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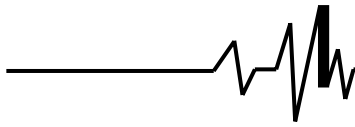
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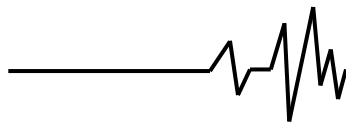
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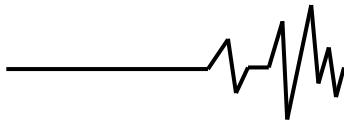
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університет****UDK 621.928****DOI: 10.37128/2306-8744-2022-2-8****SYSTEMS OF AUTOMATIC
CONTROL FOR HYDROPONIC
TECHNOLOGICAL COMPLEXES**

Hydroponic equipment allows to resolve a problem of supply with fresh greenery, vegetables and fruits for quite different countries and regions regardless climatic conditions, type of soil and availability of natural water resources. In developed countries there is a continuous and significant requirement of an all-the-year-round production of wide range crops for the population and enterprises of food and processing industry. By our notion, a rational mean of increase of efficiency of functioning of large hydroponic complexes, their further development and improvement is automation of all technological and auxiliary operations of the corresponding production process beginning from receipt orders and up to delivery of ready products to consumers. Solution of this task will provide effective using of time and material resources (areas, soil, equipment, energy, nutrients, microelements, water), more even loading and operation of productive capacities, increase of productivity of enterprises and quality of ready products, decrease of their prime cost. There is conducted an analysis of main types of control devises and their executive elements (mechanical, hydro-mechanical, pneumatic-mechanical, electro-mechanical), their advantages and shortcomings. Also, the work contains an elaborated a structural scheme of an automated regional hydroponic production-logistic association, that provide production and delivery to consumers greenery, fruits and vegetables. There is proposed a block-scheme of an algorithm, ensuring rational automatic functioning of hydroponic technological complexes with examination of volumes and content of consumer orders, qualitative characteristics of the products, admissible terms of the orders fulfilment, availability of hydroponic equipment, its capacity and technological possibilities.

Key words: *hydroponic equipment, control system, automatic technological projecting, block-scheme, algorithm.*

Problem formulation. In the last decades a lot of scientists and engineers pay attention to improvement of hydroponic technologies and equipment, that provide an effective solution of an actual problem of supply with fresh greenery, vegetables and fruits for quite different countries and regions regardless climatic conditions, type of soil and availability of natural water resources. In developed countries there is a continuous and significant requirement of an all-the-year-round production of wide range of crops for population and enterprises of food and processing industry. Main tendencies of the improvement of these technology and equipment are widening of nomenclature of raised crops, their yield capacity,

more effective using of areas, soil, nutrients, minerals, water, energy, decrease of prime cost of ready products [1]. For this purpose, there are introduced new methods of hydroponics and new types of installations for their realization, including large technological complexes with automation of all main and auxiliary operations [2, 3]. By our notion, for further development of such complexes there will be rational an automation of all stages of the production process: formation of orders from consumers; their grading by given terms of fulfilment, volumes and content; search for accessible production capacities; evaluation their technological possibilities; distribution of orders over enterprises with provision of reserved



capacities for liquidation of consequences of different wrecking and contingencies; formation of orders for delivery of necessary planting stock, nutrients and minerals; planting; growing with optimization of main working parameters and regimes, using of automatic control and regulation of feeding of heat, air, illumination, water, other necessary components; harvesting; packing and delivery of the ready products to consumers.

Realization of such complex automation is possible on basis of a corresponding technical level of all enterprises as elements of these technological complexes (plant-growing, accessory and transport manufacturers), their main and auxiliary equipment, logistic and control systems, software. There are need close relations and effective interaction between of all enterprises of the technological complex with using of a specified computer program for automatic synthesis of possible variants of functioning of a technological complex for fulfilment of an order or a block of orders, their analysis by main efficiency criterions, foundation and selection of a most rational variant [4, 5, 6].

A necessary condition for creation of high effective automatized hydroponic technological complexes is an analysis and selection of optimal variants of systems of automatic control and regulation for provision of water, nutrients and microelements, change of parameters of illumination and ventilation, pressure, temperature and humidity in production areas of the hydroponic enterprises.

Analysis of last researches and publications. Let us examine main types of apparatuses for automatic control and regulation, thermal and physical characteristics of hydroponic installations.

There are several main classifications of automatic system of control and regulation. By designation they are divided into [7]:

- stabilizing (for support of a constant value of a given parameter);
- programming (for support of some parameters values in accordance with a given program);
- observing (for regulation of some parameters depending from some beforehand unknown values at the exit of the system).

