6th International Conference
ð Computational Mechanics and Virtual Engineeringð
COMEC 2015
15-16 October 2015, Braşov, Romania

ESTABLISHING TO CONFIGURATION AND MATHEMATICAL MODEL OF SYSTEM BY AUTOMATICALLY ADJUSTMENT FOR HUMIDITY AND AIRFLOW IN GREENHOUSES FOR VEGETABLES AND FLOWERS

Gh. Brătucu[1],C.G. Păunescu[1], D.D Păunescu[1], C.E. Badiu[1]
[1]Transilvania University of Braşov, Braşov, ROMANIA, gh.bratucu@unitbv.ro

***Abstract**: The paper proposes a scheme of automated control humidity and airflow greenhouses for vegetables or flowers. For the mathematical modeling of these parameters is considered a greenhouse cylindrical cone the air contains a lot of infinitesimal elements on which acts inlet and outlet pressures at a distance x along airflow ventilation. To construct the auto were passed equations of the time in Laplace, the initial conditions null knowing the transfer function, as well as the entry and exit of air, get representation system functional automatic adjustment of MIMO system . With these functions built in Simulink model to transfer control of the proposed system, but before it was examined stability of each transfer functions in MATLAB, observing that the system is fully observable and controllable.*
***Keywords**: vegetable and flower greenhouses, humidity and airflow, mathematical and dynamic modeling*

1. INTRODUCTION

The greenhouses for vegetables and flowers are special constructions which must provide shelter, optimal climate conditions for the development of vegetables and flowers throughout the year. To this end research focuses on the most precise and reliable systems capable of automatically adjust temperature, humidity and airflow inside greenhouses in line with the needs of plants at a time regardless of outside weather conditions. Implement a system of automatic adjustment of this type involves numerous researches and expenses, which can simplify or reduce if we rely on simulation and modeling of processes related to climate. On the other hand, the results of this research will be more reliable and powerful, how modern methods of study, and the variables are as close to real situations.

2. MATERIALS AND METHOD

2.1. Establishing scheme and a mathematical model to automatically adjust the humidity and airflow in the greenhouse

Ventilation and air conditioning, active or passive, can be achieved in several ways: as radial tree or as ladder airflow. These configurations are important if we take into account the overall effectiveness of the ventilation system and energy required for continuous ventilation [1], [5], [9], [10]. Ventilation and air conditioning systems should operate continuously, regardless of changes the inner and outer dynamic environment (which may have significant variations of pressure, temperature and humidity).
It was considered a greenhouse that has two recirculation fans, and an area where the air is humidified to the optimal percentage. A filter is used and the recycled air introduced from the outside. It is also necessary control air temperature and humidity obtained by mixing outdoor air with the recirculation. Figure 1 introduced such a system is used in modern greenhouses [2], [3], [4].
Diffusivity ventilated air volume has the effect of changing indoor air quality and temperature variation also stored products. Typically, the entrained air flow is described by two different air flow patterns.

Normally these two models of the air diffusers are present within the cells of storage under steady state mixture, with the ability to adjust the proportion of each in order to provide the desired movement of the air, and to maintain its quality [6], [16].

