunting task. Total Quality Management and Lean Six Sigma are only two recognized examples of continuous improvement management (CIM) systems [5]. Other management tools, such as ISO 9001, EN 16001, ISO 50001, benchmarking, FMEA Methodic, control and flow chart, voluntary agreements and labeling can also be applied in the context of energy management.

In this paper, we will strive to highlight the position of energy management in terms of TQM and propose a group of quality factors according to which the quality of Energy Management can be evaluated and improved. Furthermore, the paper is also aiming at identifying appropriate quality tools and techniques in the Energy Management.

Quality and total quality management in energy management

In the last decade, parallel with the advancing technology, quality, productivity and efficiency have become more of an issue for all parties, from governments, producers to the consumers. In the wake of global warming debates and volatile energy prices, there is no doubt that the efficient and ecological utilization of energy sources is one of the most daunting tasks for all.

Parallel to this, growing number of organizations witness the positive outputs and monetary rewards of enhanced energy management performance. They have come to recognize that improving efficiency in the utilization of energy, water and other energy sources ensure not only environmental improvements (reduced energy consumption and reduced waste and emissions), but also substantial financial savings as the costs of materials purchase and waste treatment decrease accordingly [6].

In the meantime, the Total Quality Management (TQM) has gained the recognition as an instrument for promoting corporate performance across all aspects of business,

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including environmental and energy management [7]. Today, many companies have come to recognize that TQM can be an effective way to continuously improve their environmental performance. Total quality management is the integration of all functions and processes within an organization in order to achieve a continuous improvement of the quality of goods and services [5]. Total quality management, next to the word quality, is probably one of the most frequently used catchphrases in the quality movement. It means thinking about quality in terms of all functions considering the interaction between the various elements of the organization [8]. Hence, the total effectiveness of the system is more than the sum of the single outputs from the subsystems, such as the life cycle of the product, design, planning, production, field service and distribution.

The TQM philosophy's extended concept of quality leads to the confrontation of all functions and areas of a company with the topic of quality management, thus making it relevant to energy management. In this respect, energetic operation analyses are conducted holistically, that is on all energy sources, from the acquisition, conversion, distribution and use to the disposal.

The view that an analysis should start not with the overall system but with the largest energy source is often held in operational practice. This approach does not correspond to the one suggested by total quality management, since significant saving potential often lies in areas with low energy consumption. Examples for such areas are consumers of energy which are not directly linked to production (e.g. space heating, room ventilation or compressed air). Thus the integration of quality management into operational energy management is defined as a further qualitative aspect. Cost-benefit-related view, process-related view, stakeholder -orientation and continuous improvement can be seen as further qualitative aspects, corresponding to the essential modules of total quality management, which are relevant within quality management as well as in energy management.

Quality considerations in energy management

Quality, energy and environment are important success factors in the current competition. They are interrelated and cannot be considered in isolation but must be considered holistically and continually (on-line). Therefore, all employees of a company, not only the specialist departments, have to be invariably responsible for the achievement of the quality, energy and environmental objectives of a company. QM promotes and demands the necessary inclusion and the delegation of direct responsibility to all employees appropriate to their respective levels. Therefore QM is an ideal management concept for the realization of the aforementioned new and crucial competitive advantages.

Product quality

The Federation of German Power Plants (Vereinigung Deutscher Elektrizitätswerke, VDEW) offers a specific definition of the term product in regard to electricity as "all electricity products and services which are offered to the client in connection with their supply of electricity [9]." A product can therefore be understood as a combination of provided goods and services fulfilling the needs of the customer. In this paper the product for the operational performance establishment is defined as the supply of electricity, gas and oil and is made up of a combination of goods and services. Particularly the issue of electricity quality is regarded as one of the crucial part of overall quality and uninterrupted production ability in the organizations since the poor electricity quality, electricity interruptions and inadequate electricity frequency result the difficulties such as production cut-off, raw material loss, equipment failure and increase in the production cost. According to the European Union, yearly cost of poor energy quality is about 10 Billion Euro to the European industry and by investing only 5 percent of this cost in the electricity infrastructure; many of the quality problems of the electricity can be overcome.

