Energy Monitoring System for Industries and Buildings

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1. INTRODUCTION

This paper discusses the development of the Energy Monitoring System (EMS) and problems associated with the implementation of EMS at industries and commercial/ administrative buildings. The system is a hierarchical computer-aided one with subsystems for commercial billing, monitoring, analysis and control of energy use. The subsystem for emissions monitoring can be included optionally. The EMS is of open structure and flexible: an initially installed system, *e.g.* electricity monitoring, can be supplemented with new systems for water, heat, or new metering devices can be added.

2. ENERGY EFFICIENCY AND MONITORING

At present, Lithuania faces an immense challenge in restructuring its economy to free market principles. Energy efficiency is a key issue during the transitional period, and estimations show that the energy saving potential is sufficient [1]. Various Demand Side Management (DSM) projects carried out in Lithuania so far have confirmed that there are some possibilities to improve energy efficiency in Lithuania. Short-term energy saving proposals, which are characterized by low investment cost, would allow to save 8–10% of energy with the payback period less than one year. The modern, energy-efficient equipment and the new processes connect the long-term energy saving recommendations with the replacement of the existing obsolete machinery. In this case the total energy savings could amount to 30–40% of the present consumption level. The possible areas of implementation are plants of construction materials, milk factories and light industry plants. However, the practical implementation of energy saving proposals is carried out with some delay. The main reason is the lack of financial resources and the inability to evaluate and see the benefits of saving measures in the near future. Therefore very attractive is the installation of a computerised energy monitoring and sub-metering system, which enables the personnel to monitor effectively and to target utilization of resources at all levels of plant processes or in various parts of commercial/ administrative buildings. The EMS developed at the Lithuanian Energy Institute is based on modern information technologies and provides management with information on the use of energy and associated production outputs at regular intervals against the pre-set targets.

3. STRUCTURE OF THE SYSTEM

Successful energy management programmes are sustained by two key factors – accountability and performance targets. These factors require a human-oriented system for energy management at industries or buildings. Such system should in effective way integrate the efforts of operators, machines and information [2, 3].

The best option is the development of an hierarchical Energy monitoring system (Fig. 1) with a number of subsystems for: *i*) commercial accounting, *ii*) monitoring and control of energy use. The EMS comprises a network of submeters, associated computer hardware and special software products – customised DSM programmes tailored to the needs of

