Igor Sikorsky Kyiv Polytechnic Institute

2019 IEEE 39th International Conference on ELECTRONICS AND NANOTECHNOLOGY (ELNANO)

CONFERENCE PROCEEDINGS

April 16-18, 2019
Kyiv, Ukraine

2019 IEEE 39th International Conference on ELECTRONICS AND NANOTECHNOLOGY (ELNANO)

Copyright © 2019 by the Institute of Electrical and Electronics Engineers, Inc.
All rights reserved.

Copyright and Reprint Permission

Copyright and Reprint Permission: Abstracting is permitted with credit to the source. Libraries are permitted to photocopy beyond the limit of U.S. copyright law for private use of patrons those articles in this volume that carry a code at the bottom of the first page, provided the per-copy fee indicated in the code is paid through Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923. For reprint or republication permission, email to IEEE Copyrights Manager at pubs-permissions@ieee.org.

All rights reserved. Copyright@2019 by IEEE.

IEEE Catalog Number: CFP1905U-USB
ISBN: 978-1-7281-2064-5

Organizing Committee of IEEE ELNANO-2019
Work phone: +38 (044) 204-99-09 E-mail:
elnano@ieee.org.ua Faculty of Electronics,
Igor Sikorsky Kyiv Polytechnic Institute
Polytekhnichna Str. 16/9, Block #12, off. 423,
03056, Kyiv, Ukraine

ORGANIZERS& PARTNERS

IEEE
UKRAINE SECTION

IEEE COMMUNICATIONS SOCIETY
MTT-S
IEEE
Central Ukraine chapter
ELECTRONICS PACKAGING SOCIETY
SSCS
ELECTRON DEVICES SOCIETY

IEEE
EMB Ukraine Chapter

IEEE EAST UKRAINE
JOINT CHAPTER 1995

IEEE Ukraine Section
IE/IA/PE Societies
Joint Chapter

IEEE Ukraine Section
PE/IE/PEL Societies
Joint Chapter

IEEE KPI
Student Branch

Ukraine
IEEE AES\SP
Joint Chapter

НАН УКРАЇНИ
ІФН
ISP
NAS UKRAINE

INTERNATIONAL TECHNOLOGY CENTER
UNITED STATES ARMY
ATLANTIC

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
MCMXXXIII

IMD
INSTITUTE OF MICRODEVICES
NATIONAL ACADEMY OF SCIENCE OF UKRAINE

FINANCIAL SUPPORT

Теле Оптик
НЕО

COMMITTEES

ORGANIZING COMMITTEE

General Chairperson:

Prof. Yuriy Yakymenko	Academician, First Vice Rector of Igor Sikorsky Kyiv Polytechnic Institute, IEEE Life Member, Kyiv, Ukraine

Technical Program Committee Chairpersons:

Prof. Alexander Nosich	Institute of Radiophysics and Electronics of NASU, IEEE Fellow, Kharkiv, Ukraine
Prof. Volodymyr Timofeyev	Igor Sikorsky Kyiv Polytechnic Institute, IEEE Senior Member, Kyiv, Ukraine
Prof. Klaus-Jurgen Wolter	Technical University of Dresden, IEEE Senior Member, Germany
Prof. Felix Yanovsky	National Aviation University, Vice Chair of IEEE Ukraine Section, IEEE Fellow, Kyiv, Ukraine
Prof. Valerii Zhuikov	Igor Sikorsky Kyiv Polytechnic Institute, Kyiv, Ukraine

Publication Chairpersons:

Prof. Alexander Borisov	Igor Sikorsky Kyiv Polytechnic Institute, Kyiv, Ukraine
Prof. Yuriy Poplavko	Igor Sikorsky Kyiv Polytechnic Institute, Kyiv, Ukraine

Finance Chairpersons:

Dr. Mikhail Balaban	Institute of Radiophysics and Electronics of NASU, Treasurer of IEEE Ukraine Section, Kharkiv, Ukraine

TECHNICAL PROGRAM COMMITTEE

Full list of TPC can be found at ***http://elnano.ieee.org.ua***

LOCAL ORGANIZING COMMITTEE

Local Chairpersons:

Dr. Kateryna Ivanko, Igor Sikorsky Kyiv Polytechnic Institute, Ukraine

Anna Poreva, Igor Sikorsky Kyiv Polytechnic Institute, Ukraine

Members:

Oleksandr Stefanovskyi, Igor Sikorsky Kyiv Polytechnic Institute, Kyiv, Ukraine

Oleksandra Karnaukh, Igor Sikorsky Kyiv Polytechnic Institute, Kyiv, Ukraine

TABLE OF CONTENTS

2019 IEEE 39th International Conference on Electronics and Nanotechnology (ELNANO)

Comparison Between PID and Fuzzy Regulator for Control Evaporator Plants

Mykhailo Hrama
Department of integrated automated control systems
National University of Food Technology
Kyiv, Ukraine
mpgmay6@gmail.com

Viktor Sidletskyi
Department of integrated automated control systems
National University of Food Technology
Kyiv, Ukraine
vmsidletskiy@gmail.com

Igor Elperin
Department of integrated automated control systems
National University of Food Technology
Kyiv, Ukraine
ivelperin@gmail.com

