

Research and Development the Adaptive Control Model Using the Spectrometer Detector.

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ABSTRACT

In this paper there are consider the automatic adaptive control system, selected adaptive control system with the standard model. The mathematical model of adaptive control system with the etalon-model is developed. Constructed and researched mathematical model of adaptive system with a reference model using MathLab Simulink software. There are researched adaptive control system responds to various external influences.

Keywords: Adaptive control system, etalon-model, automation control system.

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I. INTRODUCTION

The introduction of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper. Modern process automation is widely applied in automatic control systems based on adaptive systems, which allow implementation of various management and control capabilities.

The faster and more accurate will be implemented control and stabilizing the facility in case of emergency, because the facility will be safer functioning and use.

The goal of this paper - to develop the mathematical model for adaptive control system with a etalon-model and analyze the results. One of the elements is a spectrometer detector, which is necessary to determine the radiation level and the radiation element analysis of an emergency.

Spectrometer detector determines the radiation intensity and spectrometric composition. Automatic adaptive control systems with a etalon model has good adaptation characteristics to adapt to significant external and internal working conditions as well as high-speed channel parameter settings. Mathematical model of adaptive properties of influence was used with a variety of external influences. Such systems relatively easy realization of technical terms, those contribute to such a system wide application in various technical fields. The mathematical model is designed in MATLAB Simulink environment.

The spectrometric detector measured level of radiation, and if this level increases, spectrometric detector automatically switches in control and safety system against radiation.

X-ray fluorescence spectrometers are used:

- Ecology and environmental protection: Determination of heavy metals in soil, water, sediment and other;
- Geology and mineralogy: the quality and quantity of soils, minerals and other analysis;
- Metallurgy and chemical industry: raw materials, production process and finished goods quality control;
- Paints and varnishes industry: lead paint analysis;
- Jeweler industry: Measuring the concentration of precious metals;
- Oil industry: oil and fuel contamination determination;
- Food industry: toxic metals in food ingredients;
- Agriculture: Analysis of trace elements in the soil and agricultural products;
- Archaeology: Element Analysis;
- Space research: celestial body elemental composition investigation orbit;
- Army: environmental parameters violation analysis, military units and surrounding areas check with toxic elements contamination;
- Energy - corrosion analysis of the product mix, the reactor washing performance, fuel quality determination. [1]

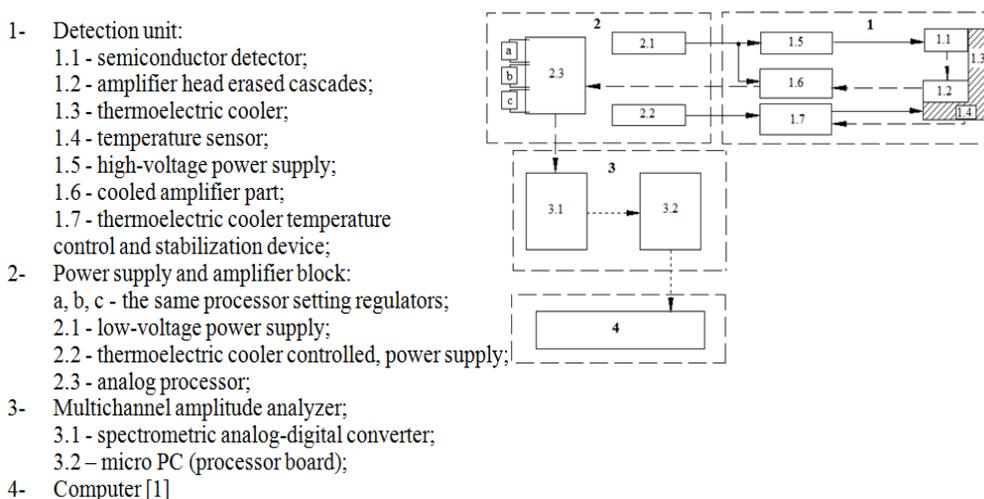


Figure 1. Spectrometer with semiconductor detectors block diagram

Multi-channel amplitude analyzer is designed for information gathering, processing and output of computer pulse amplitude after allocation that comes from the detection device.

