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Energy efficient intellectual control system of the electro-technological complex of a bread-baking plant

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Abstract: *Energy efficient intellectual control system of the electro-technological complex of a bread-baking plant***.** Rationalization for the block schematic diagram of energy efficient control system of the processes on a bread-baking plant using artificial intelligence technologies based on the theory of neural networks was provided, the algorithm and structure of the control system of the process of baking bread was formed. Economic viability of the use of the proposed intellectual control system of the electro-technological complex of a bread-baking plant was demonstrated.

Key words: *bread-baking plants, mathematical model, electro-technological complex, control system, neural networks*.

ACTUALITY OF RESEARCHES

There are 205 specialized companies operating in Ukraine [Drobot 2002], which combine 384 bread-baking plants and 168 confectionery shops.

Recently such enterprises as public limited company "Kyivkhlib", private limited company "Ukrzernoprom", public limited company "Concern Khlibprom", and limited liability company "KhlibniInvestytsii" have been the leading manufacturers in the bread-baking market across the country [Kozyrskyj 2016].

As a rule, the most efficient enterprises have foreign equipment which is characterized by reliability and accuracy. Throughout Ukraine the most popular equipment examples for bread-baking plants are: dough mixers (Sigma, VMI Berto, Effedue, Fimar); mixers (Sigma, Teknostamap, Starmix); divider machine and divider and rounder machine (Rollrex, Vitella, Abapan); dough molder and kneading machines (Rollmatic, GGF, Teknostamap); proofing cabinets and convection ovens (Unox, Bassanina, Inteko-Master); rotary ovens and hearth ovens (Bassanina, DanziForni, Laser).

However, most industrial companies still use energy-intensive equipment which was installed more than twenty years ago. 48 per cent of the total amount of industrial equipment in the country had been installed by 1985. In the meantime, electricity prices are growing steadily and the study of energy saving has revealed the fact that energy savings can be potentially by 50-70 per cent higher than at the time being which consequently determines the relevance of modernization of the electro-technological complex [Kozyrskyj 2016].

The following technical and economic dependence is a key background for energy-efficient management of the electro-technological complex [Drobot 2002, Kozyrsjkyj 2016]. If electricity costs of a bread-baking plant make 2.5 per cent of the total costs while its profit equals 5per cent of the turnover, decrease in electricity costs by 10 per cent amounts to increase of the profit by 5 per cent.

Therefore, energy-efficient control of the electro-technological complex of a bread-baking plant is an important task in terms of improving profitability and competitiveness of the enterprises.

ANALYSIS OF RECENT PUBLICATIONS

Analysis of works on technology and automation of the bread-baking manufacture has shown that a significant number of scientists have been engaged in the study of the problems of technological support and development of automation systems: Scherbatenko V.V. [Moderation of the bread-making processes and improvement of quality 1976]; Zlobin L.A., Blagoveschenska M.M. [Optimization of the technological processes of bread-making manufacture 1987]; Yurchak V.G. [Development of the dough quality evaluation tests 2003]; Kyshenko V.D. [Efficient management of the processes of dough-making 1995]; Sharuda S.S. [Automated system of the multi-task control over the technological processes of bread-baking production based on scenario approach 2009] ; Shved S.M. [Development of forecasting model in control system by the process of preparation bread with the use of neural networks 2012]. However, these works do not deal with the problem of energy efficiency and they lack comprehensive approach to the problems of operating the technological processes of bread-baking as a whole. The purpose of the research is to substantiate, create and test energy efficient intelligent control system of the electro-technological complex of a bread-baking plant in a production environment.

MATERIALS AND METHODS

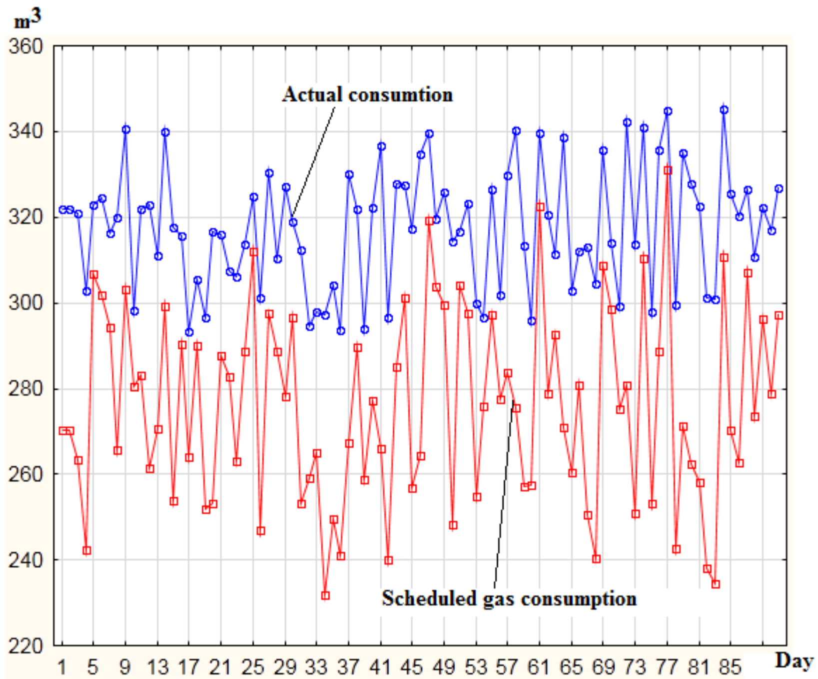
To develop and analyze a mathematical model of the energy resources distribution of a bread-baking plant experimental data was used while the list of basic electro-technological equipment was received from the bread-baking plant “New Perspectives” Ltd. located in the village of Varkovychi, Dubno district, Rivne region. The information was obtained due to a passive experiment which was carried out during the period of 90 days [Kozyrskyj 2016].