In hydroponic systems there should be used these three types of the control systems. The stabilizing and programming systems – in case of growing of the same kinds of crops in course of quite long period, with using of the same equipment. The third type of the control system of this classification is necessary in case of experiments with new kinds of crops for continuous or periodical analysis of content of some nutrients or minerals in their stalks and leaf

on purpose of determination of an optimal regime of their nutrition.

Depending from number of control contours of the system it can be [7]:

- single-circuit systems;
- multiple-circuit systems.

The multiple-circuit or feedback systems are more effective for using in hydroponic complexes because they provide necessary optimal working parameters in course of the all growing process.

One more classification of the control systems its their division by the number of controlled values [7]:

- one-dimensional systems – with one regulated parameter;
- multi-dimensional systems – with several regulated parameters, that are more necessary for large modern hydroponic technological complexes.

With consideration of significant number of controlled parameters in course of operation of hydroponic complexes, especially in case of a growing of several kinds of crops at the same enterprise the second type of system of this classification will be much more effective than the first one.

By technological destination there are systems and devices for control of pressure, feeding, temperature, humidity, content of some nutrients, minerals or chemical elements, level of illumination etc. All these systems and devices are quite important for hydroponic complexes.

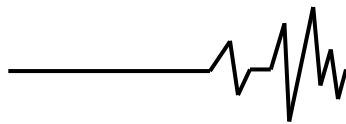
With consideration of a functioning character (frequency of conducting of measurements and regulations) the control systems are divided into [7]:

- periodic systems – with periodic control and regulation of the given parameters;
- continuous systems – with continuous control and regulation of the given parameters.

Depending from a kind of growing crop, necessary feeding of water, nutrients, microelements, regime of temperature, humidity, illumination, ventilation there can be used periodic and continuous systems of control and regulation.

By principle of operation of executive elements of these apparatuses they can be mechanical, hydro-mechanical, pneumatic-mechanical, electromechanical and electromagnetic. There are analogous and digital programs of functioning of the control systems.

Mechanical systems with a control from cams, formers, templates are wide spread in the machine-tool-construction, providing change of speed or direction of movement of the machine's executive elements in correspondence with configuration of the control element. The mechanical systems have quite simple and reliable design, but provide limited possibilities for realization of different regimes and parameters of control, besides the process of their adjustment for



fulfilment of other regimes is enough labour-consuming. By our notion, these systems do not correspond to demands of effective using in modern hydroponic technological complexes.

Electromechanical and electromagnetic systems are more compact and flexible (provide wider possibilities for realization of various regimes and parameters with less time expenses) in comparison with the mechanical control systems. There are several types of electro-mechanical and electromagnetic systems; some of them are presented in fig. 1 [8]. Their shortcomings: high enough complexity and consumption of materials.

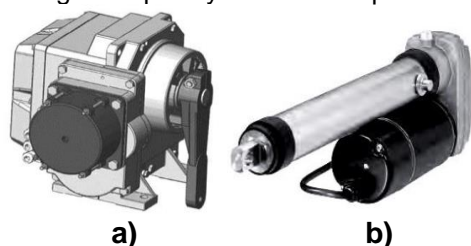


Fig. 1. Executive mechanisms of electromechanical control systems: a – single-turn electric mechanism MEO-100; b – linear executive mechanism Electrapak-PPA-AC115

Electropneumatic control devices (fig. 2) [8] have simple and reliable design and can provide accurate and stable functioning of systems of feeding of water, nutrients, minerals, conducting of electric energy for warming, ventilation and illumination in correspondence with given regime of crops growing. Their shortcomings are: uneven working regime of the automatic, due to using of compressible energy carrier (air), significant noise level in course of the operation, necessity of using of a compressor for provision of functioning of the executive elements. There are membrane and piston electropneumatic executive elements [8].

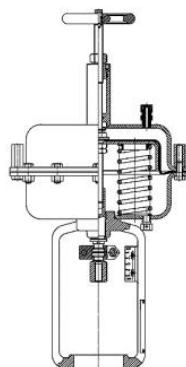


Fig. 2. Scheme of a membrane executive mechanism with an upper manual understurdy element

Advantages of hydro-mechanical executive mechanisms of control system are: a simple and reliable design, compact dimensions, uniformity

and high accuracy of functioning, low level of noise. Their shortcomings are: quite high expenses of time for over adjustment of the system, using of a bulky hydraulic station as a drive for the executive elements (fig. 3) [8].

