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INTELLIGENT ENERGY-EFFICIENT AUTOMATIC CONTROL SYSTEM OF MICROCLIMATE IN GREENHOUSES

Yakymenko Inna, PhD student, icheshun@gmail.com
Lysenko Vitaliy, Doctor of Technical Sciences, Professor, lysenko@nubip.edu.ua
National University of Life and Environmental Sciences of Ukraine

High energy prices lead to the fact that in the cost structure of products grown in greenhouses, the share of energy is about 60% [1]. Therefore, an important task is the development of new energy-efficient automated control algorithms that allow increasing the overall profitability of production by minimizing energy costs.

Keywords: *energy efficiency, resource efficiency, microclimate parameters, protected soil structure, greenhouse.*

The purpose of the study is development an intelligent energy-efficient control system of the microclimate in greenhouses which basis on energy consumption forecasting, including tariff`s zoning in payment for the electricity using.

The main task of energy-efficient control system of greenhouse equipment is to ensure a continuous balance between energy supply and demand [2]. To minimize energy costs in the process of growing vegetable products in greenhouses, was proposed an automated control system of temperature and humidity control by combining intelligent algorithms of stabilization technological equipment at the lower management level, optimization of energy costs by forecasting them at the top level and optimization of electricity costs by using a fuzzy logic model, which include an energy price. This approach allows to reduce the energy costs for the control microclimate control in greenhouses differs from existing solutions, that the top level of control is provided by a neural network model for forecasting energy costs and natural gas consumption.

The methodology for the development of an intelligent energy-efficient control system of microclimate parameters in greenhouses includes a sequence of justified steps involving appropriate functional and informational approaches and technical and technological means for the implementation of the relevant algorithm, the structure of which is presented in Fig. 1.

At the first stage of the system development is carried out an experimental study, on which is based a database of microclimate parameters in greenhouse. The next step is to create a fuzzy expert system for managing groups of coolant supply equipment to the greenhouse, air ventilation and the formation of rules by experts based on requirements for ensuring the quality of grown products. Next, there is the processing of information on projected energy consumption, based on choice of equipment management strategy is made to minimize energy consumption by adjusting the regulator's settings. The next step is to determine the parameters of the regulator and conduct modeling for further synthesis of an energy-efficient system for managing the parameters of the microclimate in the greenhouse. This allows to get an energy-efficient control system of growing vegetables in the greenhouse, the use of which leads to a decrease in energy consumption by 10-15% compared to traditional technologies of control microclimate parameters.

To implement the intelligent energy-efficient control system of microclimate, was developed the software in the programming language "C++", considering the sequence of development sown on Fig. 1. The software implementation of the control system includes 3 blocks:

1) block of measuring technological parameters and accounting of energy carriers; performs the following functions:

- reflects the temperature and humidity in the middle of the greenhouse, the coolant temperature in the heating circuits, quantitative characteristics of external disturbances; data is sent to the unit in real time from installed sensors;
- registers the expenditures of energy resources;
- records production information entering the database for further analysis;

