INFORMATION SUBSYSTEM FOR ENERGY EFFICIENCY MONITORING

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INTRODUCTION

Development of science and technology during the last years, it became evident that energy consumption and production are enlarged. Irrationality in energetic system and inefficient production, transportation and usage of energy are so large and obvious that enlarging of total amount of total energetic efficiency is the quickest and the best way not only for increasing available non-restorable energy and cutting down the losses in industry, but also for reduction of energetic dependence. In this study the focus was on dealing with problem of energetic efficiency observing the primary criteria that is, production of electric energy, heating energy and technological steam.
This study presents solution realization for the energy efficiency monitoring of distributed technological processes and integration with company’s business information system, which gives support to postoperative analysis, to operative and strategic decision-making and it has internet web access over three-leveled authorization. This information subsystem relies on data and calculation which gets from: technical and technological data base (BTP), mathematics model of technological process (MMTP), dislocated SCADA information subsystems, planned documents of system - technological process, centralized financial and material accountancy of the system. Integrating these subsystems, daily energetic and economical indicators of energy efficiency in company’s business are generating and by that have retroactive influence on production process. The special stress is given to solution realization for dynamic defining of discreet mathematics model of any control object - technological process without need for programming, which is done over the developed mathematics editor, is such a way that mathematics model is saved in relation data base and it is easy to change. This solution makes possible simulation and analysis using model “if - then“, effects of some parameters on production process over the mathematics models for work simulation in complete plant, when it is possible to apply planned method of control over “FUZZY logics“ and linear programming.

DEVELOPMENT AND PROJECT ASPECTS OF THE PROBLEM

Requirements analysis

Automation trend of technological processes has come to a point in which application for universal analysis of process dominates. Analyzing the process during its duration, on one hand and finished product on the other, considering the results of measuring all important parameters some technological

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stages, including tracking of operator work, it is possible timely bring conclusions about possible causes of error in technology as well as the way of their correction. Čukalevski (7).
Tracking of energetic efficiency is of great interest in all companies that produce and sell electric, heating, and other types of energy. In this group of companies belong - thermo-power stations - heating plants, which possess geographical distributed plants which during heating season work in combined work regimes and during summer, plants are in cold reserve and they are used in case of need of electro energetic system. This study is the result of such needs.
A large number of parameters and values are gathering during production and maintenance using "on - line" way, which are involved in the formulation of the company energy efficiency indicators. The management has daily needs for certain number of text and graphic reports which present information on energy efficiency through which the process can be influenced retroactively. Reports are created as a result of technological process analysis and they can have statistical, analytical and numerical access (through the mathematical system model), and they present "off-line" way of getting information from production.
The basic request that has been set is manual or automatic record of technological data from measuring points in technological process, within periodical or arbitrary intervals. With automatic record of technological data about measurements with SCADA subsystems, it is necessary to put all data in order, their processing and adapting to relation data base to take into - linking through mathematical process model. It is also necessary to keep record of planned events of the drive work.
On the basis of *predefined mathematical model of technological processes*, in this case geographically dislocated thermo power plants - heating plants, measured hourly and daily values of technological data, energy delivery records and consumption of production raw materials, it is necessary to generate daily reports, which are used to compile energy and economical efficiency indicators and drive work efficiency. Therefore, the application shouldn't be used for an immediate "on - line" manner production management, for that purpose there are already process computers available, that is SCADA systems.

Technical conditions and requirements for the project creation

Energy production companies are as a rule regionally distributed and integrated through an appropriate computer network (intranet or internet). By this, the conditions are right to avoid the creation of an automation island, which would result in a data redundancy, information model incompatibility and loose data usage outside application or information system itself. (Figure 1).
The application should be connected with the existing basis for material operation and programme which should monitor financial operations, that is from the user point of view to make them a whole. (Figure 2).
It is necessary to form a unique technical and technological data base (BTP), measurement sensors, management units, realization devices for more dislocated technological processes and its plants.
The connection is available using classical file transfer with the existing dislocated SCADA SERVERS / PLC RTU units in the technological process acquisition and control systems, from which the application retrieves the values of measurements of certain frequency, in the automatic work regime. These data are daily updated and transferred by SQL*Loader into relation data base. Then their processing is made and adjustment for updating them into a daily entry document for each plant - a complete technological process depending on from which SCADA server the data were received. Čobanov (6).