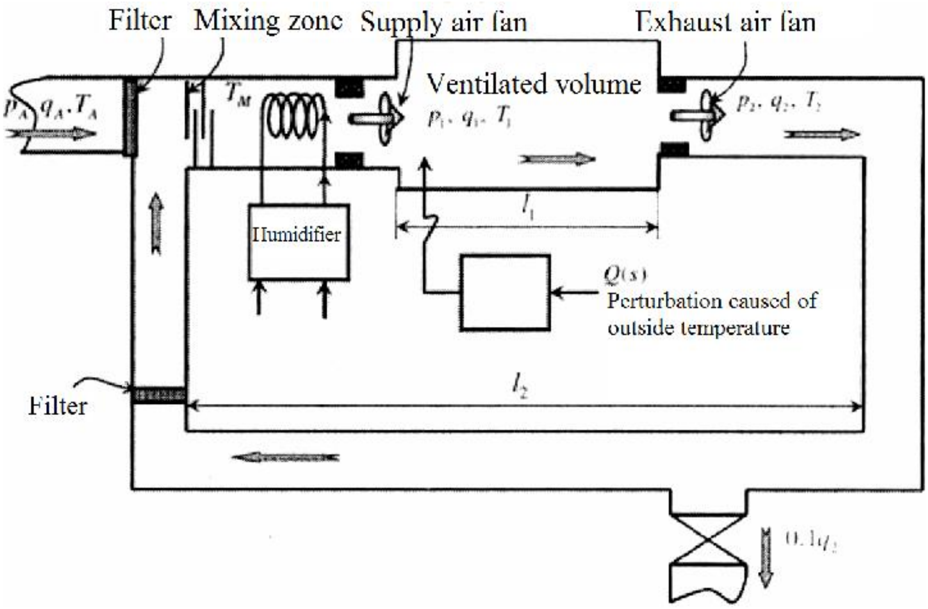

Figure 1 The scheme of automatic control humidity and airflow in greenhouses

The two fans used will be modeled as parametric focus, so the pressure changes of input and output can be controlled by varying the voltage of the fan motors, so they will be two of the actuators that will receive the order from the control system. However, the size and volume of ventilation air conditioning will be modeled by incorporating distributed energy storage parameters and the effects of inductance and capacitance of the air.
To achieve mathematical model of air flow pressure with distributed parameters is considered as length and diameter storage cell, which is considered to have a cylindrical shape. Air cone comprises an infinite series of infinitesimal elements on which it acts *dx* inlet pressure *p(t, x)* and output *p(t, x+dx)* at a distance x along the flow of the ventilation air.
The volume of these elements is properly flow *q(t, x)* for input and *q(t, x+dx)* to exit. Each element has an associated inductance L, which represents the inertia of the gas per unit of length, and a capacitance loads representing the conformity of gas flow per unit length. These are expressed mathematically by the relationship [8]:

$$L = \frac{l_1}{® \cdot r_1^2}\,; \tag{1}$$

$$C = \frac{V}{R \cdot T_n}\,, \tag{2}$$

where: *V* is the room volume, $V = ® \cdot r_1^2 \cdot l_1$ in m^3; l_1 - length of the room in m; *r*- the radius of the room in *m*.
In order to perform the analysis is considered that the air flow consists of an infinite series of infinitesimal elements, as shown in Figure 2.
The differential equations that describe the process are:

$$p(t,x+dx) - p(t,x) = -L \cdot \frac{\partial q}{\partial t}(t,x+dx)dx\,; \tag{3}$$

$$q(t,x+dx) - q(t,x) = -C \cdot \frac{\partial q}{\partial t}(t,x+dx)dx\,. \tag{4}$$

At the limit, the equations (3) and (4) are [7] [13]

$$\frac{\partial p(t,x)}{\partial x} = -L \cdot \frac{\partial q(t,x)}{\partial t}\,; \tag{5}$$

$$\frac{\partial q(t,x)}{\partial x} = -C \cdot \frac{\partial p(t,x)}{\partial t}\,. \tag{6}$$

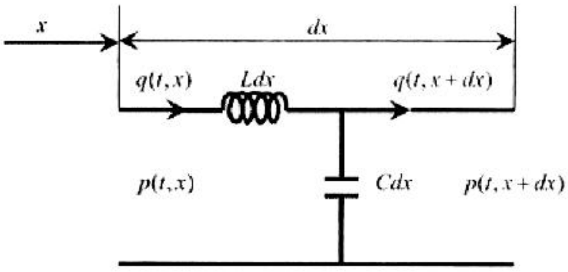

Figure 2 Schematic representations of the elements of the air flow

For building automatic control system will pass the time in the equations of Laplace, at baseline void. Then equations (5) and (6) become:

$$\frac{dp}{dx} = -L \cdot s \cdot q\,; \tag{7}$$

$$\frac{dq}{dx} = -C \cdot s \cdot p\,, \tag{8}$$

where p = p (s, x) and q = q (s, x).
These equations longer derives once again depending on the variable x and obtain:

$$\frac{d^2 p}{dx^2} = -L \cdot s \frac{dq}{dx}\,; \tag{9}$$

$$\frac{d^2 q}{dx^2} = -C \cdot s \frac{dp}{dx}\,. \tag{10}$$

Insert equations (1) and (2) in equations (3) and (4) to give:

$$\frac{d^2 p}{dx^2} = L \cdot C \cdot s^2 \cdot p\,; \tag{11}$$

$$\frac{d^2 q}{dx^2} = L \cdot C \cdot s^2 \cdot q\,. \tag{12}$$

It is obvious that the equations (1) and (2) have the same shape and the same general solutions. If defined in Laplace domain propagation function of the form:

$$\Gamma(s) = s \cdot \sqrt{L \cdot C}\,, \tag{13}$$

then general solutions are in the form:

$$p(s,x) = A \cdot \cosh \Gamma(s)x + B \cdot \sinh \Gamma(s)x\,; \tag{14}$$

$$q(s,x) = C \cdot \sinh \Gamma(s)x + D \cdot \cosh \Gamma(s)x\,; \tag{15}$$

For x = 0 we obtain:

$$A = p(s,0);\; D = q(s,0). \tag{16}$$

If derives equations (14) and (15) as a function of the variable x and then calls the equations (7) and (8) we obtain:

$$-L \cdot s \cdot q(s,x) = A \cdot \Gamma(s) \sinh \Gamma(s)x + B \cdot \Gamma(s) \cosh \Gamma(s)x\,; \tag{17}$$

$$-C \cdot s \cdot q(s,x) = C \cdot \Gamma(s) \cosh \Gamma(s)x + D \cdot \Gamma(s) \sinh \Gamma(s)x\,. \tag{18}$$