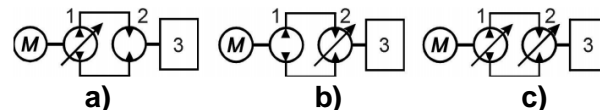


Fig. 3. Schemes of hydraulic drives for automatic control systems: a - with change of productivity of a hydraulic pump; b - with change in the speed of a hydraulic motor; c - with change of productivity of a pump and speed of a hydraulic motor; M - electric motor (asynchronous); 1 - hydraulic pump; 2 - hydraulic motor; 3 – executive element

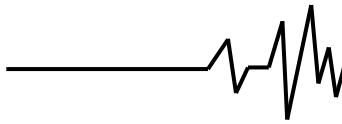
As a main type of information carriers in the control systems of modern machines of quite different destination, including the hydroponic equipment, in the last decades, there are used digital microprocessor devises [7, 9, 10, 11] (fig. 4). In comparison with analogous control elements (cams, formers, templets) the digital devises provide much wider possibilities for realization of various parameters and regimes of functioning of the hydroponic equipment and also a quick change of these regimes.



Fig. 4. Microprocessor regulator MTP-44

With consideration of the results of the conducted analysis one can conclude, that electromechanical and hydromechanical executive elements with digital microprocessor control devices are most suitable types of the regulation systems for the hydroponic equipment with the regard of their operational advantages and specific of functioning of the controlled installations.

Purpose formulation. The purpose of the work its elaboration of a structural scheme of a automation systems of functioning of modern hydroponic equipment, providing a rational planning and organization of fulfilment of all preparatory and working processes and operations with optimal distribution of the works between several enterprises. Also, there is need to elaborate a block-scheme of an algorithm, ensuring rational automatic functioning of



hydroponic technological complexes with examination of volumes, content and quality characteristics of consumer orders, admissible terms of their fulfilment, available hydroponic installations, their capacity and technological possibilities.

Presentation of main material. The authors propose a structural scheme of an automated regional hydroponic production-logistic association, that provide production and delivery to consumers greenery, fruits and vegetables (fig. 5).

transport companies) form a data base 2 (*DB2*). A computer program of the automatic center analyzes the data of *DB1* and *DB2* and with consideration of main criterions of efficiency (terms of the orders fulfilment, prime cost of the fulfilment, qualitative characteristics of the products) realizes a synthesis of possible variants of the orders fulfilment – configurations of the hydroponic technological complexes, that will provide the working processes. In the same time there is carried out a search of suppliers of necessary

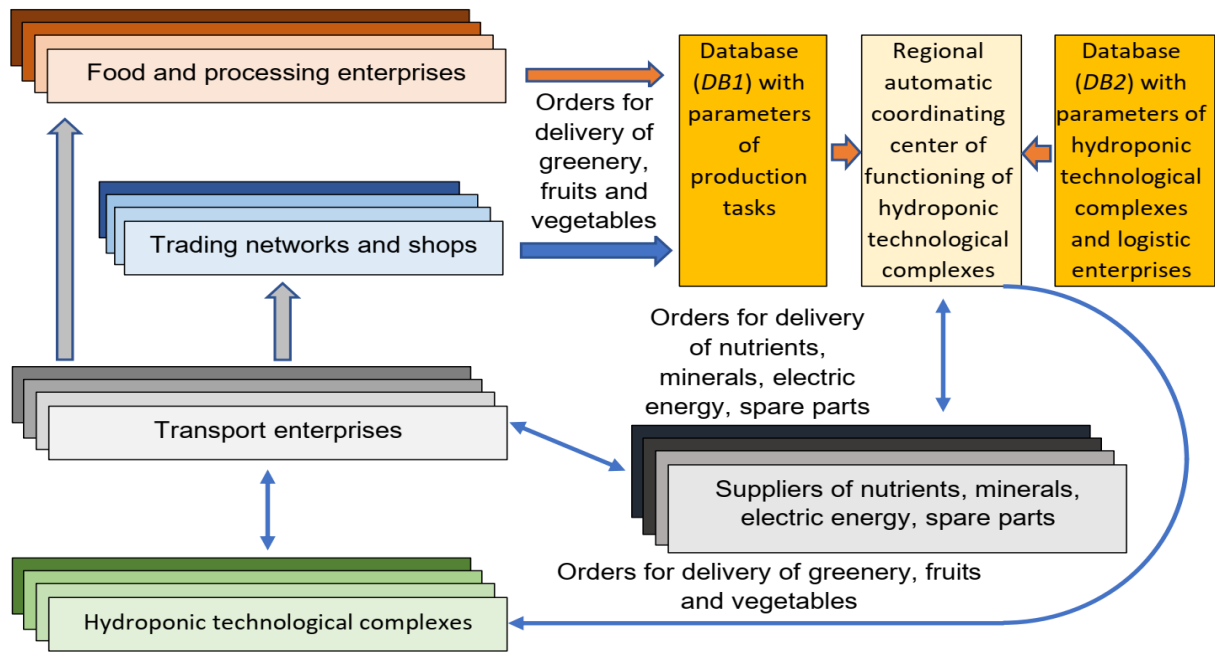


Figure 5 – Structural scheme of an automated regional hydroponic production-logistic association

