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# DYNAMIC BEHAVIOUR OF A TRACKING SYSTEM WITH ONE DEGREE OF FREEDOM, USED FOR THE PLATE, DISH AND TROUGH TYPE SOLAR COLLECTORS

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**Keywords:** solar collector, tracking system, dynamics, control, displacement error.

**Abstract:** The paper presents the dynamic behavior of a tracking system which assures the orientation of the solar collectors through the daily motion. The simulations are made for a tracking system which is used in the case of plate, dish and trough type solar collectors. The actuator of the tracking system is represented by a pneumatic cylinder and it has implemented a proportional-integrative-derivative controller. The results are represented by the actuator's displacements and the errors of the displacements for the three studied cases.

## 1. Introduction

Renewable energy, according to the national policies of Romania and to the EU policies, will have an important amount in the national and EU's energy production.

As its component, solar energy conversion can be achieved by converting the energy from the sun in electricity (in this case the conversion system is the PV panel) or in heat (in this case there are used the solar collectors as conversion systems) [4].

The solar collectors, according to their characteristics, can be as plate, dish and trough type [4].

## 2. The tracking system

The tracking systems designed for the solar collectors are used to increase the efficiency of the tracked solar collectors. The tracking process is dedicated to maximize the incident direct solar radiation on the solar collectors surfaces [5].

The relative motion of the Sun can be described with two components: a daily motion and a seasonal motion. Figure 1 shows the Sun-ray angles according to the two components of the relative motion [5].

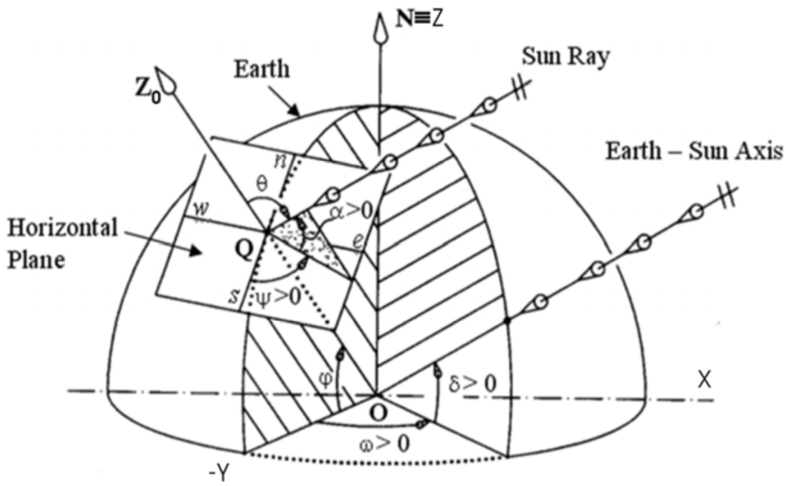



*Figure 1: The sun-ray angles*

According to the Romania's latitude the paper presents the dynamic behavior of a tracking system with one degree of freedom (figure 2) [5] (the tracking process is achieved for the daily motion) which has a proportional-integrative-derivative controller implemented and is used to track the three variants of solar collectors: plate, dish and trough type. The controller is implemented in a pneumatic cylinder as actuator.

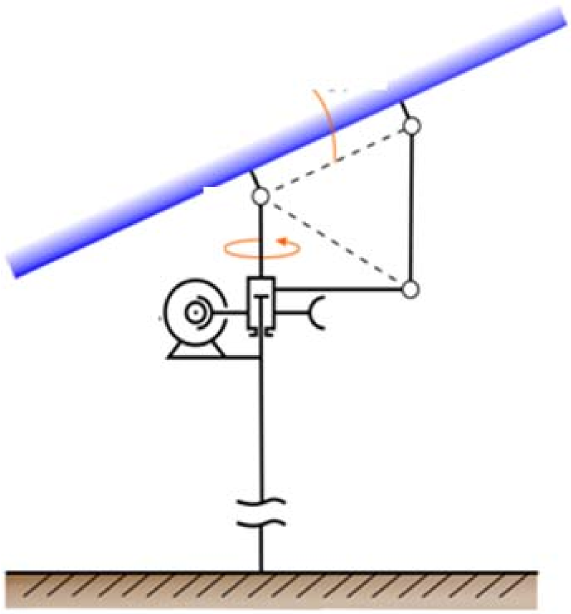


*Figure 2: The tracking system with one degree of freedom*

## 3. The modeling of the control system

The control of the tracking system is focused on the imposed daily motion which is described by the variable $q_2$ (the parameter $q_1$ is describing the seasonal position).