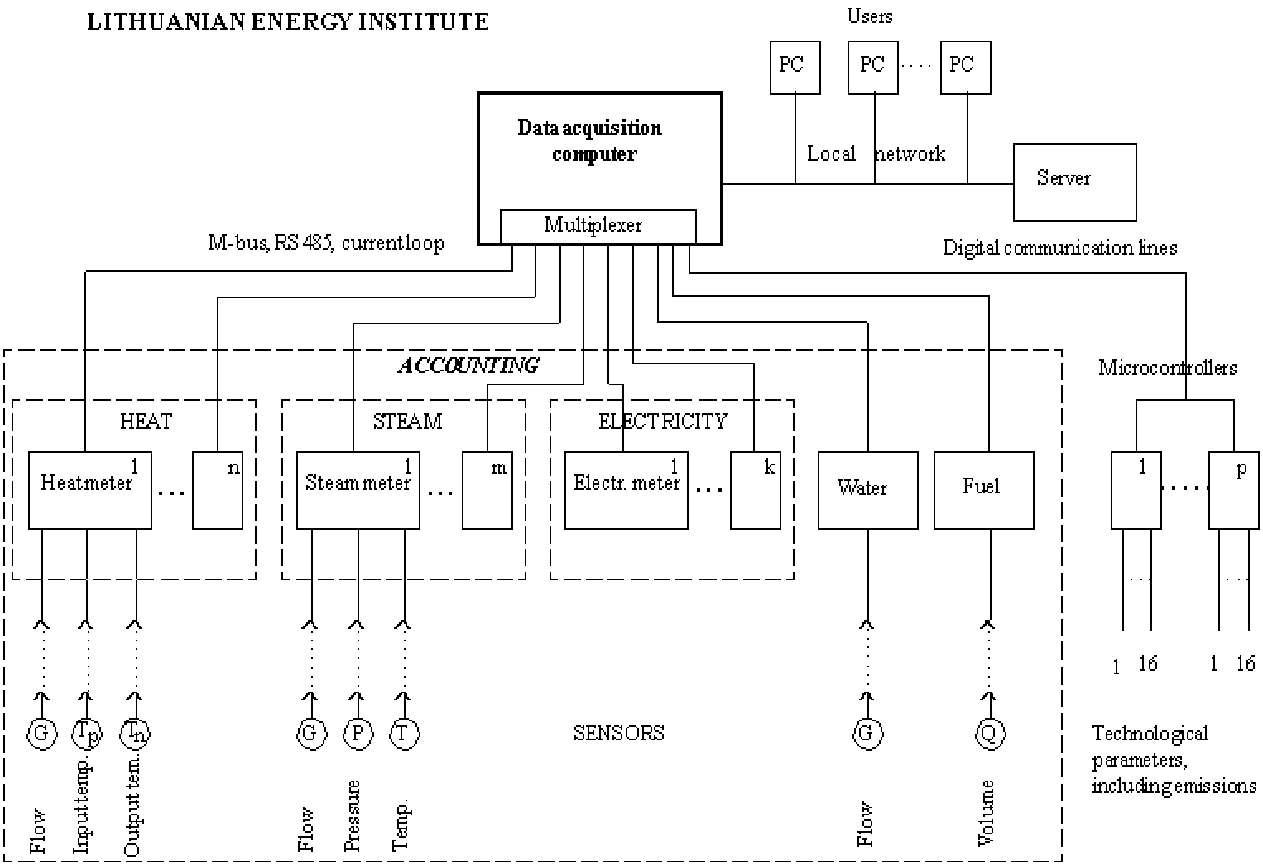

Fig. 1. Energy monitoring system

customer. The EMS allows energy (electricity, heat, fuel) usage to be attributed to separate shops or buildings of a plant.

There are three levels of hierarchy. Allocation of the subsystems to an appropriate level is based on response time criteria, *i.e.* the lowest level of hierarchy is characterised by the shortest time required for information request or data acquisition.

The first level of hierarchy includes the following subsystems:

• commercial accounting meters for all sorts of energy – electricity, heat, steam, fuel, water and emissions. The meters contain microprocessors, are very precise and reliable, they may be connected with data acquisition computers by the digital communication lines. Standard sensors for every kind of parameters – flow, temperature, pressure, etc. (dotted circles) are installed. The equipment of the commercial sub-system should be included in the State Register and approved for the commercial billing;

• optional computer-aided meters for monitoring the internal energy consumption in separate workshops, divisions of plant or by a selected technological equipment in building. The data from sensors via communication lines are transferred to the computer-aided metering devices, where measuring and primary processing are performed. Then the data are converted into digital codes, which via the digital commutators reach the multiplexer at regular intervals. The multiplexer is installed at the data acquisition computer. The digital communication lines do not increase the error rate of the metering;

• communication devices: *i*) interfaces RS 485, “current loop” or M-bus, *ii*) *Digi* multiplexer (USA), which enables to receive data from a big number of meters and microcontroller units. The above interfaces are characterised by galvanic disconnection. Therefore the digital communication cables connecting the data acquisition computer and the meters can be up to 1–3 km long. Computerised electricity meters (LZQM, LZKM type) are equipped with inside “current loop” interface.

At the second level the data acquisition computer at regular intervals performs: *i*) metering, data checking and processing, *ii*) calculation of control signals. The results via the local computer network are put in the server for storage and archiving. The customers can at any time retrieve data from the server and apply them for an analysis at their computers. Part of the data can be also retrieved via the modem and transferred to the higher level authorities. Both the acquisition computer and the server are active night and day. The subsystem of technology data acquisition and control consists of a number of multicontroller devices. They receive data from different sensors of technological parameters, transduce them into digital codes, and via the connectors and the multiplexer feed into the computer for final processing. The microcontroller and the data acquisition computers issue signals for the control of technological parameters. At this level, the emissions monitoring subsystem can be installed as well.

The third system level includes a set of customised energy analysis, management and control programs. Software for the suggested system is adapted to the specific architecture of a system, and with algorithms and outputs tailored for the plant's operation. The programs solve the main energy management tasks:

• *power demand* – detailed results about the total power value and its shares at submetering points are estimated at regular intervals; also the maximum and minimum loads are determined;

• *optimum shifting* of consumption – possible shifting to a less expensive tariff zone and reduction of peak loads are calculated. This program uses data of monthly energy consumption at all submetering points (measurement interval 30 min);

• *specific energy indices* – this program calculates energy intensities for various equipment groups of a factory or building. Results are displayed as tables and plots either on the monitor screen or as printed documents, and they are compared with target figures or previous results. At this level, human skill plays a key role for decision-making regarding possible changes of industrial processes or energy usage patterns.