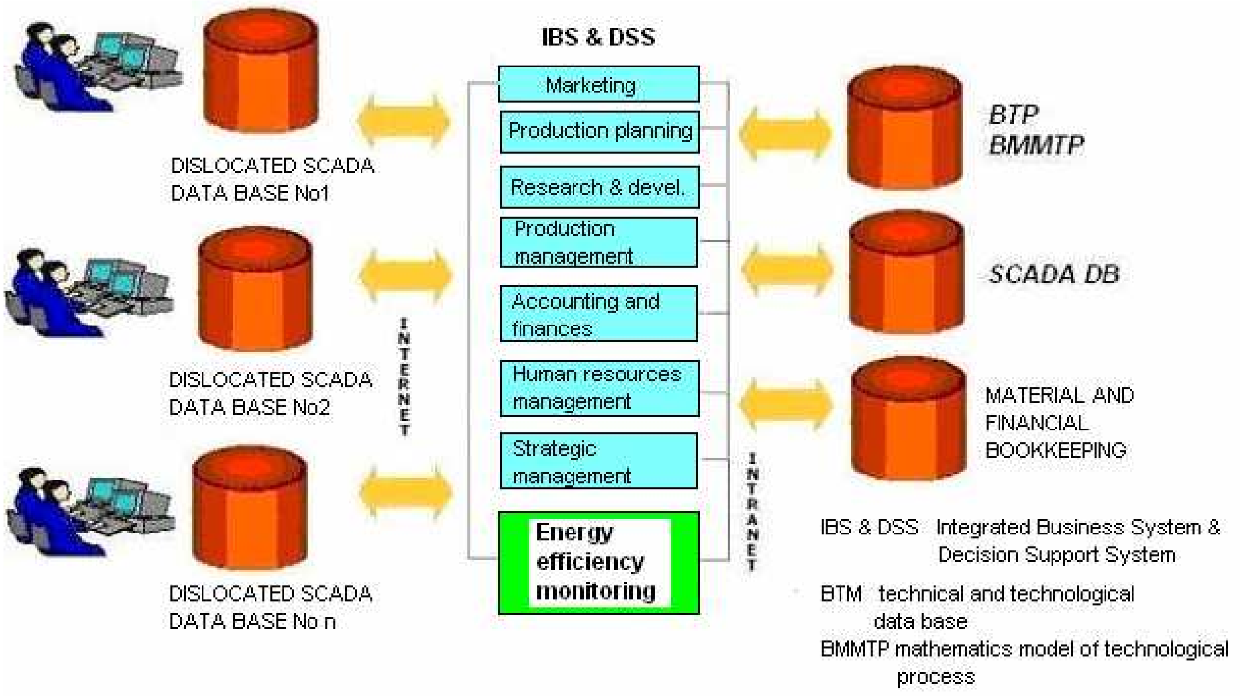

Figure 1. Conceptual representation of application integration solution for energy efficiency monitoring