The aim of the control system is represented by small transitory periods and small positions errors; due to these is chosen the solution of a PID (proportional – integrative – derivative) control system. The control law (the input signal in the tracking system) is given by the equation [2, 3, 6]

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de}{dt}, \qquad (1)$$

or, if it is applied the *Laplace* transformation

$$U(s) = \left[ K_p + \frac{K_i}{s} + K_d s \right] E(s). \qquad (2)$$

The meaning of the parameters from the equations (1) and (2) is: $e(t)$ – the position's error; $K_p$ – the proportional gain; $K_i$ – the integrative gain; $K_d$ – the derivative gain; $\tau$ - the generalized load; $U(s)$ – the *Laplace* transformation of the output signal; $E(s)$ – the *Laplace* transformation of the position's error.

The structure of the control system is presented in the figure 3 [2, 3, 6].

The gains $K_p$, $K_i$ and $K_d$ are chosen according to some considerations:

- by increasing the proportional gain $K_p$, the position's error and the transient period of the system's dynamic response will be reduced;
- the integrative gain $K_i$ is generating a group of dynamic responses and it attenuate the history of the error (the transient period is reduced);
- the derivative gain $K_d$ is generating a group of dynamic responses and is damping the position's error to a constant value;
- the system is considered with critical damping.

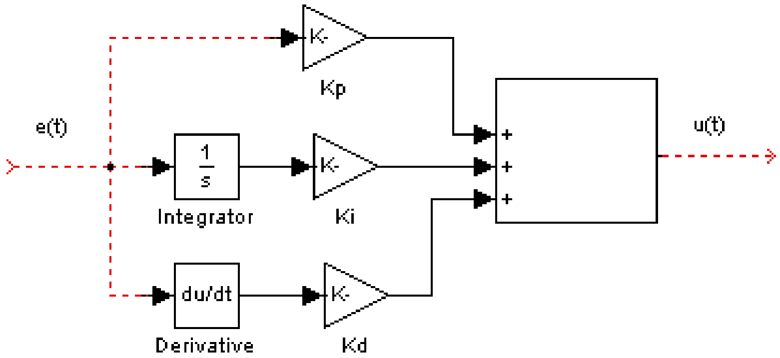



***Figure 3: The structure of the control system***

The sketch of the control system, modeled by using the *Simulink* toolkit of the *Matlab* software, is presented in figure 4.

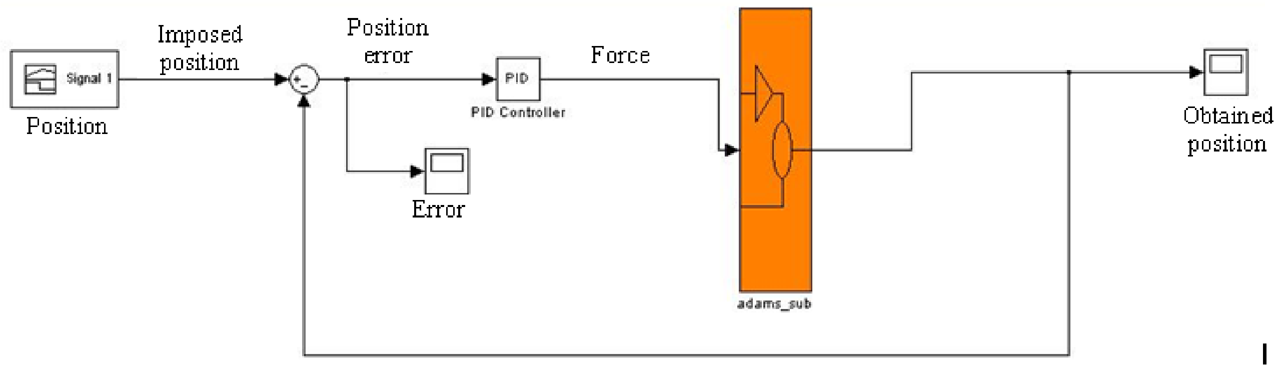



***Figure 4: The control system modeled in Simulink / Matlab***

The parameters from the figure 4 are referring on:
*adams_sub* – the sub-system of the tracking system which is modeled by using the ADAMS software (the input parameter is the force of the pneumatic cylinder and the output parameter is the linear displacement of the cylinder) [1];
*PID* – the proportional-integrative-derivative controller which contains the gains *Kp*, *Ki*, *Kd*;
*Kp*=2.3 – the proportional gain for the daily motion;

*Ki*=0.125 – the integrative gain for the daily motion;

*Kd*=12 – the derivative gain for the daily motion;

*Position error* – the difference between the imposed position and the obtained position.