***Abstract*— In this paper, a comparison is made between FID and fuzzy controller. The purpose of the study is to determine when the use of which type of regulation will achieve the best indicators of quality control for the regulation of the evaporator. The regulation of such responsible parameters as levels of concentrated juice in the evaporator's buildings, which directly affect the quality and cost of manufactured products, is carried out. First, a mathematical model was developed in the space of states in the Matlab environment and results were obtained with respect to the variation of the problem relative to the initial conditions and with respect to perturbation. Secondly, a mathematical model with a PID-regulator was developed and transient processes for control circuits in all control channels were obtained. Thirdly, a mathematical model with a fuzzy controller was developed and transient processes for control circuits in all control channels were obtained. When comparing the mathematical model with PID and the fuzzy controller, it was concluded that the use of neuro-fuzzy regulation is more appropriate as it leads to an increase in the qualitative parameters of the process compared with the system with PID regulators.**

Keywords— **sugar juice, mathematical model, evaporator plant, neuro-fuzzy regulation**

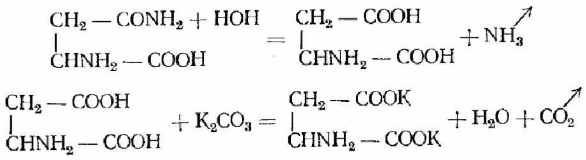
I. INTRODUCTION

The work of this evaporator plant has several advantages: reducing the sensitivity to the changes in the flow and condensation of the juice that enters the evaporation stage; reducing the time of juice stay in high temperature zones due to the transportation of steam extractions from the first body into the last one; reduction of the duration of cooking concentrated juice in evaporators at a vacuum by increasing the temperature of the heating steam.

Since the evaporation process is uninterrupted, and the amount of juice that comes in and extraction of juice vapor varies over time. Maintaining the optimal operating mode of the evaporator plant is possible only in case of the automatic control of the evaporation process. The optimal operating mode is a mode that provides a given productivity of the evaporator plant provided that the juice levels are stabilized in the bodies of evaporating apparatus, which guarantees the best conditions for evaporation and the uninterrupted supply of consumers with the necessary vapor of the required capacity [1].

An analysis of the existing evaporator plant automation systems has shown that the evaporation capacity of the evaporator plant is determined by the useful temperature difference between the heating and the juice vapor in the bodies. It is ensured by stabilizing the heat transfer on the evaporator plant as the difference between the solution temperature in the first body and the fifth body (concentrator). The process of evaporation intensifies and becomes more economical in case of increase of heat dissipation between the first and fifth bodies. There are many options for adjusting the levels on the evaporator plant circulation bodies. The simplest ones are level regulation on the inflow with blocking on the drainage and regulation on the drainage with the blocking on the inflow. However, this causes an increase in the irregularity coefficient of juice flow. Therefore, systems of smooth action on the drainage and inflow of juice into the apparatus were developed.

In case of deviations from the optimal regime in the process of evaporation leads to the decomposition and caramelization of sucrose and causes a decrease in alkalinity. Reducing of alkalinity at the evaporator plant leads to a decomposition of amides, such as aspargine (Fig. 1.). Juice vapors and condensates (ammonia waters) from the evaporator contain ammonia, carbon dioxide and carbon monoxide.



$$\begin{array}{l} CH_2-CONH_2 + HOH \\ | \\ CHNH_2-COOH \end{array} = \begin{array}{l} CH_2-COOH \\ | \\ CHNH_2-COOH \end{array} + NH_3\nearrow$$

$$\begin{array}{l} CH_2-COOH \\ | \\ CHNH_2-COOH \end{array} + K_2CO_3 = \begin{array}{l} CH_2-COOK \\ | \\ CHNH_2-COOK \end{array} + H_2O + CO_2\nearrow$$

Fig. 1. Aspargin decomposition

The above factors cause a change in the properties of glucose ($C_6H_{12}O_6$), which is contained in sugar juice. In case if glucose is heated to a temperature of 160°C and hold for a long time, glucose anhydride is formed from it, as a result of splitting off of one of two water molecules ($C_6H_{10}O_5$). It is not possible to form granulated sugar out of such juice. In case of further increase of temperature to 220°C sugar juice turns into caramel without taste or bitter assaram (a substance formed during heating of products of plant and animal origin). These substances are no longer capable of fermentation and sugar formation. In order to prevent overheating and overexposure of sugar syrup, the best quality control parameters must be observed. That is why the comparison between PID and fuzzy regulator for control evaporator plants is carried out.

II. ANALYSIS OF RECENT STUDIES AND PUBLICATIONS

Improving the evaporation process is an urgent task. In this paper [2] author consider the model of the evaporation process, which takes into account the balance of mass and energy in the three components of the evaporation process. There is a unique distributor surface of the juice heater if the overall surface of the heater is fixed. In this paper [3], the