Semiconductor detector converts roentgen rays proportional amplitude electrical signals, which are reinforced and then treated with analogous devices. The analogue output processor formed rectangular pulses with a positive polarity, which is filtered and edited in an appropriate way, to send them spectrometric analog-digital converter.

II. THE ADAPTIVE CONTROL MODEL

Adaptive System is a system that automatically changes its functioning algorithm data, and (sometimes) its structure with a view to maintaining and achieving an optimal state of the changing external conditions. [[1]].

In order to ensure the required system performance quality (accuracy, stability, performance) control unit and the control object parameters must be strictly coordinated [[1]].

Adaptive control system can be described as follows - the main advantage is the ability to adapt previously unknown changes in management facility, which makes it possible to provide the same high quality of the system in changing working environments.

Analytical adaptive management systems, directly or indirectly, is a model with the desired dynamic characteristics.

Adaptation algorithm task is to tune the regulator coefficients of a kind to reduce the discrepancy between the control and the object model to zero. Such leadership is called direct adaptive management and systems - adaptive systems with a reference-model.

To direct adaptive control, adaptive circuit after working in closed cycle, which allows controlling the object parameter and regulatory changes in the functioning in time.

However, each self-confidence circuit increases the order of the system to the minimum ones, and thus a significant impact on the overall dynamics of a closed system [[1]].

In Fig. 2 it appears adaptive automatic control system in which the adaptation unit is connected in parallel.

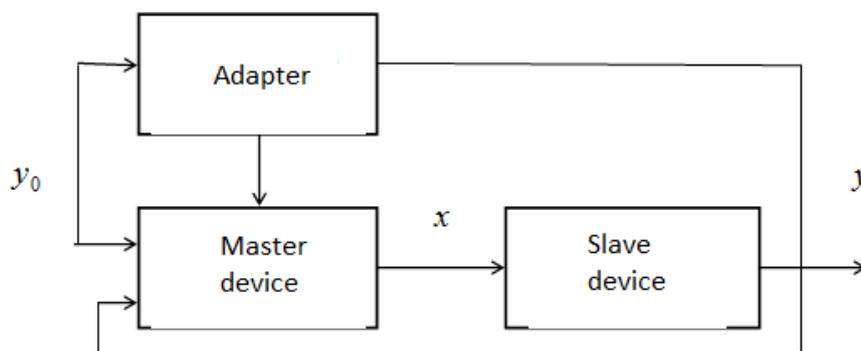


Figure 2. The Adaptive System Functional scheme

Adaptive control system consists of the main control circuit with negative feedback and self-confidence equipment adaptation of the principle of realization. It is based on a closed system with feedback that includes automatic control system and automatic control object. It is complemented by an adaptation device which realizes the control object identification and automatic control equipment parameters alignment changing control characteristics of a facility. [[2]]

III. THE ADAPTIVE SYSTEM WITH THE ETALON-MODEL

Etalon-model is a model that, in its dynamic performance is a benchmark for control systems.

Control object and have etalon-model outputs are compared and the difference is used to change the organization of the system. Changes may be as configurable parameters, and compensation signals.

Adaptive control systems with etalon-model, quality of management depends on the etalon-model of the dynamic properties and how exactly suited to the properties of a dynamic object of control [[3]].