## 4. The dynamic behavior

The simulation for the daily motion of the tracking system is achieved by considering the imposed motions for each type of the solar collectors (plate, trough and dish). The graphs of the imposed motions are presented as following, in the figures 5, 6 and 7.

The simulation is achieved for a time period equal with 720 s which corresponds to a displacement of the linear actuator between two consecutive positions.

The results obtained after the simulation are characterizing the dynamic behavior of the analyzed tracking systems, as following.

Figure 8 and figure 9 are showing the variations of the displacements for the actuator and the position's error in the case of the plate type solar collector.

The imposed position, in *m*

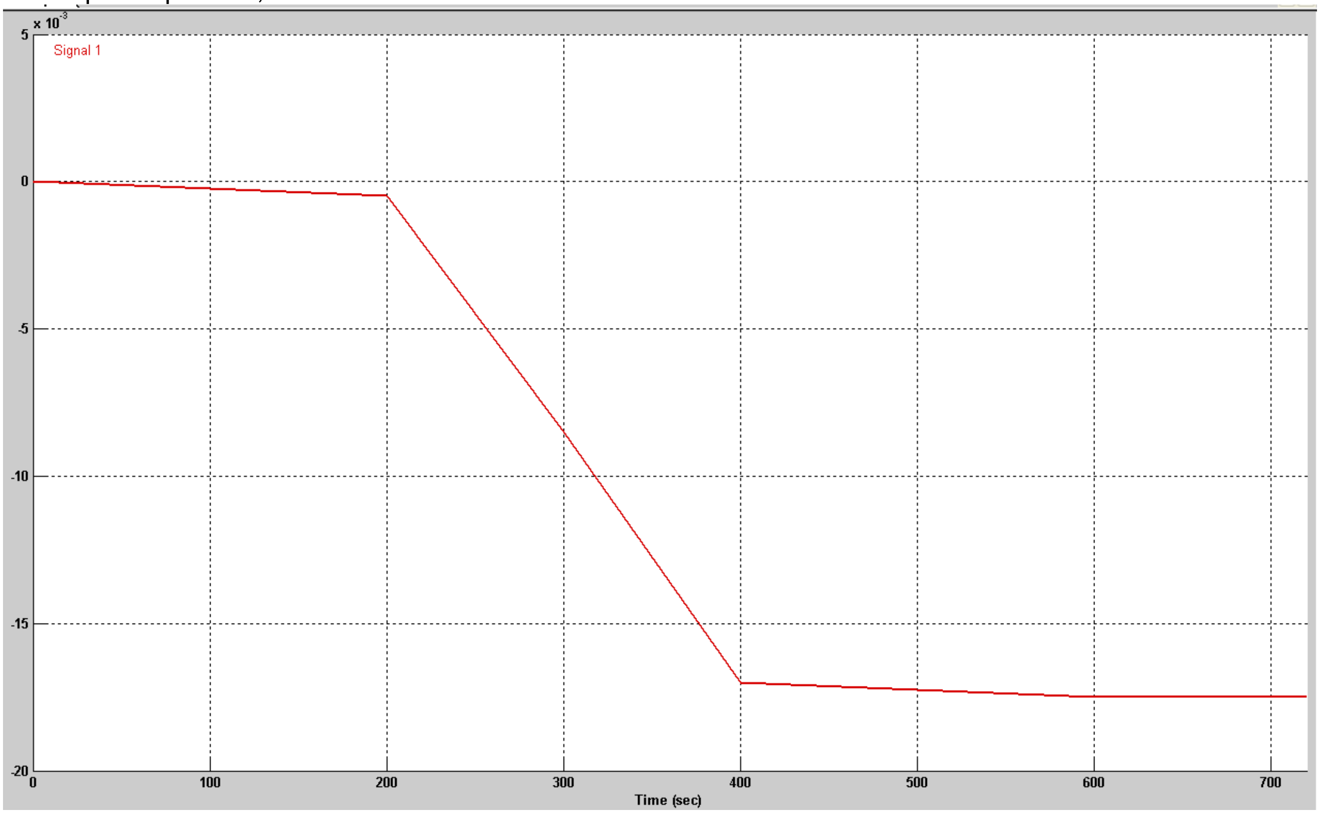



***Figure 5: The imposed position for the plate type collector***

The imposed position, in *m*

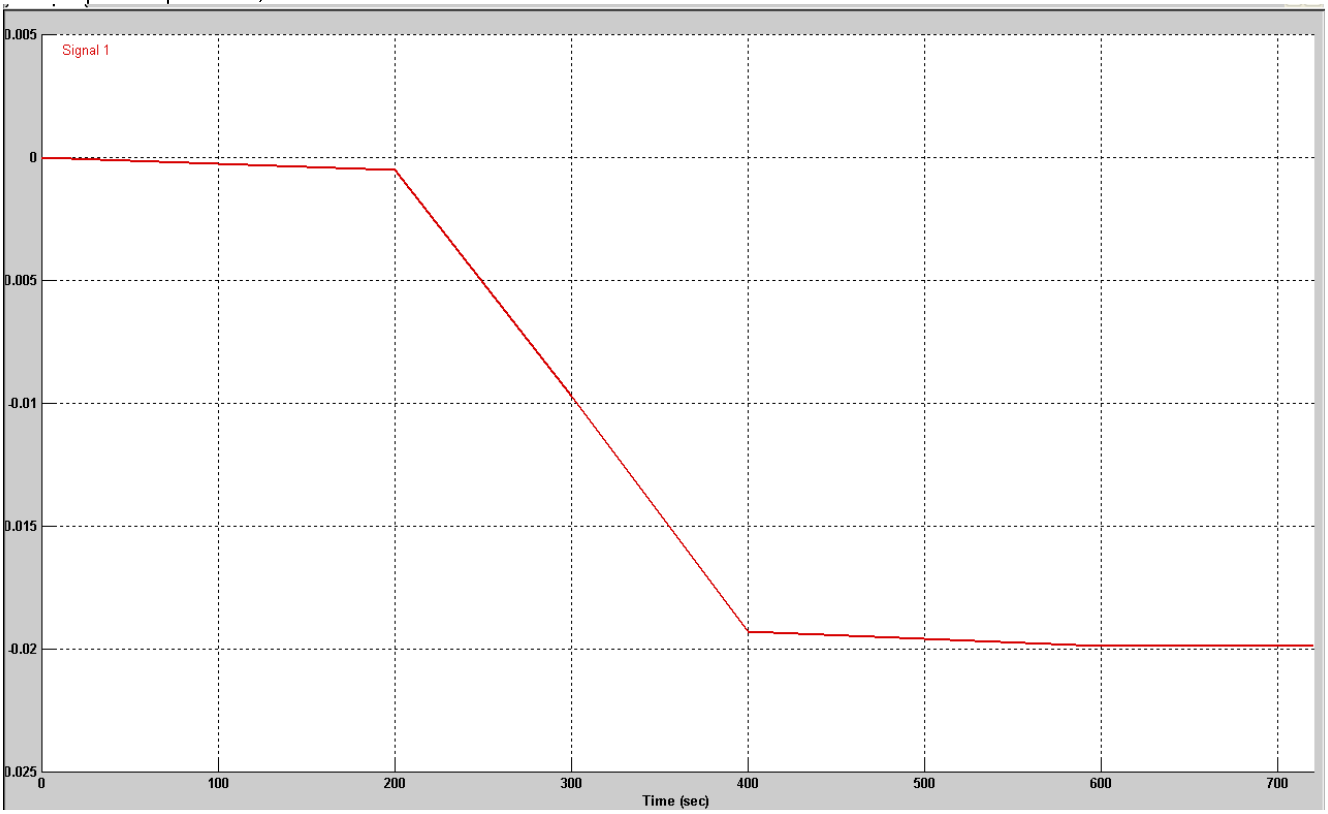



***Figure 6: The imposed position for the dish type collector***

The imposed position, in *m*

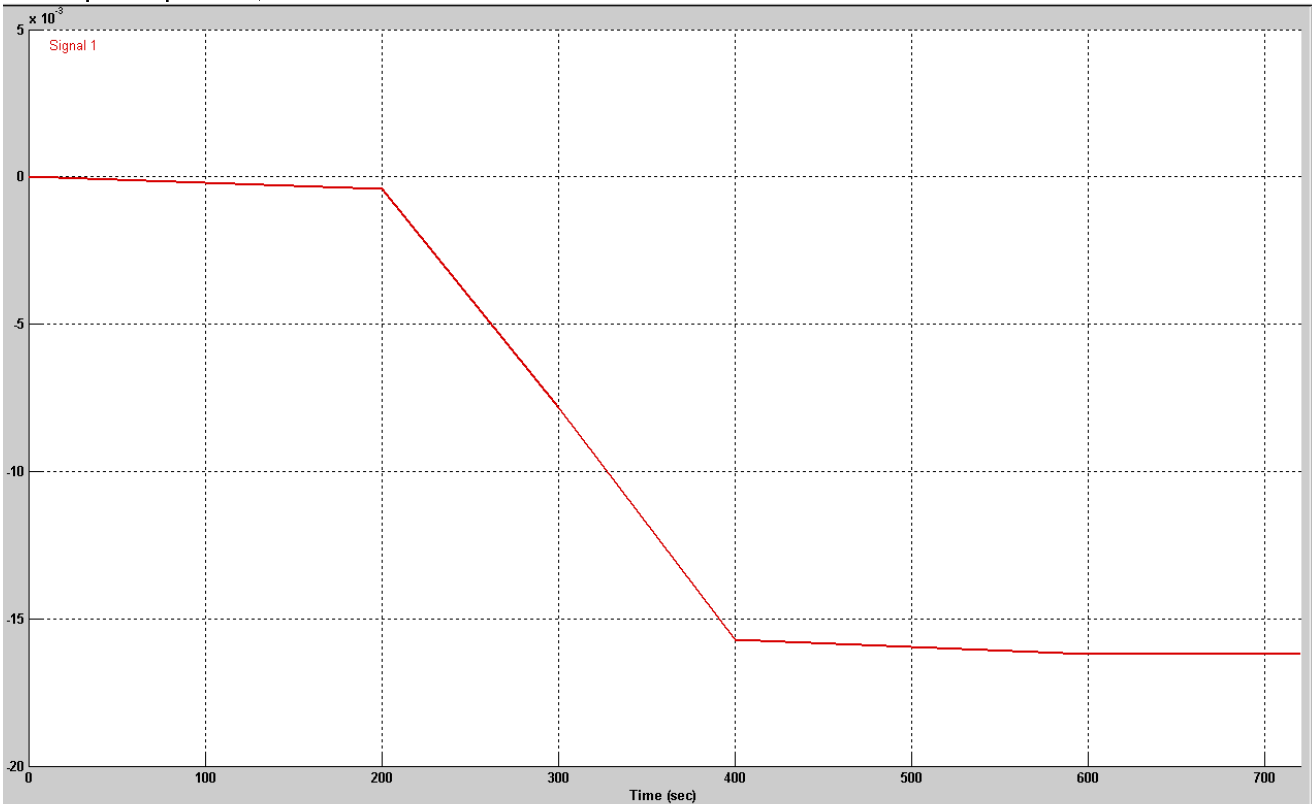
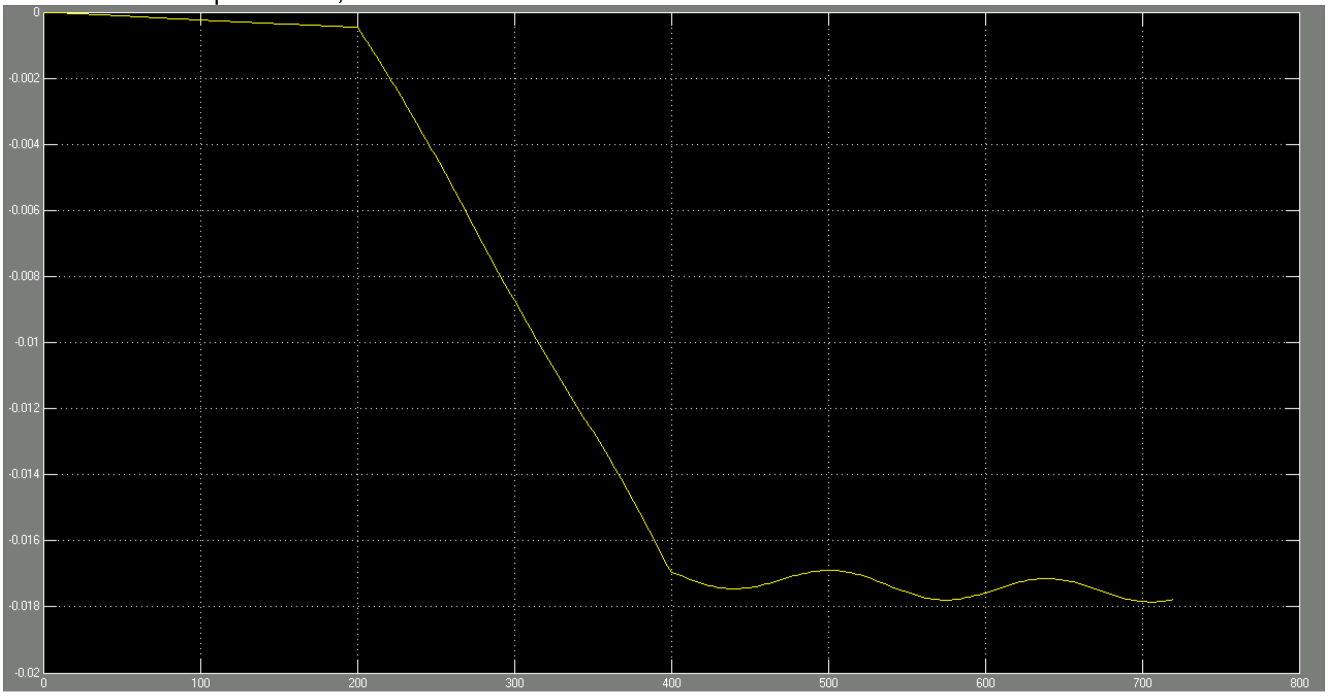



