Annals of Warsaw University of Life Sciences – SGGW
Agriculture No 67 (Agricultural and Forest Engineering) 2016: 149–154
(Ann. Warsaw Univ. Life Sci. – SGGW, Agricult. 67, 2016)

Information technology identification process of the technological complex

ANDRZEJ CHOCHOWSKI[1], ANATOLII LADANYUK[2],
VOLODYMYR RESHETIUK[3], REGINA BOYKO[2], YAROSLAW SMITYUKH[2]
[1]Warsaw University of Life Sciences – SGGW
[2]National University of Food Technologies of Ukraine – NUFT of Ukraine
[3]National University of Life and Environmental Sciences of Ukraine – NUBIP of Ukraine

Abstract: *Information technology identification process of the technological complex.* The article deals with the TC of a sugar mill, whose process operation is described by a large number of technological variables as well as technical and economic indicators, which together form powerful information flows. Suffice it to note that the TC of a sugar mill has nearly 400 points of control of technological variables and requires the implementation of about 250 management features, including automatic control.

Key words: technological complex, identification, process, information technology, automatic control

INTRODUCTION

In the operation of technological complexes (TC), which always consist of subsystems and whose models are characterized by management criteria and constraints on resources, there is always a problem related to estimation of basic operational indicators using modern information technologies with special software [Ladanyuk et al. 2013, Chochowski et al. 2014]. This makes it possible to take into account the main features of the TC: multivariate, non-stationary, non-linearity, fuzziness and uncertainty of information, participation in the management process of a human – the decision maker (DM), etc.

PROBLEM FORMULATION

Processes within the TC are implemented on the basis of heat and mass transfer, fluid dynamics, physical and chemical transformations of matter, which makes it possible to obtain a final product by means of necessary transformation of raw materials (sugar beet), and raise the necessary material and energy resources. Usually, parts of the TC activate individual subsystems, such as preparation of raw materials (feed path and washing compartment), beet processing department (beet slicer, diffusion devices), extract purification (preliming, main liming, first and second saturation), evaporation and grocery department. Sometimes filtration and condensate management subsystems are allocated separately. Besides the main technological equipment, the TC includes a large number of intermediate collectors, pipelines, pumps, adjustment and shut-off valves.

The technological complex has a hierarchical structure, which concerns the elementary technological operators, processes, departments (subsystems) and the TC in general. According to this structure, an integrated management system is developed, encompassing a number of control functions, management, processing of current information, and providing advice regarding management of the TC and its subsystems. Aside from traditional tasks, the modern management theory defines such important functions as definition of condition of a complex object, current production situation and its development. For the production and realization of these functions, modern systems of automation of complex objects employ a sophisticated method combining deterministic (clear, analytical) model with a fuzzy approach (qualitative evaluation and fuzzy logic). In addition, for certain subsystems, technological processes and aggregates, mathematical models and solutions can be obtain with the necessary degree of detail, and for the TC in general – generic indicators that are technical and economic in nature. The sugar factory allocates a number of indicators to the TC, in particular the amount of sugar and total losses [Ladanyuk et al. 1987]. Each of the subsystems, as well as individual technological processes and units have a certain set of condition coordinates and control action output variables, which characterize the state of the object, and define the production situation in conjunction with assessment of external perturbations.

INVESTIGATION METHOD

The TC is always characterized by a set of functional conditions caused by several factors, including performance of the plant's raw material (beet), consumption of juice (pumping), consumption of lime milk, water consumption for washing sludge from the filter. The problem related to identification of the functioning of the TC is facilitated by the fact that many sugar mills operate microprocessor automation systems, and some of them – integrated management systems, which have a hierarchical structure based on networks of different levels and purposes. In such systems, there is the possibility of obtaining operational information, such as trends from SCADA devices. In addition to the desired signal, such information always includes noise components, so its use requires pretreatment methods, mainly statistical, including descriptive analysis, as well as modern intelligent methods of analysis and processing of time series as a sequence of numerical values of process variables, technical and economic indicators – wavelet analysis, neural networks, fuzzy logic. Together, these methods provide an opportunity to assess the production situation, state of the objects in order to obtain performance trends of the situation and a forward-looking assessment. Information from technological magazines and provided by experts is used as well.