In the following chapter, as a kind of secondary energy resource, the electricity will be investigated in terms of quality considerations such as voltage quality and supply quality. Service quality aspect of energy management will be addressed in the coming chapter as well. In the final section, as a part of internal management system, energy management process will be evaluated.

Criteria for the quality of goods

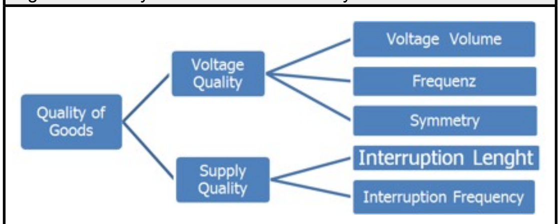
The quality criteria for the electrical energies supplied only concern the first quality level, the core product, and comprise voltage quality and supply reliability. Often these criteria are also described by the term 'technical quality'. The definition of voltage quality according to the standard CENELEC EN 50160 specifies the three essential quality criteria at the transfer point to the customer fulfilled under normal operating conditions [10]:

Voltage: At a voltage of 230-400 volt, the mains voltage at the transfer point can deviate from the mains voltage by up to 6% or resp. -10%.

Frequency: The nominal frequency is 50 Hz. Under normal operating conditions the frequency can deviate from the nominal value by +/- 1%.

The minimum quality defined by the standard CENELEC EN 50160 can first and foremost be seen as a guideline for the assessment of the quality of voltage. For measuring and/or assessing the voltage quality specified by the standard either attributive or variable measurands can be used, depending on the sensitivity of energy use [11]. For the exact assessment of voltage quality Bochanky defines the following parameters as follows: slow voltage variations, voltage drops, rapid voltage variations (flicker), curve form (harmonics) and symmetry of voltage [12].

Figure 1: Quality criteria for the electricity



Source: Author

Nowadays the demands of the customers to the voltage quality are very high. Thus already a slight deviation of the voltage form from the ideal sinus curve can cause problems. Particularly critical in this respect are the voltage drops which last only a fraction of a second and which mainly cause failures in continual, computer supported production processes.

Reliability of supply

The reliability of supply involves the length of supply interruptions (interruption duration) and the frequency of supply interruptions (interruption frequency). With the scaled evaluation method two quality criteria can be determined the interruption duration and the interruption frequency. If greater accuracy is required, defined measurands concerning duration and frequency of supply interruptions should be established.

Based on the two quality criteria for the reliability of supply, two key figures can be determined:

- The relativity of unavailability [min/year) resulting from the multiplication of interruption duration and interruption frequency,
- the amount of energy not supplied [kWh/year) serving as economic aid to decision making in the implementation of quality improvement measures. It is dependent on the relativity of unavailability and the power requirement in the area concerned.

Through this division into classes also the requirements of a company's internal customers regarding the reliability of supply can be easily determined. The meaning of those quality criteria is different for every customer. To give an example, in a weaving mill every supply interruption caused by new threading of the machines leads to production downtime. Thus the interruption frequency is the decisive quality criterion. In contrast to that the decisive criterion in a deep-freeze warehouse would be the interruption duration, since it would cause a rise in temperature. Examples for technical approaches towards the fulfillment of the customers' requirements by the energy suppliers are:

- Active filters (compensation of harmonics and flickers),
- uninterruptible power supplies (UPS systems compensating longer voltage breakdowns with little effort for the customer),
- emergency generators (compensation of longer voltage breakdowns) etc.

Through these measures, energy is no longer a non-differentiable commodity, but is developing into a product tailored to the customers' needs.

Service quality and criteria for service quality

The criteria for the quality of industrial energy services, which are part of every service within the energy management, are divided into the categories potential, process and result quality. For the assessment of the service quality of an energy supplier or for the determination of requirements concerning industrial energy services attributive measurands are used. Product-parallel energy services are in direct relation with the supply of electricity, while basic energy services mainly pertain to the informing, consulting and training of energy customers. All further services belong to the category of complex energy services.

Another example of a quality criterion in the illustration is the offer of new services such as control of the load curve for energy customers with multiple locations. In England, for example, an energy supplier has developed a program monitoring the power consumption in multiple locations. The load curves are recorded, load peaks are reported and locations with unusually high consumptions are informed immediately.