The purpose of the adaptation systems with a reference model, is described as follows:

$$\lim_{t \rightarrow \infty} \varepsilon = \lim_{t \rightarrow \infty} (y - y_m) = 0. \quad (1)$$

If the result of the setting of the object transmission function coincides with a etalon-model transmission function, then:

$$\lim_{t \rightarrow \infty} \varepsilon = 0 \text{ [14].}$$

At etalon-model for automatic quality control are done with self-confidence system. This quality is measured by self predisposing criterion is the extremum of a error function [14]:

$$Q = Q(\varepsilon) = Q(y - y_m) \rightarrow \min. \quad (2)$$

In many cases, conveniently choose conventional criteria instantaneous square error.

$$Q = \varepsilon^2(t). \quad (3)$$

Etalon-model schemes are often used setting the gradient method. If you apply the gradient definition, the function should be examined as a criterion, which is the system predisposing parameter β function.

Then, after the gradient method self predisposing system parameters change function:

$$\beta = \pm \lambda \text{grad}Q, \quad (4)$$

Where:

λ – the positive coefficient;

λ sign "+" refers to the function with extremum - maximum;

λ sign "–" function with extremum- minimum.

The partial derivative of the criterion Q by parameter β can count as follows:

$$\frac{\partial Q}{\partial \beta} = \frac{\partial Q}{\partial \varepsilon} \cdot \frac{\partial \varepsilon}{\partial \beta}. \quad (5)$$

This equation how the partial derivative can be obtained as a multiplier of two results:

- a derivative of the criteria by errors;
- the partial derivative of the error after the parameter β .

Adaptive system with etalon- model is used with the function Q extremum- minimum.

To equation (4) will get:

$$\beta = -\lambda \frac{\partial Q}{\partial \beta} = -\lambda \frac{\partial Q}{\partial \varepsilon} \cdot \frac{\partial \varepsilon}{\partial \beta}. \quad (6)$$

Where

λ – Proportional coefficient ($\lambda > 0$) [[3]].

IV. MATHEMATICAL MODEL FOR ADAPTIVE CONTROL SYSTEM

A mathematical method for use in any system operation study is necessary to draw up its mathematical model.

In first, mathematical model for drawing up it is necessary to determine the size of the package, which may serve as a system of functioning of the quantitative characteristics. Secondly, it is necessary to determine the relationship between these characteristics, the description about the actual functioning of the system. Adaptive automatic control system parameters of the object change takes place external exposure factors. Adaptive automatic control system with etalon- model structural scheme is shown in *Fig 3*.

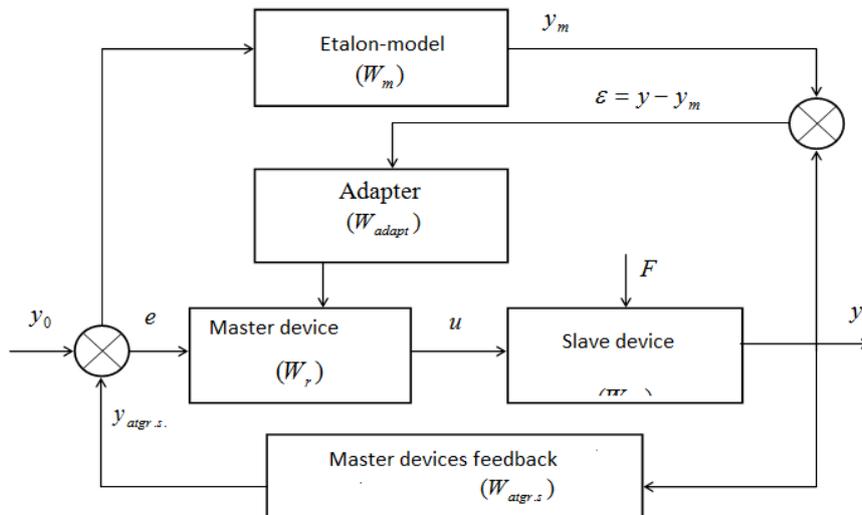


Figure 3. Adaptive System Functional block scheme

In this scheme (Fig 3) the controlled object - this space, this can be affected by external agents (reactive materials, such as radiation). The etalon-model is a model of the space with the optimal settings (without external influences). Adapter - a spectrometric detector that responds to external stimulus. Using the spectrometer can determine the direct effect of substance objects and can be measured (emission) intensity exposure. Based on the data of this substance can choose which type of protection can be used in various cases. This case is used type of protection - closing the door space for insulation. It is assumed that the type of lead radiation shielding door. The control unit - is the regulator. External exposure F is added to the object transfer function W_{ob} parameters. In the case of the model structure is used in a closed system with a controlled device and the object first round aperiodic a function.