RESULTS

The technological complex of sugar production was analyzed, whose parametric diagram is shown in Figure 1.

Proposed solution of this problem involves creation of neural networks and implementation of Sugeno's inference algorithm. It can be implemented with the Matlab tool environment. The unit underlying the construction of these networks has the following main advantages: flexible interpretation of the causal relationships that are generated on the basis of neuro-fuzzy structure and the possibility of further development of the

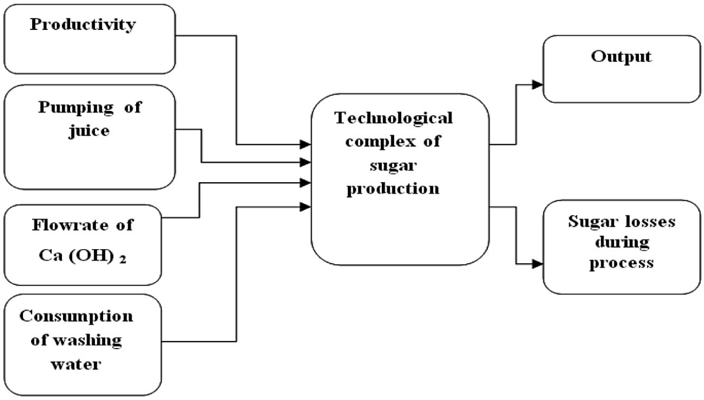

FIGURE 1. Parametric diagram of the main stream

structure. In order implement a solution of the problem, use of an internal subsystem environment Matlab-subsystem development of neuro-fuzzy structures ANFIS (Adaptive Network Based Fuzzy Inference System) – adaptive network fuzzy inference is suggested. It was proposed by Jang [1993] in the early nineties. ANFIS is one of the first versions of hybrid neuro-fuzzy networks – neural network of direct propagation of a special type. Architecture of the neuro-fuzzy network is isomorphic to fuzzy knowledge base. The neuro-fuzzy networks are used for differentiated implementation of triangular norms (multiplication and probabilistic OR), as well as smooth membership functions. This allows applying for adjustment of neuro-fuzzy networks fast learning algorithms of neural networks based on the method of the back-propagation. The architecture and rules for functioning of each layer of ANFIS networks are described below.

ANFIS implements the Sugeno's fuzzy inference system in the form of a five-layer neural network of direct propagation. Establishment of subsequent layers: first layer – terms of input variables, second layer – antecedents (parcel) of fuzzy rules, third layer – normalization of regulation levels, fourth layer – conclusion of the rules, fifth layer – aggregation of results, obtained based on different rules.

Inputs to the network are not allocated into a separate layer. Figure 2 shows the ANFIS network with three input variables (×1, ×2, and ×3) and a set of fuzzy rules. Three terms are used for the assessment of each linguistic input variable. The notation needed for further discussion is hereby introduced: $x1$, $x2$,…, xn – network inputs; y – network output, $R1$: *IF* $x_1 = a_{1,r}$ *AND…AND* $xn - a_{n,r}$ *THEN* $y = b_{0,r} + b_{1,r}x_1 + \dots + b_{n,r}xn$ – fuzzy rule with a serial number r; m – number of rules, $r = \overline{1,m}$; $a_{n,r}$ – vague term with the membership function $\mu_r(x_i)$, used to assess linguistic variable x_i r's rule, $r = \left(\overline{1,m}, i = \overline{1,n}\right)$; $b_{q,r}$ – real numbers in the conclusion of r's rule $r = \left(\overline{1,m}, q = \overline{0,n}\right)$.

The output of each node of the first network layer is the grade of membership, which corresponds to the definition of the term of fuzzy dependence:

$$\mu_r(x_i) = \frac{1}{1 + \left|\frac{x_i - c}{a}\right|^{2b}} \quad (1)$$

where: a, b, c – parameters of the membership function.

The second network layer is a set of logical rules that define the main cause – effect relationships. Outputs of the layer nodes are denoted $\tau_r, r = \overline{1,m}$.

