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SIMULATION OF A TEMPERATURE CONTROL SYSTEM WITH DISBRIBUTED PARAMETERS

Marius Constantin POPESCU, Anca PETRISOR

University of Craiova, Faculty of Electromechanical Engineering

***Abstract* – In this paper is simulated, both numerical and on experimental model, a glass annealing system, usefully to study those phenomenon that appear to the control system implementation of the technological process for glass annealing.**

***Keywords*:** *distributed parameters system, glass annealing.*

1. INTRODUCTION

The manufacture process developed in the glass factory it doesn't stop together with the forming or modeling of the glass products. After these stages some operations are required, the most important of them been the stress relieving through annealing.

The annealing process consists of the glass products cooling according to a special annealing condition, having four stages [6]: heating of the glass articles up to the annealing or stress relieving temperature; stress relieving and maintaining of the articles to a temperature between the limits of the stress relieving interval; slow cooling of the glass in order not to get arisen new internal stresses in the product and quick cooling of the glass. Through the technical analysis of the glass products one can elaborate the temperature profile that has to be maintained (figure1).

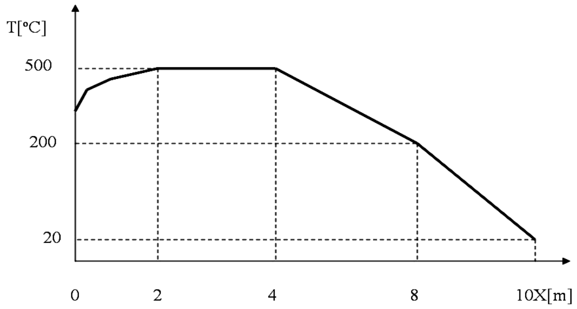


Figure 1: The shape of the temperature imposed in the glass annealing process nonlinear characteristic.

2. EXPERIMENTAL MODEL OF THE PRODUCTION SYSTEM

The heating furnace is like a four areas divided tunnel, each area representing one stage of the annealing process (figure 2).

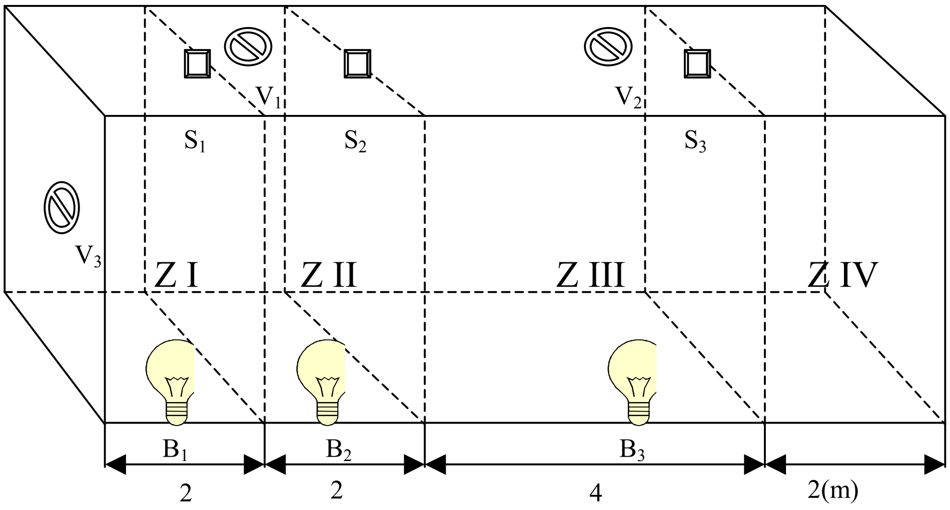


Figure 2: Experimental model used for simulation of the glass annealing process.

3. THE STRUCTURE THE STRUCTURE OF ACQUISITION AND CONTROL SYSTEM

Processing the data from the process, respectively reading the temperature, is realized with an integrated sensor LM 35 DZ made by National Semiconductor. The electronic diagram for connecting the temperature sensor is presented in figure 3. The resistances dimensioning was made in such way that for T=100°C to obtain an output voltage u_0=5V – maximum value of the analogical input voltage for the acquisition board.

