DEVELOPMENT OF GREENHOUSE MICROCLIMATE CONTROL SYSTEM PROTOTYPE

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Abstract: *The aim of the paper is to develop Matlab Simulink model that is substantiated by mathematical methods, in order to carry out further investigations of the climate control in the greenhouse and elaboration of a practical solution. Greenhouse environment is complex and it is necessary to understand greenhouse environment to create advanced models to describe nature processes and ensure effective crop production process. Our research is dedicated to convergence of mathematics, modeling and programming. Inaccuracy in system building methods, methodics and methodology can lead into more expensive system building and unreasonably difficult system maintenance. It is necessary to use structured methodics that have been developed by other researchers and field professionals. This research is not limited by greenhouse, nature processes is the same in different applications the same mathematical methods can be applied to describe similar differential equations of the processes. Author's recent studies in operating systems field show that such system can have client – server model utilizing innovations in hardware and software development. (Campi, N., Bauer, K., 2009) In the future such system can be integrated into a cluster with bio-diesel plant, ethanol still, methane bio-digester to improve efficiency and production of bio-gas and bio-diesel, co-generation unit to improve energy efficiency and plasma arc waste disposal to decrease environment pollution. Some ideas to build greenhouse system can be borrowed from smart house systems. (Goodwin S., 2010) Hardware interfaces and data transmission protocols are the same. One of the proposals for an ultimate goal is to build cloud system which can be accessed from anywhere on the planet to control production processes in the factory facilities.*

Keywords: Microclimate, Matlab, Control system, SCADA

Introduction

In system building certain levels exists as shown in fig.1. The lowest is the statistics and analysis, main objective of this process is to gather data from sensor network and analyze it. On process recognition stage using data from previous level we can make one or another decision on how to control heat, humidity or light process using programmable logic controller or personal computer or custom electronic solution. When it is done we can model our solution in Matlab or other alternative. And finally mathematical model can be optimized to gain better output results. The quantity of the quality information increases in each level. Nowadays science mostly is datacenter-science, scientist summarize theory, carry out experiments and simulate results. Using process data exploration and data mining (data obtained from instruments, simulated results and data collected from sensor networks). (Stalidzāns and Osadčuks, 2008) Also if we want Latvian agriculture to be able to compete for market share it is necessary to provide economically verifiable product at the lowest cost possible and the quantity is giving huge impact on the output revenue and market coverage. Such manufacturing production systems are the necessary part of modern rural development in giving sustainable and predictable profit ground for businesses. Synergy of Economics, Information technology, Automation can give boost for Latvian economics. In cooperation with other professionals options can be varied for example minimized pollution from production processes or minimized energy consumption with maximized production output from greenhouse production plants. So before modeling data sensor network must be deployed and result must be summarized in database for data further analysis.

In our opinion modeling can be divided into three stages:

1. Conceptual model
2. Control system model
3. Numerical process model

- **Conceptual model**

This is the entry level of modeling on that stage scientist must have perception of the control process physics. Figure 2 shows greenhouse control system functional model input data, output data and external perturbations. It was assumed that the heat exchange process interfere with gas to gain more accurate greenhouse model. It is also necessary to control CO_2 emission and consumption for biological process monitoring. Conceptual model represents 'concepts' (entities) and relationships between them. Conceptual model can be developed using various notations, such as UML or object-modeling technique (OMT) for object and their relation modeling. Also UML model enables to generate source code this option can be very useful in system development.

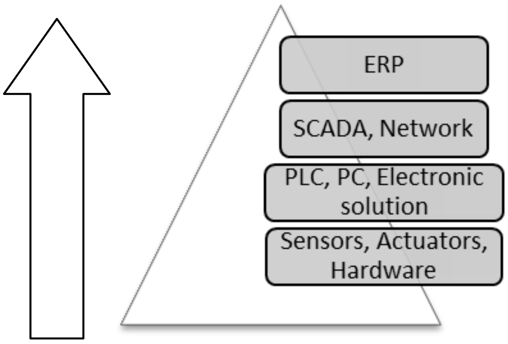

Fig.1. **System building methods**

Classic model for computer integrated manufacturing typically splits the control and monitoring functions of an automation system into 4 discrete levels.