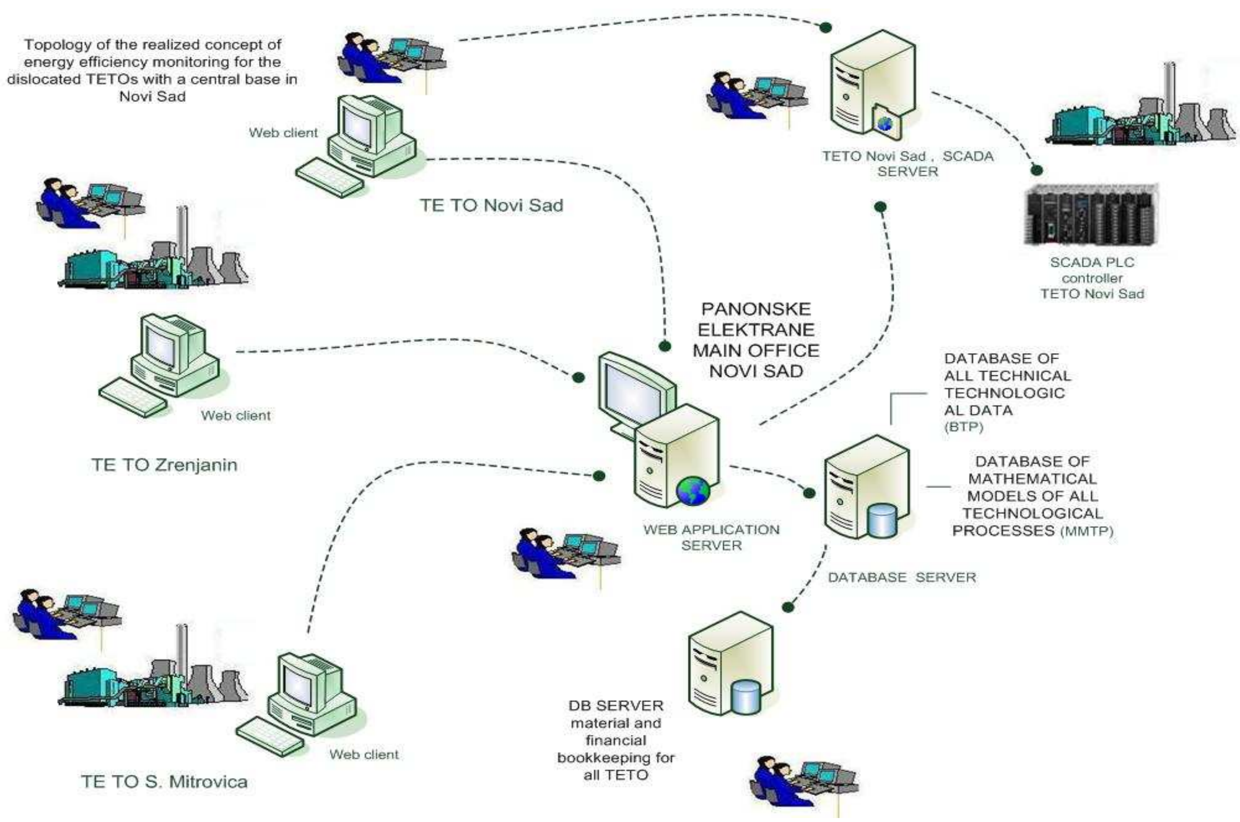

Figure 2.Topology of the realized concept of energy efficiency monitoring for the dislocated technological processes