For x = 0 equation (17) becomes:

$$-L \cdot s \cdot q(s,0) = B \cdot \Gamma(s)\,; \tag{19}$$

$$\Rightarrow B = -\frac{L \cdot s}{\Gamma(s)} \cdot q(s,0) = -\sqrt{\frac{L}{C}} \cdot q(s,0)\,. \tag{20}$$

If the characteristic impedance is expressed as in the following relationship:

$$¶ = \sqrt{\frac{L}{C}}\,, \tag{21}$$

where equations (14) and (15) become:

$$p(s,x) = \cosh \Gamma(s)x \cdot p(s,0) - ¶ \cdot \sinh \Gamma(s)x \cdot q(s,0)\,; \tag{22}$$

$$q(s,x) = -¶^{-1} \cdot sinh\,\Gamma(s)x \cdot p(s,0) + cosh\,\Gamma(s)x \cdot q(s,0). \tag{23}$$

From the equations (12), (14) and (15) we obtain

$$B = -¶ \cdot q(s,0)\ si\ C = -¶^{-1} \cdot p(s,0). \tag{24}$$

At a distance *l* along the air flow is obtained equations:

$$\begin{bmatrix} p(s,l) \\ q(s,l) \end{bmatrix} = \begin{bmatrix} l\,cosh\,\Gamma(s) & -\xi l sinh\Gamma(s) \\ -\xi^{-1} sinh\Gamma(s) & l\,cosh\,\Gamma(s) \end{bmatrix} \begin{bmatrix} p(s,0) \\ q(s,0) \end{bmatrix}. \tag{25}$$

This equation may also be set from the point of view of impedance:

$$\begin{bmatrix} p(s,l) \\ q(s,l) \end{bmatrix} = \begin{bmatrix} -\xi l ctnh\Gamma(s) & \xi l csch\Gamma(s) \\ -\xi l csch\Gamma(s) & \xi\, l ctnh\Gamma(s) \end{bmatrix} \begin{bmatrix} q(s,l) \\ q(s,0) \end{bmatrix}, \tag{26}$$

where: $ctnh\Gamma(s,)l = \frac{e^{2\Gamma(s)l}+1}{e^{2\Gamma(s)l}-1} = w(s)$, and $csc\,h\Gamma^2(s,)l = (ctnh^2\Gamma(s)l-1)^{1/2} = (w^2(s)-1)^{1/2}$

With this new notation equation (7) and (6) become:

$$p(s,0) = p_1(s);\ p(s,l) = p_2(s); \tag{27}$$

$$q(s,0) = q_1(s)\ si\ q(s,l) = q_2(s), \tag{28}$$

or as the matrix is obtained:

$$\begin{bmatrix} p_1(s) \\ p_2(s) \end{bmatrix} = \begin{bmatrix} ¶w(s) & -¶(w^2(s)-1)^{\frac{1}{2}} \\ ¶(w^2(s)-1)^{\frac{1}{2}} & -¶w(s) \end{bmatrix} = \begin{bmatrix} q_1(s) \\ q_2(s) \end{bmatrix}. \tag{29}$$

If considered as $p_2(s) = f(p_2)q_2$ constituting pressure to distance *l* then obtain:

$$\begin{bmatrix} p_1(s) \\ 0 \end{bmatrix} = \begin{bmatrix} ¶w(s) & -¶(w^2(s)-1)^{\frac{1}{2}} \\ ¶(w^2(s)-1)^{\frac{1}{2}} & -¶w(s) - f(p_2) \end{bmatrix} = \begin{bmatrix} q_1(s) \\ q_2(s) \end{bmatrix}. \tag{30}$$

To be found MIMO transfer function system control and adjustment will be deemed to humidity variation inside the greenhouses is a linear function of pressure, according to Dalton's Law. Also, fan speed variation by automatically adjusting system will ensure a laminar flow of air.

To be properly described the physical phenomena that occur when ventilation air masses are taken into account the following assumptions:

- introducing air fan power required is the sum of the following components: the power required to drive air through filters and flow through the mixing humidified air to the interior of the greenhouse; power necessary to overcome resistance to the entry into interior volume; power required to drive airflow to the volume of greenhouse;
- ventilator power required evacuating air and recirculates it is the sum of the following components: power output required to overcome resistance inside the greenhouse; the power needed to drive the flow of air inside the greenhouse to air recirculation system.

For expression of the equations that describe mass of air entering the greenhouse and the air mass at the outlet of the gases are introduced coefficient of friction f_1, which occurs due to resistance to entry of air into the volume vented and the coefficient of friction f_2, which occurs due to the resistance at the outlet volume ventilated and entry into the circulation system.