The control device transmission function:

$$W_{r0}(p) = \frac{k_r}{T_r p + 1}; \quad (7)$$

The object transfer function without external influences:

$$W_{ob0}(p) = \frac{k_{ob}}{T_{ob} p + 1}; \quad (8)$$

The transfers function of the model:

$$W_m(p) = \frac{W_{r0}(p) \cdot W_{ob0}(p)}{1 + W_{r0}(p) \cdot W_{ob0}(p)} = \frac{k_r \cdot k_{ob}}{(T_{ob} \cdot p + 1) \cdot (T_r \cdot p + 1) + k_r \cdot k_{ob}}; \quad (9)$$

Where:

$W_{ob}(p)$ - the object transmission function without external influences;

k_r - control device transmission coefficient;

k_{ob} - object transmission coefficient;

T_r - control device time constant;

T_{ob} - object time constant;

p - Laplace operator.

If there is only one external impact F , then it is added to the factor. In this case, the object transmission function is expressed by the following formula:

$$W_{ob}(p) = \frac{k_{ob} + F}{T_{ob} p + 1}. \quad (10)$$

If the adapter is a proportional regulator, then the transfer function can be expressed as follows:

$$W_{adapt}(p) = k_{adapt} \cdot \quad (11)$$

Where:

$k_{adapt} < 0$ – adapter transmission ratio should be less than zero in order to reduce system error ε [[4]].

Now look at look like the control of the transmission function. At the controls of the transmission functions will be added Δk_r [[4]]:

$$\Delta k_r = k_{adapt} \cdot \varepsilon = k_{adapt} \cdot (y - y_m) \quad (12)$$

New controls transmission function is as follows:

$$W_r(p) = \frac{k_r}{T_r \cdot p + 1} + \Delta k_r \quad (13)$$

Now that are aware of the subject and controls the transmission functions can determine the basic system control loop transfer function:

$$W_{AVS}(p) = \frac{W_{ob} \cdot W_r}{1 + W_{ob} \cdot W_r} = \frac{(k_{ob} + F) \cdot [k_r + (T_r \cdot p + 1) \cdot \Delta k_r]}{(T_{ob} \cdot p + 1) \cdot (T_r \cdot p + 1) + (k_{ob} + F) \cdot [k_r + (T_r \cdot p + 1) \cdot \Delta k_r]} \quad (14)$$

If in formula (3.6) replace the expression of the formulas (9) and (14) will get the following [[4]]:

$$\Delta k_r = k_{adapt} \cdot \left\{ \frac{(k_{ob} + F) \cdot [k_r + (T_r \cdot p + 1) \cdot \Delta k_r]}{(T_{ob} \cdot p + 1) \cdot (T_r \cdot p + 1) + (k_{ob} + F) \cdot [k_r + (T_r \cdot p + 1) \cdot \Delta k_r]} - \frac{k_r \cdot k_{ob}}{(T_{ob} \cdot p + 1) \cdot (T_r \cdot p + 1) + k_r \cdot k_{ob}} \right\} \quad (15)$$

V. THE ADAPTIVE AUTOMATIC CONTROL SYSTEM SIMULATION

Now look at the appearance of the automatic control system with benchmark-model scheme in MathLab Simulink environment (Fig 4.).

Input signal:

$y_0 = 1$ - constant.

Scope will appear in the output signal y , the signal between the subject and the control u and the difference between input and output signal e .