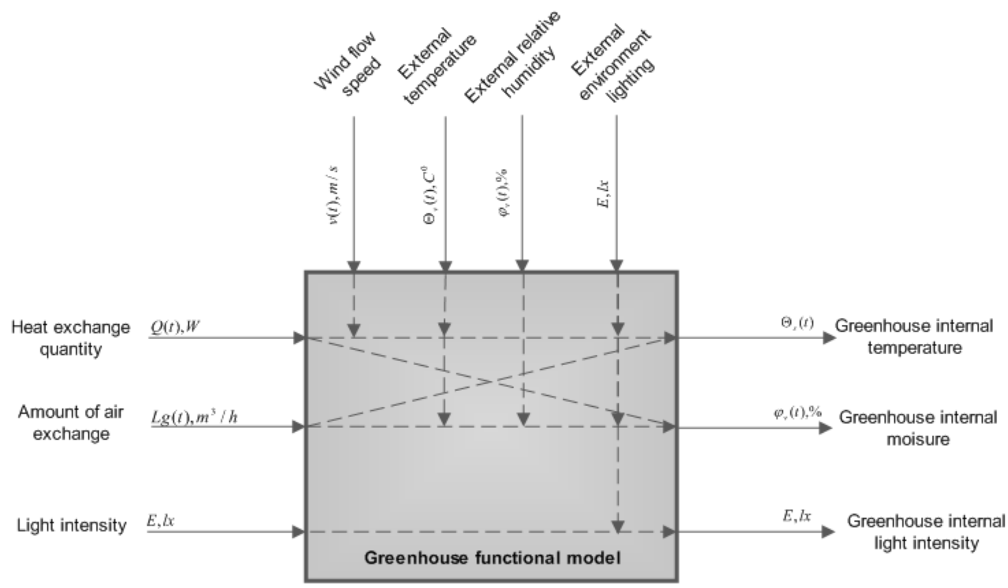

Fig.2. **Greenhouse control system functional model**

Greenhouse model is based on classic model for computer integrated manufacturing and as system gets more sophisticated it is often difficult to fault it and find time of the fault. Because of that fact system building must be structured it can decrease solving problem time and finding working solution.

- Control system model

This is the second level of modeling which introduces control system concept substantiated by mathematical calculations. It is classical control system with the feedback link. Processes are controlled by the PID and PI controllers.