Laplace equation written in describing the air mass m_1 entry into the greenhouse vegetable or flower is:

$$\Delta p_1(s) - \frac{(m_1 s\Delta q_1(s) + f_1\Delta q_1(s)}{a_2} = ¶w_1(s)\Delta q_1(s) - ¶(w_1^2(s)-1)^{\frac{1}{2}} \cdot \Delta q_2(s), \tag{31}$$

and the equation describing the air mass m_2 of the volume extracted and inserted into the ventilated circulation system is:

$$-\Delta p_2(s) + \frac{(m_2 s\Delta q_2(s) + f_2\Delta q_2(s))}{a_2} = ¶(w_1^2(s)-1)^{\frac{1}{2}} \cdot \Delta q_1(s) - ¶w_1(s) \cdot \Delta q_2(s). \tag{32}$$

For the calculations are the following notations:

$$\text{¥}_1(s)=\frac{m_1 s+f_1}{a_2};\tag{33}$$

$$\text{¥}_2(s)=\frac{m_2 s+f_2}{a_2}\tag{34}$$

where a_2 is recirculating air duct section.
This system of equations is written in matrix form in order to more easily work with him and get:

$$\begin{bmatrix}\Delta p_1(s)\\ -\Delta p_2(s)\end{bmatrix}=\begin{bmatrix}\P w_1(s)+\text{¥}_1(s) & -\P(w_1^2(s)-1)^{\frac{1}{2}}\\ \P(w_1^2(s)-1)^{\frac{1}{2}} & -\P w_1(s)-\text{¥}_2(s)\end{bmatrix}\begin{bmatrix}\Delta q_1(s)\\ \Delta q_2(s)\end{bmatrix}.\tag{35}$$

Below are the following notations:

$$w_1(s)=\frac{e^{2l_1 r_1(s)}+1}{e^{2l_1 r_1(s)}-1}\tag{36}$$

and:

$$\Delta(s)=\P(\text{¥}_1(s)+\text{¥}_2(s))w_1(s)+\text{¥}_1(s)\text{¥}_2(s)+\P_1^2,\tag{37}$$

where $\Delta(s)$ is the determinant of the matrix.
Equation (35) is rewritten:

$$\begin{bmatrix}\Delta q_1(s)\\ \Delta q_2(s)\end{bmatrix}=\frac{\begin{bmatrix}\P w_1(s)+\text{¥}_1(s) & -\P(w_1^2(s)-1)^{\frac{1}{2}}\\ \P(w_1^2(s)-1)^{\frac{1}{2}} & -\P w_1(s)-\text{¥}_2(s)\end{bmatrix}}{\Delta(s)}\begin{bmatrix}\Delta p_1(s)\\ \Delta p_2(s)\end{bmatrix}.\tag{38}$$

When including the dynamics of the fan and the effect of pressure which is directly proportional to the change in the voltage v_1(s) and $v_2(s)$, the effect of pressure of air flow on the moisture $ph_1(s)$ and $ph_2\ (s)$ and make the following replacements [15] :

$$p_1(s)=\frac{K_1 v_1(s)}{\text{²}_1 s+1}+p_{h1}(s);\tag{39}$$

$$p_2(s)=\frac{K_2 v_2(s)}{\text{²}_2 s+1}+p_{h2}(s),\tag{40}$$

where: ²_1 and ²_2 are time constants of introducing air fan motor or discharging air; k_1 and k_2 - amplification factors of fan motors, we get the following relationship:

$$\begin{bmatrix}\Delta q_1(s)\\ \Delta q_2(s)\end{bmatrix}=\frac{\begin{bmatrix}\P w_1(s)+\text{¥}_1(s) & -\P(w_1^2(s)-1)^{\frac{1}{2}}\\ \P(w_1^2(s)-1)^{\frac{1}{2}} & -\P w_1(s)-\text{¥}_2(s)\end{bmatrix}}{\Delta(s)}\left[\begin{bmatrix}\frac{K_1}{\text{²}_1 s+1} & 0\\ 0 & \frac{K_2}{\text{²}_2 s+1}\end{bmatrix}\begin{bmatrix}\Delta v_1(s)\\ \Delta v_2(s)\end{bmatrix}+\begin{bmatrix}\Delta p_{h1}(s)\\ \Delta p_{h2}(s)\end{bmatrix}\right]\tag{41}$$

Equation (41) gives the transfer function between input and output automatic control system, that is:

$$\begin{bmatrix}\Delta q_1(s)\\ \Delta q_2(s)\end{bmatrix}=H(s)\cdot\begin{bmatrix}\Delta v_1(s)\\ \Delta v_2(s)\end{bmatrix}.\tag{42}$$

If we consider the time constants of the two fans to be equal to 10 s, $(\text{²}_1=\text{²}_2=10s)$ the transfer function becomes:

$$H(s)=\frac{\begin{bmatrix}\P w_1(s)+\text{¥}_1(s) & -\P(w_1^2(s)-1)^{\frac{1}{2}}\\ \P(w_1^2(s)-1)^{\frac{1}{2}} & -\P w_1(s)-\text{¥}_2(s)\end{bmatrix}\begin{bmatrix}k_1 & 0\\ 0 & k_2\end{bmatrix}}{\Delta(s)(\text{²}s+1)}.\tag{43}$$

Knowing the transfer function, input and output, it can get the system functional representation (Figure 3).