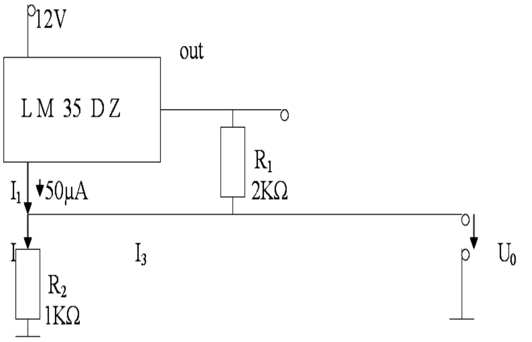


Figure 3: Schema of temperature controller.

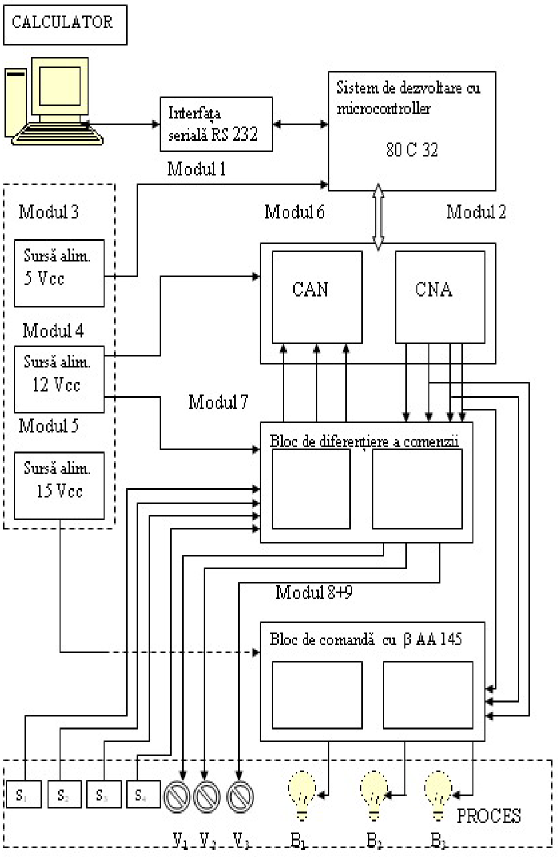
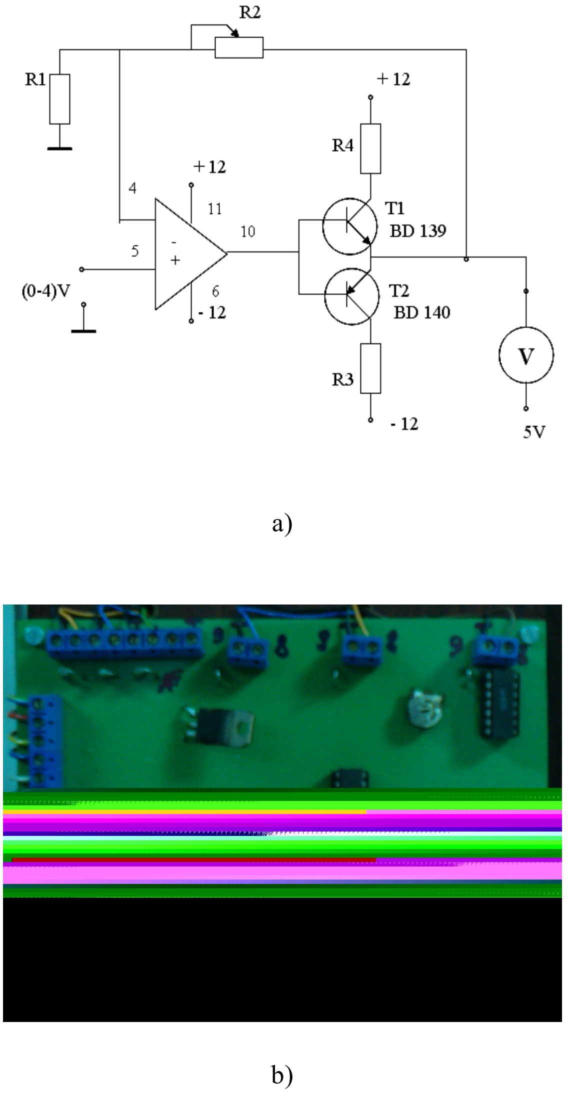


Figure 4: Configuration of the acquisition and control system.

The acquisition and control system is realized with a micro-controller board INTEL80C32 and has the structure from figure 4 [1], [3].