The results of the experiment as well as their visual interface showed nonlinearly variation in the measured product range and power settings while the processes are unsteady, which greatly complicates further study of the impact of the product range task on the energy flows in the production of bread.

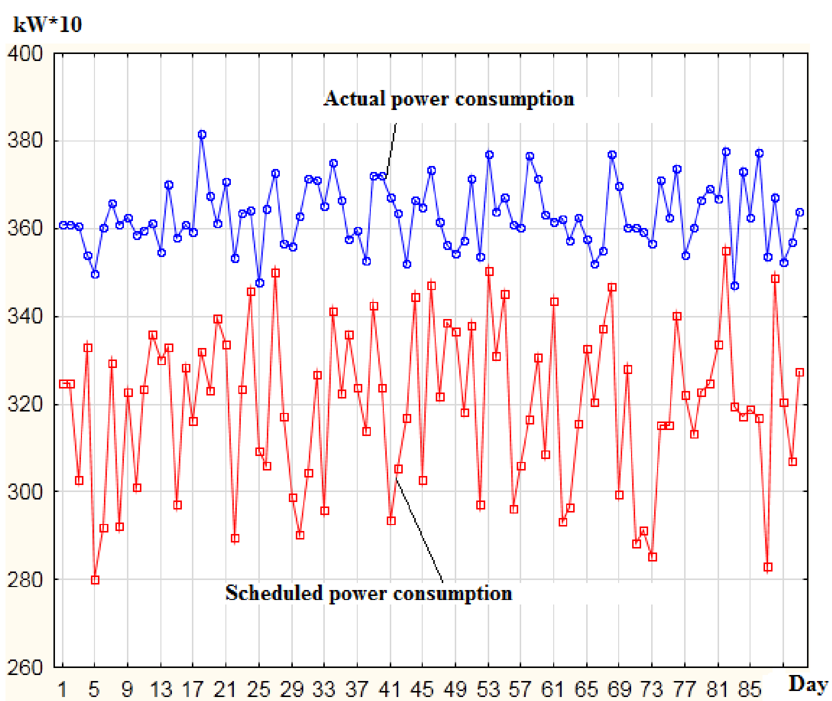
The effect of the key economic factor, the product range task, on energy efficiency was evaluated by using the method of statistical correlation analysis [Shtepa 2014]. The latter figure was calculated as follows (Fig. 1).

Energy efficiency = FVE - PNVE (1)

where FVE is the actual charges of power resources; PNVE is the scheduled charges of power resources.



A)



B)

C)