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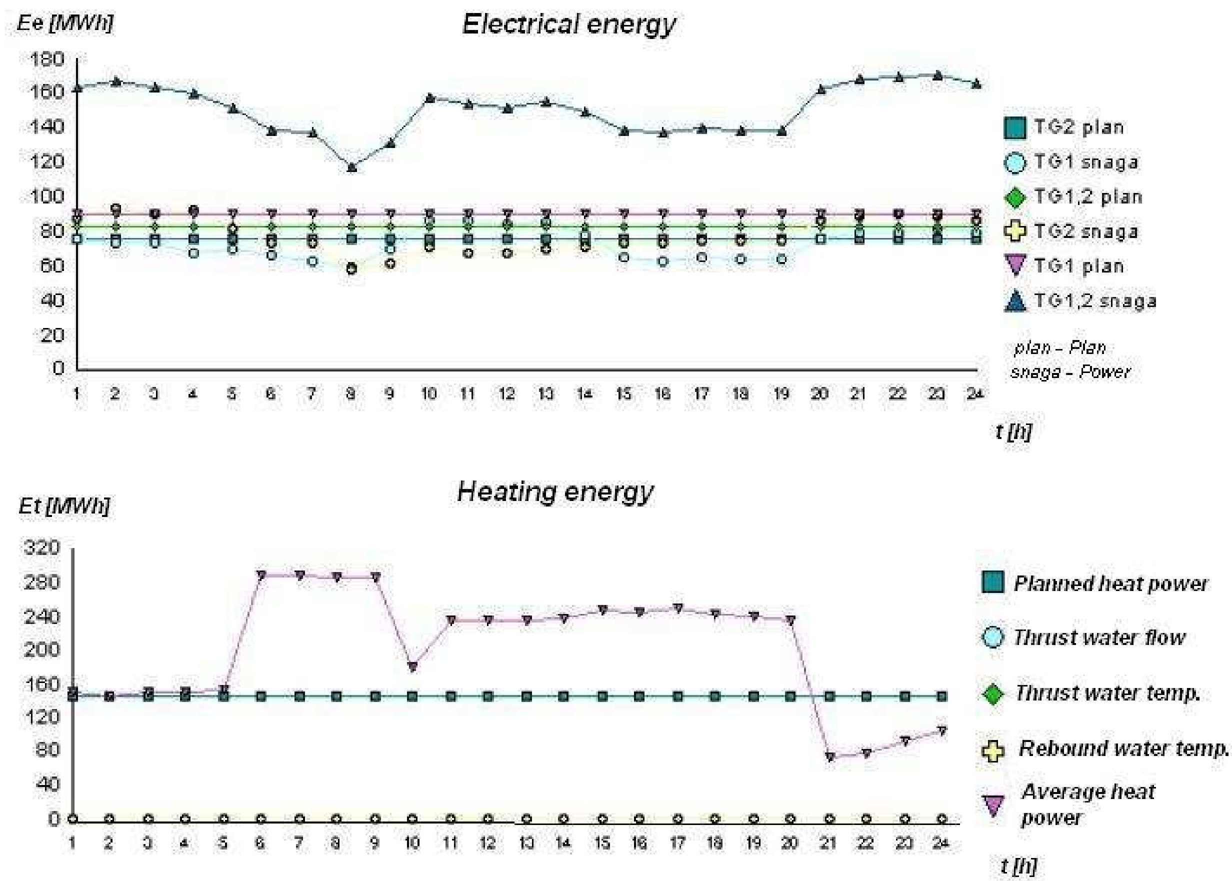

Figure 3. Examples of the parts of daily energy reports for TE TO in the form of graph

WORK RESULTS - TECHNICAL REALIZATION

Definition of universal mathematical model of the monitoring subject - technological process

Discreet model of monitoring subject. In order to model a universal, dynamic production system and adjust it for the computer processing, we started from defining a simplified discreet model, Kostić (1), Marinković (2), (3), (4), event which is the most convenient as a solution background. In this type of model variables are discreet values which represent the subject state, in our case these are production attributes Xn (kT) i.e. technological data of the drives with a certain frequency of events:

Xn(kT) = (X1(kT),X2(kT), … , XN(kT)) … Subject state vector in a discreet moment k * T, k=0,1,2,…N

where T is a set fixed time interval (hour, day, week, month,..)

which practically goes into [2]:

UNSn(kT) = (UNS1(kT),UNS2(kT), ….,UNSN(kT)) with a set frequency T (hour, day, ...)

MDNSn(kT) = (MDNS1(k-1)T,MDNS1(k-2)T,MDNS2(k-1)T, …MDNSN(k-1)T, UNSt) ,

where is UNSn(kT), represents values of technological data UNS ordinal number n in the time kT, which depends on other technological data, and MDNSn(kT) represents the value of formula ordinal number n, which is obtained on the ground of values from the same formula and values of other formulas of the same or different frequency, as well as values of technological data of different frequencies, which describe the subject - technological process in discreet time intervals.

Real modeling. User takes in values of technological data (manually or automatically) on a daily basis, which characterize hourly and daily production for determined technological whole, which are starting points for all further calculations. Real mathematical model should enable value calculation of the each defined variable to match with frequency, class and category of value that variable belongs to.