Optionally EMS can include the environmental monitoring subsystem. The key element of this subsystem, a PENTOL gas analyzer, is used for measurement of CO, NO_x and H_2O vapour in flue gas. Measured emission data are transduced into digital codes, and via the communication lines (interface RS 485) and the *Digi* multiplexer are fed into the computer for final processing. Regularly an environmental review is carried out – comprehensive analysis of emissions, impact and performance related to the activities at a site and the environmental database is filled in as well. Such an environmental monitoring subsystem was installed in a combined heat and power plant. Figure 2 shows an example of emissions data at a CHP plant.

Results attained by the EMS can be used for identification and eventual implementation of energy saving and environmental measures. The EMS is of open structure and flexible: it is possible to the initially installed, *e.g.* electricity monitoring system later to join an EMS for heat, water, emissions, etc.

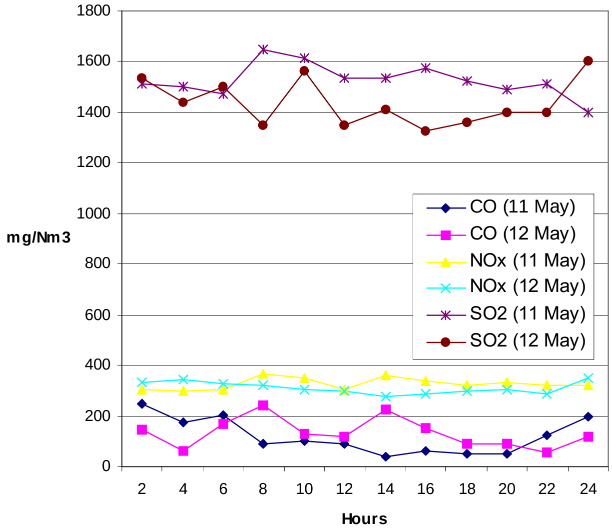

Fig. 2. Emission data

4. SYSTEM IMPLEMENTATION AT INDUSTRIES AND BUILDINGS

Practical experience in Lithuania. The EMS technology is a good tool for permanent energy auditing and for taking care of customers. In the last years we have already installed the EMS at 12 industrial plants and at a few administrative buildings. These systems have been successfully working for 3–5 years. Main benefits of EMS are associated with: *i*) energy management improvement due to better management of process line operations and reduction of energy consumption; *ii*) increased staff awareness about energy saving; *iii*) load profile monitoring. EMS is also very useful for follow-up of long-term energy saving investments.

Interesting results were achieved at three industrial plants in Kaunas, in which the EMS were installed and energy audits were carried out in 1995–96. In 1999 we evaluated the information about the 3-year experience. Our experience has shown that such systems increase the awareness of management and allow achieving sufficient energy savings. The system allows to save 7–15% of electricity (Fig. 3) with the payback period for this investment less than one year. Introduction of pre-set targets allows to increase operator's engagement into process control. Operator's competence and his willingness to improve the process quality are very important in striving for better results. The EMS has confirmed its usefulness and contributed to the process and product quality improvement.

A special promotion campaign was launched for the EMS implementation in the Lithuanian industrial sector. This activity was carried out in the framework of the FEMOPET network (according to the main contract between the FEMOPET – LEI

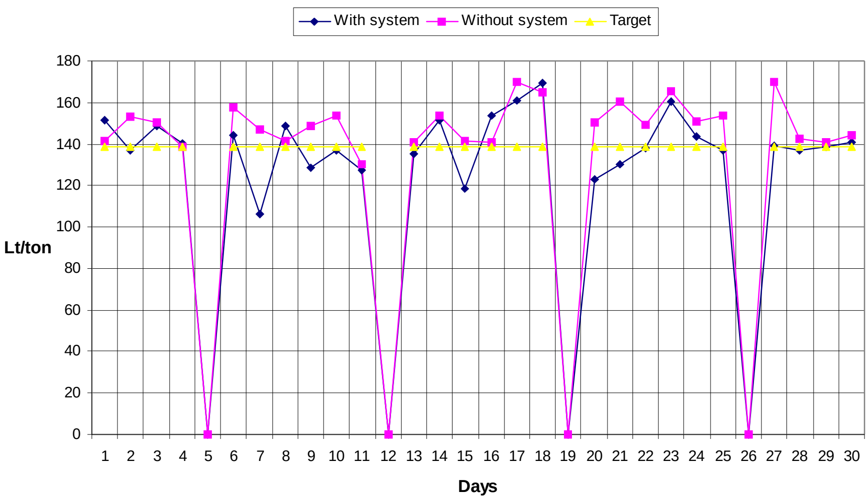

Fig. 3. Electricity expenses per production unit

Lithuania and the European Union). The main objective of this activity was to improve the market penetration of the new EMS technology and to foster the rational use of energy at the Lithuanian industries. We have used our recent experience in DSM activities and developing computerized EMS. After meetings and discussions with market actors, including two seminars and EMS demonstration sessions, a potential of energy saving resulting from EMS in industry was evaluated to 180 GWh/year. The first priority savings at 14 industries were estimated to about 20 GWh/year, investments needed – MECU 0.24. The meetings with market actors and end-users fostered interest for installation of EMS – about 14–16 industries expressed serious interest and later six new contracts were concluded with industries for system installation.