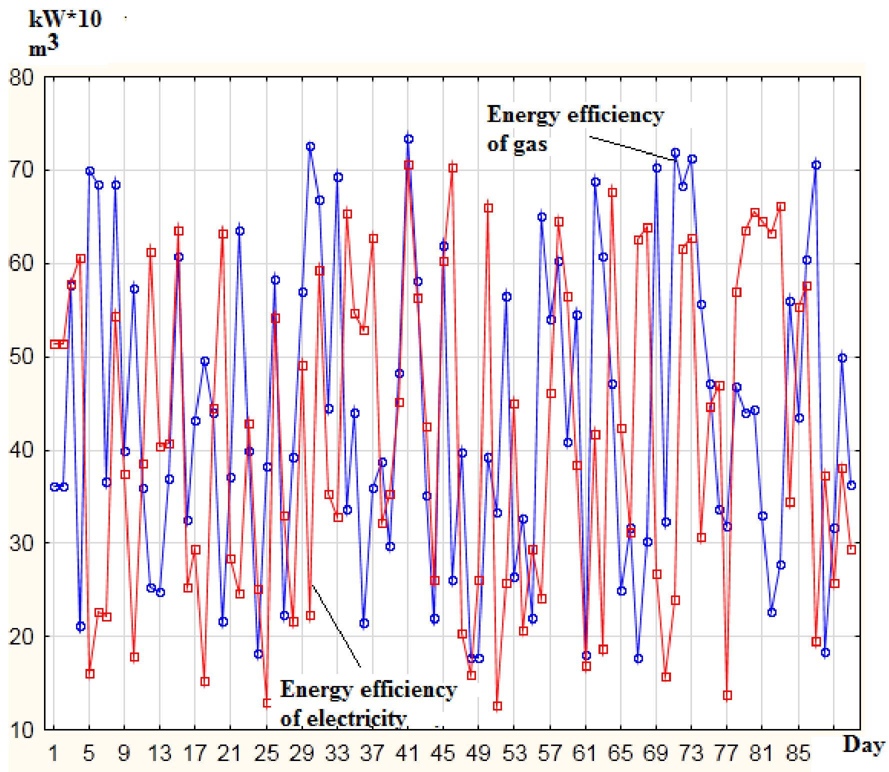


FIGURE 1. Evaluation of the energy characteristics of the manufacture of bakery products within the daily product range task: A - charges of electric power; B – charges of natural gas; C – energy efficiency

Results of the correlation analysis showed the impossibility of establishing the degree of linear relationship between these important parameters of the manufacturing processes - all the correlation indices are less than 0.3. Thus, non-linearity and transience of processes was determined, as well as actual failure to formalize the relationships between the production parameters using classical approaches (the linear correlation analysis), particularly between the product range task and energy efficiency of the manufacture.

Therefore, for the synthesis of the energy efficient systems of controlling the electro-technological complex of bread-baking, taking into account the established nonlinearity relationships between the production and economic parameters (Fig. 1) and their unsteady changes in time, it is advisable to use intellectual approaches which demonstrate efficiency in the analysis and evaluation of the following processes: stochastic, nonlinear, with diffused information component [Leonenkov 2005, Lysenko 2011, Shtepa 2014].

The structure of energy flows was built with the use of UML software design notations (Fig. 2)