978-1-7281-2064-5/19/$31.00 ©2019 IEEE

linearization process of a nonlinear model consisting of 14 nonlinear levels of the primary order, which is a dynamic model of the evaporator apparatus, is studied. In the work, for the first time, a function was found regarding the change in product concentration on the deviation of the flow rate of the liquid. The paper [4] proposes a fuzzy evaporator model that reduces the computational time using an evaporator based on the Rankine cycle. The results showed that fuzzy technology can significantly reduce the time of calculation by predicting the outlet of the supercritical evaporator in the waste heat recovery system. In the paper [5] the author argues that using intelligent control, it is possible to provide a faster decrease in the temperature of the housing and achieve a more stable overheating control in the first evaporator tank. It has been proved in this paper [6] that evaporation control can be implemented by recirculating the liquid in the evaporation section or by feeding only the liquid into the evaporator. In this paper [7], the fuzzy PID controller is investigated as a discrete version of the usual PID controller, so it retains the same structure, but has a self-adjusted control factor. The author proves that it is possible to improve the classical PID regulator with a certain adaptive control ability. This paper [8] represents a new PID regulator of fuzzy logic. This regulator is a fuzzy PID controller with a computational efficient analytical circuit. The author proves that the controller is stable with a restricted input / restricted output The need to upgrade existing management systems is specified in paper [9]. This study presents some approaches used for the distributed level of technological processes control. The elucidation of these approaches is useful for better understanding of the processes occuring during the formation of control action, especially in cases when the software developers for industrial ACS use the big amount of settings for system customatization. This approach is reasonable only for the qualified specialists with significant work experience. However, knowledge of the internal processes by such specialists can also provide more flexible work when structuring the data. In paper [10] states that one of the advanced methods of improving control systems is the addition of fuzzy and neuron-clear logic. A method of dynamic power control of steam boilers at CHP of small power according to the current needs of consumers was studied. The methods of dynamic control of the power of boiler systems were analyzed using fuzzy logic and adaptive neural networks. One of the possible options for boiler capacity control is the use of fuzzy inference units (so-called fuzzy system). The control action is formed by consistency checking of fuzzy rules to the actual parameters of the system. Rules are created according to the operator's experience, which reflects his / her actions when changing the technology parameters.

III. MATHEMATICAL MODEL OF FIVE-BODY EVAPORATOR PLANT

In the mathematical models of the evaporator plant (Fig. 2), often there are no distinct channels of disturbance and control that are inconvenient during the development of the automation system.

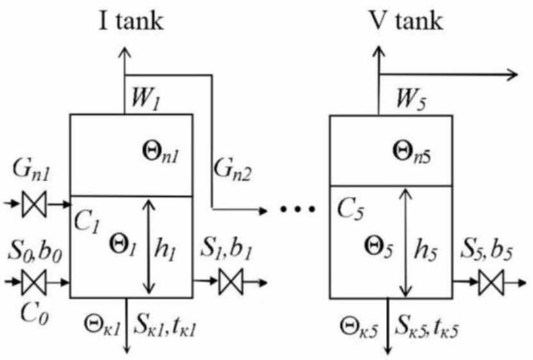


Fig. 2. Mathematical model of evaporator plant

Θ_i — the temperature of the boiling juice in the i-body of evaporator plant [°C]; i = 0...5 — corresponds to the number of evaporator plant body; Θni — the temperature of the steam in the i-body of evaporator plant [°C]; h_i— the level of juice accordingly in the i body of evaporator plant [m, % to the length of the tubes of the heating surface]; S_0,S_1,S_2,S_3,S_4,S_5— inflow of juice into the I body, outflow of juice from the I body and an inflow into the II body, outflow from the II body and an inflow into the III body, outflow from the III body and an inflow into the IV body, outflow from the IV body and an inflow into the V body, outflow from V body accordingly [kg/s]; W_i — the flow of steam generated in the i-body of the evaporator body [kg/s]; G_{ni} — the consumption of a warming steam in the i-body of evaporator plant [kg/s]; b_i — concentration of dry substance in the i-body of evaporator plant [%]; S_{ki}- — consumption of condensate in the i-body of evaporator plant [kg/s]; Θ_{ki} — condensate temperature in the i-body of evaporator plant [°C]; C_i — content of sucrose in juice in the i-body of evaporator plant [%]. It is necessary to divide this system into subsystems, which are united by essential internal interconnections between variables, and are described by mathematical models that are similar in structure and regulated according to a similar scheme

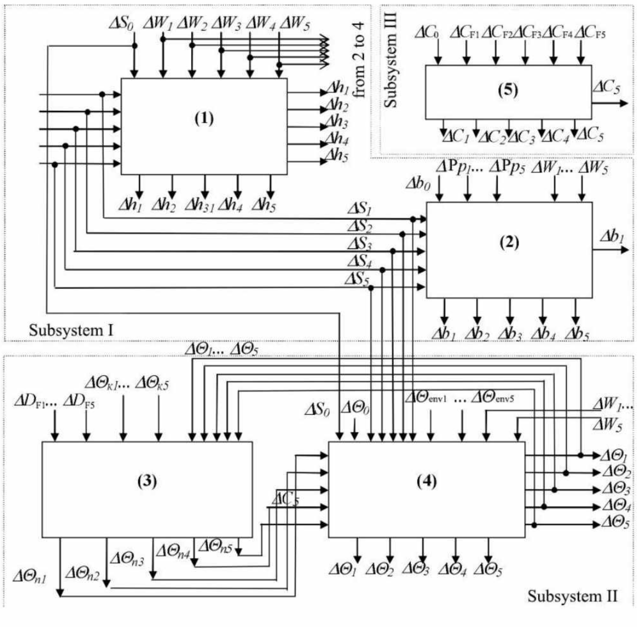


Fig. 3. Parametric scheme of evaporator plant

A simplified parametric scheme of the evaporator plant with distinguished subsystems is shown on Fig. 3. [11]. Here are the differential equations of each of the subsystems for the nominal mode:

subsystem I

$$\begin{cases} 4{,}391\dfrac{\partial(\Delta h_1)}{\partial t}=\Delta S_0-\Delta S_1-\Delta W_1, \\ 6{,}820\dfrac{\partial(\Delta h_2)}{\partial t}=\Delta S_1-\Delta S_2-\Delta W_2, \\ 5{,}056\dfrac{\partial(\Delta h_3)}{\partial t}=\Delta S_2-\Delta S_3-\Delta W_3, \\ 4{,}973\dfrac{\partial(\Delta h_4)}{\partial t}=\Delta S_3-\Delta S_4-\Delta W_4, \\ 3{,}974\dfrac{\partial(\Delta h_4)}{\partial t}=\Delta S_4-\Delta S_5-\Delta W_5. \end{cases} \tag{1}$$

equations that describe the levels according to bodies of evaporator plant (1).