General organization and control of association's functioning is realized from a regional automatic coordinating center, that receives orders from food and processing enterprises, trading networks and shops for delivery of products. Data about these products form a data base 1 (*DB1*). A detailed content of the data cited lower in the article (see also fig. 6). One more important source of information the data about of hydroponic technological complexes of the region (configuration of their production capacities and equipment, specialization, technological and operational characteristics, extent of loading of the capacities for the moment of time, availability of the capacities – see more detailly lower). There can be facilities of different production complexes and various enterprises [4, 5, 6]. The data about of equipment of the hydroponic technological complexes and logistic enterprises (suppliers and

nutrients, minerals, electric energy, spare parts for the equipment and also a selection of transport enterprises for implementation of corresponding necessary logistic operations. After determination of all possible variants of the main technological and auxiliary logistic complexes there is realized their ranging by the main criterions of efficiency with a definition of the most rational variant and a consideration of a time reserve and guaranteed securing of the qualitative characteristics of the products.

A block-scheme of an algorithm of automatic synthesis and analysis of variants of functioning of a regional association of hydroponic automatic technological complexes is presented in fig. 6.

The *DB1* should contain parameters of an order, including:

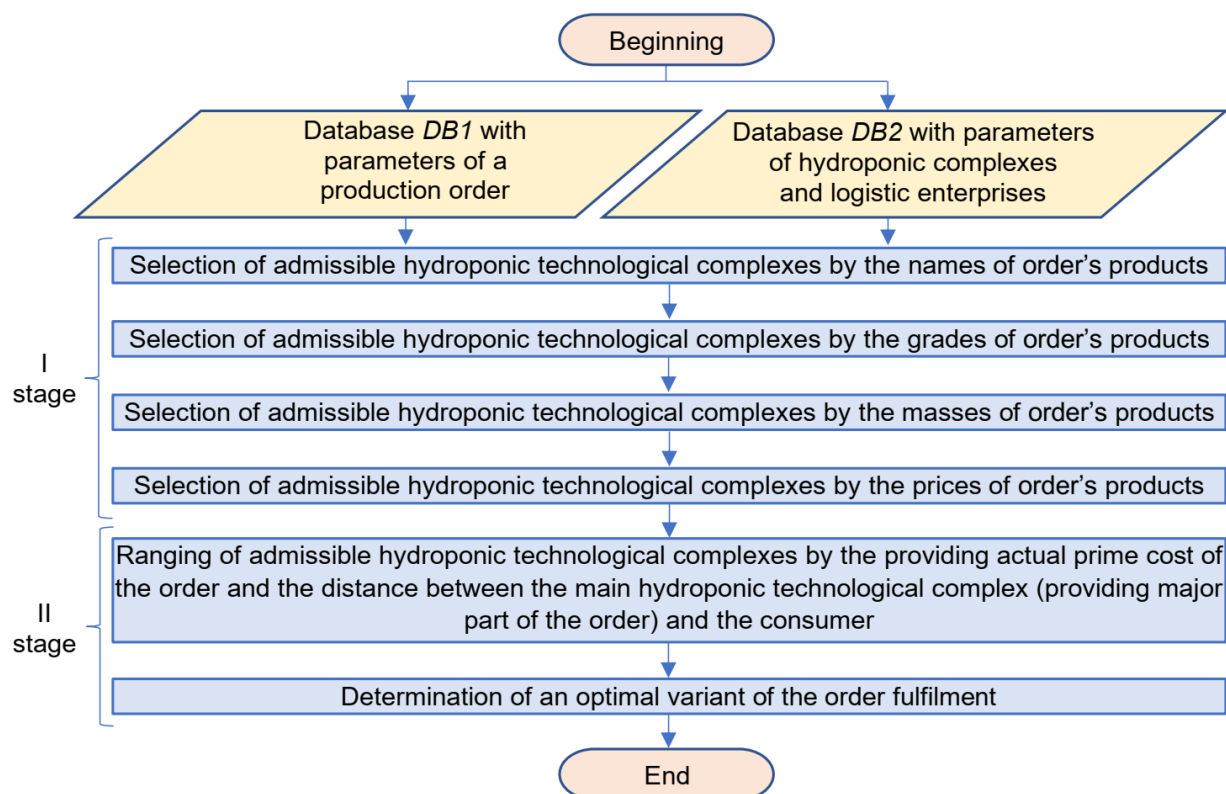
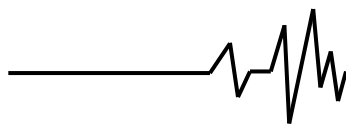


Figure 6 – Block-scheme of an algorithm of automatic synthesis and analysis of variants of functioning of a regional association of hydroponic automatic technological complexes

- codes for names of order's products: $N1, N2, \dots, NM$; these codes can be specially elaborated for using in the computer program of automatic synthesis and analysis, for example, the codes for main types of salads are: Oak Salad – $N11$, Lollo Rosso – $N12$, Butter Head – $N13$, Iceberg – $N14$; ...; codes for main types of cucumbers: Bunch of Magnificence – $N21$, Spirit – $N22$, Herman – $N23$, Herda – $N24$,...