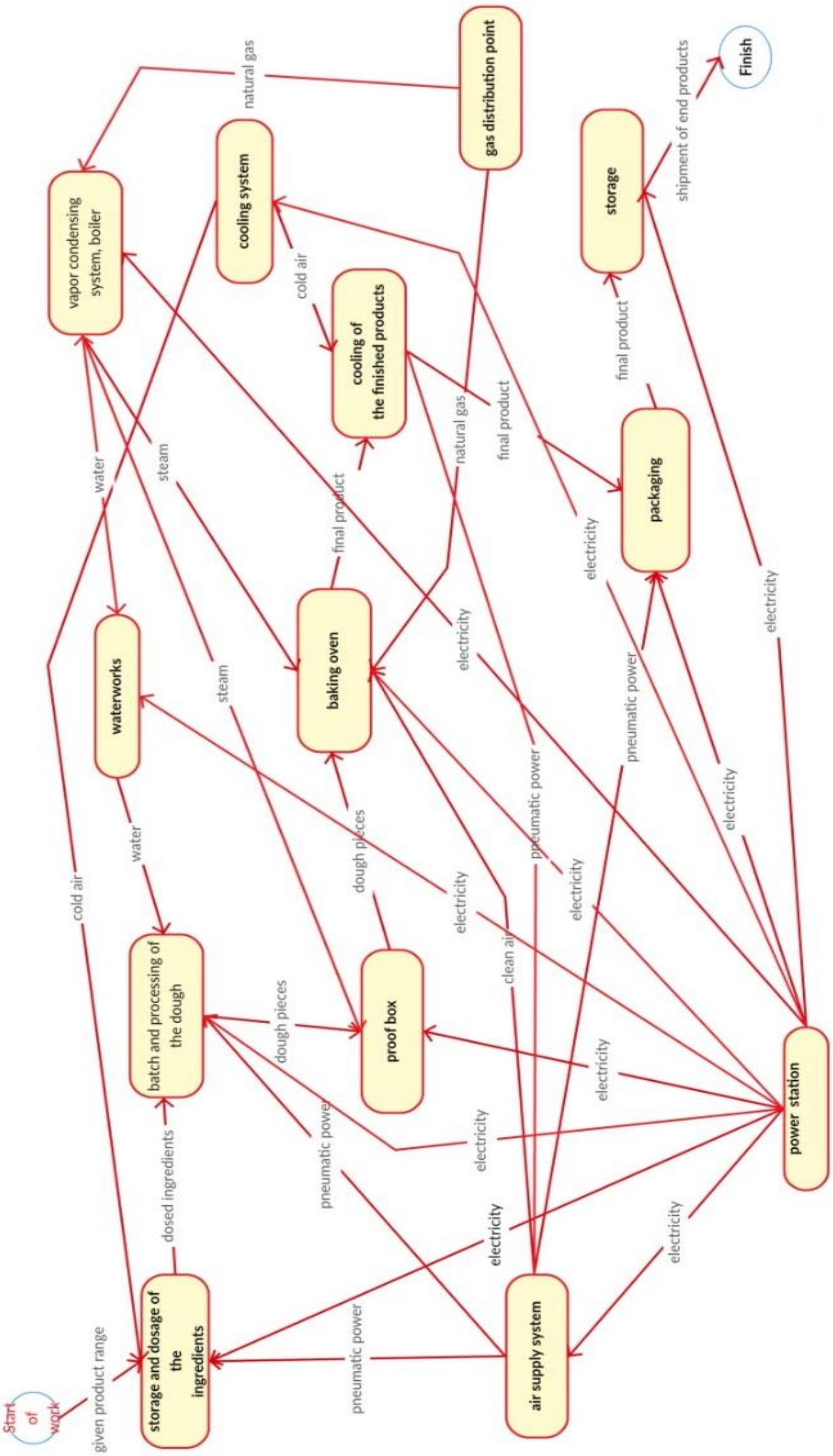


FIGURE 2. Diagram of the energy flows of the manufacture of bakery products

The concept of intelligent control over a bread-baking plant with accordance to the zone cost of electricity was developed (Fig. 3)

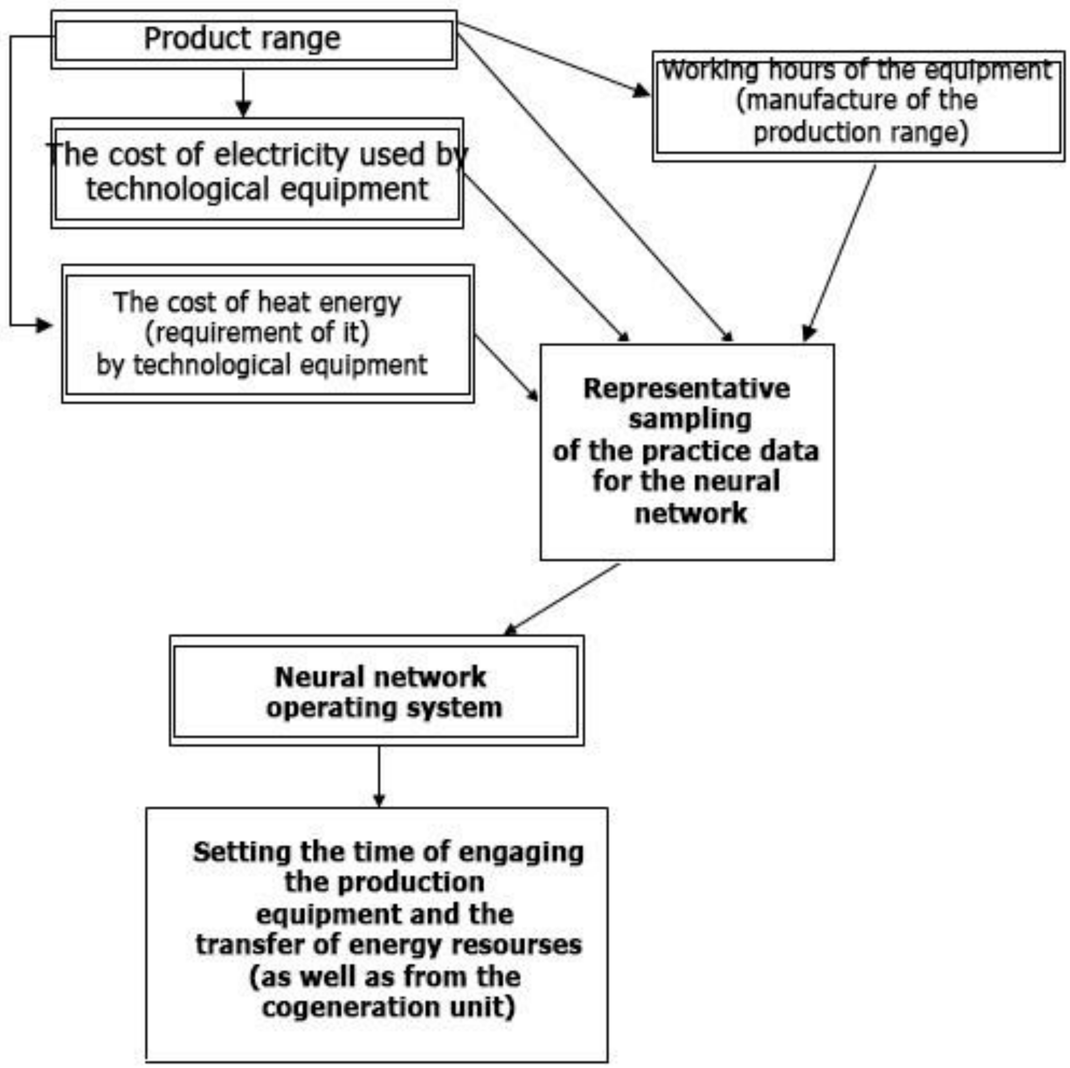


FIGURE 3. The conceptual idea of using electro-technological control system targeted at increasing energy efficiency of baking bakery products

It was singled out that one of the most difficult tasks for creating training sample for the neural network is to develop adequate and representative values of the manufacture worksheet. For this purpose Petri net was used [Leonenkov 2005], as well as the results of passive experiment at the plant (to assess the time of functioning of the electrical technical equipment during the performance of the product range task) and the zone cost of electricity. The corresponding neural control network was created on the basis of the latter (Fig. 4).