***Figure 7: The imposed position for the trough type collector***

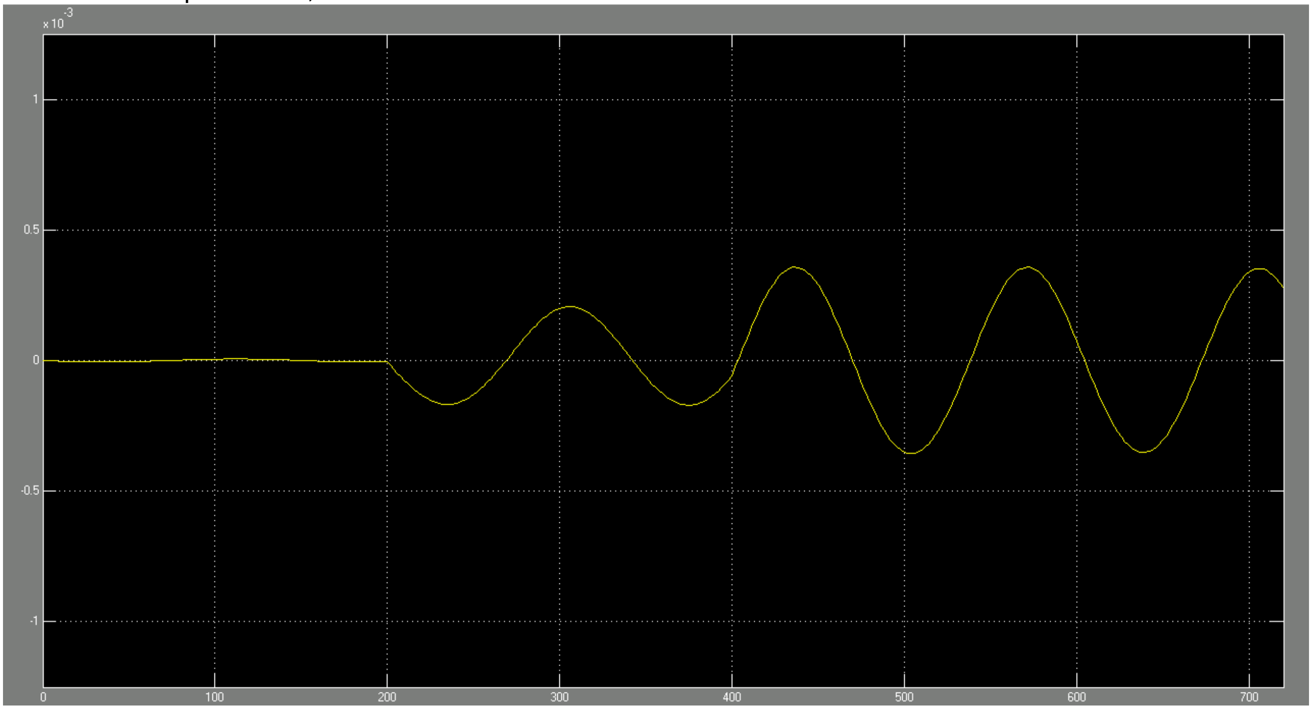
The actuator's displacement, in *m*




Time, *s*

***Figure 8: The actuator's displacement for the plate type collector***

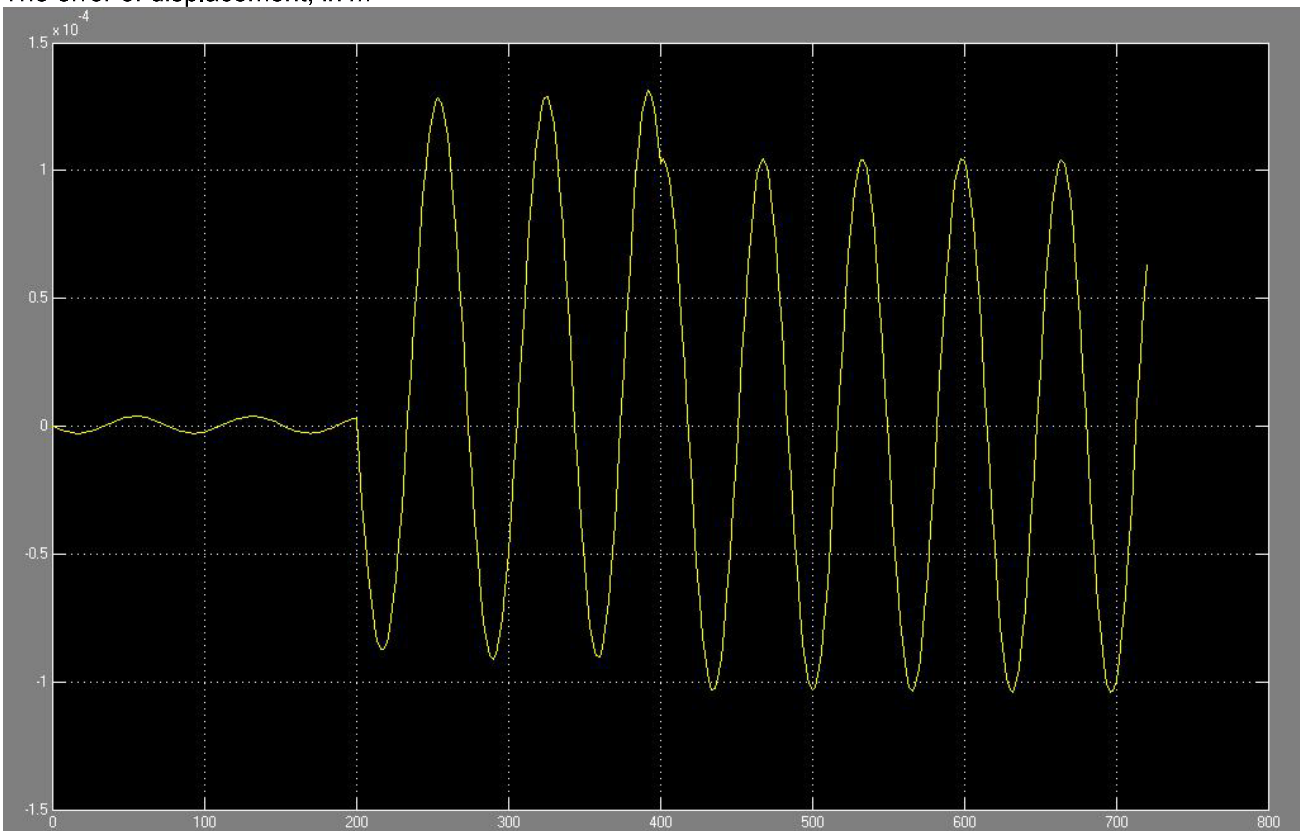
The error of displacement, in *m*




Time, *s*

***Figure 9: The error of displacement for the plate type collector***

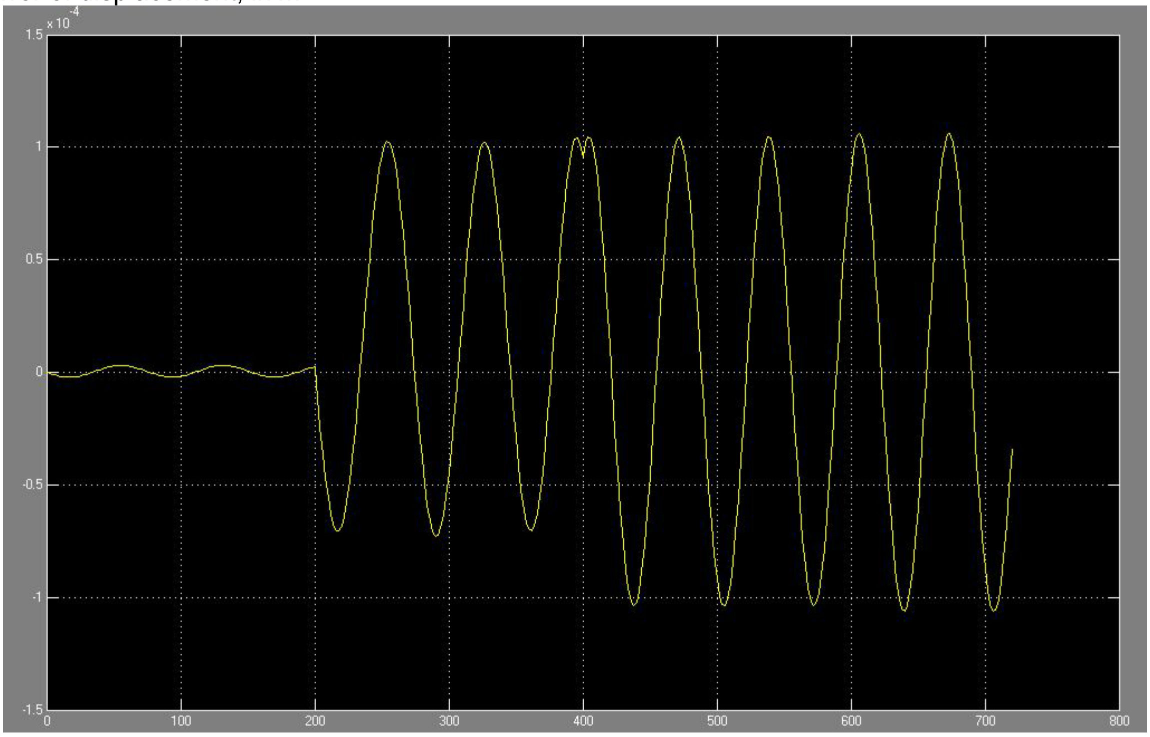
The error of displacement, in *m*




Time, *s*

***Figure 10: The error of displacement for the dish type collector***

The error of displacement, in *m*




Time, *s*

***Figure 11: The error of displacement for the trough type collector***

Figure 10 and figure 11 are presenting the variations of the displacements error for the dish and trough type solar collectors, respectively.

From the diagrams analysis results that the system is dynamically a stabile one, in the entire simulation period; the error of the position is stationary and the transient period is small. The value of the error is small (less than 0.5 mm).

## 5. Conclusions

According to the obtained diagrams the following conclusions can be expressed:

- the value for the error of the position is small (less than 0.5 mm), so the system is a precise one;
- maximum values for the error of the position are obtained in the case of the plate type solar collector (approx. 0.5 mm) and minimum values in the case of trough type solar collector (approx. 0.1 mm); for the dish type solar collector is obtained a maximum error equal with 0.15 mm.

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