$$\begin{cases} 187{,}34\dfrac{\partial(\Delta b_1)}{\partial t}+\Delta b_1=-0{,}2\Delta S_0+1{,}38\Delta b_0+0{,}72\Delta W_1-0{,}04\Delta Pp_1, \\ 589{,}17\dfrac{\partial(\Delta b_2)}{\partial t}+\Delta b_2=0{,}8\Delta S_1+1{,}67\Delta b_1+2\Delta W_2-0{,}066\Delta Pp_2, \\ 655{,}43\dfrac{\partial(\Delta b_3)}{\partial t}+\Delta b_3=-1{,}5\Delta S_2+1{,}5\Delta b_2+4{,}49\Delta W_3-0{,}1\Delta Pp_3, \\ 1131{,}42\dfrac{\partial(\Delta b_4)}{\partial t}+\Delta b_4=-1{,}67\Delta S_3+1{,}29\Delta b_3+7{,}46\Delta W_4-0{,}13\Delta Pp_4, \\ 853{,}1\dfrac{\partial(\Delta b_5)}{\partial t}+\Delta b_5=-1{,}01\Delta S_4+1{,}12\Delta b_4+9{,}37\Delta W_5-0{,}14\Delta Pp_5. \end{cases} \tag{2}$$

equations that describe concentrations according to bodies of evaporator plant, where Pp_i — loss of sugar during a thermal decomposition in the i-th apparatus (2);

subsystem II:

$$\begin{cases} 13{,}89\dfrac{\partial(\Delta\Theta_1)}{\partial t}+\Delta\Theta_1=0{,}1868\Delta S_0+0{,}0482\Delta\Theta_0+0{,}9999\Delta\Theta_{n1}+ \\ \qquad +6{,}50\cdot10^{-6}\Delta\Theta_{env1}-0{,}1792\Delta S_1-0{,}9251\Delta W_1, \\ 21{,}78\dfrac{\partial(\Delta\Theta_2)}{\partial t}+\Delta\Theta_2=0{,}1620\Delta S_1+0{,}0315\Delta\Theta_1+0{,}9826\Delta\Theta_{n2}+ \\ \qquad +8{,}42\cdot10^{-6}\Delta\Theta_{env2}-0{,}1394\Delta S_2-0{,}8362\Delta W_2, \\ 22{,}50\dfrac{\partial(\Delta\Theta_3)}{\partial t}+\Delta\Theta_3=0{,}2136\Delta S_2+0{,}0266\Delta\Theta_2+0{,}9839\Delta\Theta_{n3}+ \\ \qquad +8{,}98\cdot10^{-6}\Delta\Theta_{env3}-0{,}1794\Delta S_3-1{,}28\Delta W_3, \\ 35{,}97\dfrac{\partial(\Delta\Theta_4)}{\partial t}+\Delta\Theta_4=0{,}2948\Delta S_3+0{,}0264\Delta\Theta_3+0{,}9815\Delta\Theta_{n4}+ \\ \qquad +1{,}45\cdot10^{-6}\Delta\Theta_{env4}-0{,}242\Delta S_4-2{,}1\Delta W_4, \\ 45{,}10\dfrac{\partial(\Delta\Theta_5)}{\partial t}+\Delta\Theta_5=0{,}4905\Delta S_4+0{,}0374\Delta\Theta_4+0{,}9704\Delta\Theta_{n5}+ \\ \qquad +2{,}58\cdot10^{-6}\Delta\Theta_{env5}-0{,}386\Delta S_5-4{,}26\Delta W_5. \end{cases} \tag{3}$$

equations (3) that describe the temperature of the steam-juice mixture according to bodies of evaporator plant, where Θ_{envi} - heat loss into the environment in the i-th apparatus [°C].

$$\begin{cases} 7{,}07\dfrac{\partial(\Delta\Theta_{n1})}{\partial t}+\Delta\Theta_{n1}=0{,}7229\Delta G_{n1}+\Delta\Theta_1-0{,}0146\Delta\Theta_{k1}- \\ \qquad -0{,}9251\Delta D_{F1}, \\ 9{,}025\dfrac{\partial(\Delta\Theta_{n2})}{\partial t}+\Delta\Theta_{n2}=\Delta\Theta_2-0{,}076\Delta\Theta_{k2}-0{,}851\Delta D_{F2}, \\ 8{,}04\dfrac{\partial(\Delta\Theta_{n3})}{\partial t}+\Delta\Theta_{n3}=\Delta\Theta_3-0{,}0153\Delta\Theta_{k3}-1{,}3\Delta D_{F3}, \\ 13{,}19\dfrac{\partial(\Delta\Theta_4)}{\partial t}+\Delta\Theta_{n4}=\Delta\Theta_4-0{,}0138\Delta\Theta_{k4}-2{,}1445\Delta D_{F4}, \\ 14{,}28\dfrac{\partial(\Delta\Theta_5)}{\partial t}+\Delta\Theta_{n5}=\Delta\Theta_5-0{,}094\Delta\Theta_{k5}-4{,}4\Delta D_{F5}. \end{cases} \tag{4}$$

