SIMULATION OF VARIATION THE POWER LOAD OF INDUSTRIAL PLANT FOR CHOICE AN ECONOMY RATES OF ENERGY

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ABSTRACT

Multi-tariff billing of the consumed energy is one of the most important advantages that give using modern technologies for measuring the electricity. Thoroughly analysis of the tariff rates enables to chose the optimal one for the given technology process. The proposed method of choosing the tariff is based upon the simulator of costs for the consumed power and energy. Tariff's plan is analyzed for the given power demand and calculated costs that are compared to find the minimal one. Due to additional costs, resulting from time depended factors of tariff, the flattening of the dynamic range of consumed power is necessary. That procedure meets also the constraints of power system, defined by DSM (Demand Side Management) policy that are usually included in the tariff plan. The costs of existing plants are calculated upon the base of data exported from electricity measuring device – using SCADA system or data logger. For the designed plants the power load is simulated using the schedule of technology operation, stated for the given process, and planned volume of production in the given time period. The proposed solution method is applicable in industry for any enterprise as well as for existing and designed installations. The developed simulator may be used in the MRP and ERP systems as a module (procedure) for assessing the costs of planned production. The simulator is running in the interactive mode.

INTRODUCTION

Different forms of the energy are demand by the industrial process and home installation, but the majority of the users consume the electric power and energy. Automated production lines are usual supplied with electric power, pressured air, hydraulic engines, warm water and technological steam. Only the first form of energy - electricity - may be treated as the primary energy, supplying the installations of pressured air and hydraulics. Therefore the calculation of the electric power level is involved due to interactions and load curve that is not flat. The operations schedule of the technological process effect the variation of electric load demanded for given products. Assessment of the peak load for given technology is necessary and also very convenient during the processes of conception and designing the electric installation. If the schedule of technology operation is known it is possible to assess the variation of electric load and therefore it enables choosing the energy rates, the most economical one in the given circumstances.

The structure of the electric energy rates takes into account the requirements of the power system stability and economy of generation (Baltierra et al. 1998). It is quite natural that some deviations of load and generated power in power system, in the same moment, are in the opposite phase. The restrictions stated to omit that kind of phenomena given by power system operator and energy delivers (Meister 1992, Sroczan 1994) are very strong. In the rates structure they are defined as additional cost of demanded and consumed power, that are charging the final consumer of energy.

VARIATION OF ELECTRIC POWER LOAD

The modern electricity meters incorporates multitariff functions are giving the possibility of tariff control. The main features of electricity meters enable to cover present and future tariff requirements. The electric companies provide the opportunity of billing the consumed power and

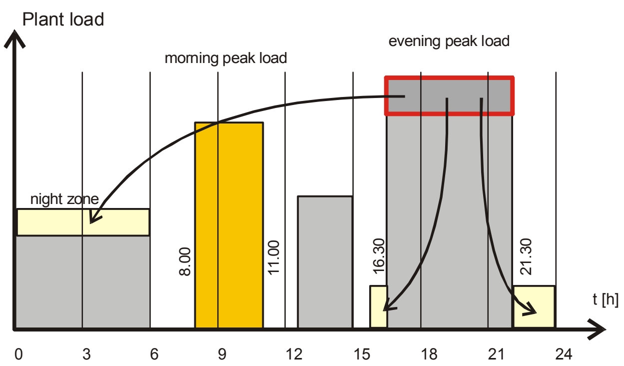

Fig. 1. The modelling a dynamic of variation the consumed power for a given technology process

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energy in more than two energy rates (day and night) and seasonal tariff switching. Energy providers as well as producers can effect the level of the power demanded by the consumers, realized as DSM - demand side management.

One of the methods of reducing the power load in the power system peak zone is shown in the fig.1. Technological process is rescheduled to omit the tariff zone in which the energy is more expensive. As result the cost of demanded power is reduced.

Variations of the load curve effect the cost of consumed energy depending on peak load value and rates of power and energy.

A proper operation of load, done by the energy manager supervising the industry plant, depends on technology cycle and flexibility of supply circuits. The energy manager of industry plant should take into account:

- the specific demand of electric power for the given technology of supplied process;
- minimization of the dynamic range of demanded power – as low as reasonable acceptable,
- respecting the EMS policy.

The main tasks that should be considered by the manager of power system (electric company) are following:

- dispatching of electric power and energy should preserve stability and safety of the power system as well as minimization of costs for each step of the generation and transmission of delivered energy,
- balancing the power (energy) delivery and demand in power system in each moment of considered time period in accordance with DSM policy.

The goals of both managers – power system as deliver and industry plant as consumer – are in opposite. Therefore it is necessary to find a compromise solution based upon the tariff rates as well as DSM and EMS correlation.