Heat model

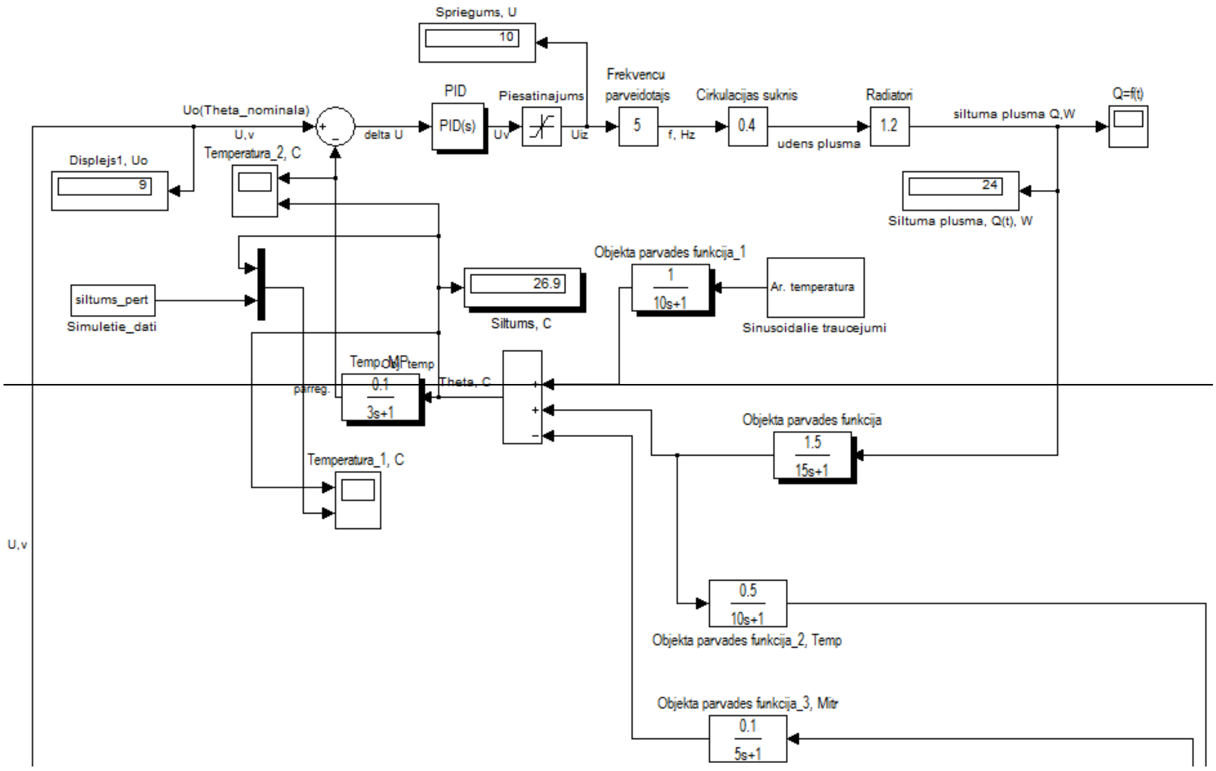

Fig.3. **Control system heat process modeling**

Heat process involves PID electronic execution hardware, frequency converter and circulation pump and heater system. It is the main heat process execution equipment. Heat feedback link equipment is process measurement sensors, monitoring server and software. (Šnīders, 2008)

Automation system quality indicators:

- Greenhouse air temperature $\theta_{iekš} = 26^0C$;
- Static error $\varepsilon \leq \pm 10\%$;
- Maximal allowed over regulation level $\sigma \leq \pm 10\%$;

Humidity model

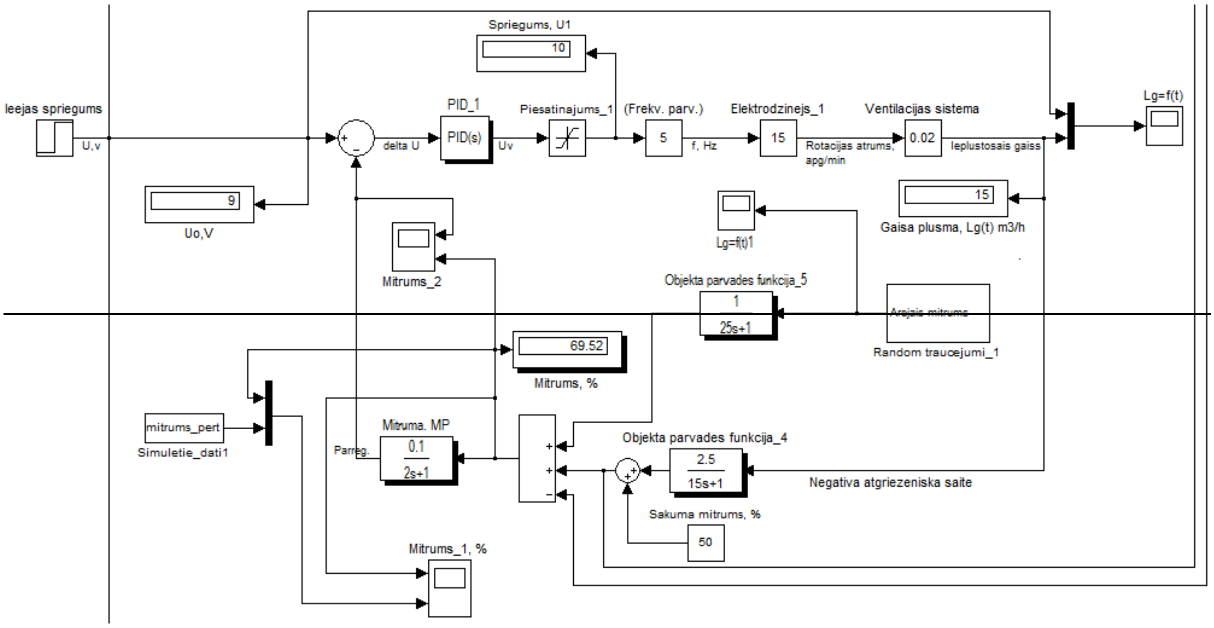

Fig.4. **Control system humidity process modeling**

Humidity process involves PID controller, frequency converter and motor and ventilation shaft system. It is the main process equipment. (Šnīders, 2008)

Automation system quality indicators:

- Greenhouse humidity level $\varphi_{iekš} = 70\%$;
- Static error $\varepsilon \leq \pm 10\%$;
- Maximal allowed over regulation level $\sigma \leq \pm 10\%$;