- masses of each type of the products: $M11, M12, \dots, M21, M22, \dots$ (numbers in the designations of the masses must correspond to the numbers in the codes of the products);

- grades for each type of the products: $G11-i, G12-i, \dots, G21-i, G22-i, \dots$. Depending from the type of the product and with consideration of the corresponding standard, the grade ($i = 1, 2$ or 3) can be determined by middle size of fruits or vegetables, their mass, density, ripeness, firmness etc);

- admissible prices of each type of the products: $P11, P12, \dots, P21, P22, \dots$;

- distances from the technological complexes of the association to the consumer (delivery distances): $D1, D2, \dots, DM$.

DB2 should contain parameters of equipment of the hydroponic technological complexes ($H1, H2, \dots, HM$), suppliers ($S1, S2, \dots,$

SM) and transport enterprises ($T1, T2, \dots, TM$), including:

- names of products, that can be grown with using of the association technological complexes: $N11, N12, \dots, N21, N22, \dots$ - for $H1$; $N11, N12, \dots, N21, N22, \dots$ - for $H2$; $N11, N12, \dots, N21, N22, \dots$ - for HM ;

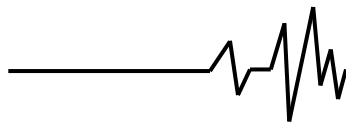
- available areas [ha, m^2] of the hydroponic technological complexes for growing of designated crops: $A11, A12, \dots, A21, A22, \dots$ - for $H1$; $A11, A12, \dots, A21, A22, \dots$ - for $H2$; $A11, A12, \dots, A21, A22, \dots$ - for HM ;

- middle crop capacity, provided for each crop by the hydroponic technological complexes, [t/ha, kg/m^2]: $C11, C12, \dots, C21, C22, \dots$ - for $H1$; $C11, C12, \dots, C21, C22, \dots$ - for $H2$; $C11, C12, \dots, C21, C22, \dots$ - for HM ;

- grades for each type of the products: $G11-i, G12-i, \dots, G21-i, G22-i, \dots$ - for $H1$; $G11-i, G12-i, \dots, G21-i, G22-i, \dots$ - for $H2$; $G11-i, G12-i, \dots, G21-i, G22-i, \dots$ - for HM ($i = 1, 2$ or 3);

- prime cost for each type of the products, [hrn/t or hrn/kg]: $PC11, PC12, \dots, PC21, PC22, \dots$ - for $H1$; $PC11, PC12, \dots, PC21, PC22, \dots$ - for $H2$; $PC11, PC12, \dots, PC21, PC22, \dots$ - for HM ;

- necessary specific expenses of electric energy, [kW h/t], nutrients, [kg/t], microelements [kg/t], water [m^3 /t] for each type of the products: $E11, MC11, NU11, W11$ - for $N11$; $E12, MC12,$



NU_{12} , W_{12} - for N_{12} ; ...; E_{21} , MC_{21} , NU_{21} , W_{21} - for N_{21} ; E_{22} , MC_{22} , NU_{22} , W_{22} - for N_{22} ... (there can be used several different types of nutrients and microelements for growing of a certain type of crop. In this case there is need to use more detailed data and a corresponding system of their designation);

- prime costs of electric energy, [hrn /kW h], nutrients, [hrn /kg], microelements [hrn /kg], water [hrn /m³] of each supply enterprise: E_1 , M_1 , N_1 , W_1 - for S_1 ; E_2 , M_2 , N_2 , W_2 - for S_2 ; ...; EM , MM , NM , WM - for SM .

- prime costs for delivery of ready products, nutrients, microelements, [hrn /km t] from each transport enterprise to each hydroponic complex: DV_1 - for T_1 , DV_2 - for T_2 , ..., DVM - for TM .