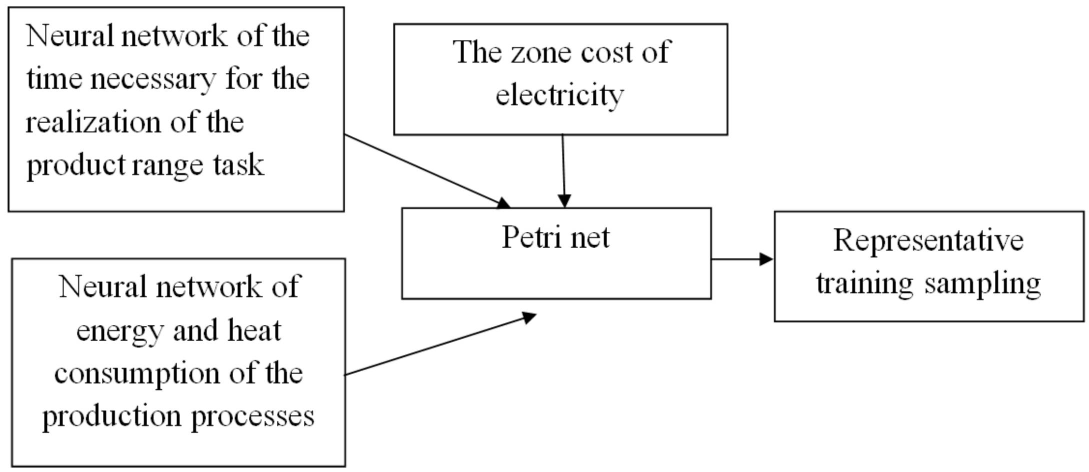


FIGURE 4. The structure of the formation of the training sampling for the neural networks using Petri nets

The major objective of the control system based on the conceptual block schematic diagram and the zone cost of electricity is ultimate concentration of the use of technological equipment within the daily time "gaps" with a minimum value of electricity, in order to minimize the time of functioning of the electrical technical units during the time of the maximum value. As follows, the electro-technological complex should work within the zone of 0.25 tariff, that is during the hours of minimum night load of the energy system (from 23 pm to 6 am). For this purpose Petri net was iteratively applied [Leonenkov 2005].

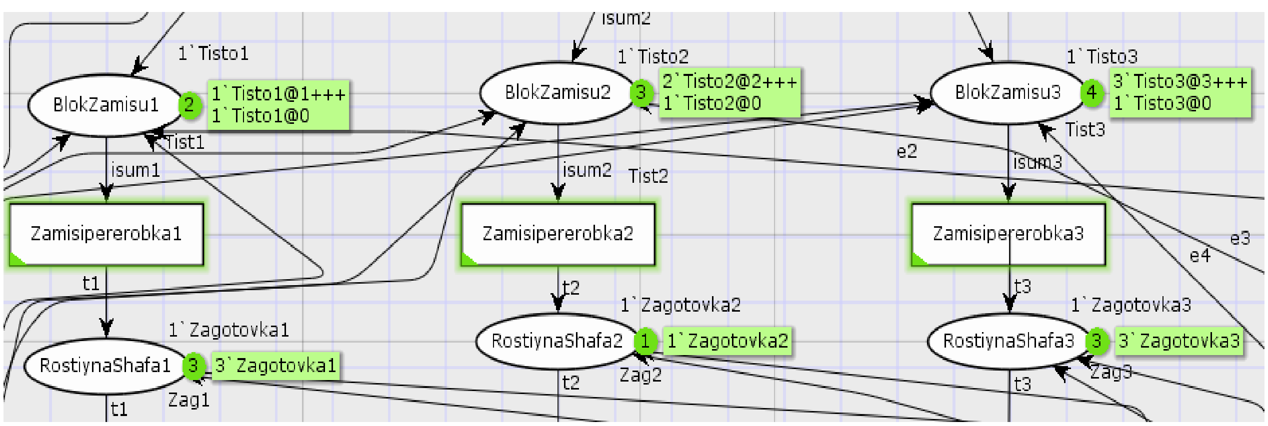


FIGURE 5. A fragment of the time simulation of the product range task execution («CPN Tool» software)

Analyzing the most efficient time for using the equipment (Fig.5) (that is a set of training data which was obtained on the basis of Petri nets and experimental research during one of the typical product range tasks) we can state that the cost of the consumed electric energy decreased by 7.3 per cent (compared to a linear product range task performance). The iterative modeling included 24 expert ages (Fig. 6).