equations (4) that describe the temperature of the steam according to bodies of evaporator plant, where D_{Fi} — the consumption of non-subsidized gases in the i-th apparatus, subsystem III

$$\begin{cases} 398{,}59\dfrac{\partial(\Delta C_1)}{\partial t}+\Delta C_1=1{,}38\Delta C_0-0{,}04\Delta C_{F1}, \\ 753{,}49\dfrac{\partial(\Delta C_2)}{\partial t}+\Delta C_2=1{,}67\Delta C_1-0{,}04\Delta C_{F2}, \\ 1399{,}89\dfrac{\partial(\Delta C_3)}{\partial t}+\Delta C_3=1{,}5\Delta C_2-0{,}1\Delta C_{F3}, \\ 1948{,}73\dfrac{\partial(\Delta C_4)}{\partial t}+\Delta C_4=1{,}29\Delta C_3-0{,}13\Delta C_{F4}, \\ 1523{,}92\dfrac{\partial(\Delta C_5)}{\partial t}+\Delta C_5=1{,}12\Delta C_4-0{,}14\Delta C_{F5}, \end{cases} \tag{5}$$

equations (5) that describe the content of sucrose according to bodies of evaporator plant, where C_{Fi} — content of sucrose, which is decomposed into the i-th apparatus.

For a subsystem III, it is impossible to construct an optimal regulator, because it only includes coordinates of state and disturbance, that is, the subsystem is uncontrolled. In practice, only the content of sucrose C_5 in the fifth body of the evaporator plant is controlled [11].

The mathematical model is compiled taking into account the following assumptions: the evaporation apparatus is considered an object with concentrated parameters as a link of complete mixing; through channels of disturbance and control the delay in the juice pipeline shall be not taken into account as insignificant for the dynamics of the evaporation plant; the parameters included in the equation are taken independent of time and average by body.

In order to transfer the control object into the space of the state variables, it is first necessary to record the vectors (each component of the vector), that is x(t), u(t), w(t). Then, based on the system of differential equations (1) and a mathematical model in the space of state variables (6)

$$\begin{aligned} \dot{x}(t)&=Ax(t)+Bu(t)+Fw(t), \\ y(t)&=Cx(t). \end{aligned} \tag{6}$$

Then the stationary reverse (7) connection will be:

$$u(t)=-Kx(t) \tag{7}$$

where K – an array of size m x n.

The object equation (8) can be rewritten as follows:

$$\dot{x}(t)=Ax(t)-BKx(t)=[A-BK]x(t) \quad (8)$$

Then MATLAB environment shall be used.

The matrix were created on the basis of expressions (1-5) using the synthesis of modal control

Enter matrix:

Matrix A and D of the model has components that are equal to zero.

$$\text{Matrix } C=\text{diag}(1,1,1,1,1) \quad (9)$$

$$B=\begin{vmatrix} -0.2277 & 0 & 0 & 0 & 0 \\ 0.1466 & -0.1466 & 0 & 0 & 0 \\ 0 & 0.1978 & -0.1978 & 0 & 0 \\ 0 & 0 & 0.2011 & -0.2011 & 0 \\ 0 & 0 & 0 & 0.2534 & -0.2534 \end{vmatrix} \quad (10)$$

$$F=\begin{vmatrix} 0.2277 & -0.2277 & 0 & 0 & 0 & 0 \\ 0 & 0 & -0.1466 & 0 & 0 & 0 \\ 0 & 0 & 0 & -0.1978 & 0 & 0 \\ 0 & 0 & 0 & 0 & -0.2011 & 0 \\ 0 & 0 & 0 & 0 & 0 & -0.2534 \end{vmatrix} \quad (11)$$

The actual part=0. Consequently, the roots of the imaginary axis of such an object are on the verge of stability.

The observation matrix Nk can be constructed in two ways: by directly setting the formula or by using the *ctrb* function, the input parameters of which are matrices A and B. In order to determine the rank of the matrix Nk one shall use the built-in *rank* function: Nk=ctrb(A, B), rank(Nk). The matrix rank is 5

Since the rank of the matrix coincides with the dimensionality of the state spaces, the object is completely observable.

For calculation of the amplification matrix of the K regulator using the modulator's algorithm, the *place* library function shall be used (p1=0,0003), the input parameters for which are matrices A and B, and the output is the synthesized matrix K.

In order to construct the roots of a closed system, one shall use the *pzmap* function. The input parameter for which there is an object in the space of variables of state ss-type, which is given using the ss function of the format: sys=ss(A_sys,F,C,D) (Fig. 4.).

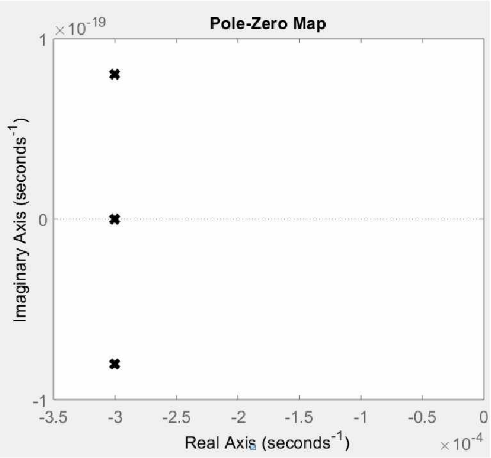


Fig. 4. Pole-zero map for T=10000

Consequently, the closed system is stable, since the poles are located in the left half-plane of the complex plane.