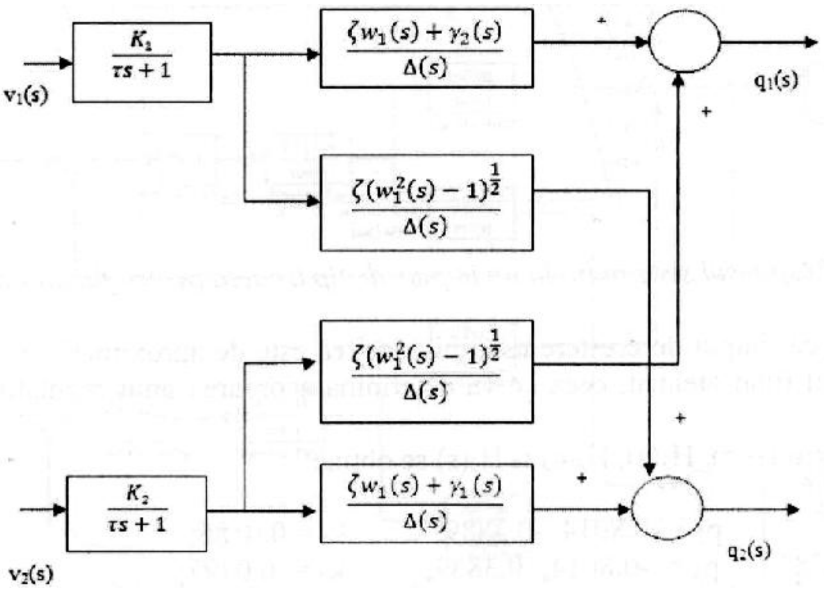

Figure 3 Functional representation system for automatic adjustment of the humidity and flow air, the MIMO type

The fan introducing the air in the greenhouse, and the extracted air from the greenhouse to provide a flow of air of about $K_1\%$, respectively $K_2\%$ these values being a function of the voltage applied to the fan. In addition, the air introduced into the greenhouse is conditioned so that the moisture thereof will be chosen by computer control, thus realizing to maintain a constant humidity within the greenhouse.

To achieve numerical simulation are chosen following values: K_1 = 0.02124 m^3V/s; K_2= 0.01416 m^3V/s; v_{1max} = 360 V; v_{2max} = 360 V; p_{1max} = 1.0342 bar, p_{2max} = 1.0342 bar, ¶ = 0.2526 m^{-2}, $\Gamma(s) = s\sqrt{LC}$ = 0.0036 s, l_1 = 30 m; m_1 = 3.723 kg/s; m_2 =4.407 kg/s; f_1 = 1.281 Ns/m^3; f_2= 1.922 Ns/m^3; a_2 = 0.371 m^2.

In this case, it will obtain the following transfer function:

$$H_1(s) = \frac{¶w_1(s)+¥_2(s)}{\Delta(s)} = \frac{11.88s+7.55}{125.84s^2+149{,}79s+39.22}; \quad (44)$$

$$H_2(s) = H_2^{'}(s) = \frac{¶(w_1^2(s)-1)^{\frac{1}{2}}}{\Delta(s)} = \frac{2.3431}{125.84s^2+149.79s+39.22}; \quad (45)$$

$$H_3(s) = \frac{¶w_1(s)+¥_1(s)}{\Delta(s)} = \frac{10.03s+5.8}{125.84s^2+149.79s+39.22}; \quad (46)$$

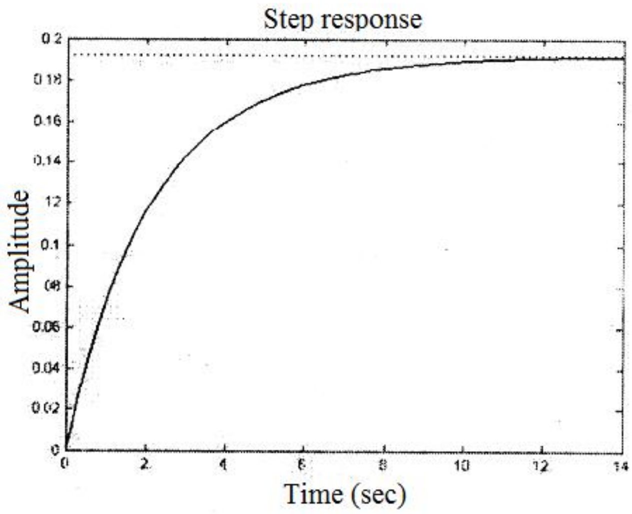

Figure 4 The system's response to an impulse type gear for the transfer function H_1

