# AUTOMATED CONTROL SYSTEM IN GREENHOUSE WITH NEURAL NETWORK PREDICTIONS OF EXTERNAL DISTURBANCES

***A. Dudnyk, PhD***

*Efficiency of creation automation control system in a greenhouse with using solar radiation intensity and temperature predictions by neural networks is shown.*

***Key words: greenhouse, neural network, control system.***

Greenhouse environment is an incredibly complex and dynamic environment. The pressures of labor availability and costs, energy costs, and market demands increasingly make efficiency and automation key components for success and profitability. Environment control technology affects all of these critical areas, and many others, so understanding controls and implementing their use is more important than ever. Precise control of the greenhouse environment is critical in achieving the best and most efficient growing environment and efficiency.

Greenhouse environments present unique challenges to good control. Temperature changes occur rapidly and vary widely depending on solar radiation levels, outside temperatures and humidity levels, wind speed and direction, the amount of plant material in the greenhouse, watering routines, etc.

Environmental control is the main feature of modern systems. Ultimately, the objective of any greenhouse system is to reduce the input cost per unit of production and maintain or increase the quality of production. While some investments effect the input cost and/or quality of one or two specific tasks (i.e. transplanters, soil handling equipment, etc.), a well-integrated environment system will have a positive effect on virtually every function in a facility. Even a small percentage of improvement in several areas will yield substantial improvements overall. Better equipment coordination and more accurate control can reduce heating fuel and electrical costs [2].

**Purpose of research –** to substantiate efficiency of automation control system creation in a greenhouse with using solar radiation intensity and temperature predictions by neural networks.

**Material and methods.** Many studies about greenhouse environment control systems have been based on the concepts of energy and mass balance and physical modeling. But the practical realizations of these concepts are difficult and expensive. This work exploits other method for creation control system which based on neural network and also takes into consideration biological particularities of plants.

Greenhouse, which was researched as biotechnical object is situated in Brovary district Kyiv region called Public Company “Combinat “Teplichniy”. Based on the statistical data obtained through information-measuring system and current information on performance of tomato static characteristic of the object was acquired (Fig. 1). Direct correlation of natural gas cost and the outside temperature and the solar radiation intensity was determined.

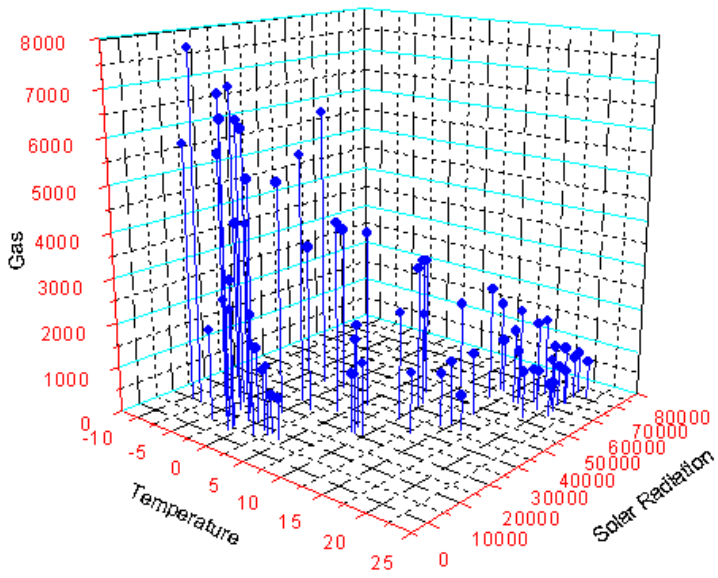



**Fig. 1. Static characteristic of biotechnical object**

**Results and Discussion.** Information-measuring system (IMS) for recording and monitoring such environmental parameters, as solar radiation intensity and outside air temperature, was placed in PC "Combinat “Teplichniy” (Fig. 2).