The name of tech. data	DESCRIPTION OF TECHNOLOGICAL DATA	MARK	UNIT OF MEASUREMENT	FREQUENCY	DATA CLASS
UDS031	TG1 - average power Turbo generator	$P_{ee-TG1-s}$	MW	Hourly	Production
UDS032	TG1 - threshold energy	$E_{ee-TG1-d}$	MWh	Daily	Production
UDS033	The number of working hours during the day TG1	$T_{ee-TG1-h}$	hh:mm	Daily	Production
UDS034	TG2 – average power	$P_{ee-TG2-s}$	MW	Hourly	Production
UDS035	TG2 – threshold energy	$E_{ee-TG2-d}$	MWh	Daily	Production
UDS036	The number of working hours during the day TG2	$T_{ee-TG2-h}$	hh:mm	Daily	Production
UDS095	Daily use of crude oil K1	MAZP-k1-d	t	daily	Consumption

TABLE 1 - The example of technological data with a class of electrical energy production with hourly and daily frequency and one technological data - consumption

In table 1 we can see some of the daily and hourly technological data that have been updated on a daily basis. Apart from those, there are technological data which are recorded monthly, yearly or on other time periods. Technological data are divided according to frequency, class, category and type. Based on those, formulas of categorized mathematical models are calculated according to state of belonging to a technological process. Those formulas describe fully in details all production processes in all energy drives, their current values, power, energy, flow, temperature, as well as cumulative values, then, average values for different time periods, etc.

The name of FORMULA	DESCRIPTION OF FORMULA	Unit of Meas.	DESCRIPTION OF FORMULA FUNCTION	FORMULA FACTORS
MDS032	Power TG1 daily-max Turbo generator	MW	Maximum from $P_{ee-TG1-s}$	Max (UDS031)
MDS033	Power TG1 daily average	MW	Average value from $P_{ee-TG1-s}$	UDS031/UDS032
MDS037	The hour of realized MIN El. en. on TG1	h	The hour in which is the value of realized el. energy the lowest during one day	Time from value MDS031
MDS041	El. Energy – Monthly production TG1	MWh	SUM (Eee-TG1-d)	UDS032 + MDS041 from the previous day
MDS045	El. Energy – daily production TG1 and TG2	MWh	Eee-TG1-d + Eee-TG2-d	UDS032 + UDS035
MDS136	Total of daily use of crude oil K1+K2+K3	t	MAZP-K1-d + MAZP-K1-d + MAZP-K1-d	UDS095+UDS096+ UDS097

TABLE 2 - The example of formulas for daily frequency - daily mathematical model, different classes in the production process

Formulas are being calculated daily, in the process of generating the reports. The report for a certain day is review of all formulas of mathematical model in data base for a certain technological process, primarily with daily frequency. There are also shift, weekly, monthly, yearly or periodical reports.
Those reports can be according to the type of review be graphic (Figure 3) and text, and according to the class, energy and economic. Once generated the reports for a certain period can be put into archive in the selected format. Energy reports give a review of production from a technical point of view (the amount of produced electrical energy, heat energy and technological steam, its own production, work regimes, review of boiler operation, graphs, number of stoppages, fuel consumption…).
Based on the above defined real discreet mathematical model, a universal model has been modeled convenient for dynamic formula defining of any technological process without a need for programming. Formula input is done using a developed mathematic editor, so that mathematical model is saved in the related data base and is easy to change. This method gives the opportunity of simulation and analysis of "if - then" model, the effect of individual parameters to production process, on the basis of mathematical models for simulation and work management of entire plants, when it is possible to apply a combined management method using "FUZZY logic" and linear programming.

General model of mathematical formula supported in data base : $M_{jd} =$

$$\sum_{i} \left[Ai\, F(Xi) \pm Bi\, F(M_{km}(Xi)) \pm Ci\, Xi^{\pm Q} \pm Di\, M_{kd}(Xi) \pm m\, Xi^{\pm P} / nYi^{\pm Z} \pm Ei\, M_{kd}(Xi) /\; Fi\, M_{kd}(Yi) \right]$$

LEGEND

Mjd : mathematical formula No j for daily processing of tech. processes, for the d day