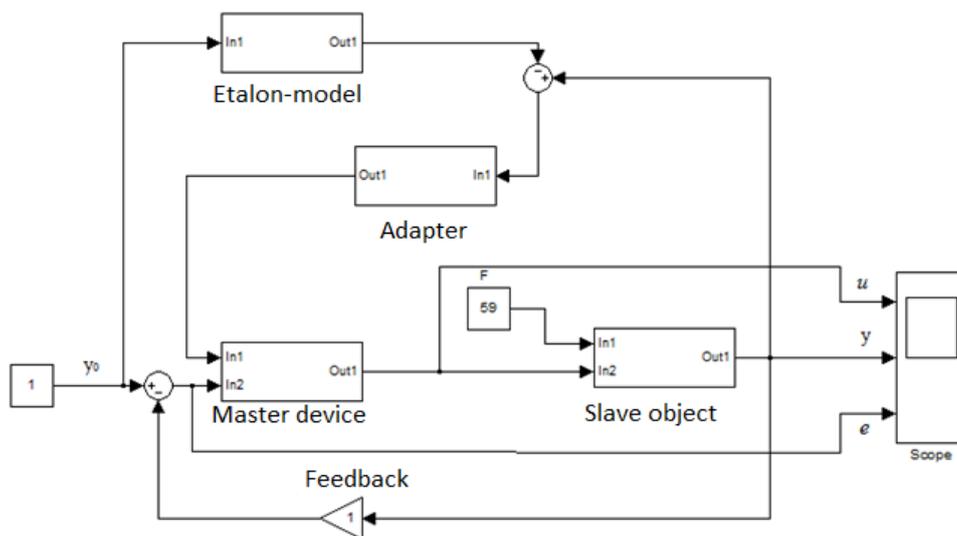


Figure 4. Adaptive control system scheme in MathLab

Slave object MathLab Simulink scheme shown in Fig 5.

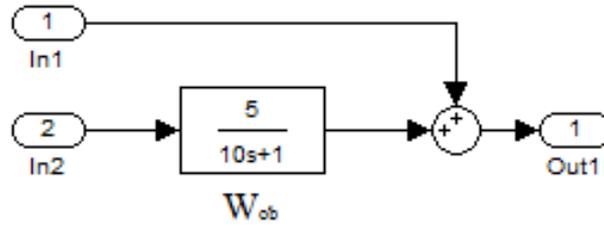


Figure 5. Slave object scheme

Describe the circuits controlled by the transfer function of the object - an appropriate transfer function:

$$\frac{5}{10s + 1} - \text{conform } \frac{k}{Tp + 1} \text{ transmission function,}$$

Where:

$s = p$ - Laplace operator.

$W_{ob}(p)$ - object transfer function

$k_{ob} = 5$ - coefficient

$T_{ob} = 10$ - time constant

External exposure is given by F . spectrometer responds to radiant energy, once the size of the energy spectrometer distinguishes reactive elements which act on the object. Therefore, the external impact will be constant, which indicates the radiant energy.

Now we look for additional controls, the adapter and the resource block model. Mathlab Simulink reference model block shown in Fig 6.

Reference model of the transfer function of the first stage of aperiodic function $\frac{k}{Tp + 1}$.

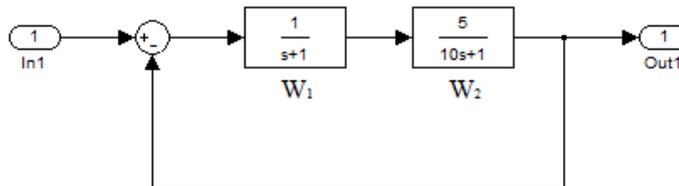


Figure 6. Etalon-model block scheme in MathLab Simulink

Etalon-model transfer function:

$$W_m(s) = \frac{W_1(s) \cdot W_2(s)}{1 + W_1(s) \cdot W_2(s)} = \frac{5}{10 \cdot s^2 + 11 \cdot s + 6} \quad (16)$$

Where :

$s = p$ - Laplace operator.