Process quality

The term quality so far was referring to the input quality or product quality of the supplied electric energy which at the same time constitutes the output quality of the external supplier. In accordance with TQM and the process-related definition of quality what follows now is the process-oriented observation of the production of goods and services within the energy management process model (figure 2). The achievement of the optimum process result from the customers' point of view is dependent on the efficiency and effectiveness of the process according to the figure. The process efficiency describes the accuracy of a process and the effectiveness describes the benefit created for the customer, also taking into account not value enhancing parts of the process.

Figure 2: Quality as a process parameter

Source: Osanna P.H, Durakbasa N.M, Sadat A.Afjehi: Quality in Industry, Vienna, 2004

Within the energy management process model, controlling of the process effectiveness falls within the responsibility of the management and is assessed by comparing the customer requirements with the customer satisfaction. In this paper the term process efficiency only pertains to the process of the production of goods and services.

Quality techniques in energy management

This section shows to what extent the chosen methods and techniques of quality management can be used in energy management and which adaptations are necessary. This section's aim is not to illustrate as many methods as possible, but to provide further information on methods which are already established in the field of quality planning and which are already widely accepted. The fields of application for the following quality techniques in energy management will be illustrated:

- Benchmarking,
- failure Mode and Effects Analysis (FMEA).

According to Engelke, techniques should be conceptually delimitated from instruments which are defined in more detail as tools, techniques and auxiliaries [13]. In contrast to this, Kamiske defines quality techniques as an umbrella term for the entirety of methods and tools applicable in the field of quality management [14]. For the rest of the paper a clear separation is not necessary so that the terms techniques and methods can be used synonymously.

Benchmarking

Benchmarking leads the way to becoming a best-practice-based company in the international competition and thus attaining world-class status. It is the aim of this concept to improve the own work based on a comparison and benchmarking of other leading companies of the same branch [15]. With regard to energy management, benchmarking provides a means to compare the energy use within one company or plant to that of other facilities producing similar products or to national or international best-practice energy use levels. Benchmarking can compare plants, processes or systems.

Benchmarking thus enables the assessment of the own performance in comparison to others, to learn from this comparison and achieve improvement. Therefore, benchmarking can be seen as a building block in a comprehensible total quality management.

Benchmarking in the energy management

Benchmarking energy management is more than simply gathering energy use and maintenance operations data from other organizations and comparing them with each other. As far as a benchmarking is considered, one of the most difficult tasks is the identification of similar organization. Once similar facilities have been identified, data on the operation of those organizations, including energy accounting and maintenance efficiency measures, will have to be collected. By studying the various performance measures, the areas where gaps in performance exist can be identified. For example, if two factories have been identified as being similar in operation, size and construction, the two facilities should have similar energy consumption data. If there are differences, the other facility will have to be closely examined to find the factors that lead to the difference in performance.

To give an example for company-related benchmarking; in the summer of 1999 the efficiency of energy use and the resulting product-specific cost on three locations of a foundry plant (in Austria, Germany and Hungary) with a total energy use of 132,7 GWh were analyzed[16]. The following requirements for the search of benchmarking partners were determined:

Products: The companies should produce the same or at least similar products (material, size, weight, vertical range of manufacture …).

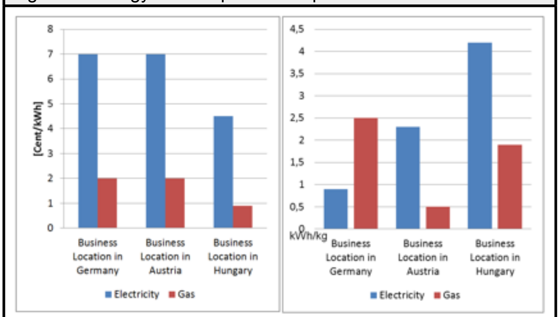
Production: The companies should use the same or similar manufacturing methods and technologies.

Output: The companies should have roughly the same dimensions (output).

The effective energy costs and the specific consumptions of electricity and gas are illustrated in the figure 3. The costs for electricity and gas show that the Hungarian location is by far below the level of the other two locations; the difference for electricity is minus 43 percent and for gas it is minus 60 percent. The specific energy use is lowest at the Austrian location due to high utilization. The Hungarian location has a high proportion of base-load consumers due to low utilization and oversized plants and thus has the highest specific energy use by far. It is remarkable that at the German location about two thirds of the overall energy use is covered by gas.