Light control model

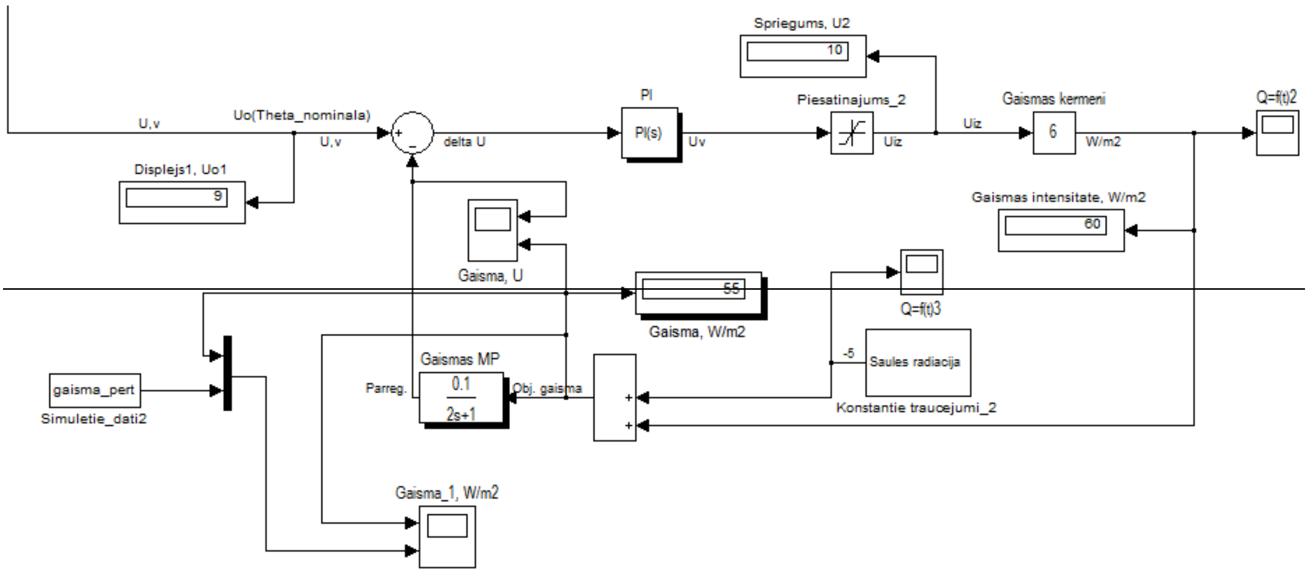

Fig.5. **Control system light process modeling**

Light control process involves PI controller, frequency converter and light panels. It is the main process equipment. (Šnīders, 2008)

Automation system quality indicators:

- Greenhouse artificial light intensity $E_t = 55\ W * m^{-2}$

- Static error $\varepsilon \leq \pm 10\%$;
- Maximal allowed over regulation level $\sigma \leq \pm 10\%$;

Heat and humidity processes are not linear processes exception is light and regulation appropriate for process control is the PID controller. For light control we choose PI controller especially for light attenuation in the greenhouse. System also should make CO_2 emission and consumption evaluation to prevent errors in biological process to maximize productivity. CO_2 concentration decrease or increase in air can be as a signal for other process correction. CO_2 impact on biological process is complex as if carbon dioxide concentration is too high plants cannot cool themselves and humidity will decrease and temperature will increase slowing down plant development process. If carbon dioxide concentration decreases again plants will not develop properly slowing down vegetation process. (Stalidzāns and Osadčuks, 2008)

- Numerical process model

This is most complicated level of the modeling because of mathematics complexity in real-time world equations that describes processes. We can model differential equation of the process but to fully understand for example gas motion in the greenhouse we have to use Navier–Stokes equations, those arise from applying Newton's second law to fluid motion, together with the assumption that the fluid stress is the sum of a diffusing viscous term (proportional to the gradient of velocity), plus a pressure term. This differential equation system describes fluid and gas motion in Newton physics world.
With Fourier method or d'Alembert method heat differential equation can be solved to show changes that occur during the process. Maxwell's equations are the set of partial differential equations with Lorentz force, form foundation of electrodynamics, optics and electronic circuits. Those problems mostly can be solved with Matlab software. (Seibold, 2009)