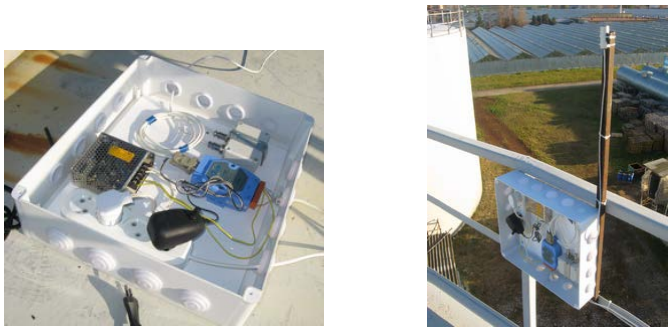
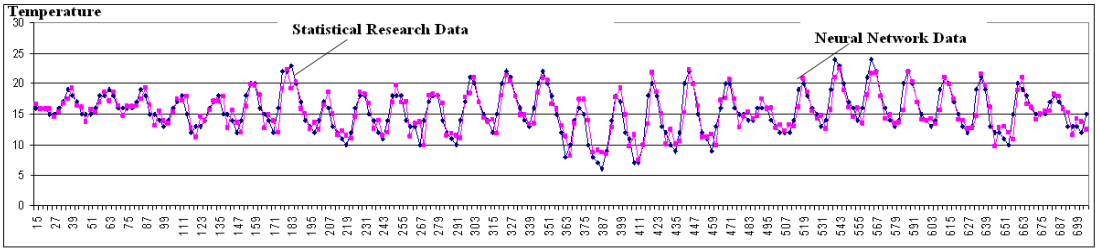
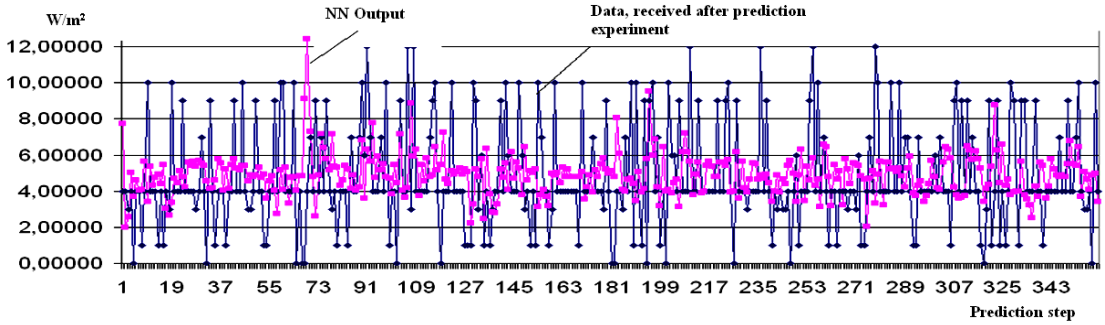


**Fig. 2. Information-measuring system of external disturbances**

Based on statistical data collected by IMS, in order to forecast the external disturbances time series prediction using neural networks technologies for temperature and solar radiation intensity was applied [1].




**a)**




**b)**

**Fig. 3. Temperature time series (a) and the time series of solar radiation intensity (b) forecasting**

The software package Statistica Neural Networks was used for the synthesis and study of neural networks. In order to obtain the solar radiation intensity predictions a variety of neural network - multilayer perceptron was chosen; it's preliminary investigations showed the smallest error and the best predictive ability

for nonstationary and nonlinear processes that contain elements of uncertainty. For temperature time series acceptable accuracy forecasts was obtained by multilayer perceptron with two neurons in the hidden layer (Fig. 2a).

The necessary efficiency of solar radiation intensity predictions wasn't obtained (Fig. 2b). It is caused by data signal noise associated with the possible influence of such significant natural factors as the clouds height and type, absolute humidity, the horizontal and vertical components of wind speed, aerosol concentration and crystals size, water content, precipitation rate, etc.

The improvement of predicted values is possible with the implementation of mathematical filters. The necessary conditions for the adequate data representation and the possibility to form an adaptive basis are provide by the Hilbert-Huang transform (HHT). The adaptive basis will depend on the functionally meaningful of the signal component and will not be pre-selected, that is available in the classical approaches. The Hilbert-Huang transform is the method of time-frequency analysis based on empirical mode decomposition (EMD) of nonlinear and non-stationary processes and Hilbert spectral analysis (HSA) [5].

EMD essence composes of successive (iterative) establishing of empirical functions $c_j(t)$ and residues $r_j(t) = r_{j-1}(t) - c_j(t)$, where $j = 1, 2, 3, ..., n$ at $r_0 = y(t)$. The decomposition result is the signal representation as the sum of modal features and the final residue [5]:

$$x(t) = \sum_{j=1}^{n} c_j(t) + r_n(t), \qquad (1)$$

where $n$ - number of empirical events, which is set in the calculations.