In course of the first stage of the automatic synthesis of variants of fulfilment of an order there is realized a selection of regional hydroponic technological complexes, that can provide growing of corresponding types of crops. The check up is conducted with using of the formulas

$$\begin{aligned} N_{11}(DB_1) &\rightarrow N_{11}(DB_2); \\ N_{12}(DB_1) &\rightarrow N_{12}(DB_2); \dots; \\ N_{21}(DB_1) &\rightarrow N_{21}(DB_2); \\ N_{22}(DB_1) &\rightarrow N_{22}(DB_2); \dots \end{aligned} \quad (1)$$

The technological complexes, that correspond fully or partially to the conditions (1) analyze with using of the conditions

$$\begin{aligned} G_{11-i}(DB_1) &\rightarrow G_{11-i}(DB_2); \\ G_{12-i}(DB_1) &\rightarrow G_{12-i}(DB_2); \dots; \\ G_{21-i}(DB_1) &\rightarrow G_{21-i}(DB_2); \\ G_{22-i}(DB_1) &\rightarrow G_{22-i}(DB_2); \dots \end{aligned} \quad (2)$$

The selected complexes verify on basis of the one more block of conditions consecutively for each technological complex of the association. For example, for the complex H_1 the conditions will be

$$\begin{aligned} M_{11}(DB_1) &\leq A_{11} \cdot C_{11}(DB_2); \\ M_{12}(DB_1) &\leq A_{12} \cdot C_{12}(DB_2); \dots \\ M_{21}(DB_1) &\leq A_{21} \cdot C_{21}(DB_2); \\ M_{22}(DB_1) &\leq A_{22} \cdot C_{22}(DB_2); \dots \end{aligned} \quad (3)$$

The final check up of the first stage of the automated synthesis is carried out for each variant of the technological complex, each supplier and transport enterprise by conditions:

- for the variant of using of the technological complex H_1 , the supplier S_1 and the transport enterprise T_1 :

$$\begin{aligned} P_{11} &\geq PC_{11} \cdot M_{11} + E_{11} \cdot E_1 + MC_{11} \cdot M_1 + \\ &+ NU_{11} \cdot N_1 + W_{11} \cdot W_1 + DV_1 \cdot D_1 \cdot M_{11}; \\ P_{12} &\geq PC_{12} \cdot M_{12} + E_{12} \cdot E_1 + MC_{12} \cdot M_1 + \\ &+ NU_{12} \cdot N_1 + W_{12} \cdot W_1 + DV_1 \cdot D_1 \cdot M_{12}; \dots \\ P_{21} &\geq PC_{21} \cdot M_{21} + E_{21} \cdot E_1 + MC_{21} \cdot M_1 + \\ &+ NU_{21} \cdot N_1 + W_{21} \cdot W_1 + DV_1 \cdot D_1 \cdot M_{21}; \\ P_{22} &\geq PC_{22} \cdot M_{22} + E_{22} \cdot E_1 + MC_{22} \cdot M_1 + \\ &+ NU_{22} \cdot N_1 + W_{22} \cdot W_1 + DV_1 \cdot D_1 \cdot M_{22}; \dots \end{aligned} \quad (4)$$

- for the variant of using of the technological complex H_1 , the supplier S_2 and the transport enterprise T_1 :

$$P_{11} \geq PC_{11} \cdot M_{11} + E_{11} \cdot E_2 + MC_{11} \cdot M_2 +$$

$$\begin{aligned} &+ NU_{11} \cdot N_2 + W_{11} \cdot W_2 + DV_1 \cdot D_1 \cdot M_{11}; \\ P_{12} &\geq PC_{12} \cdot M_{12} + E_{12} \cdot E_2 + MC_{12} \cdot M_2 + \\ &+ NU_{12} \cdot N_2 + W_{12} \cdot W_2 + DV_1 \cdot D_1 \cdot M_{12}; \dots \\ P_{21} &\geq PC_{21} \cdot M_{21} + E_{21} \cdot E_2 + MC_{21} \cdot M_2 + \\ &+ NU_{21} \cdot N_2 + W_{21} \cdot W_2 + DV_1 \cdot D_1 \cdot M_{21}; \\ P_{22} &\geq PC_{22} \cdot M_{22} + E_{22} \cdot E_2 + MC_{22} \cdot M_2 + \\ &+ NU_{22} \cdot N_2 + W_{22} \cdot W_2 + DV_1 \cdot D_1 \cdot M_{22}; \dots \end{aligned} \quad (5)$$

- for the variant of using of the technological complex H_1 , the supplier S_1 and the transport enterprise T_2 :