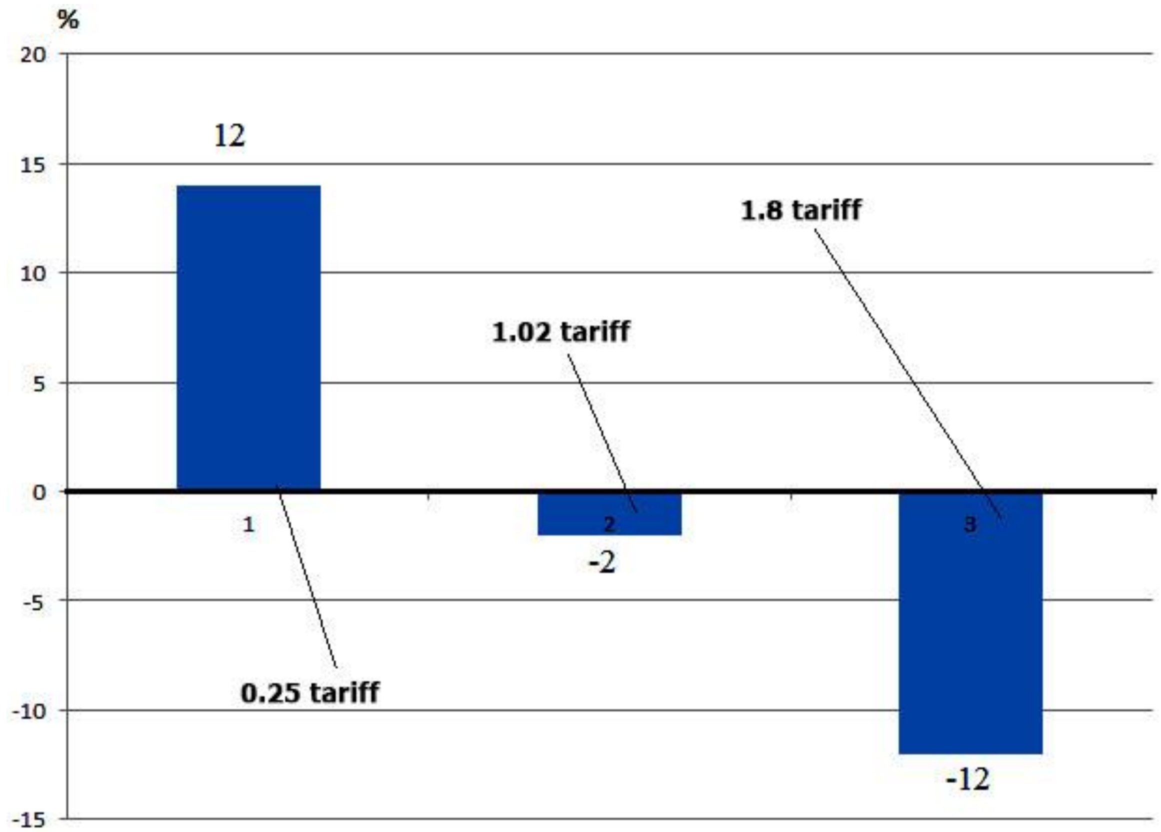


FIGURE 6. The change of the time of using the electro-technological equipment of the bread-baking plant in different tariff zones (an average typical product range task and work of the equipment from 12:00 am in a justified continuous mode are accepted as default task)

For the further optimization a multilayer perceptron was selected (Fig. 7) (MLP 24-10-29) with the following relative root-mean-square errors of the synthesis: testing amounts to 3.8 per cent, controlling amounts to 3.6 per cent, verifying amounts to 3.2 per cent. The iterative gradient based learning was carried out with the use of optimization approaches to the settings of the weighting coefficients of the hidden layer (Fig. 8).

Simulation studies of neural functioning were conducted in the package of the applied mathematic software “MatLAB Simulink” which contains a block of neural network modeling with the use ofthe established software implementation. The input of the network accepted the production range values that were not recorded during the passive experiment; minimizing of the error was determined in real time while evaluatingthe ability of neural networks to self-learning (Fig. 9). However, to simplify the simulation, the mean relative error of 5 per centwas assumed to amount to "0" on the diagram.