Mkm : mathematical formula No k previously calculated during the month

Mkd: mathematical formula No k calculated on the d day

F : function *: SUMs,AVGs,MINs,MAXs, SUMmes,SUMgod,H_piks, ...*

Xi, Yi: technological data with hourly, daily, monthly, yearly measurement frequency, which are used in production, consumption, el. energy planning, heat energy, technological steam

Ai, Bi, Ci, Di, m, n, Ei, Fi: constants or coefficients

Criteria and energy efficiency measurement

Efficiency criteria in general form is defined according to set or planned the aims of the management subject. When solving this problem we took natural results - production indicators which characterize the goals of technological process management, (1), and these are: quantative, qualitative, financial. In accordance to the mentioned the quantative indicators are the amount of produced electrical and heat energy and technological steam, which we get through energy reports. Qualitative indicator is measured through economy and profitability. The first is relation between realized profit and used values, and the other is the relation of realized profit and investment. However, one of the main aims of long-term development is the improvement of persons living conditions, to stop the degradation of environment by uncontrolled usage of energy sources, and to achieve the production quality as well. Therefore, it can be deduced that the energy efficiency of technological energy production process through the above mentioned main aim, and only then through other goals which could be more or less important. Mathematical formulation of energy efficiency in a general form can be somewhat shown using minimal or maximum of functional **J** values:

J energy efficiency = **F** (Energy indicators, Economic indicators, Set goals and management).

In this application it is made possible through economic reports which are created on the basis of energy and economy values of mathematical model system and which are mainly intended for the company management, to show the indicators of energy work efficiency of the dislocated energy plants. Daily

report about economic indicators shows daily spending of fuel and chemicals, as well as comparative representation of assumed fuel spending and actual spending, and financial effect of that difference.
First part of the report shows gas and crude oil that was spent on production of each type of energy (electric energy, heat energy and technologic steam), price for both fuel types in all three cases and financial expense for given quantity of fuel at given price, as well as summed values.
Apart from that spending of all chemicals is listed, with unit price and value.
Prices of gas, crude oil and chemicals are taken from the system of material bookkeeping, and appropriate spending from daily energy report for that day.
Second part of the report is displayed by fuel and energy type:

- How much fuel was spent,
- How much energy was made,
- What is the recognized normative,
- What are the planed expenses,
- How much is fuel spending in case of adhering to the normative,
- Difference between actual and normative spending,
- How much money was saved from that difference,

In case there is a loss, savings are represented by a negative value.
Data about spending and volume of production is taken from daily energy report for that day, norms and planed expenses from documents and general incoming data, fuel spending by normative is regarded as a product of production scope and normative, fuel savings as a difference between actual and normative spending and money saving as a product of price and fuel saving.
Finally the sum of savings for every fuel type is listed, from which financial effect of fuel spending for that day is deducted in order to get total savings (or loss).
Since we have mathematical models for number of technological processes stored in a relation database comparative analysis of labour and energy spending is possible for several technological processes concurrently.

Application web access security

Application requires username and password to be supplied, which makes database logon, and after user is identified, type of work should be chosen - application prompt, after that working space appears with the main menu. With the roles predefined privileges for access to different parts of the company – technological process are clearly set, choice of work functions (Figure 4), accessing data for desired business year. Which means that one user on a higher level of decision making, can have more than one (password protected) logon, in that way he/she can register with the system – technological process in relation to what kind of work needs to be done in the company.

Technology, development and application platform

In a process of planning development of this information we used “BSP” (Business System Planning) methodology, which implies set of activities needed for managing development of business – production system via development of IS.
Methodology approach to development of IS, in a phase of analysis and specification, is based on two most commonly used methods for modelling of processes and data, structural system analysis and model objects – connections.
It was proven that object orientation in development methodology, during analysis (OOA – Object Oriented Analysis) was primarily implementation abstraction, and not abstraction suitable for describing real system. For describing real system functional models, process models and data models, for business systems such as this one, had considerable advantage. During the phase of project planning it was made possible to implement object oriented database and certain applications, which are based on already mentioned methodology of IS analysis. So it was made possible to have mixed model of development lifecycle of informational object relation systems.
In scope of implementation, development platform is based on MS Windows / Oracle Designer, in three layered - Web architecture [8]. Development platform provides application availability on all hardware and software (OS) platforms. Topology of informational system that is computer network practically has no technological limitations.