SIMULATION OF THE COST OF THE CONSUMED POWER AND ENERGY

The tariff rates are usually defined for the given: range of time for day and night zones depending on annual seasons, the rated voltage, allocation of the supply point and the maximum level of the power load and consumed energy. Additionally, power failures and supply reliability are resulting in the increase of the cost of demanded energy. Modern electricity meters (Landis&Gyr) provide the option of ripple control receiver (RCR) to remote tariff change over facility and remote operating the customer loads. Moreover the electricity meters are counting the total forward and reverse running energy as well as for 2 or 4 tariff planes. The load can be switched by predetermined time sequence too. The manager of energy and designer of electric circuits should take into account the possible states of load according to proposed tariff rates. A proposed structure of the simulator of the load curve, should enable: tuning to the considered technology, analysis of technical and economical aspects of different processes effecting the electric power and energy cost. The comparison of tariff's plane for given power load should be possible too.

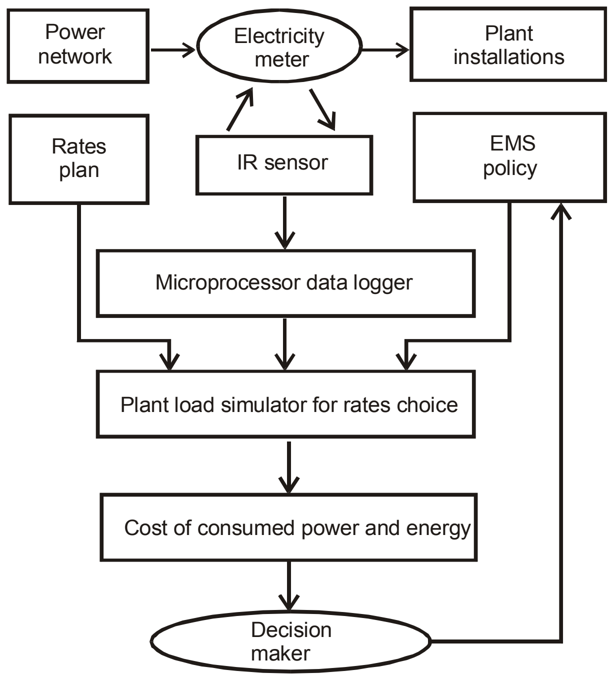

Fig. 2. The structure of the simulator of consumed energy costs.

In the fig. 2 there is shown the structure of costs simulator. That simulator consists of three main modules: a simulator of the power load, a simulator of the cost of the consumed energy and data files. The set of the data includes: tariff plane for given group of energy consumers, the load variation curve of discussed plant (process) and rules of EMS policy.

In the case of investigating the existing plant, the real power load curve is imported from electricity meter using the IR adapter and microprocessor data logger.

The main aim of analysis the load curve variation is following: chose the best energy rates with respect to technology requirements and restrictions caused by energy deliver. The load curve should be flat. For given technology process the load curve is simulated with respect to the following assumptions and data:

- rated power is defined for each operation by a set of electric drivers, heaters, lamps, pumps etc,
- the beginning and duration time of each operation is fixed for all operations by technology staff,
- some operation are involved in interactions and could not be separated,
- some operations could be replaced in the schedule with regard to predefined time sequence,
- daily switching schedule is defined and respected for all class of energy devices,
- minimum and maximum possible time of shut down for all sets of aggregates is defined,
- daily switching schedule take into account the daily load zones,
- the basic load curve is simulated for 24 hour period,
- a week variation of load is taken into account by overlap the basic load curve with a mask of specific week days,

- all of rates coefficients are defined,
- the simulated load curve is calculated upon the base of technology schedule,
- simulated cost is calculated upon the base of power and energy consumed during the month.

The modular structure of the proposed simulator enables a very convenient modification of the data – stored in files, and algorithms of scheduling the technology process.

SIMULATION OF THE POWER LOAD FOR THE GIVEN PROCESS

The proposed algorithm of simulation enables the developing of the power load curve upon the base of description of the schedule of the technological process. The time schedule of power demand is shown in the fig. 3. The first version of power demand varying is obtained upon the requirements stated by technologist. Some modifications of that schedule are applied to minimize the peak power load in the given zones of the time. The method of smoothing the load curve by rescheduling the process or by operating the possibility of shut down the set of energy devices is shown in the fig. 3. The line match the time of operation the group of energy devices.

In the developed simulator the set of energy consumer is represented by 12 groups of rated power. The value of that power is fixed in the initial data file. The entity of data describing the power load is represented by:

$$r(k,t) = \left[k, t_{on,k,t}, \Delta t_{k,t}\right] \tag{1}$$

where: k - group number, $t_{on,k,t}$ - the moment of turn on the group, $\Delta tk,t$ - range of the operation time.