$$H_4(s)=\frac{K_1}{{}^2s+1}=\frac{0.02124}{10s+1}\;; \qquad (47)$$

$$H_5(s)=\frac{K_2}{{}^2s+1}=\frac{0.01416}{10s+1}\;. \qquad (48)$$

With this transfer function can be built in Simulink control system model proposed but before that check the stability of each transfer functions in MATLAB and obtain:
For $H_1(s)$ we obtain:

$Z_1 = 0, -0.6355$; $p_1 = -0.8014, -0.3889$; $k_1 = 0.0944$,

where Z are zeroes system, p - poles of the system and k - the gain.
The system is completely observable and controllable as the transfer function poles and zeros are in the left half-plane. It is also clear that the system is stable; its step response is illustrated in Figure 4.

It is noted that the rise time is small, the output is about 5 times smaller than the input, the answer is weakened, leading to the grant of a controller to increase the output.
Analog for $H_2(s)$, $H_3(s)$, $H_4(s)$ şi $H_5(s)$ is obtained:

$Z_2 = 0$;	$p_2 = -0.8014, 0.3889$;	$k_2 = 0.0186$;
$Z_3 = 0; -0.5783$	$p_3 = -0.8014, 0.3889$;	$k_3 = 0.0797$;
$Z_4 = 0$;	$p_4 = -0.1000$;	$k_4 = 0.0021$;
$Z_5 = 0$;	$p_5 = -0.1000$;	$k_5 = 0.0014$;

2.2. Simulation automatically adjust the humidity and airflow

Transfer functions that describe the processes taking place are completely observable and controllable, so stable. However, it appears that the rise time is very high, so very hard to respond to a step input type and the output is vitiated by large errors.

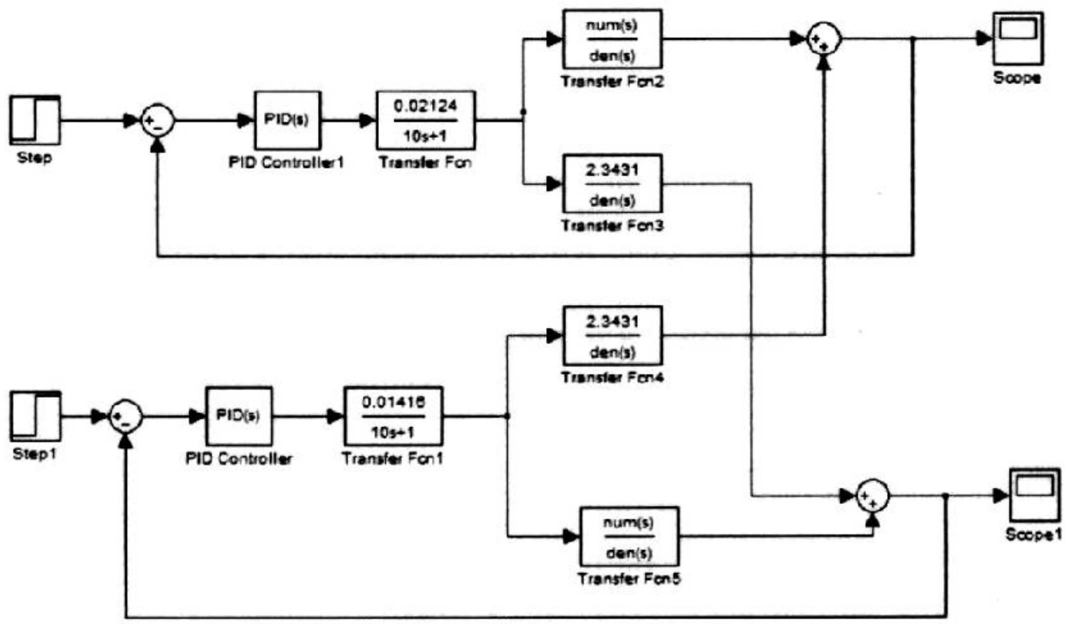

Figure 5 Scheme automatic adjustment MIMO system as a P-canonical structure

Further, the analysis is done M1MO system. It adopts a P-canonical structure, where H_1 (s) and H_3 (s) are the main transfer functions, and H_2(s) and H'2 (s) are transfer functions coupling
Figure 5 shows a schematic diagram of the system which is subject to automatic adjustment type input stage.
The calculation and optimization of Simulink controllers attached to this automatic adjustment have the following form:

$$H_{R1} = k_{p1} + k_{d1}s + k_{i1}/s\;; \qquad (49)$$

$$H_{R2} = k_{p2} + k_{d2}s + k_{i2}/s\;; \qquad (49)$$

where: k_{p1} = 433.15; k_{d1} = - 422.42; k_{i1} = 53.16; k_{p2}= 184.45; k_{d2} = 103.10; k_{i2} = 22.28;
With these values and transfer functions of regulators, this system exits the application forms for an entry level unit type are shown in Figures 6 and 7.