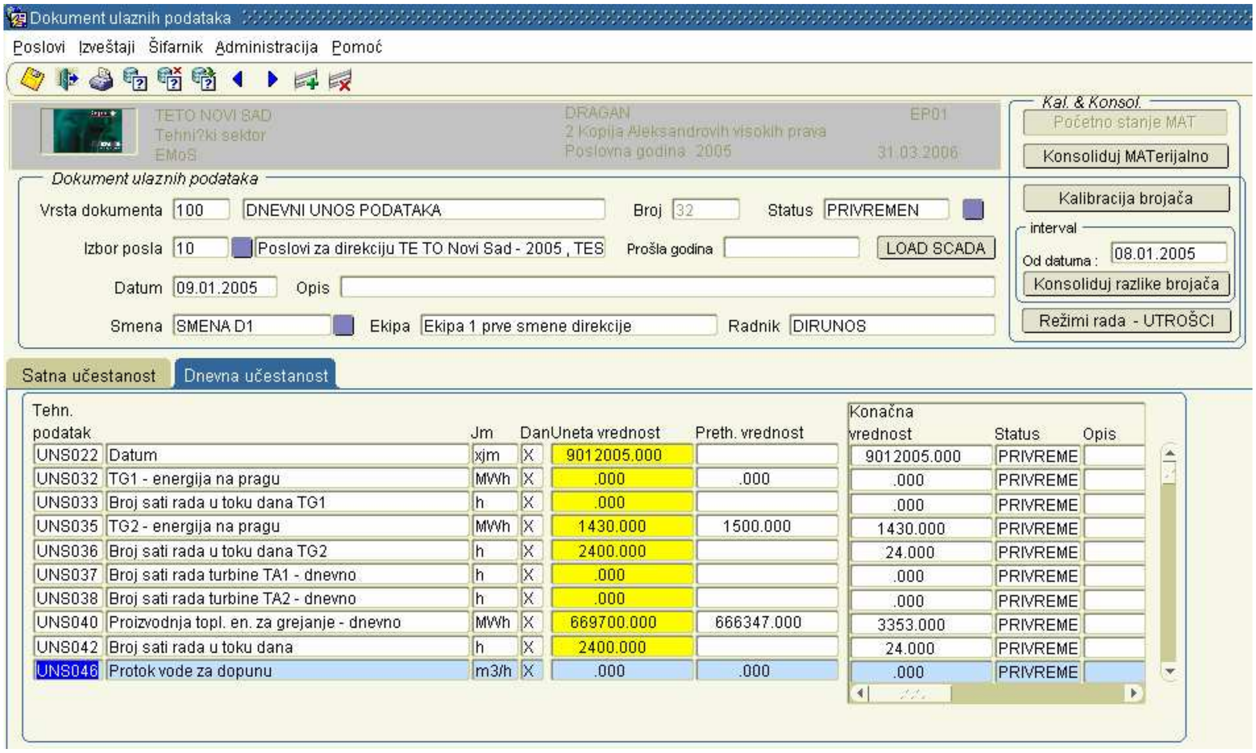

Figure 4. Web input screen (automatically) values of technological data from production facility

CONCLUSION

With integration of application for tracking energy efficiency into existing IS the quality of production can be raised, better choice of fuel and equipment can be made, and significant savings of natural energy sources and money can be made while increasing company's competitive position.
In this way application represents a part of DSS (Decision Support System) information system, namely system for support and decision making, just as DSS represent a part of EIS (Executive Information Systems), executive or corporative informational systems, which are a part of business – technical systems. Application also provides usage of DM methodologies (Data Mining) discovering information from data, and DW (Data Warehousing) keeping data.
Implementation of new informational technologies can provide long-term planning, stop environment degradation by uncontrolled fuel usage, and all thanks to tracking, universal analysis and feedback on technological production process.

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