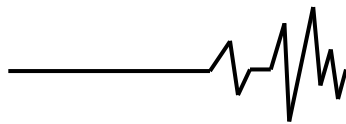
$$\begin{aligned} P_{11} &\geq PC_{11} \cdot M_{11} + E_{11} \cdot E_1 + MC_{11} \cdot M_1 + \\ &+ NU_{11} \cdot N_1 + W_{11} \cdot W_1 + DV_2 \cdot D_1 \cdot M_{11}; \\ P_{12} &\geq PC_{12} \cdot M_{12} + E_{12} \cdot E_1 + MC_{12} \cdot M_1 + \\ &+ NU_{12} \cdot N_1 + W_{12} \cdot W_1 + DV_2 \cdot D_1 \cdot M_{12}; \dots \\ P_{21} &\geq PC_{21} \cdot M_{21} + E_{21} \cdot E_1 + MC_{21} \cdot M_1 + \\ &+ NU_{21} \cdot N_1 + W_{21} \cdot W_1 + DV_2 \cdot D_1 \cdot M_{21}; \\ P_{22} &\geq PC_{22} \cdot M_{22} + E_{22} \cdot E_1 + MC_{22} \cdot M_1 + \\ &+ NU_{22} \cdot N_1 + W_{22} \cdot W_1 + DV_2 \cdot D_1 \cdot M_{22}; \dots \end{aligned} \quad (6)$$

Hydroponic technological complexes, that are synthesized for fulfilment of the order can include areas and main equipment, that belong to different enterprises of the region. For example, various kinds of crops of the same order can be grown by several enterprises. Such approach gives possibilities of using of a longstanding experience and the same plots for production of invariable crops, without change of the equipment adjustments, sets of using nutrients and minerals. So, there is a quite rational mean of increase of efficiency of functioning of the regional hydroponic technological complexes.

Also, for the purpose of formation of more optimal additional variants there can be drew different suppliers and transport enterprises, that will realize a supply of sets of necessary nutrients and minerals and delivery of consignments of the order to the consumer. In this case the formulas (4 - 6) should be corrected.

All this provides saving of time, energy and materials, increase of general efficiency of the production and quality of ready products, decrease of their prime cost. So, the number of variants of an order's fulfilment (variants of combinations of equipment of hydroponic technological complexes, suppliers, transport companies) may be quite large. The synthesis and analysis of this number of the variants with consideration of the several main criterions can be realized only under utilization of the corresponding computer program [4, 5, 6].

In course of the second stage of these synthesis and analysis there is fulfilled a ranging of the all admissible variants (after their selection by the conditions (1 - 6) on basis of the criterions: actual prime cost of the production under realization of some main hydroponic technological equipment, attraction of some suppliers and transport companies - PC_{Aij} and distance DV_i between the main hydroponic technological complex (providing major part of the order) and the consumer. The conditions for the ranging and



selection of an optimal variant with minimal PCA_{ij} and DV_i have the appearance [12]

$$PCA_{ij} = PC_{ij} \cdot M_{ij} + E_{ij} \cdot E_i + MC_{ij} \cdot M_i + \\ + NU_{ij} \cdot N_i + W_{ij} \cdot W_i + DV_i \cdot D_i \cdot M_{ij}; \quad (7) \\ \text{MINIMUM from: } PCA_{11}, PCA_{12}, \dots, PCA_{mn} \\ \text{MINIMUM from: } DV_1, DV_2, \dots, DV_m.$$

The selected optimal variant of the order fulfilment is brought for realization with using of corresponding facilities of the regional automatic hydroponic complexes, suppliers and transport enterprises.

Conclusions. 1. Increase of the main parameters of efficiency of hydroponic equipment can be realized on basis of an automatic selection of an optimal variant of a structure of technological complexes, suppliers and transport enterprises for fulfilment of each concrete production order and with a complex automation of planning and fulfilment of all technological and auxiliary operations beginning from the order receipt and up to its delivery to the consumer.

2. There were analyzed classifications of types of automation systems, that can be introduced in a regional hydroponic production-logistic associations. There are stabilizing, programming and observing multi-dimensional systems of control and regulation, with one or with several control contours, providing an automatic periodic or continuous change of main working parameters (pressure, feeding, temperature, humidity, content of some nutrients, minerals or chemical elements, level of illumination etc). The most effective types of executive elements for the hydroponic systems are electromechanical and hydromechanical elements with digital microprocessor control devices.

3. In order to realize the high effective complex automation of hydroponic technological equipment there were elaborated a structural scheme of an automated regional hydroponic production-logistic association and a block-scheme of an algorithm of automatic synthesis and analysis of variants of its functioning. A computer program can be elaborated on basis of the schemes, that in case of its introduction will allow to select an optimal variant of fulfilment of each concrete order with provision of minimal expenses of time, materials and energy, under condition of an appropriate quality of ready products.

References

1. Wood, Laura (2018) "Global Hydroponics Market Report 2017-2023 - Research and Markets". Business Wire. Berkshire Hathaway. Retrieved Apr 1.
2. Sevostianov, I., Melnyk, O. (2021) Elaboration of improved hydroponic installations, *Vibratsii v tekhnitsi ta tekhnolohiiakh*, 1 (100), 66-75.