Practical experience in buildings. The EMS, however to a less extent was also implemented in buildings. Table 1 shows main data about EMS in a set of 4 administrative buildings (total area 14 000 m^2).

Initially the electricity subsystem was installed and next year the water subsystem was joined to it. Afterwards the heat metering system was included as well. The main benefits of the electricity subsystem were associated with change of load pattern and shifting of consumption to less expensive tariff zones. The payback of the electricity subsystem was calculated including expenses for personal computer and software development. Results also show the benefits of the water and heat subsystem implementation – payback periods are rather short.

5. CONCLUSION

The new energy monitoring system developed in Lithuania has confirmed its usefulness and contributed to the industrial process and product quality improvement. The EMS influences the consumer's behaviour in terms of electricity, heat and other kinds of energy, including the environmental concerns. The EMS technology is a good tool for the permanent energy auditing and for taking care of customers. The EMS promotes the economical operation of

Table 1. **EMS in buildings**

	Project cost	Annual energy consumption	Annual energy savings	Money savings	Payback
	USD	kWh/yr	kWh/yr	USD/yr	yr
Electricity Subsystem (1997)					
6 meters ELGAMA - LZQM	3600	640000	13500	12200	0.93
Water Subsystem (1998)					
3 meters DS 02	2100	6800 m^3/yr	940 m^3/yr	1040	2.02
Heat Subsystem (1999)					
5 meters Multical, Clorius	3750	1800000	400000	11000	1.36
SUBTOTAL					
PC & Software	**9450**				
1. Personal computer & printer	1200				
2. Multiplexer	1000				
3. Communication lines	750				
4. Software development	2750				
5. System design and installation	2000				
TOTAL	**17150**			**13240**	**1.3**

energy facilities and allows to identify the possibilities for energy saving. Operator's competence and his willingness to improve the process quality are very important in striving for better results. Introduction of pre-set targets allows to increase operator's engagement into plant operation and energy consumption control. The suggested system is flexible and allows gradual expansion including additional processes, facilities or other kinds of energy.

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ENERGIJOS PRAMONĖJE IR PASTATUOSE MONITORINGO SISTEMA

S a n t r a u k a

Straipsnyje nagrinėjami energijos monitoringo sistemų sukūrimo ir įdiegimo klausimai. Nustatyta, kad optimali struktūra turi būti trijų lygių hierarchinė sistema, kurią sudaro kompiuterizuotos įvairių rūšių energijos apskaitos, tyrimo, analizės ir valdymo posistemės. Esant reikalui, galima prijungti ir emisijų monitoringo posistemę.

Išnagrinėti atskiruose lygiuose sprendžiami energijos apskaitos ir monitoringo, vidinės vartojimo analizės bei technologinių procesų valdymo uždaviniai. Aprašyta sistemos įdiegimo pramonės įmonėse ir administraciniuose pastatuose patirtis. Sistemos struktūra yra lanksti ir atvira: ją galima pradėti kurti, pvz., nuo elektros posistemės, o vėliau prijungti papildomus matuoklius ar naujas šilumos, vandens apskaitos ir monitoringo posistemes.

Raktažodžiai: energija, monitoringo sistema, vartojimas, valdymas

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СИСТЕМА ДЛЯ МОНИТОРИНГА ЭНЕРГИИ В ПРОМЫШЛЕННОСТИ И ЗДАНИЯХ

Р е з ю м е

В статье рассматриваются проблемы создания и внедрения систем для мониторинга энергии. Установлено, что оптимальной структурой является иерархическая система трех уровней, в которую входят компьютеризированные подсистемы для учета, мониторинга, анализа и управления. При необходимости можно подключить и подсистему для мониторинга эмиссий.

Рассмотрены задачи учета и мониторинга энергии, анализа внутреннего потребления и управления технологическими процессами, решаемые на различных иерархических уровнях. Описан опыт внедрения систем на промышленных предприятиях и в административных зданиях. Система имеет гибкую и открытую структуру: ее создание можно начинать, например, с подсистемы для электроэнергии, а затем подключить дополнительные счетчики или новые подсистемы для учета и мониторинга тепла и воды.

Ключевые слова: энергия, система для мониторинга, потребление, управление