For implementing on the experimental model of the technological process, there have been realized several electronic diagrams, most relevant of them being [2], [5]: the supply source for the acquisition board (–5V); the supply source for the triac control board (±15V); the supply source for the differential control board and the analogical extension of the acquisition board (±15V); the differential control (figure 5); connecting of the triac (figure 6) and control of the triac (figure 7).



a)

b)

Figure 5: Differential control: a) electronic diagram; b) general view of the electronic card.

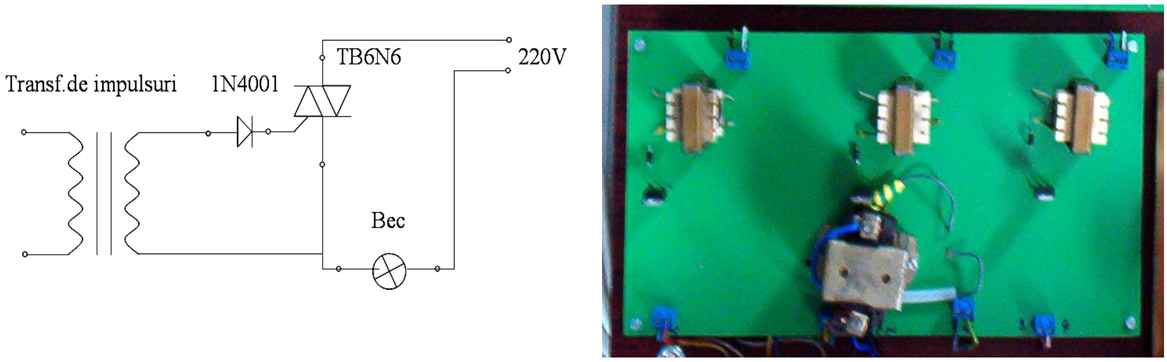


Figure 6: The triac connection: a) electronic diagram; b) general view of the electronic card.

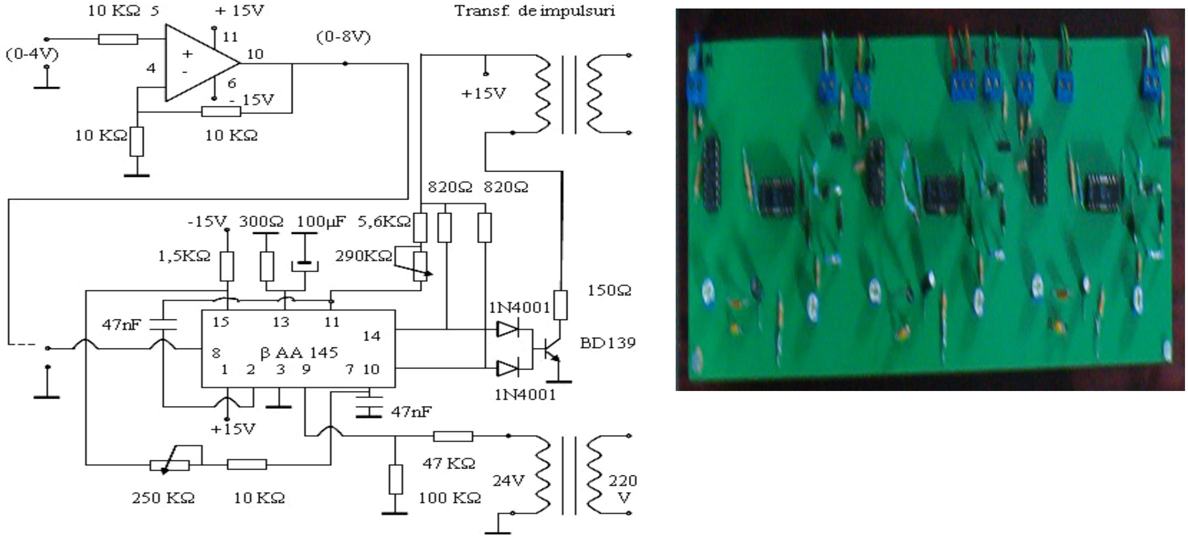


Figure 7: The triac control: a) electronic diagram; b) general view of the electronic card.