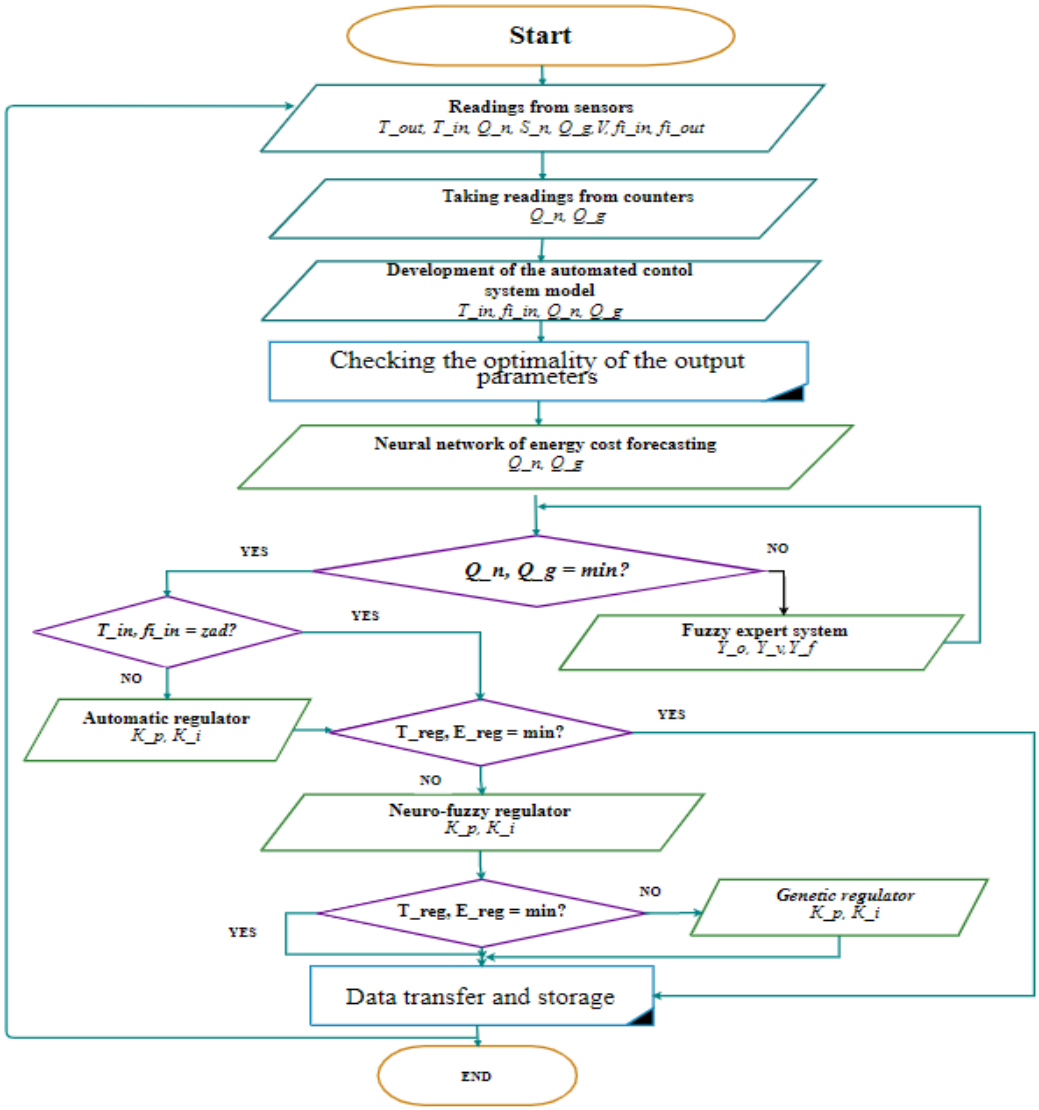

Fig. 1 – Algorithm of functioning of energy-efficient control system of microclimate parameters in the greenhouses

2) energy efficient control unit - allows to choose the mode of operation: automatic or manual mode; in automatic mode are displayed the results of the fuzzy expert decision-making system for control operation modes of equipment; in manual mode, the operator chooses to turning heating "on/off".

3) block of forecasting energy consumption; on the basis of the obtained quantitative characteristics of natural perturbations and information about the parameters of the microclimate, the forecasting of energy losses per day with a discreteness of 1 hour is performed.

Assessment of economic efficiency from the introduction an intelligent control system of the microclimate in greenhouses with forecasting energy costs and considering the tariffs in payment for electricity is determined using general performance indicators that characterize economic efficiency should be attributed: payroll fund; total profitability of sales; energy capacity of production, etc.