Adapter block realization in MathLab Simulink environment is shown in Fig 7.

Adapter transmission coefficient is $k_{adapt} = -1$.

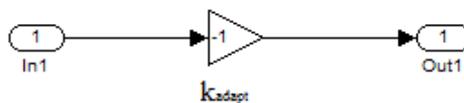


Figure 7. Adapter block scheme

Next, look at the control unit, which is shown in Fig 8.

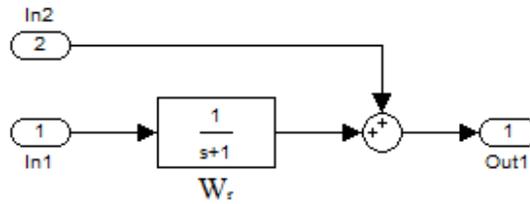


Figure 8. Master device block scheme in MathLab Simulink.

Describe circuit controls the transmission function in Fig 8:

Where:

$$\frac{1}{s + 1} - \text{conform } \frac{k}{Tp + 1} \text{ transmission function,}$$

$s = p$ – Laplace operator.

$W_r(p)$ – object transfer function

$k_r = 1$ – coefficient

$T_r = 1$. – times constant

During the experiment, the working scheme was changed external exposure of the object. Diagrams can be seen as a change in the output signal y , the signal between the subject and control, etc., as well as input and output signal difference to various external influences. The main objective of the scheme is to compensate for the external effects. Experiment assumed that the simulation time is 10 seconds.

Let's look at the first results. The first case of external exposure of the object was not, it is that F is equal to zero.

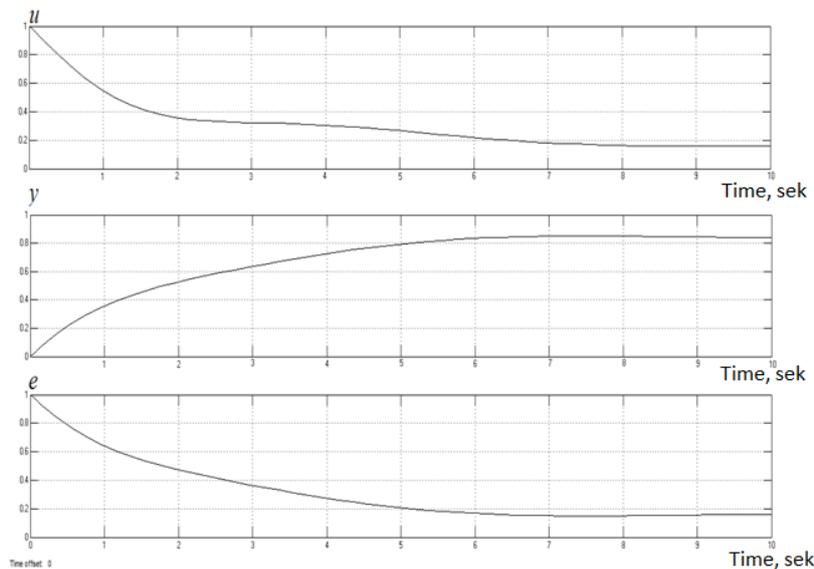


Figure 9. Adaptive control system without effect ($F = 0$)

In Fig 9 shows that the amplitude of the output signal y will increase to almost 1. Thus, suppose that the output signal amplitude is almost equal to the ones, and this is the normal state of the object. But the signals between the control device and the object, etc. and between the outgoing and incoming e decreases to a value of 0.17. It appears that all signals stabilizes around 10 (ten) simulations in second.

When an external force is greater than zero it can be said that in this case the object exposed to radiation, then an error occurs ε the exchange of the object transmission function for reasons arising from the difference between the output signal y and the reference-model output signal.

Fig 10 it is to show the adaptive control system signals. In this case, the control system is affected by external impact F , which are identical to the ones ($F = 1$).