4. IMPLEMENTATION OF THE REGULATION SYSTEM WITH DISTRIBUTED PARAMETERS

4.1. Calculation of the decoupling matrix

Temperature control systems are slow processes, described by time constants bigger than 10 s. The transfer functions for the fixed parts of the heating furnace areas are approximated as [7]:

$$H_E(s) = \frac{k_E}{T_E s + 1} \cdot e^{-\tau s} \qquad (1)$$

The fixed part of the heating furnace will be considered as a multivariable system with the inputs U1, U2, U3 and the outputs Y1, Y2, Y3, as in figure 8.

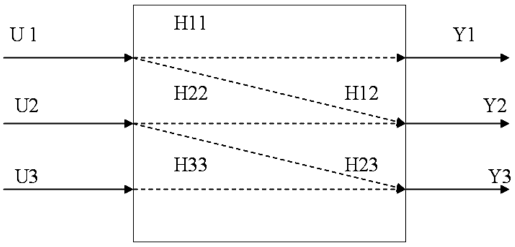


Figure 8: The structure of a multivariable system.

The transfer function of the fixed part it was considered as:

$$\begin{bmatrix} Y_1(s) \\ Y_2(s) \\ Y_3(s) \end{bmatrix} = \begin{bmatrix} H_{F11}(s) & 0 & 0 \\ H_{F12}(s) & H_{F22}(s) & 0 \\ 0 & H_{F23}(s) & H_{F33}(s) \end{bmatrix} \begin{bmatrix} U_1(s) \\ U_2(s) \\ U_3(s) \end{bmatrix} \qquad (2)$$

It shall be calculated a decoupling matrix, attempting to decouple the input/output channels, in such way to obtain an equivalent transfer function $H_v(s)$.

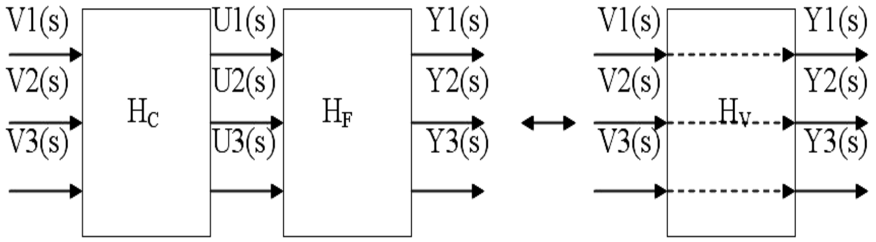


Figure 9: Explanatory regarding channels decoupling.

Imposing a desired behaviour for $H_v(s)$, meaning been at most of order II, it results:

$$\overline{y}(s) = H(s)\cdot\overline{V}(s) = H_C(s)\cdot H_F(s)\cdot\overline{V}(s) \Rightarrow$$

$$H_V(s) = H_C(s)\cdot H_F(s) \qquad (3)$$

Having the conditions $H_F(s)$-estimated, $H_V(s)$-imposed, results that $H_C(s)$ can be determined by solving the equations system [4]:

$$\begin{bmatrix} H_{11}(s) & 0 & 0 \\ 0 & H_{22}(s) & 0 \\ 0 & 0 & H_{33}(s) \end{bmatrix} =$$

$$\begin{bmatrix} H_{C11}(s) & H_{C21}(s) & H_{C31}(s) \\ H_{C12}(s) & H_{C22}(s) & H_{C32}(s) \\ H_{C13}(s) & H_{C23}(s) & H_{C33}(s) \end{bmatrix}\begin{bmatrix} H_{F11}(s) & 0 & 0 \\ H_{F12}(s) & H_{F22}(s) & 0 \\ 0 & H_{F23}(s) & H_{F33}(s) \end{bmatrix} \qquad (4)$$

The following values are obtained for the elements of the matrix H_C**:**

$$H_C = \begin{bmatrix} \dfrac{H_{11}}{H_{F11}} & o & o \\ -\dfrac{H_{22}\cdot H_{F12}}{H_{F22}\cdot H_{F11}} & \dfrac{H_{22}}{H_{F22}} & o \\ \dfrac{H_{33}\cdot H_{F12}\cdot H_{F23}}{H_{F22}\cdot H_{F11}} & -\dfrac{H_{33}\cdot H_{F23}}{H_{F33}\cdot H_{F22}} & \dfrac{H_{33}}{H_{F33}} \end{bmatrix} \qquad (5)$$

4.2. System identification

For the system identification, a program in Labwindows/CVI developing environment was realized. With this program, the computer will control the inputs U_1, U_2, U_3, through the acquisition and control system. First area implementation is realized by the control Bec_1=1L, Bec_2=0L, Bec_3=0L, the ventilator V_1=0%; V_2=0%; V_3=0%;, that implements a control U_1=100% for the heating process (figure 10).