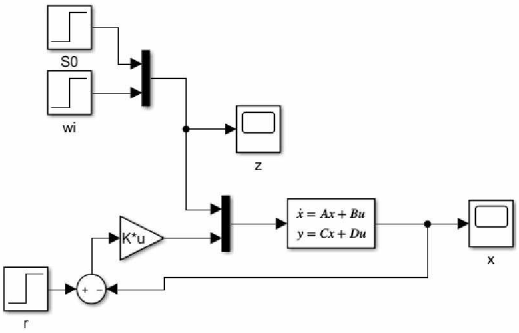


Fig. 5. The schematic structure of an object in the Simulink environment

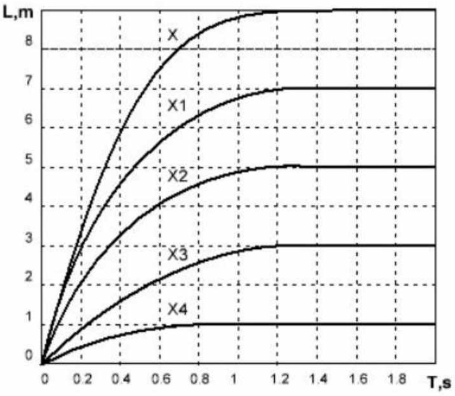


Fig. 6. The results in relation to the task change: X – level tank I, X1 – level tank II, X2 – level tank III, X3 – level tank IV, X5 – level tank V

In order to construct a schematic diagram of an object with a matrix controller (Fig. 5), one shall use the State-Space (Continuous section) block in the Simulink environment for entering an object into the space of the state variables. It should be remembered that the inputs and outputs of the State-Space block are vectors, so Mux and Demux blocks shall be additionally used (Signal Routing section). For task and disturbing signals, Step blocks (Sources section) shall be used. For construction of transient processes relative to initial deviations, one shall use the Initial conditions option in the block of State-Space object.

The results in relation to the task change are shown in Fig. 6. The results in relation to the initial conditions are shown in Fig. 7. The results in relation to the disturbance are shown in Fig. 8.

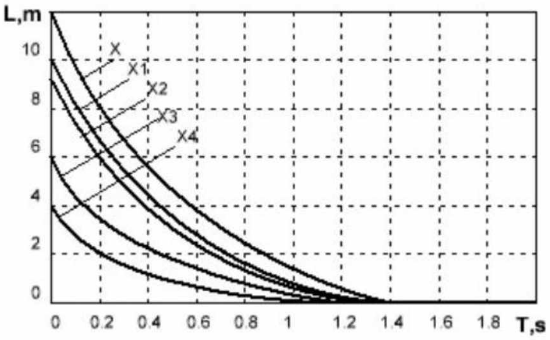


Fig. 7. The results in relation to the initial conditions: X – level tank I, X1 – level tank II, X2 – level tank III, X3 – level tank IV, X5 – level tank V

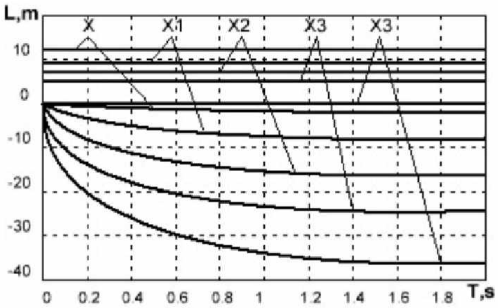


Fig. 8. The results in relation to the disturbance: X – level tank I, X1 – level tank II, X2 – level tank III, X3 – level tank IV, X5 – level tank V

IV. MATHEMATIC MODEL WITH PID-REGULATOR

Mathematic model with PID-regulator is shown in Fig. 9.

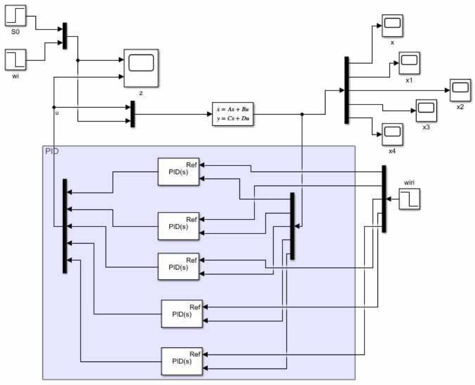


Fig. 9. Mathematic model with PID-regulator.

Setting parameters for regulators are calculated in the Matlab system:

Channel X: proportional: 1.36; integral: 0.08; derivative: 0,95; channel X1: proportional: 4.85; integral: 0.64; derivative: 1.47; channel X2: proportional: 0.65; integral: 0.02; derivative: 0.12; channel X3: proportional: 2.38; integral: 0.21; derivative: 0.9; channel X4: proportional: 2.99; integral: 0.42; derivative: 0.7;

Transition processes for each control loop are shown in Fig. 10.