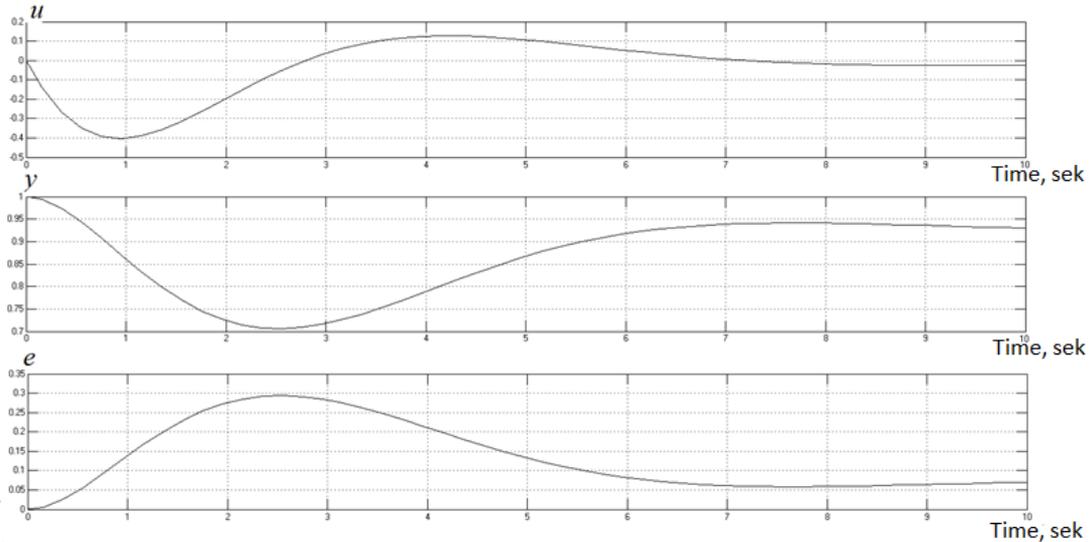


Figure 10. Adaptive control system with effect ($F = 1$)

The Fig10. shows that the amplitude of the signal between the control signal U and the object changes. The signal amplitude reaches negative values. About 9 (nine) seconds signal is stabilization. When the signal is stabilized, the amplitude is a negative value.

Now look at the output y . The signal amplitude also fluctuates. In start time ($t = 0$) the signal amplitude decreases from 1 to 0,7 and then committed to 1.

The signal e (difference between input and output signal) and the amplitude range is trying to achieve stabilization.

Fig 11 showing amplitude adaptive system, when the external force acting on the object is 15 ($F = 15$).

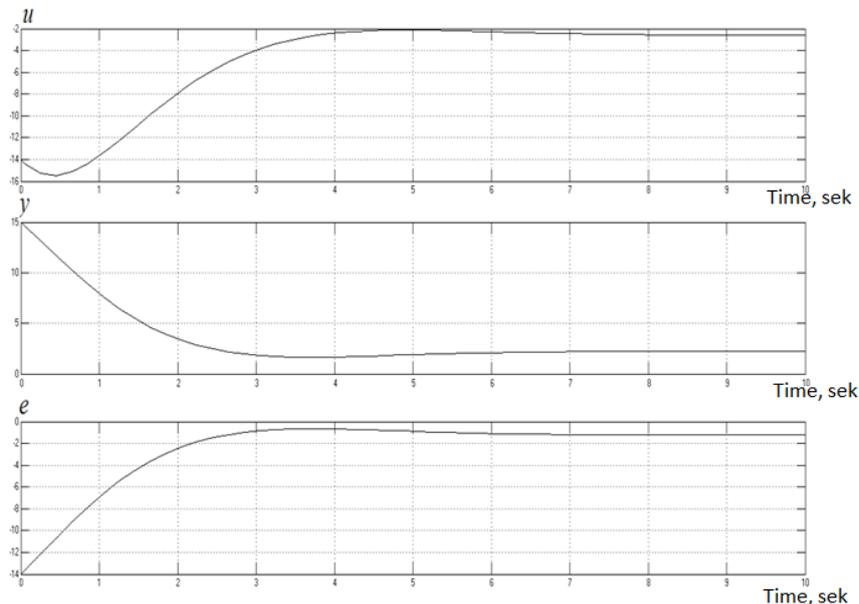


Figure 11. Adaptive control system with effect ($F = 15$)