The set of $r(t)$, written in the random mode, is stored in the file and used by a module of simulator that combines all entities to value of demanded power load:

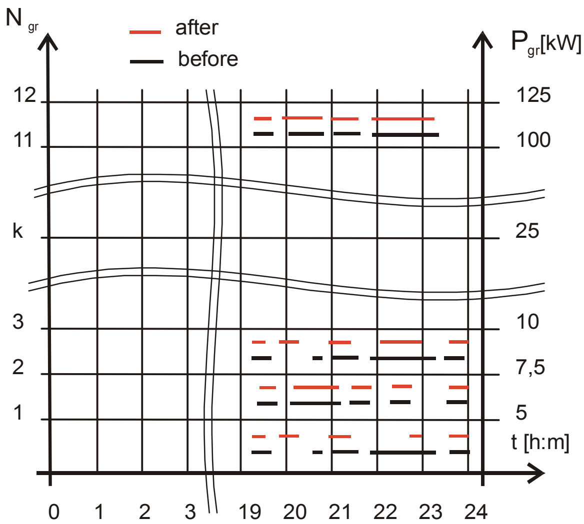

Fig. 3. The base (before optimization) and the modified (after optimization) schedule of demanded power load curve.

$$\{P_t\} = \sum_{k=1}^{N} a(t)P(k) \tag{2}$$

where: $a(t)$ = <0, 1>.

The value of P_t is calculated with time step τ.

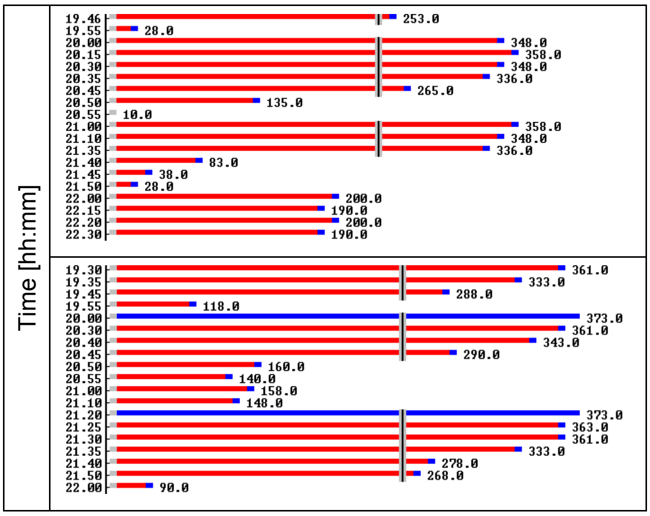

Fig. 4. The load power variation before and after the peak flattening process.

The value of $a(t)$=1 if the power load is occurring in the t moment of time, otherwise $a(t)$=0. Typical processes can be defined by one cycle multiplied for the considered range of the time, more involved should be described for one day or a week. The example time schedule (fig.3.) is build for one, typical day.

In the next step of data processing some procedures converts the typical section into load curve for the week or month, depending on time of the billing accounts from delivery of energy. The results of converting the time schedule to load curve are shown in the fig. 4.

A similar kind of the curve is obtained from electricity meter by using the data stored in the data logger.

The mode of data representation enables the possibility of rescheduling and decreasing the value of peak load demand.

Analysis of load variation, modified by simulator procedure is checked and operated in the following manner:

$$P_{dt} \le P_{Mr} \Rightarrow expected\ \ state$$

$$P_{dt} \ge P_{Mr} \ \ \Rightarrow \begin{cases} 0 \le t_{ol} \le t_{co} \Rightarrow accepted\ \ state \\ t_p > t_{co} \Rightarrow turn\ \ off\ \ the\ \ load\ \ for\ \Delta t_{off} \end{cases} \tag{3}$$

$$t_{off} \ge \Delta t_{off} \Rightarrow turn\ \ on\ \ the\ \ load$$

where: P_{dt} – current load, P_{Mr} – maximal accepted load, t_{off} – duration of shut down time , Δt_{off} – defined maximum time range of turn off the load, t_{ol} – time of peak over load, t_{co} – an accepted time period of overloading.

The process of simulation is realized in an interactive mode. The result obtained for each chosen variant of the analyzed rates are compared with regard to the essential coefficients effecting the cost of consumed energy. Parameters describing the character of simulated process and all factors of rates could be changed to meet the requirements of the stated problem or for purposes of tariff data modification.

RESULTS OF SIMULATION

The impact of manager's decision on consumed energy cost is defined for two different tariff rates: A and B. It was assumed that the demanded energy is varied in the same manner, but due to calculation procedures some differences may occur.

The calculated values of the costs are illustrating the expected benefits as the result of changing the tariff rates.

Simulation proceeds in two steps in the man-in-the-loop mode.

In the first step of simulation the schedule load program is converted to proper class of power and energy and time zone, defined in the tariff plane. This processing runs for all considered tariffs described in the initial file The form chart to input the data of tariff rates is shown in the fig. 5.