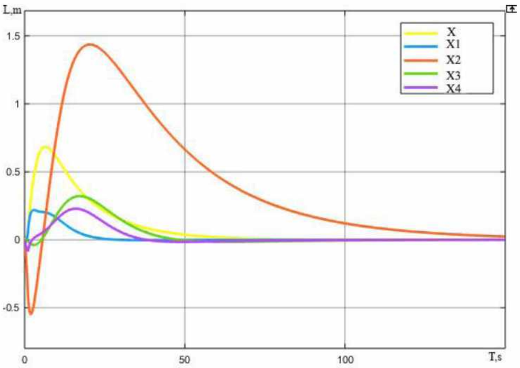


Fig. 10. Transition process via channels: X – level tank I, X1 – level tank II, X2 – level tank III, X3 – level tank IV, X5 – level tank V.

V. MATHEMATIC MODEL WITH FUZZY REGULATOR

Mathematic model with fuzzy-regulator is shown in Fig. 11.

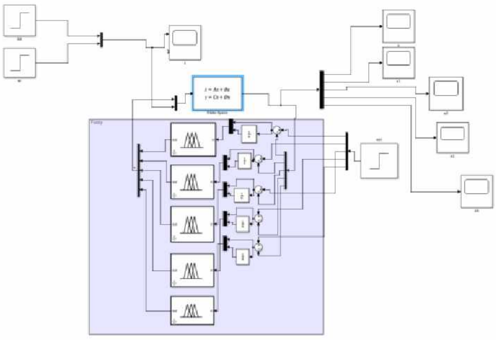


Fig. 11. Mathematic model with fuzzy regulator

Setting the fuzzy level controller in tank I (Fig.12-13)

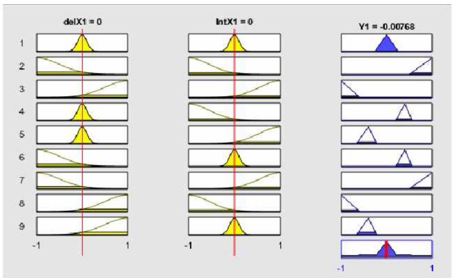


Fig. 12. Graphical representation of the operation of the fuzzy conclusion algorithm: delX1 – proportional term; IntX1 – integral term; Y1 – result.

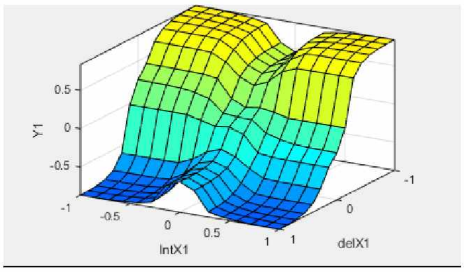


Fig. 13. Reflecting surface of the response of the fuzzy algorithm: delX1 – proportional term; IntX1 – integral term; Y1 – result.

Similar settings for other fuzzy controls. Transition processes for each control loop are shown in Fig. 14.

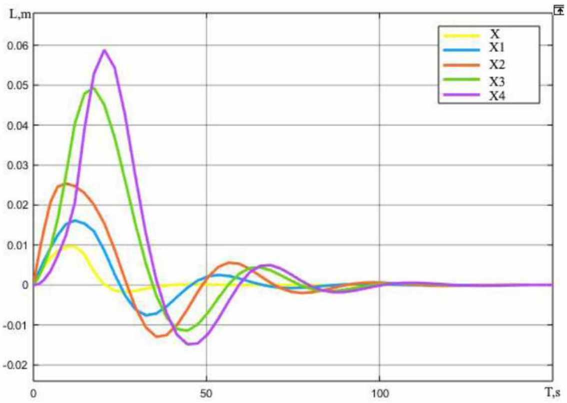


Fig. 14. Transition process via channels: X – level tank I, X1 – level tank II, X2 – level tank III, X3 – level tank IV, X5 – level tank V.

VI. DISCUSSION SECTION

So, we can see that use of a fuzzy regulator via the channel X (Fig. 15) we get a significant decrease in the amplitude of the oscillation (from 0.68 m when using the PID-regulator to 0.001 m with the use of a fuzzy regulator) and a shorter transition process time (from 75 s when using the PID-regulator up to 55 s when used fuzzy regulator). When comparing PID and fuzzy controllers via the channel X1, we can see that use of a fuzzy regulator we get a significant decrease in the amplitude of the oscillation (from 0.6 m when using the PID-regulator to 0.016 m using a fuzzy regulator). When comparing PID and fuzzy controllers via the channel X2, we can see that use of a fuzzy regulator we obtain a significant decrease in the amplitude of the oscillation (from 1.3 m when using the PID-regulator to 0.025 m using a fuzzy regulator), higher quality and a shorter transition process time (from 140 s when using the PID-regulator to 110 s using a fuzzy regulator).

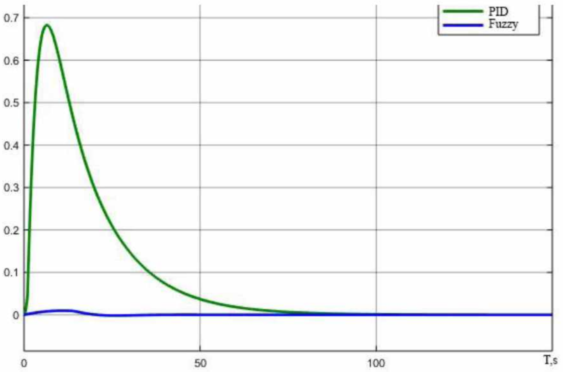


Fig. 15. Transient processes of the operation of PID and fuzzy regulators.