3. Sevostianov, I., Melnyk, O. (2021) Udoskonalennia roboty hidropionnykh ustanovok [Improvement of functioning of hydroponic installations]. *Tekhnika, enerhetyka, transport APK*, 4 (115), 119-127 [in Ukrainian].

4. Sevostianov, I., Kravets, S., Pidlypna, M. (2020) Use of criterial synthesis and analysis for modernization of objects of machine building production. *Tekhnika, enerhetyka, transport APK*, 2 (109), 88-96.

5. Sevostianov, I., Pidlypna, M. (2020) Model of optimization of functioning of modern polygraphic and publishing complexes. *Tekhnika, enerhetyka, transport APK*, 4 (111), 90-99.

6. Sevostianov, I., Tokarchuk, O., Pidlypna, M. (2021) Automated technological projection of classification processes of dry dispersive materials. *Tekhnika, enerhetyka, transport APK*, 2 (113), 15-21.

7. Larycheva, L.P., Voloshyn, M.D., Lutsenko, O.P. (2015) *Kontrol ta avtomatychno rehuliuвання khimiko-tekhnolohichnykh protsesiv: navch. Posibnyk [Control and automatic regulation of chemical-technological processes. Textbook]*. Dniprodzerzhynsk: DDTU [in Ukrainian].

8. Klymenko, O. P., Kaiun, I. H., Sheikus, A. R. (2019) *Kontrol i upravlinnia tekhnolohi chnymy protsesamy: navchalnyi posibnyk [Control of technological processes. Textbook]*. Dnipro: DVNZ UDKhTU [in Ukrainian].

9. Baralo, O.V., Samoilenko, P.H., Hranat, S.Ye., Kovalov, V.O. (2010) *Avtomatyzatsiia tekhnolohichnykh protsesiv i systemy avtomatychnoho keruvannia: Navchalnyi posibnyk [Automation of technological processes and systems of automatic control. Textbook]*. Kyiv: Ahrarna osvita [in Ukrainian].

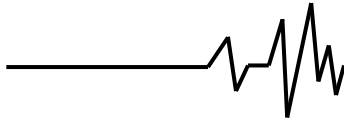
10. Popovich, M. G., Kovalchuk, O. V. (2007) *Teoriya avtomatychnoho keruvannia. Pidruchnik [Theory of automatic control. Textbook]*. Kyiv: Lybid [in Ukrainian].

11. Pushkar, M.S., Protsenko, S.M. (2013) *Proektuvannia system avtomatyztatsii: navch. posibnyk [Projection of automation systems. Textbook]*. Dnipro: Natsionalnyi hirnychyi universytet [in Ukrainian].

12. Sevostianov, I. V. (2014) *Teoriya tehnicnykh system. Pidruchnik [Theory of technical systems. Textbook]*. Vinnytsia: VNTU [in Ukrainian].

СИСТЕМИ АВТОМАТИЧНОГО КЕРУВАННЯ ГІДРОПОННИМИ ТЕХНОЛОГІЧНИМИ КОМПЛЕКСАМИ

Гідропонне обладнання дозволяє вирішити проблему забезпечення свіжою зеленню, овочами та фруктами досить різних



країн і регіонів незалежно від кліматичних умов, типу ґрунту та наявності природних водних ресурсів. У розвинених країнах існує постійна і значна потреба у цілорічному виробництві широкого асортименту сільськогосподарських культур для населення та підприємств харчової та переробної промисловості. За нашими уявленнями, раціональним засобом підвищення ефективності функціонування великих гідропонних комплексів, їх подальшого розвитку та вдосконалення є автоматизація всіх технологічних і допоміжних операцій відповідного виробничого процесу, починаючи від надходження замовлень і до доставки готової продукції споживачам. Вирішення цього завдання забезпечить ефективне використання часових і матеріальних ресурсів (площі, ґрунту, обладнання, енергії, поживних речовин, мікроелементів, води), більш рівномірне завантаження та роботу виробничих потужностей, підвищення продуктивності підприємств та якості готової продукції,

зниження їх собівартості. Проведено аналіз основних типів пристроїв керування та їх виконавчих елементів (механічних, гідромеханічних, пневмомеханічних, електромеханічних), їх переваг та недоліків. Також у роботі розроблено структурну схему автоматизованого регіонального гідропонного виробничо-логістичного об'єднання, що забезпечує виробництво та доставку споживачам зелені, фруктів та овочів. Запропоновано блок-схему алгоритму, що забезпечує раціональне автоматичне функціонування гідропонних технологічних комплексів з перевіркою обсягів та змісту замовлень споживачів, якісних характеристик продукції, допустимих термінів виконання замовлень, наявності гідропонного обладнання, його потужності та технологічних можливостей.

Ключові слова: гідропонне обладнання, система керування, автоматичне технологічне проектування, блок-схема, алгоритм.

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