Now look at how to affect the result of external impact, which is equal to 15 (Fig 11) It is seen that the amplitude of the signal u receive negative values. As well as stabilization occurs before the transition process. Signal stabilization occurs in about 8 (eighth) per second. With this signal occurs output compensation.

The output signal y start time reaches the value 15, and then gradually decreases. The transition process lasts approximately 8 seconds and then signals stabilization.

e signal amplitude in this case has a negative value. The transition process lasts 7 seconds.

Fig 12 displays signal amplitude graphs, in the case of external exposure of the object is equal to 59 ($F = 59$).

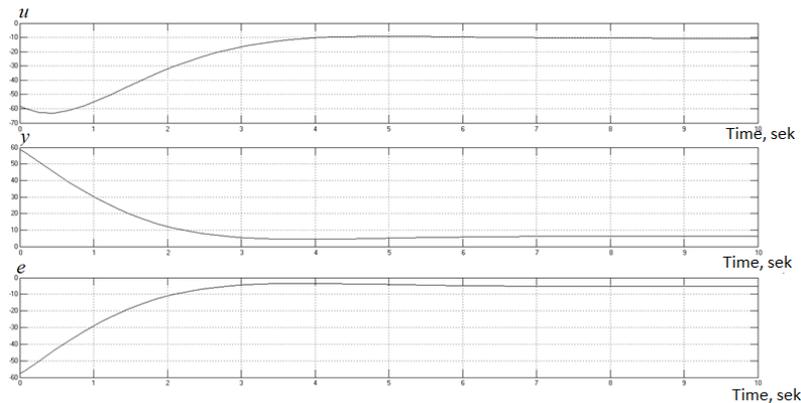


Figure 12. Adaptive control system with effect ($F = 59$)

In Fig 12 it is shown that the amplitude of the signal, etc., as well as in the case when the external effects (of any size exposure) has a negative value. Transition process takes 8 seconds, followed by the process of stabilization. The signal u compensated output signal y .

The output signal y start time $t=0$ has the value 59, and then gradually decreases. E signal amplitude where an external force is $F=59$ has negative values. Both signals the transition process lasts 7 seconds.

The aim of the experiment - to compare the output signal y , signals, etc. between the control device and the object, and e the difference between output and input signals to various external influences.

It analyzes the adaptive control system, when it is exposed to different sizes of external exposure. From the results it is evident that at various external exposure values during the transition process is nearly the same value. One can also see that the external effects of an increase in the entire signal amplitude stabilization are more important. Also, if are looking at Fig 9 and Fig 10, then it is evident that without the external effect on the object or when it is equal to the value of 1 all signal curves did not manage to stabilize the simulation ($t=10$ sec).

According to the simulation results it shows that the adaptive control system helps reduce the use of external exposure to the object, as well as to stabilize the value.

VI. CONCLUSION

- X-ray spectrometric detector use in industrial enterprises with high radiation exposure level allows quickly to determine the source of the irradiance and radiation intensity, as well as the elimination of accidents with minimal radiation exposure to personnel;
- To analyze the adaptive control system with etalona- model operation to different external influences;
- Study of adaptive control system stability;
- It was compared the results to various external influences;
- Work was carried out in the model analysis using the computer program MathLab Simulink;
- It is observed adaptive control system with etalona-model operation to different external influences;
- Automatic control systems with the use of spectrometric detection industry, where there is radiation spread a positive effect on people and the environment. This system has the advantage that an adverse event, it reacts instantly, and can avoid losses.

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