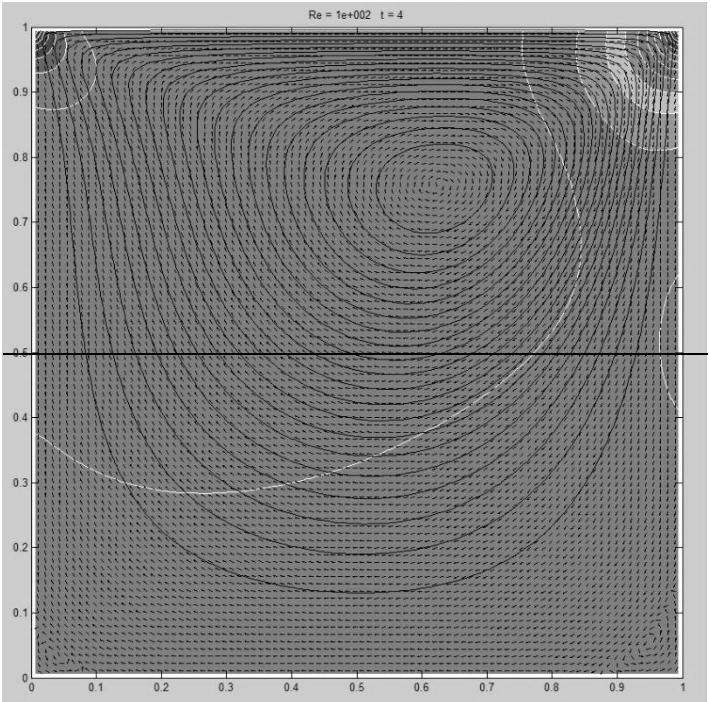

Fig.6. **Matlab model representation of Navier–Stokes equations (Seibold B., 2009)**

Materials and Methods

System building levels have been shown in Figure 7. To build system we should start with electronic circuit logic and sensors to gather data. Next is the data transmission protocols can be used. C-Bus, X10 or TCP/IP, such system require deep knowledge of Assembler, C and Java or C# and MySQL programming languages. To control low level electronics it is mostly C programming and interface programming mostly done in C# for Windows platform and Java for Linux. Also using MonoDevelop in Linux C# programs can be developed. Such system should have server-client method using for example Ubuntu Linux which is mostly stable platform for further development.
Windows or Linux platform choice will play important role on the tools available for further system development. Nowadays trend for information technologies is the cloud computing this is the typical server-

client system which utilizes benefits of remote access through TCP/IP protocol to controlled system. Application server can be installed on Ubuntu Linux with secure access to the service using openssl library. This is representing operating system level. On the system and electronics level electronic system must be developed to communicate with higher level. It is Linux based problem solving approach which is open source and requires knowledge of Java and C and electronics and MySQL.

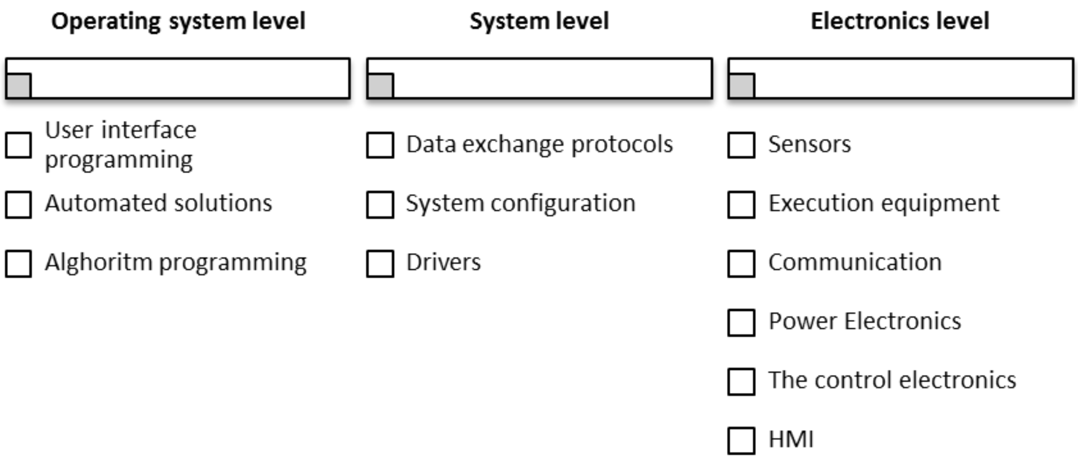

Fig.7. **Control system level classification**

Siemens Corporation offers Totally Integrated Automation suite for controlling factory machinery. It is another good solution for tasks automation. This problem solving approach requires knowledge of ladder logic, statement list or functional block diagram language and good knowledge of TIA environment for HMI development. This is Windows based automation concept for serious engineering projects because of high costs of Siemens equipment. It is necessary to calculate system and maintenance cost to evaluate economic gain from the project.

International experience of such system building is different Siemens is one of leading automation technology supplier. On other hand many promising open source technologies emerge for automation tasks for example Open Scada or MatPLC for Linux. One interesting project is the RTAI (Real Time Application Interface) which enables Linux kernel to execute applications with strict timing constraints this is critical to real time systems executing commands in real world environment. One of the common issues is the necessity of usage of standardized hardware because of that industrial pc usage is becoming trend.