Table 1: Power load and energy demand calculated for the given tariff rates

Power and energy	Tariff plan	
	A	B
Power [kW]		
Day and night maximal power load	415	411
Account power	411	411
Energy [kWh]		
Day and night energy	162770	–
Peak zone energy	–	54024
Day energy	–	71499
Night energy	–	37247

All factors of the given tariff are calculated in the second step of simulation with respect to previously obtained values of the power load.

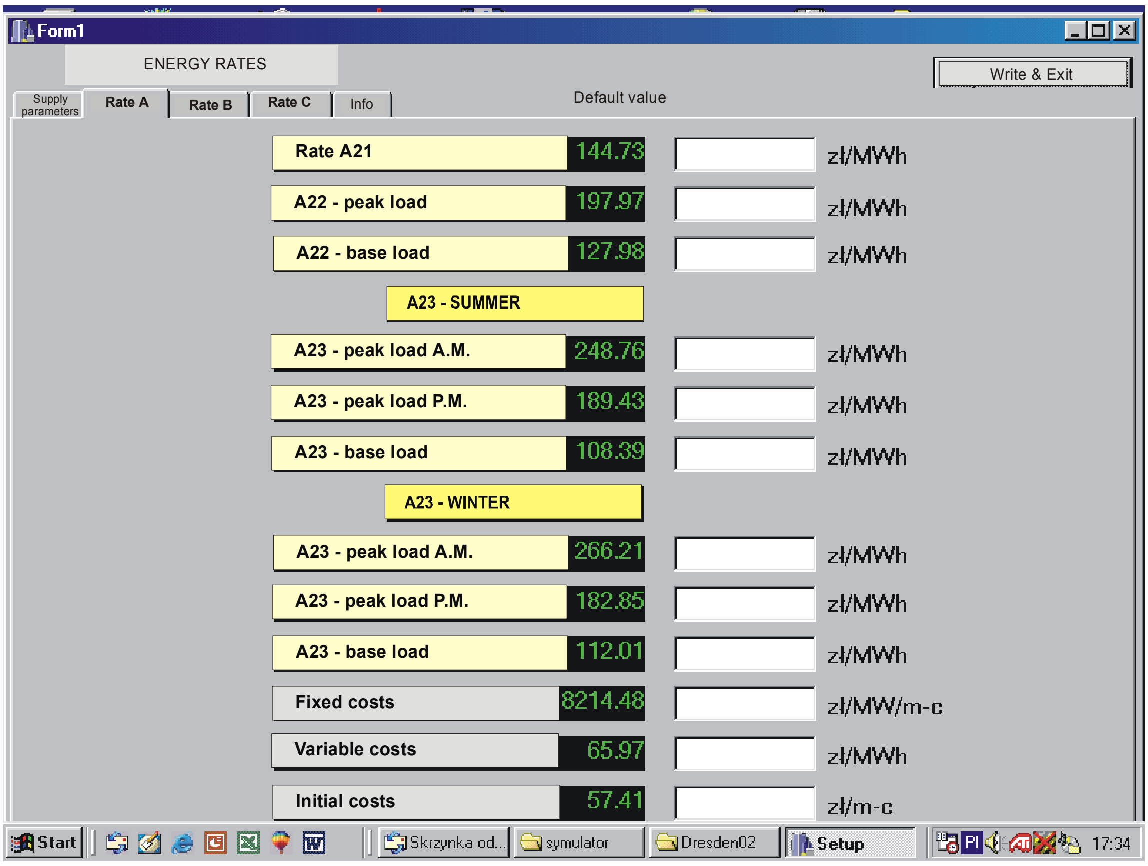

Fig. 5. The application form developed for input the coefficients data for the tariff A.

Table 2: Costs of consumed energy for the given tariff rates.

Cost factor [zł]	Tariff plan	
	A	B
Maximal power load	867	859
Account power load	2347	2347
Day and night energy	14652	–
Peak zone energy	–	6483
Day energy]	–	5005
Night energy	–	1864
Total power	3214	3206
Total energy	14652	13352
Total cost of power and energy	17866	16558
Different of the cost	-1308	

The results of simulation for assumed values of power load demand and different value of tariff rates structure and coefficients are shown in the tab.2.

CONCLUSIONS

Energy management system controls and operates the power and energy in the industry plants and buildings to meet the requirements of the energy preservation. The first step to analyze the demand of the electric energy can be realized by using a simulator of the power load variation for designed or modernized objects.

A structure of the developed simulator is based upon the modular procedures and data taken from existing SCADA system installed in a similar technology line.

Adjustment to the load curve for the given process is realized in the interactive mode with respect of the technology constraints and demand side management realized by tariff structure.

The developed simulator is feasible to apply to assess the change the tariff's policy between delivery company and industry customer groups.

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