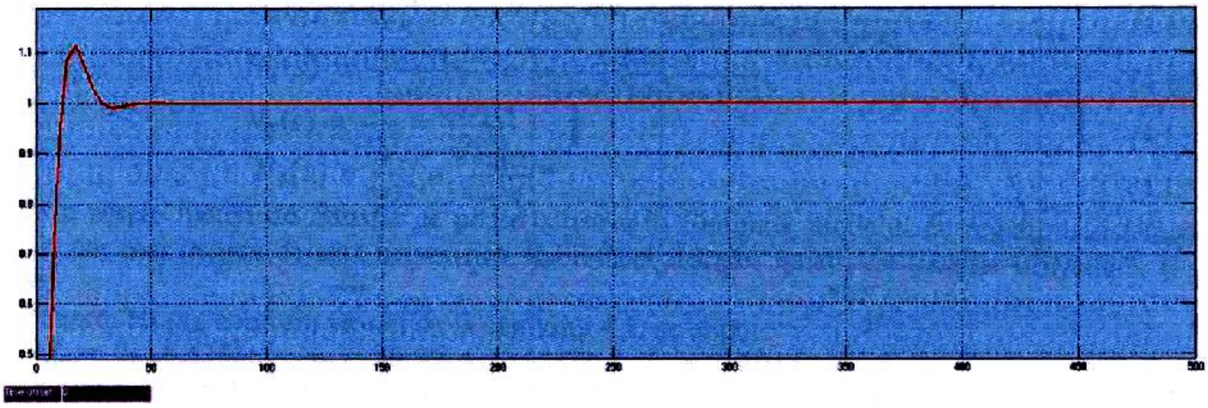

Figure 6 The response control system by granting regulators the transfer function HR_1

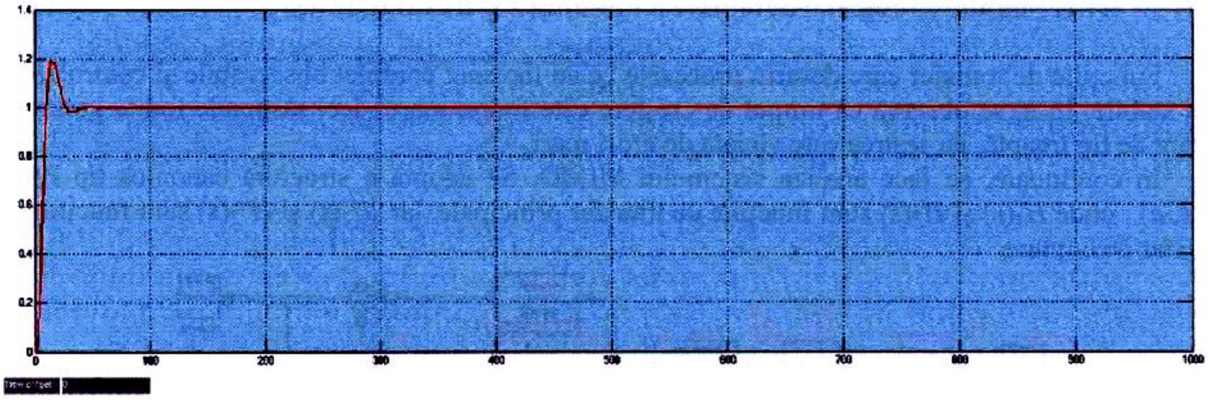

Figure 7 The response control system by granting regulators the transfer function HR_2

These two controllers attached automatic control system with two inputs and two outputs ensures stable behavior with a small over-adjustment with growth and transitional times relatively small, even if these shows high inertia.
These two controllers attached automatic control system with two inputs and two outputs ensures stable behavior with a small over-adjustment with growth and transitional times relatively small, even if these shows high inertia.

Controller parameters

	Tuned		Tuned
P	428.6914	P	184.4578
I	52.5069	I	22.2811
D	-430.2034	D	103.1047
N	0.17031	N	0.43692

Performance and robustness

	Tuned		Tuned
Rise time (sec)	7.88	Rise time (sec)	7.68
Settling time (sec)	26.3	Settling time (sec)	28.8
Overshoot (%)	9.39	Overshoot (%)	9.15
Peak	1.09	Peak	1.09
Gain margin (db @ rad/sec)	Inf @ Inf	Gain margin (db @ rad/sec)	23.3 @ 0.869
Phase margin (deg @ rad/sec)	60 @ 0.17	Phase margin (deg @ rad/sec)	60 @ 0.161
Closed-loop stability	Stable	Closed-loop stability	Stable

Figure 8 The parameter values for the two regulators

Figure 8 presents the values of the controller parameters that control the performance and robustness, the described transfer function regulator HR_1 (s) and HR_2 (s).