Similarly, when comparing PID and fuzzy controllers via the channel X3, we can see that use of a fuzzy regulator we obtain a significant decrease in the amplitude of the oscillation (from 0.25 m when using the PID-regulator to 0.05 m using a fuzzy regulator) and a shorter transition process time (from 145 s when using the PID-regulator to 110 s when used fuzzy regulator). PID and fuzzy controllers via the channel X4, we can see that the use of a fuzzy regulator we get a significant decrease in the amplitude of the oscillation (from 0.2 m when using the PID-regulator to 0.06 m using a fuzzy regulator).

VII. CONCLUSION

In this paper, a comparison was made between PID and fuzzy controller. The study found that under which conditions the use of any type of regulation would achieve the best quality control indicators for evaporator control. According to the results of the study, it can be concluded that the use of neuronecyte regulation is more appropriate, as this leads to an increase in the quality parameters of the process compared with the system with PID - regulators. The first step was to develop a mathematical model in the state space in the Matlab environment (Fig. 5). On (Fig. 6), transient processes are shown when the task is changed; on them, it can be said that the time of the transient process in the range from 0.8 to 1.2 s, which is a good result, but the values of the deviation of the levels in the cases for the evaporation process are too high (9 m by channel X, 7 m behind channel X1, 5 m behind channel X2, 3 m behind channel X3 and 1 m behind channel X4). The next step was the development of a mathematical model with the PID-regulator (Fig. 9). As a result of the simulation transient processes were obtained for control circuits in all five control channels (Fig. 10). In this case, the time of transitions is in the range of 60 s through the channel X1 to 145 s through the channel X2. Consequently, the time of regulation has increased in relation to the previous experiment, but this led to a significant decrease in the deviations of levels in the cases (0.68 m along the channel X, 0.6 m along the X1 channel, 1.3 m along the channel X2, 0.25 m along the channel X3 and 0.2 m along the channel X4). Next, a mathematical model with a fuzzy controller was developed (Fig. 11). During the simulation, transient processes were also obtained for control circuits in all control channels (Fig. 14). In this case, the transient time is in the range from 50 s through the channel X1 to 110 s through the channel X2, which is the best result compared to the PID regulator. In comparison with the previous study, the levels in the buildings (0,001 m along the channel X, 0,016 m along the channel X1, 0,025 m along the channel X2, 0,05 m along the channel X3 and 0,06 m along the channel X4) also decreased significantly. Thus, comparing the control channels with the PID regulator and the fuzzy controller (for example, Fig. 15), it can be seen that the use of fuzzy regulation significantly increases the quality of transients, in particular: in all cases, the amplitude of the oscillation decreases and in almost all cases the time of the transient the process. .

REFERENCES

[1] I.V. Elperin, O.M. Pupena, V.M. Sidletskii, S.M. Shved: Automation of production processes: Textbook. Lyra-K Publishing House, p. 378, 2015.

[2] S. Chantasiriwan, “Distribution of juice heater surface for optimum performance of evaporation process in raw sugar manufacturing,” Journal of Food Engineering, vol. 195, pp. 21–30, Feb. 2017.

[3] O. P. Verma, G. Manik, and V. K. Jain, “Simulation and control of a complex nonlinear dynamic behavior of multi-stage evaporator using PID and Fuzzy-PID controllers,” Journal of Computational Science, vol. 25, pp. 238–251, Mar. 2018.

[4] J. Chowdhury, B. Nguyen, and D. Thornhill, “Modelling of Evaporator in Waste Heat Recovery System using Finite Volume Method and Fuzzy Technique,” Energies, vol. 8, no. 12, pp. 14078–14097, Dec. 2015.

[5] P. G. Jolly, C. P. Tso, P. K. Chia, and Y. W. Wong, “Intelligent Control to Reduce Superheat Hunting and Optimize Evaporator Performance in Container Refrigeration,” HVAC&R Research, vol. 6, no. 3, pp. 243–255, Jul. 2000.

[6] S. Lahtinen, “Identification of fuzzy controller for use with a falling-film evaporator,” Food Control, vol. 12, no. 3, pp. 175–180, Apr. 2001.

[7] K. S. Tang, Kim Fung Man, Guanrong Chen, and S. Kwong, “An optimal fuzzy PID controller,” IEEE Transactions on Industrial Electronics, vol. 48, no. 4, pp. 757–765, 2001.

[8] J. Carvajal, “Fuzzy PID controller: Design, performance evaluation, and stability analysis,” Information Sciences, vol. 123, no. 3–4, pp. 249–270, Apr. 2000.

[9] V.M. Sidletskyi, I.V. Elperin, V.V. Polupan: Analiz ne vymiriuvalnykh parametriv na rivni rozpodilenoho keruvannia dlia avtomatyzovanoi systemy, obiektiv i kompleksiv kharchovoi promyslovosti. Naukovi pratsi Natsionalnoho universytetu kharchovykh tekhnolohii, vol. 22(3), pp. 7–15, 2016.

[10] M.V. Lapin, V.M. Sidletskyi: Vykorystannia system nechitkoi lohiky dlia dynamichnoho upravlinnia potuzhnistiu parovykh kotloahrehativ Naukovi pratsi Natsionalnoho universytetu kharchovykh tekhnolohii , vol. 22(4), pp. 24 – 31, 2016.

[11] N. M. Lutskaya, L. O. Vlasenko: Development of multidimensional optimal controllers for sugarmill evaporation plant which operates in interval indetermination conditions. Naukovi pratsi Natsionalnoho universytetu kharchovykh tekhnolohii, vol. 52, pp. 48–61, 2013.