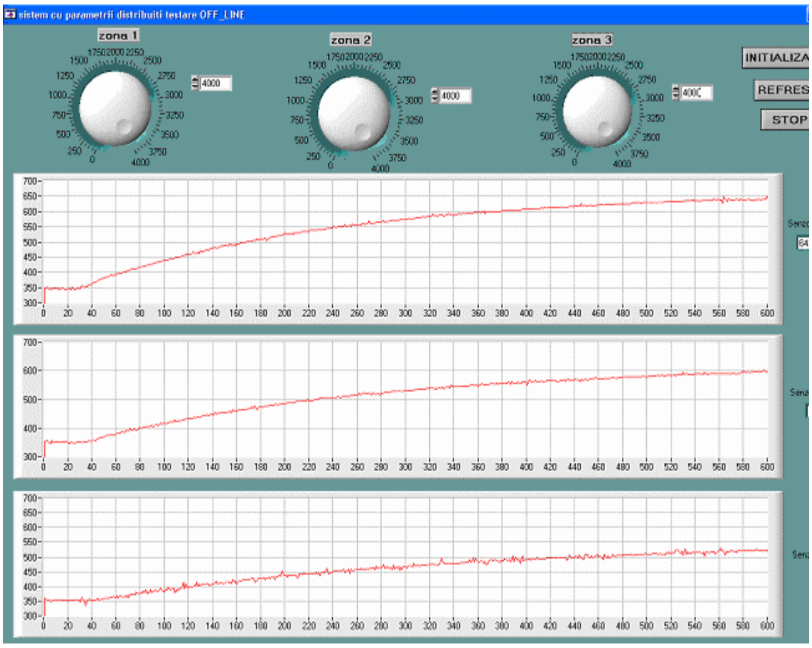


Figure 10: OFF-line testing application of the acquisition and control system.

4.3. Implementation of the control system

Implementation of the control system is realized through three controlling loops for the decoupling system.