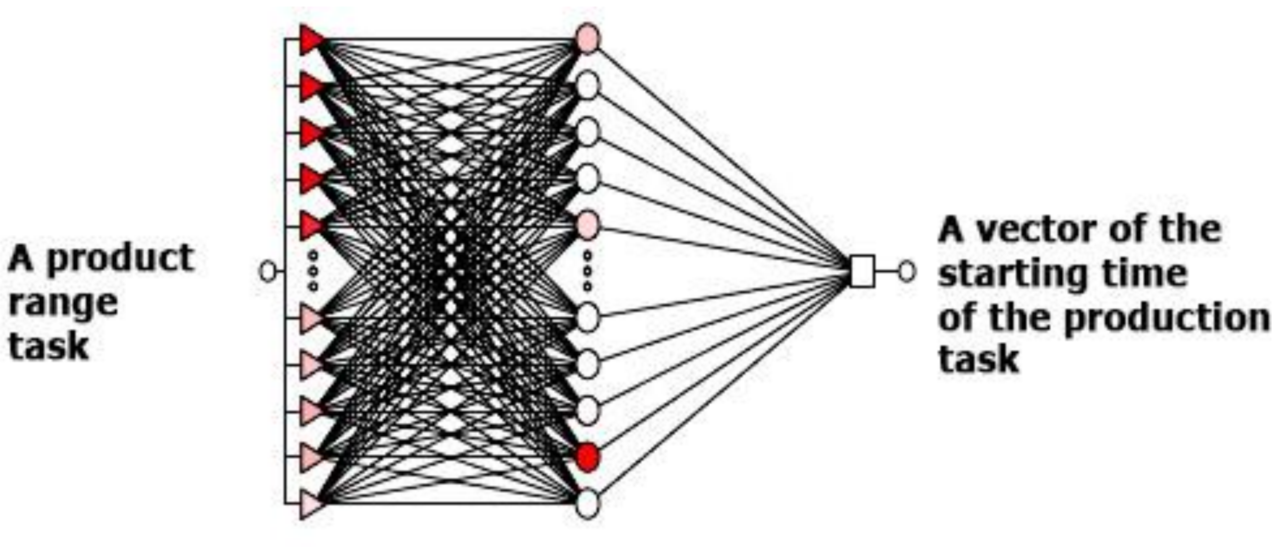


FIGURE 7. The architecture of the energy efficient neural network control system of the electro-technological complex of the bakery products manufacture

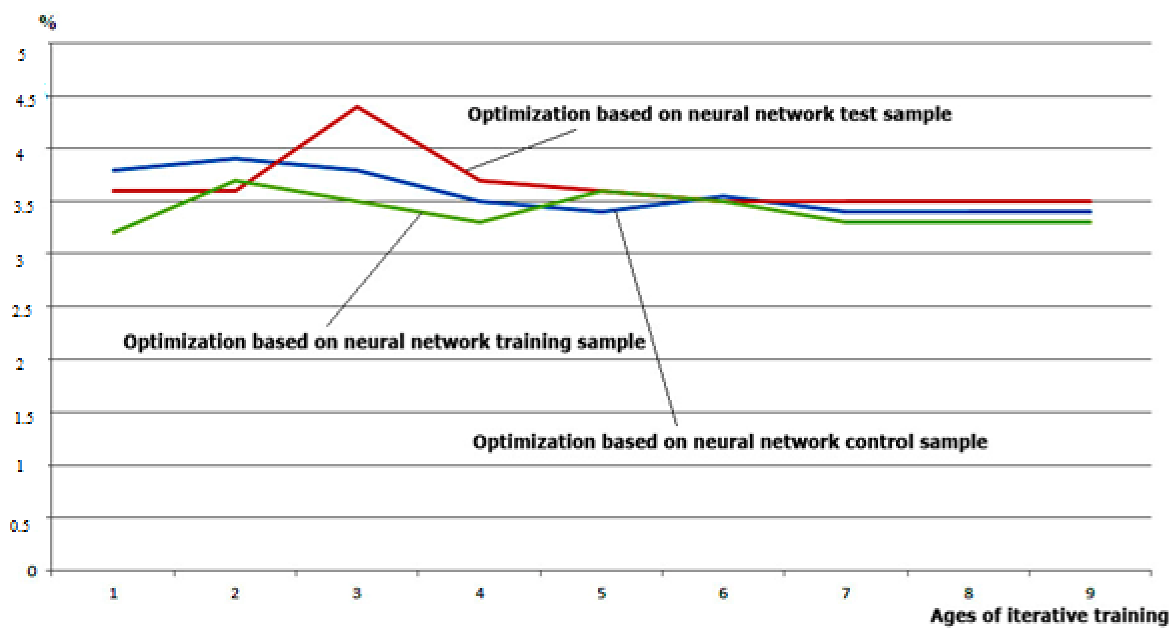


FIGURE 8. Iterative optimization of the neural network control system of the electro-technological complex of the bakery products manufacture

The achieved results of the neural network functioning demonstrated that relevant quantifiable values of the control performance (speed, number of semi-fluctuations) are technically acceptable. The maximum time of self-tuning amounts to 43 ages which will amount to no more than 30 seconds of real time provided that modern microprocessor equipment is applied.