Future possibilities of control system building (maybe autonomous systems, agent based systems) on horizon emerge adaptive control with neural networks and evolutionary algorithm concepts. For now presented system is the classic variant of PID and PI with the feedback link. (Komasilovs and Stalidzāns, 2010)

One more important topic is the model validation and verification it is important to be sure that the model is accurate representation of the real system. Validation is usually achieved through the calibration of the model; it is an iterative process of comparing the model to actual system behavior. It is utilized in the comparison of the conceptual model to the computer representation that implements that conception.

Results and Discussion

The greenhouse effective floor surface is 160 m^2 (7500mm x 20000mm) and height in along the longest side of the building 2500 mm and height at the top 3700 mm. The building has a metal backbone and white plastic wall coating with thickness of 4mm. On one sides of the greenhouse there is a plastic door 1000 mm x 2000 mm with additional insulation, on other side of greenhouse is the gates with physical parameters of 5000 mm x 2500 mm also with additional insulation.

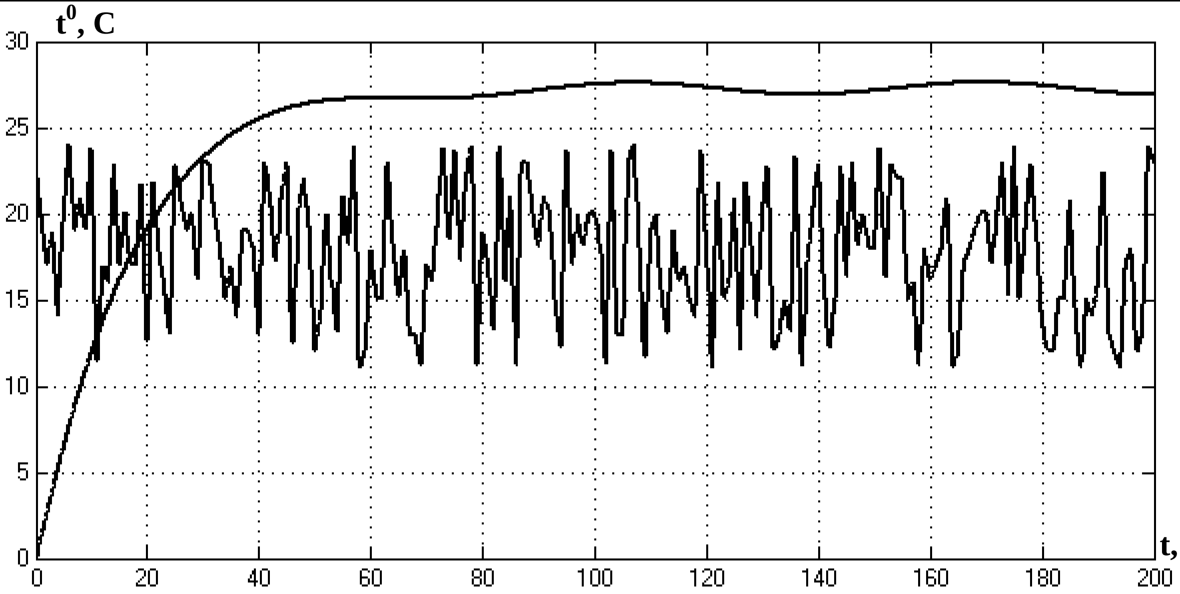

Fig.8. **Temperature change during the day and internal greenhouse temperature,** $\Theta_s(t)$