Third layer nodes are calculated relative to the degree of implementation of fuzzy rules:

$$\tau^*_r = \frac{\tau_r}{\sum_{j=\overline{1,m}} \tau_j} \quad (2)$$

Fourth layer node is calculated based on the degree of influence of each rule on network output:

$$y_r = \tau^*_r \cdot \left(b_{0,r} + b_{1,r}x_1 + ... + b_{n,r}x_n\right) \quad (3)$$

In turn, network output is calculated based on the total result of the outputs of all rules:

$$y = y_1 + ...y_r... + y_m \quad (4)$$

Typical procedures for training neural networks can be used to adjust the ANFIS network, because it only uses differentiated functions. Usually, this is a combination of a gradient descent as an algorithm of back-propagation and the least squares method. The algorithm of back-propagation configures the antecedents of the rules, that is, membership functions. The method of least squares estimates coefficients of the conclusions of the rules, because they are linearly related to the output of the network. Each iteration of the setup procedure is performed in two stages. The first stage is input training set, whereas deviation between the desired and actual behavior of network iterative method of least squares determines optimal parameters of the nodes of the fourth layer. In the second stage, the residual variance is transmitted from the output of the network inputs, and modified back-propagation parameters of nodes of the first layer. However, results of the first step of the coefficients do not change conclusions of the rules. The iterative procedure continues until the residual adjustment exceeds a predetermined value.

On the basis of experimental data for a two-week period of sugar mill operation allowed identification of impact onto sugar yield factors such as: consumption of beets, juice pumping, lime milk consumption and consumption of wash water. The neuro-fuzzy structure (Fig. 2) adopted a bell-shaped membership function, because it can reproduce adequately developed neuro-fuzzy model.

A response surface was obtained, reflecting the optimal value of sugar output or loss, according to which control measures can be undertaken. During the research, results were obtained from the network (Fig. 3) in the form of dependence of the sugar from the following factors: consumption of beet [t] and juice pumping [t]. In order to explain contents of the response surfaces of the knowledge base, the following schedules are introduced:

- *Input 1* – mill capacity;
- *Input 2* – juice pumping;
- *Input 3* – lime milk consumption;
- *Input 4* – wash water consumption;
- *Output* – sugar output.