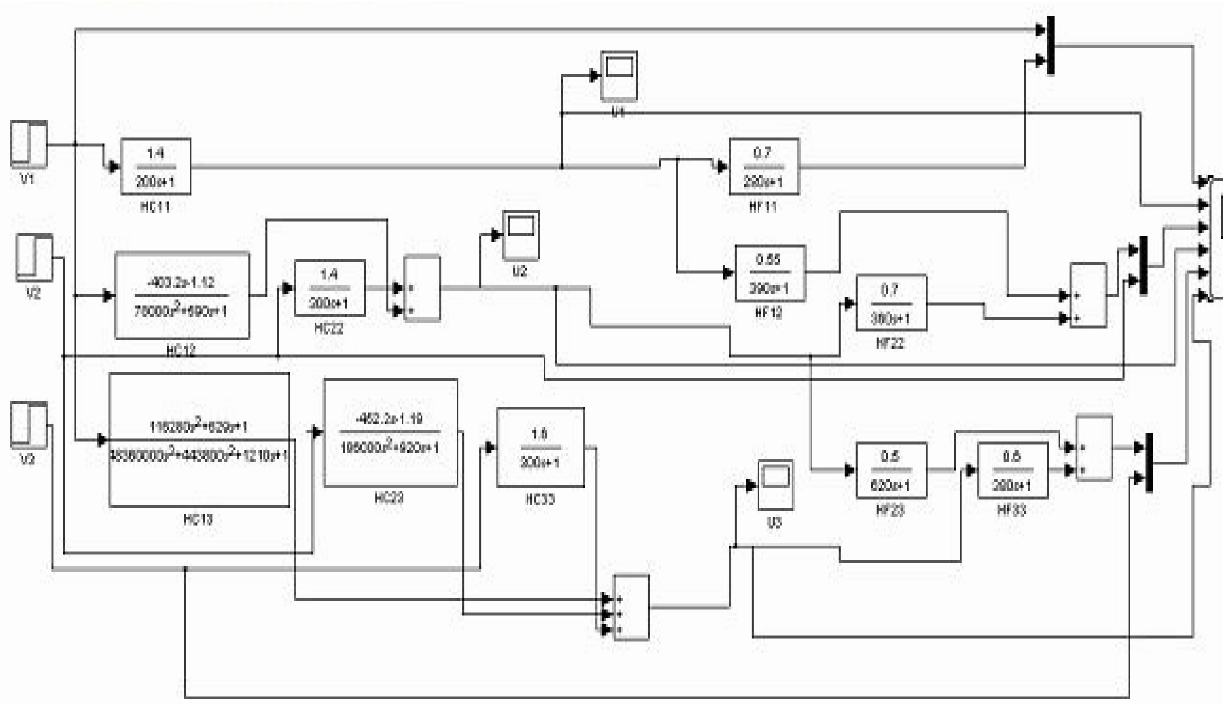


Figure 11: Simulink program.

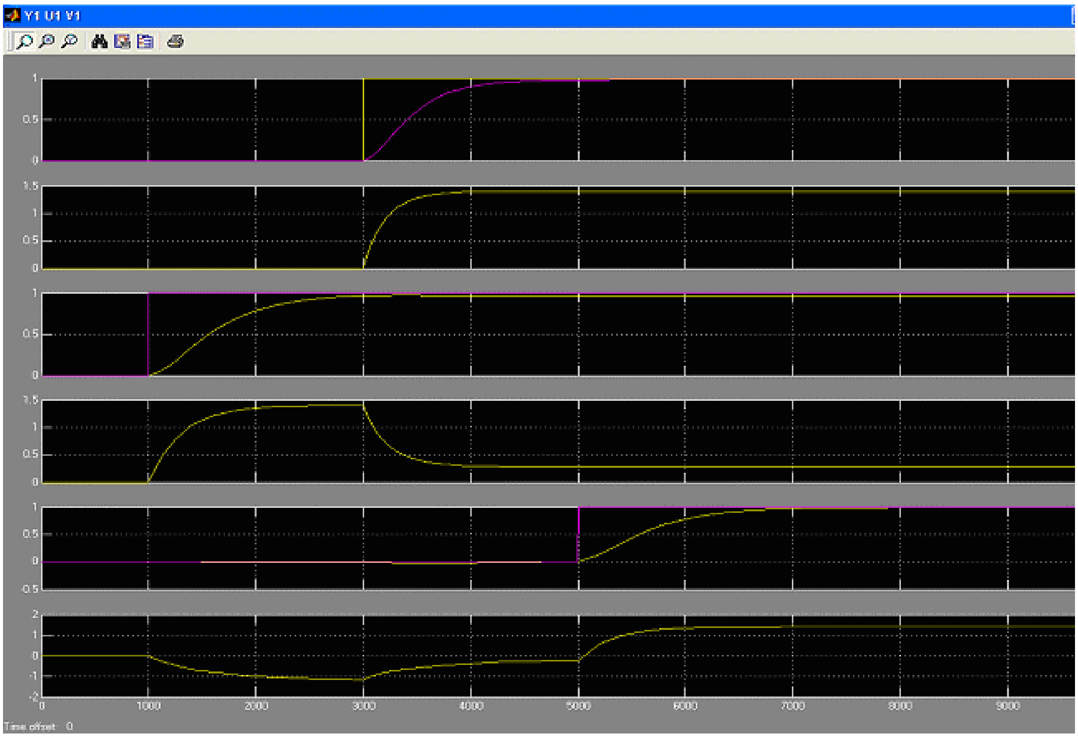


Figure 12: Multivariable system simulation using Simulink.

5. CONCLUSIONS

Static characteristic of the control to the process, using the output U_i, $i=\overline{1,3}$ is presented in figure 13.

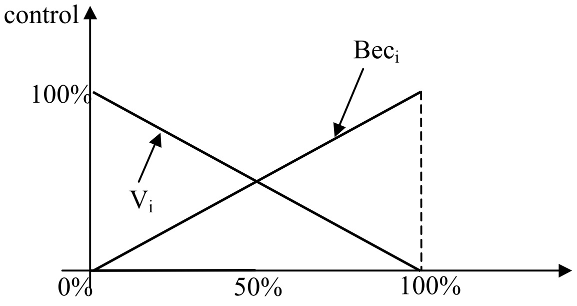


Figure 13: Static characteristic of the process.

As can be observed, the heating control of the burner is analogical, situated in the interval [0…220] V c.a., and the control speed of the ventilators is also analogical, for the range 0%÷100% corresponding a range 0V÷12V.

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