Criterion for estimation of economic efficiency:

$$\begin{cases} \textbf{Natural gas consumption} \rightarrow \boldsymbol{min} \\ \textbf{Electricity costs} \rightarrow \boldsymbol{min} \\ \textbf{Profit of the enterprise} \rightarrow \boldsymbol{max}. \end{cases} \quad (1)$$

The developed intelligent control system of energy efficient management allows to predict energy costs during the process of growing products in greenhouses, considering current disturbances and tracking the qualitative zones of values of input parameters that affect the energy cost of the vegetable growing process.

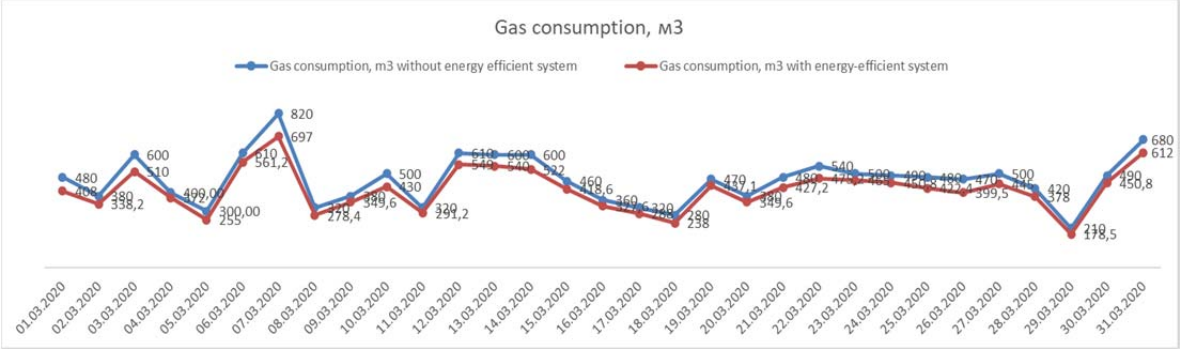

Fig. 2. – Comparison of gas during growing vegetables in greenhouses using the traditional approach and after the introduction of the intelligent control system

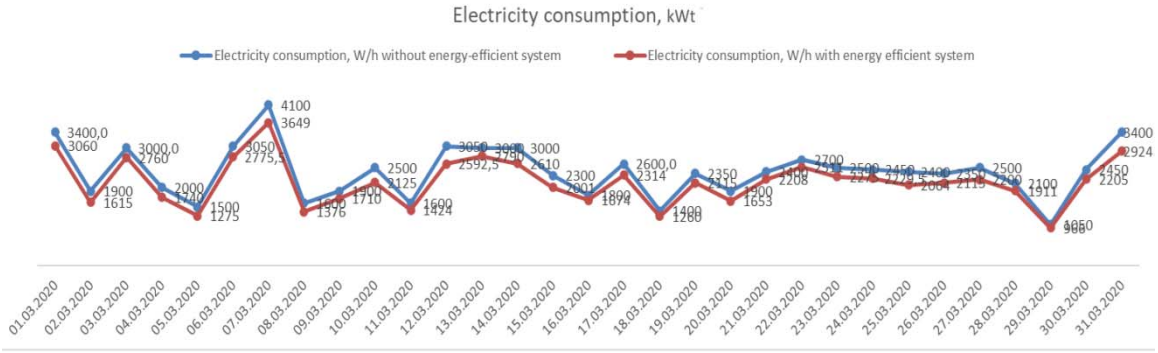

Fig. 3. – Comparison electricity consumption during growing vegetables in greenhouses using the traditional approach and after the introduction of the intelligent control system

Generalized economic indicators of the evaluation results of the using the developed energy-efficient microclimate control system at the production facility within 30 days confirm the effectiveness and prospects of this approach:

- total financial savings – UAH 12,764;
- relative reduction of financial costs for natural gas and electricity – up to 10%.

Conclusions. Was developed an intelligent energy-efficient control system of microclimate parameters in greenhouses and its algorithmic support which contains neural network forecasting unit for energy costs, decision support block, which consider prices for energy resources, block of optimization parameters based on the using of fuzzy logic and genetic algorithms.

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