The time interval of 6 hours was used for research (data obtained by IMS), which is technically justified for further predictions. This time period was extended to the end portions of 1% (43 points) to eliminate conversion errors on finite intervals processed array data analyzed. Also carried out its alignment relative to the arithmetic average of - 133.807 W/m$^2$.

Also assumed that the removal of noise time series of solar radiation would require a four-dropout noise, i.e. the formation of IMF-1 = IMF-1a + IMF-1b + IMF-1c + IMF-1d.

Renormalized filtered signal was visually analyzed. The results of the Hilbert-Huang transform allowed to determine the number of detected noise components in the incoming signal - 23.762 % (Fig. 3) [4].

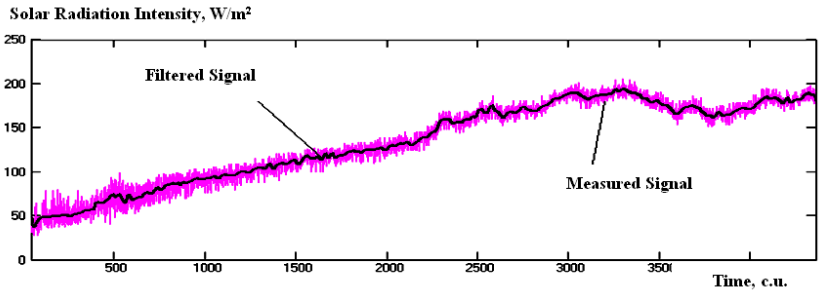
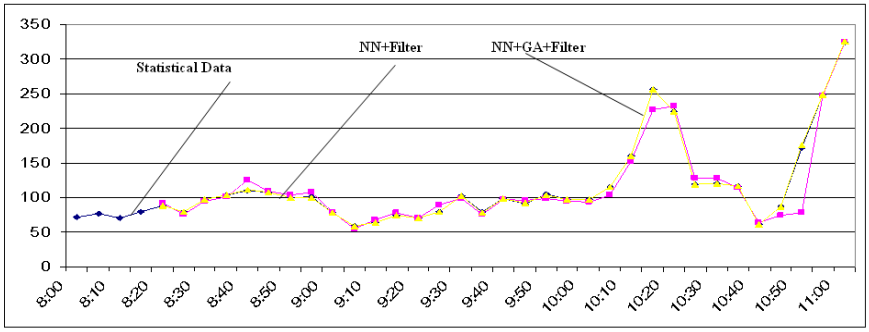
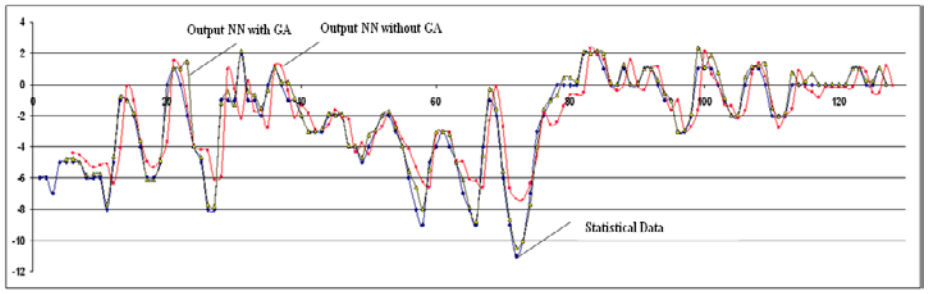



**Fig. 4. Imposition of the incoming signal and the filtered time series of solar radiation intensity**

After using of mathematical filter for solar radiation intensity predictors precision significantly increased, enabling further research of these neural networks and to search for optimization techniques that minimize their work error. Improving the predictive performance of the neural network is possible by using the optimization mathematical methods, among which genetic algorithm (GA) [3]. The definition of optimal weights for the neural network (type multi-layer perceptron) for the time series of solar radiation intensity by genetic algorithm together with the use of mathematical filter was held (Fig. 5).




**a**




**b**

**Fig. 5. Training charts for prediction of external disturbances by Neural networks:**

a – solar radiation intensity time series; b – temperature time series

Having taken into account the research the process control diagram of growing plants in the greenhouse was developed (Fig.6).