The advantage of low energy costs at the Hungarian location is offset by the high specific energy use. This shows quite clearly that an assessment only based on low energy purchasing costs is not enough.

Figure 3: Energy consumptions and prices of business locations



Source: Author

As can be seen in the figure 3, due to the different energy mix at the German location, the specific energy costs are substantially lower compared to the other locations. In this specific case, the benchmarking was taken as an occasion to reconfigure the energy mix at the Austrian location and to take steps toward a higher rate of the acquisition of gas. In summary, there are many benefits in the use of benchmarking in the context of Energy Management such as increasing energy efficiency, comparison of acquisition processes and supplier assessment and comparison with other companies for the development of best-practice towards TQM (EFQM model of excellence).

Failure mode and effects analysis

The failure mode and effects analysis (FMEA) is a formalized method for the systematic and complete detection of potential problems and risks as well as their effects before they occur. All occurring risks should be prophylactically studied, systematically analyzed and assessed in order to derive preventative measures. The aim of FMEA is the earliest possible detection of critical components or weak points. The later this detection occurs in the product development cycle, the higher the costs of remedial action. Correspondent to its objectives, a distinction is drawn between system, construction and process FMEA. Between the different forms of FMEA there is a methodical relation. System FMEA is a good base for construction FMEA from which in turn the process FMEA can be derived.

FMEA in the energy management

The fundamental aim of process FMEA in energy management is the identification and analysis of all possible failure causes. Sufficient supply of utility support is required to ensure the proper functioning of all facilities. Utility systems are complex networks in which the malfunction or failure of only one or a few crucial components is enough to disable the system or diminish its capacity. Such crucial components can be detected with risk analysis techniques.

Energy security incorporates the evaluation of utility systems and the taking of actions to decrease the effect of unscheduled failures diminishing the operational capacity of a system.[17] As known, system components in the plants can be damaged or disabled as a result of different causes, such as natural disaster, sabotage or disrupted energy network.

In order to minimize the possible losses associated with abovementioned casualties, FMEA methodology can be deemed as an effective way to understand the system, identify threats and provide appreciate solutions. With the help of systematic evaluation which gathers and organizes necessary information concerning failure modes of the system, FMEA team develops and introduces crucial methods which are expected to diminish the likelihood of failure and facilitate quick adjustment to normal operating conditions (see figure 4).

Figure 4: Data collection sheet for failure hazard analysis (FHA)

FAULT HAZARD ANALYSIS								
	FAILURE	FAILURE	% FAILURE	EFFECTS		UPSTREAM COMP.	FACTORS THAT CAUSE	
COMPONENT	PROBABILITY	MODE	BY MODE	CRITICAL	NON-CRITICAL	THAT INITIATES FAULT	SECONDARY FAILURES	COMMENTS

Source: Author

As far as mitigation of energy consumption in the company is concerned, FMEA Methodology can also be deemed as an effective way since it offers suitable tools to identify appreciate actions to eliminate analyzed potential failure modes and their effects on the workflows. FMEA has also substantial affects on diminishing the fuel consumption by implementing the suggested adjustments by FMEA.

Conclusion

Considering the fact that the production processes of goods and services have substantial affects on the quality of end product and in the same way on the customer satisfaction, quality and customer orientation are the main pillar of today's business world. Beside the product quality, the efficiency and quality of the processes are also of the significant importance for overall performance for the organizations. The Quality of energy sources and supply, as well as efficient utilization of energy sources represent an important factor in the production and product developing process. In this paper, we have studied that to what degree TQM and quality tools can improve the efficiency of Energy Management. Furthermore, it has aimed at introducing appropriate quality tools and techniques in the Energy Management. I has been identified that, implementing Energy Management standards such as ISO 50001 (recently introduced international Energy Management Standard) and EN 16001 would produce poor results in terms of energy efficiency and overall productivity of the business processes unless the organization sets out quality criteria, implements quality tools and aligns the Total Quality Management approach with the Energy Management applications.

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