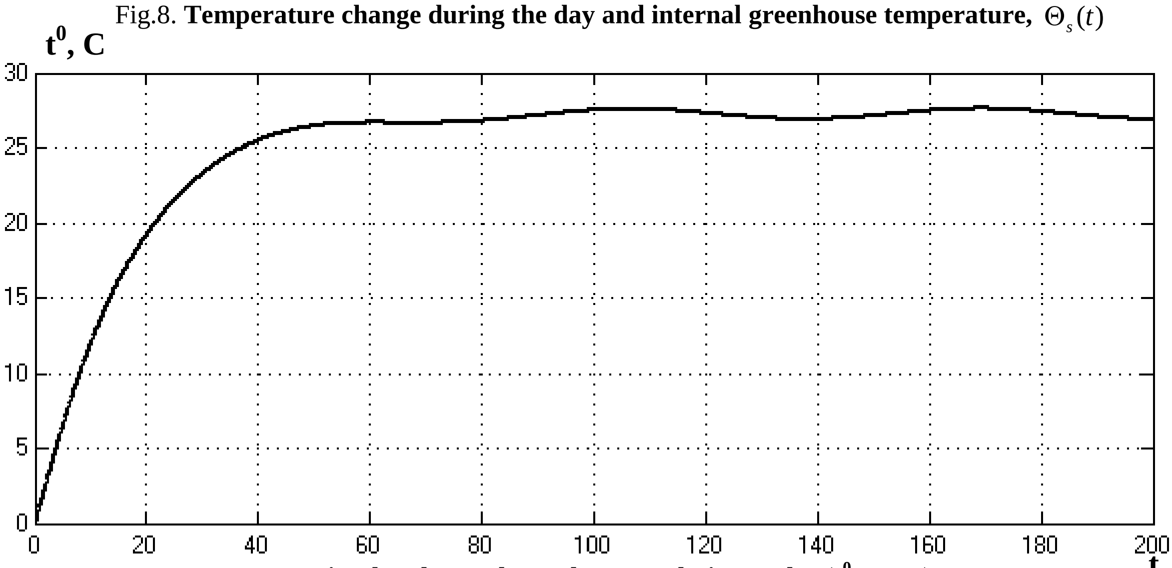

Fig.9**. Simulated greenhouse heat regulation under (t^0 = 26C)**

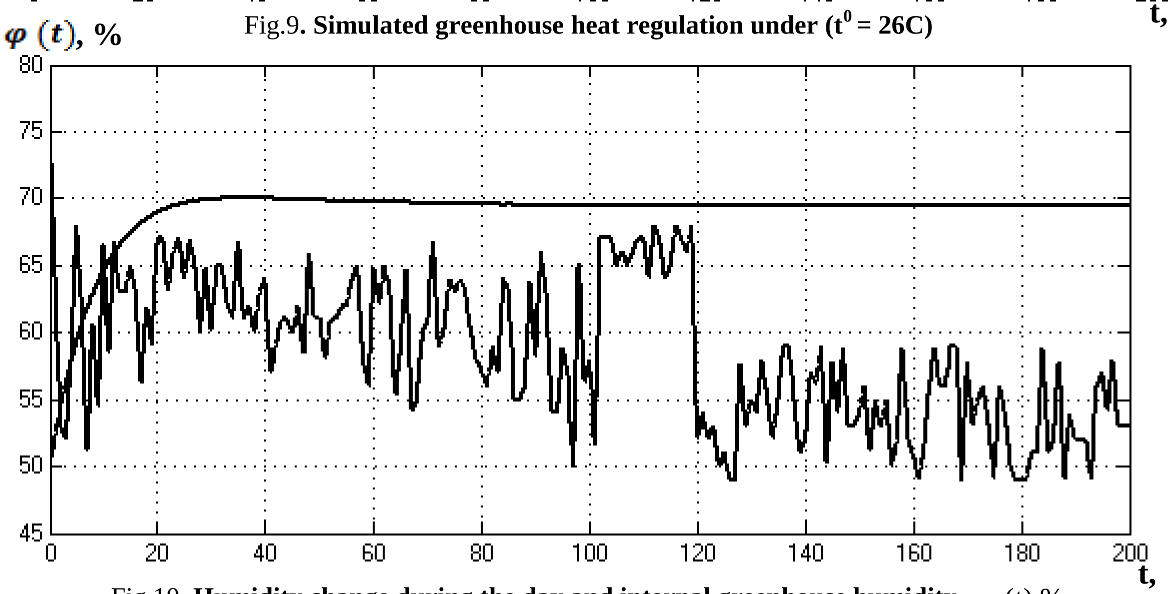

Fig.10. **Humidity change during the day and internal greenhouse humidity**, $\varphi_v(t)$,%