The result of network analysis showed almost absolute convergence of

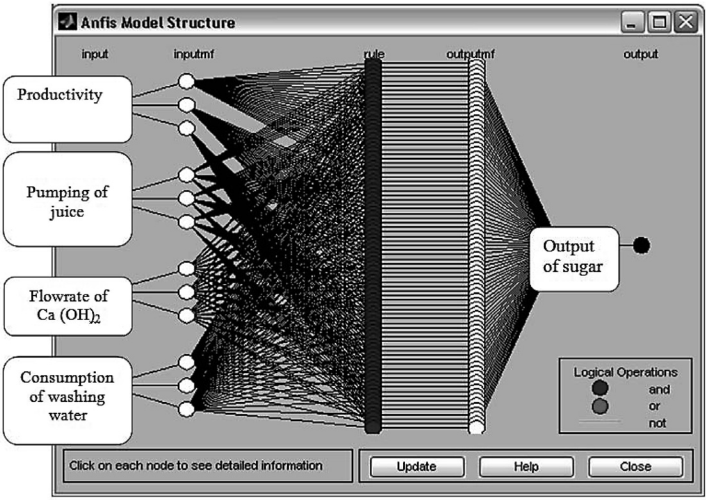

FIGURE 2. The structure of the neuro-fuzzy network

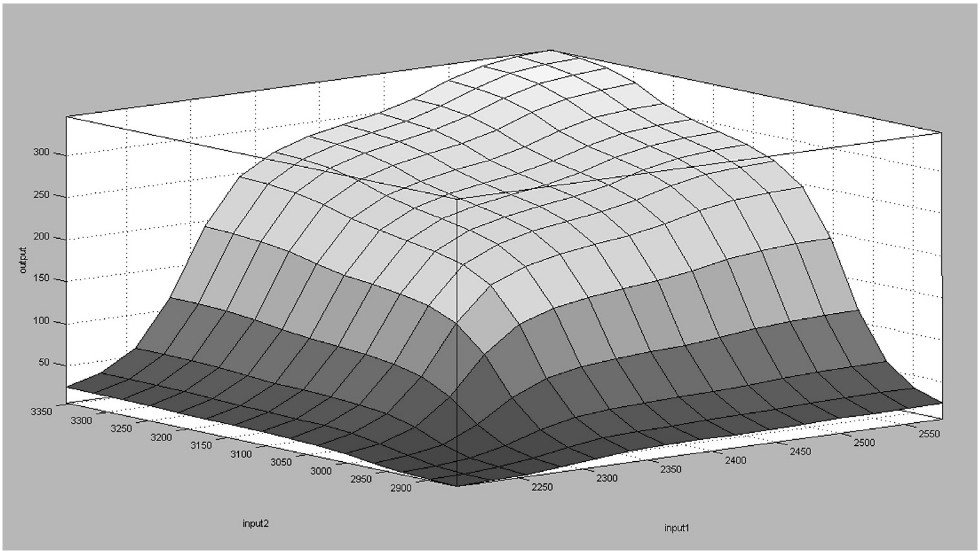

FIGURE 3. Dependence of sugar flow from beet juice and pumping

optimization of the hybrid method used to set the parameters of membership functions with the developed neuro-fuzzy structure. Similarly, the task is investigated with respect to sugar loss in the production process. The kind of response surface allows evaluating the results of functioning of TC's changes in the operating range of existing factors. The proposed approach is to simplify the work of specialists and experts by identifying key relationships between input and output variables of comprehensive sugar production process, and to create information material for decision-makers. The knowledge base was developed, which shows values calculated according to the algorithm of Sugeno's output. In the knowledge base created based on analysis of the output results, basic rules by which it is possible to identify the main causal effect of input channels on the output were determined.

CONCLUSIONS

The authors have developed a new approach to the use of modern information technology, which makes it possible to quickly obtain a basic evaluation of the functioning of the TC:

- feedstock quantity and product yield (sugar);
- manufacturing sugar losses resulting in waste production;
- possibility of obtaining an effective management impact;
- use of SCADA-systems to communicate with the technological control loops mode, individual subsystems and the complex as a whole;
- obtaining generalized technical-economic indicators of the company.

REFERENCES

CHOCHOWSKI A., CHERNYSHENKO I., KOZYRSKYI V., KYSHENKO V., LADANYUK A., LYSENKO V., RESHETIUK V., SMITYUKH Y., SHTEPA V., SHCHERBATIUK V. 2014: Innovative energy-saving technologies in biotechnological objects control. Tsentr Uchbovoii Literatury, Kiev (Ukraine).

JANG J-S R. 1993: ANFIS: Adaptive network based fuzzy inference system. IEEE Trans. Systems & Cybernetics 23: 665–685.

LADANYUK A., PEREPECHAENKO V. 1987: Operational control of technological processes in the food industry. Harvest, Kiev (Ukraine).

LADANYUK A., SHUMIGAY D., BOYKO R. 2013: Case coordinating subsystem technological systems such as continuous. Int. Scient. and Techn. Journal Problems of Control and Informatics 4: 117–122.

Streszczenie: *Technologie informacyjne w identyfikacji procesu produkcyjnego*. Na przykładzie cukrowni wskazano na problemy tworzenia systemu zarządzania i sterowania dużym kompleksem produkcyjnym (TC), w którym kontrolowana jest znaczna liczba wskaźników techniczno-ekonomicznych i kilkaset zmiennych sterujących. Realizacja planowanych zadań wymaga opracowania potężnego systemu informatycznego realizującego ponad 250 funkcji zarządzania. Autorzy przedstawili koncepcję szybkiej oceny funkcjonowania dużych zakładów produkcyjnych z wykorzystaniem nowoczesnych technologii informatycznych.

MS received February 2016

Authors' address:
Andrzej Chochowski
Wydział Inżynierii Produkcji SGGW
Katedra Podstaw Inżynierii
ul. Nowoursynowska 164, 02-787 Warszawa
Poland
e-mail: andrzej_chochowski@sggw.pl