From these two figures that rise time and during the transitional two regulators are about equal, the first regulator is higher rise time 7.88 seconds, compared to 7.68 seconds and 26.3 seconds during transient lower face 28.8 seconds, compared to the second controller. Also, the first over-control regulator is slightly higher, 9.39% to 9.15%, but both have given this peak as high performance over-adjustment is small and does not affect vegetables and flowers, these changes are within optimal conditions.

3. CONCLUSION

1. To transfer functions found functions which describe phenomena inside the greenhouse, actuators behavior, disturbances and constructive model proposed, were made automatic moisture control systems and ventilation closed loop that provides high performance adjusting both the oscillation values and as rise time and transient.
2. Satisfactory results can be obtained in the simulation automatically adjust the temperature and humidity in greenhouses for vegetables and flowers by using Fuzzy Logic controllers instead of PID. The advantage is clear from the lack of a precise mathematical model to describe physical phenomena [11], [12], [14].

REFERENCES

[1].Ashrae, P.: *Fundamental Handbook*, American Society of Heating, Refrigeration and Air Conditioning Engineers,2001.
[2].Augenbroe, G.: *Computer Models for the Building Industry in Europe*, Delft University of Technology Newsletter, 1994.
[3].Chua, K.J., Ho, J.C., Chou, S.K.:*A Comparative Study of Different Control Strategies for Indoor Air Humidity*, Energy and Buildings, 39, p. 537- 545, 2007.
[4].Haines, R.W., Hittle, D.C. : *Control System for Heating, Ventilation and Air Conditioning*, SpringerVerlag, Berlin, 2006.
[5].Jaymaha, L.: *Energy Efficient Building*, McGraw-Hill Publishing House¸2006.
[6].Lovelay D.L., Virk, G.S. , Cheung, J.Y.M. : *Advanced Modeling for Control in Buildings*, In Proceedings of Clima 2000 Conference, London, 1993.
[7].Nichols, N.B. : *The Linear Properties of Pneumatic Transmission Lines*, Boulder Inst. Soc. American, Joint Auto Control, 1961.
[8].Palm, W. : *A Concise Introduction to Matlab*, McGraw-Hill Publishing House¸2008.
[9].Păunescu, C.G., Brătucu, Gh.: *Research Regarding the Perfecting of Adjustment, Control and Monitoring Sstem for Humidity in Warehouses for Vegetable and Fruits*, In Journal of EcoAgriTurism, Vol.6 (2010), No. 3(20), p. 93-98, ISSN 1844-8577 (BIOATLAS 2010, International Conference: New Research in Food and Tourism, 28-30 May 2010, Braşov, Romania).
[10].Păunescu, C.G., Brătucu, Gh. : *Contribution to the Study of the Predictable Reliability for Humidity Automatic Adjustment Systems in Warehouses for Fruits and Vegetables*, In Journal of EcoAgriTurism, Vol.6 (2010), No. 4(21), p. 27-30, ISSN 1844-8577 (BIOATLAS 2010, International Conference: New Research in Food and Tourism, 28-30 May 2010, Braşov, Romania).
[11].Păunescu, C.G.: *Research Regarding the Temperature Automatic Control Simulation Using Fuzzy Logic*, In COMAT 2010 Bulletin Conference (International Conference Research and Innovation Engineering), 27-28 Oct. 2010. Vol. III, p. 192-196, Braşov, Romania, (under FISITA Aegis), ISSN 1844-9336.
[12].Păunescu, C.G.: *Research Regarding the Humidity Automatic Control Simulation Using Fuzzy Logic*, In The 4th International Conference Computational Mechanics and Virtual Engineering, COMEC 2011, 20-22 Oct. 2011. Vol. I, p. 244-248, Braşov, Romania.
[13].Schwartz, R., Friedland, B.: *Distributed Systems*, McGraw-Hill Publishing House, 1965.
[14].Sivanandam, S.N., Sumathi, S., Deepa, S.N.: *Introduction to Fuzzy Logic Using MATLAB*, Springer Verlag, Berlin - Heidelberg, 2007.
[15].Whalley, R., Ebrahhimi,M.: *Optimum Wind Tunnel Regulation*, In Proceedings Of the IMechE, Part G (4), p. 241-252, 2001.
[16].Zaheer-Udin, M.: *Temperature and Humidity Control in Indoor Environmental Spaces*, In Energy in Buildings, p. 275-284, 1993.