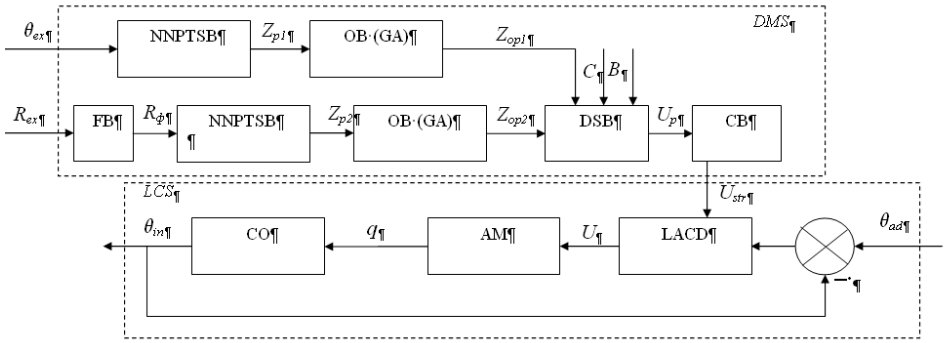



**Fig. 6. Block diagram of the process control system in the greenhouse:**

DMS –decision making subsystem ; FB – filtration block for solar radiation intensity; NNPTSB – neural network predictions for time series; OB(GA) –optimization block with genetic algorithm; DSB – decision making block; CO – control block; LCS – local control system; LACD – local automated control device; AM – actuating mechanism; CO – control object

## Conclusions

1. Complex research allowed to establish the list of factors that affect the tomatoes productivity, to single out external natural disturbances and biological characteristics of tomato as being insufficiently studied and not taken into account in decision making control actions.

2. The method of neural network prediction of natural external disturbances in biotechnical object has been developed; networks type multilayer perceptron with two and three neurons in hidden layers have high predictive ability for temperature time series and solar radiation intensity. Genetic algorithm is a method that could be use for optimizing neural networks settings.

3. Thus, the control system of growing vegetables in greenhouses allows to provide the highest profit from the sale of products and to minimize energy costs of cultivation by implementing additional unit for neural network prediction of external disturbances and determine the control actions using generalized optimality criterion.

## References


1. Lysenko V., Shtepa V., Dudnyk A. 2011: Probabilistic (Bayesian) neural network of temperature pattern classification. *Journal of Agricultural Science*. 4, 53 – 56.

2. Lysenko V., Dudnyk A. 2011: Optimal control: status and prospects in the Greenhouse industry. *Scientific Herald of National University of Life and Environmental Sciences of Ukraine.* 166, 104 – 113.

3. Lysenko V., Shtepa V., Zayets N., Dudnyk A. 2011: Neural network forecasting of outside temperature time series. *Biological Resources and Nature Management.* 3 - 4, 102 – 108.

4. Lysenko V., Shtepa V., Dudnyk A. 2012: The Hilbert-Huang transform and the filtration the time series of solar radiation. *Herald of Kharkov Petro Vasylenko National Technical University of Agriculture.* 130, 55 – 57.

5. Huang N. E. Shen Z., Long S. R., Wu M. C., Shih H. H., Zheng Q., Yen N.-C., Tung C. C., and Liu H. H. The empirical mode decomposition and the Hilbert spectrum for nonlinear and non-stationary time series analysis. *Proceedings of R. Soc. London, Ser.* A, 454, 903 – 995, 1998


## АВТОМАТИЗОВАНА СИСТЕМА УПРАВЛІННЯ В ТЕПЛИЦЯХ З НЕЙРОМЕРЕЖЕВОГО ПРОГНОЗУВАННЯ ЗОВНІШНІХ ЗБУРЕНЬ

***А. Дудник***

*Наведено результати досліджень ефективності розробки автоматизованої системи керування у теплицях з прогнозуванням збурень у вигляді інтенсивності сонячної радіації і температури повітря.*

***Ключові слова: теплиця, нейронна мережа, система управління.***

## АВТОМАТИЗИРОВАННАЯ СИСТЕМА УПРАВЛЕНИЯ В ТЕПЛИЦАХ С НЕЙРОСЕТЕВОМ ПРОГНОЗИРОВАНИЕ ВНЕШНИХ ВОЗМУЩЕНИЙ

***А. Дудник***

*Приведены результаты исследований эффективности разработки автоматизированной системы управления в теплицах с прогнозированием возмущений в виде интенсивности солнечной радиации и температуры воздуха.*

***Ключевые слова: теплица, нейронная сеть, система управления.***