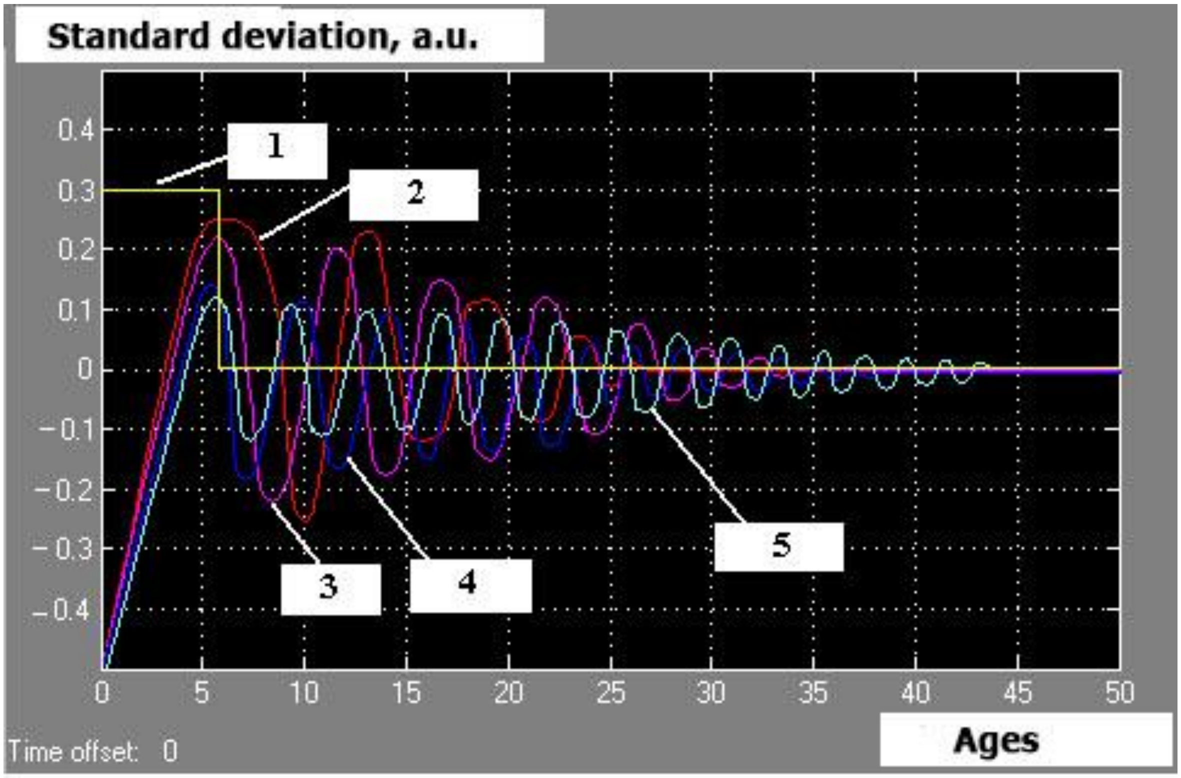


FIGURE 9. The transition process during the self-learning of the energy efficient neural control network of the electro-technological complex of a bread-baking plant: 1 - initialization of the start (arbitrarily selected); 2, 3, 4, 5 – self-learning based on the unknown product range tasks

Manufacture study of the control system was conducted on a workable company “New Perspectives” Ltd. which is located in the village of Varkovychi, Dubno district, Rivne region. Specialized software based on the synthesized energy efficient intelligent system was installed there (Fig. 7). Control over individual process components was provided by the local microcontroller systems.

Generalized economic values of the performance results of the technical equipment actuation under the performance of production range tasks in accordance with the zone cost of electricity on an industrial facility within the 30 days period confirm the effectiveness and long-term benefits of this approach (the work of the electro-technological complex of a bread-baking plant without the zone cost of electricity was determined using the previous research data on the same industrial facility). The total financial savings amount to 17 354.90 UAH; relative reduction of financial expenses connected with the functioning of the electro-technological complex of a bread-baking plant amount to 10.47 per cent.

CONCLUSIONS

1. The well-grounded and engineered energy efficient intelligent control system of the electro-technological complex of a bread-baking plant meets all the technological requirements as confirmed by the simulation modeling with 43 ages of the maximum time of self-tuning (provided that the microprocessor equipment is used, it will amount to no more than 30 seconds).

2. Industrial availability of the energy efficient intelligent control system of the electro-technological complex of a bread-baking plant demonstrated the economic validity of its use: the total financial savings amount to 17 354.90 UAH; relative reduction of financial expenses connected with the functioning of the electro-technological complex of a bread-baking plant amount to 10.47 per cent.

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Streszczenie – w artykule przedstawiono układ automatycznej regulacji procesem wypieku chleba bazujący na teorii sztucznych sieci neuronowych. Opisano algorytm oraz strukturę ukłądu automatycznej regulacji. Dokonano analizy ekonomicznej proponowanego rozwiązania.

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