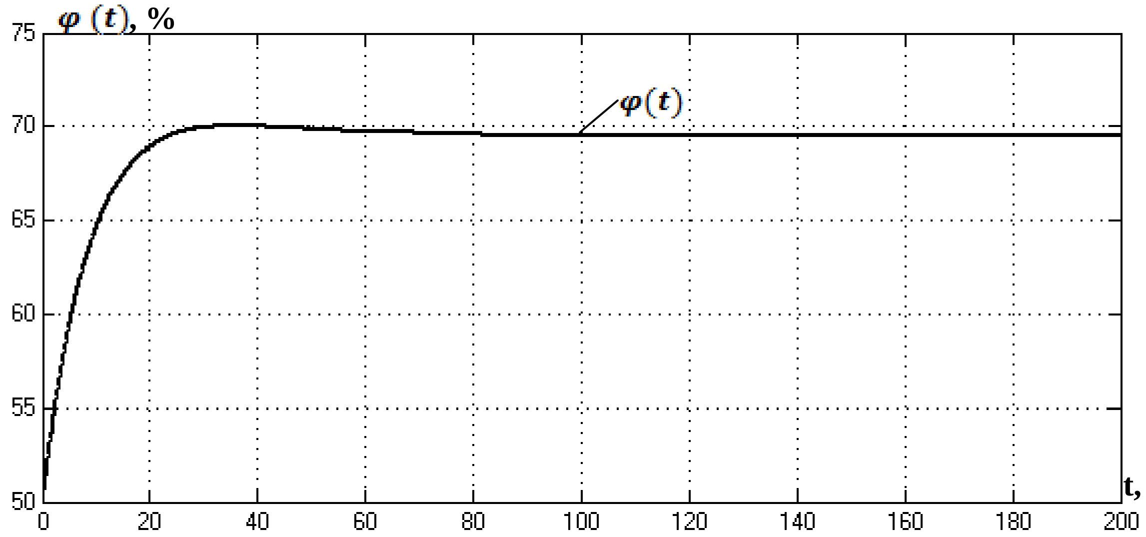

Fig.11. **Simulated greenhouse humidity regulation for model with feedback under (Lg=70%)**

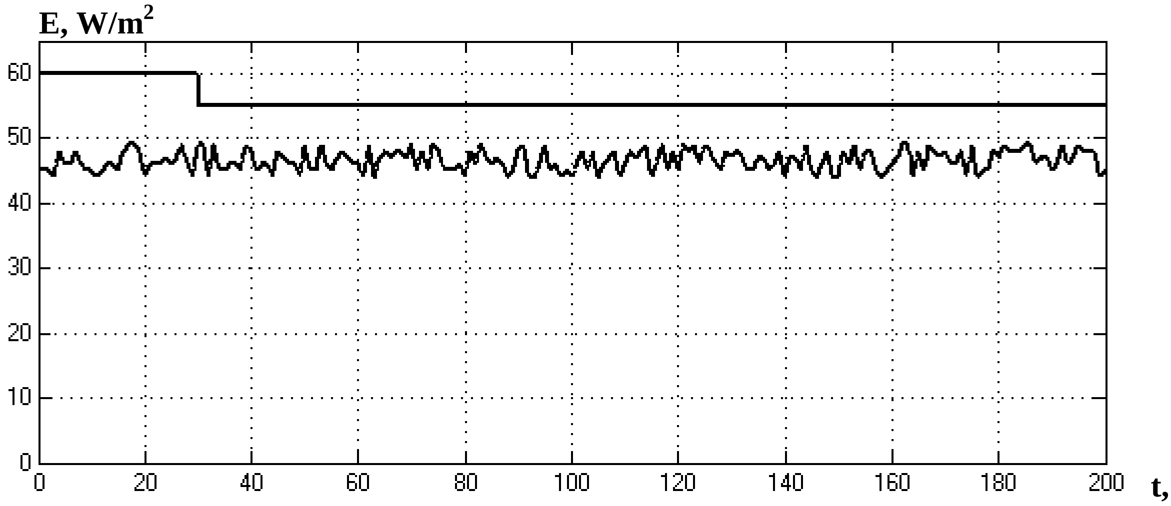

Fig.12. External light intensity change during the day and internal greenhouse lighting, $E(t), W * m^{-2}$

Conclusion

Based on the information gathered during the work and experience gained, it can be concluded that the control problems can be found in different fields of human activity. They are associated with different process research in machines and living organisms. An automatic control system with feedback control signal is formed according to the output variable values. Information about the object state through feedback into the control unit at the inlet, where, after appropriate modifications to the system is compared to the input size. Comparison of the resulting signal (error signal) is used to form devolved signal according to algorithm (enhanced, integrated, differentiated) impact. Control system is trying to reduce the output size of the deviation and return the object to the default condition.

The main advantage of systems with feedback is the ability to set the output variable, regardless of changes in the size of the bias caused by the underlying causes, which may not always be measured. System accuracy is significantly higher than in the compensation principle method.

The Lerner and Ziegler-Nicholas criteria for the regulator algorithm choices are appropriate. Using the PI and PID system shows good results in the bias compensation. On the feedback is returned set element change and then compared with the necessary element value if it is corresponding to necessary value. Depending on whether it meets or does not meet the voltage is supplied.

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