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# THE NEED OF REGULARIZATION FOR THE SYNTHESIS OF MULTI-LOOP CONTROL SYSTEMS


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**Keywords:** Multi loop control system, electric drive, regulator, real interpolation method, regularization.



**Abstract** – The article deals with the problem of the synthesis of multi loop control system. There is presented the substantiation of the need to using the regularization for solution the problem of the synthesis of multi-loop control systems. In addition, the base of the method of regularization represented there.


## Introduction

The main questions of theory and practice of the Automatic Control Theory are related with the synthesis of the compensation, which system provides desired properties. The problem has completely solution for single-loop control systems.

When the synthesized system is multi-loop control system there are some problems, which do not provide a solution to a given accuracy for chosen criterions and structures.

Traditional for calculation a single-loop systems the method is the comparison of the desired transfer function and the transfer function of the synthesized system. Using it for design a multi-loop control systems leads to complex equations, which have several unknown variables. These parameters are determined by the structure of regulators and feedbacks [1].

The complexity of the equations is nonlinearity. Consequently in general for solving those equations is necessary to use an approximate methods solution search. The most popular way is the consistent calculation of circuits. The calculation starts with the internal circuit and ends the outer loop [2, 3]. Disadvantages this variant is obvious. The adopted scheme requires the distribution of desired system performances for each circuit synthesized system. This can be done only approximately. So the final result is the synthesis of additional error.

The desire to improve the accuracy of the construction of multi-loop control systems makes look for new ways to calculate the unknown coefficients, which not be using approximate methods such as the successive circuits synthesis. This is possible only if the initial equation synthesis may be permitted. Such method is presentation in this article.

## 1. Real interpolation method

The real interpolation method (RIM) is the one form of the operator method, that for every original-function $f(t)$ assigns to image-function $F(\delta)$ [1]. The image-function $F(\delta)$ can be calculated from the formula for the Laplace transform

$$F(p)=\int_0^{\infty} f(t)e^{-pt}dt,\ \ p=\delta+j\omega \tag{1}$$

if make the change the complex variable $p=\delta+j\omega$ on the real variable $\delta$. Such replacement can be used only if the integral in equation (1) is convergent. This guarantees the existence and uniqueness of the function $F(\delta)$.

The RIM has such feature. The image of function $f(t)$ can be in analytical form $F(\delta)$ and in numeric form $F(\delta_i)$. The second has named the numerical characteristics and contains complete information about the original model. So using this form allows to solve such problem relatively simple.

The solution of the problem of synthesis of control systems by using the RIM base on the approximate equality of the numerical characteristics of the synthesized system and the numerical characteristics of the desired system

$$W_{closed}^{desired}\left(\delta_i\right) = W_{closed}^{synthesized}\left(\delta_i\right), \tag{2}$$

where $\delta_i$ – interpolation node, $i$ – number of interpolation node.

## 2. The synthesis of the dual control system

The problem of the synthesis of the dual control system (fig. 1) is reduced to solving of equation (2).

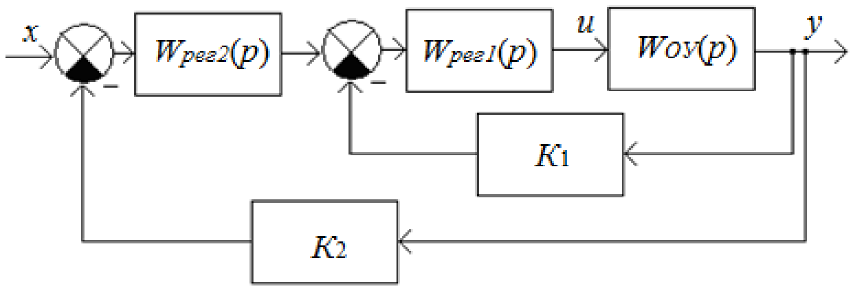


*Fig. 1. Operator block diagram of a dual control system*

Assume that the regulators $W_{reg1}(p)$ and $W_{reg2}(p)$ have the structures

$$\begin{aligned} W_{reg1}(p) &= \frac{b_{reg1_1}\delta + b_{reg1_0}}{a_{reg1_1}\delta + 1}, \\ W_{reg2}(p) &= \frac{b_{reg1_1}\delta + b_{reg2_0}}{a_{reg2_1}\delta + 1}. \end{aligned} \tag{3}$$

So, one can see that for solution of this problem it is necessary to define the values of six unknowns variables. To do this, necessary to calculate the numerical characteristics $W_{closed}^{desired}(\delta)$, for six interpolation nodes. In the result there is a system of six equations with six unknowns.

In paper [2] the solution of such problem is represented. The Newton's Method is used for solving a system of nonlinear equations. But there is complexity. It is consist of the determinant of the Jacobian in this problem has a very small value (about $10^{-26}$). When the number of unknown parameters or the computational accuracy of problem is increase, the task goes to the class of ill-posed problems. In this case, there is the need for additional computing power. The method of regularization which was proposed by the Soviet mathematician Tikhonov [3, 4] is solving these problems.

## 3. The regularization of the Tikhonov

The method of regularization of the Tikhonov [3, 4] is based on using a special addicted priori information about the solution. The concept of regularization amounts to replacing the original ill-posed problem

$$A \cdot y = B \tag{4}$$

by the problem of minimizing the following functions:

$$\Omega(y, \lambda) = \left|A \cdot y - B\right|^2 + \lambda \cdot \left|y - y^0\right|^2. \tag{5}$$

It is the Tikhonov functional.
There $\lambda$ is the small positive regularization parameter.

As part of linear systems the solution to the problem of minimizing the functional (5) reduces to the solution of a linear system of equations:

$$\left(A^T A + \lambda \cdot E\right) \cdot y = A^T B,\ \lambda > 0.$$

Selection the desired $\lambda$ depends on the given solution accuracy and stability requirements of computational algorithms.

## Conclusion

In the paper the need of using the regularization for synthesis multi-loop control systems is presented. Further work is reduced to the study of possible applications Tikhonov regularization for the synthesis of multi-loop control systems.

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## INTEGRAL VARIABLE STRUCTURE CONTROLLER

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**Abstract** – In this research, we consider the integral variable structure controller. Research includes comparison analysis of control qualities with PID-controller and system robustness analysis.

Now we consider two controller synthesis approaches. Most of industrial processes are controlled by using proportional-integral-derivative (PID) controllers. The popularity of PID controllers can be attributed partly to their good performance in a wide range of operating conditions and partly to their functional simplicity, which allows engineers to operate them in a simple, straightforward manner. To implement such a controller, three parameters must be determined for the given process: proportional gain, integral gain, and derivative gain [1]. Restrictions cannot be taken into account when we choose gain values in the controller. This problem is solved by specialized packages. In the example (fig. 3), the PID-controller was tuned in Check Step Response Characteristics. It is utility of Simulink Library of MATLAB.

Second solution is developed variable structure controller, which based on State Space analysis [2]. In order to get one more state variables we introduce integrator. This controller enables us to consider restrictions on the synthesis stage of control strategy. This is time-optimal system. It is easy to implement this control strategy with computer equipment. Such a control strategy allows us to reduce erasing actuators. But this control strategy is sensitive to variations of system parameters and can lead system to instability.

To achieve effective control strategy in industrial processes are used adaptive systems. These systems are usually based on the adjustment of gain in PID controller. It takes a long time for the selection of gain values by computer. Adaptation of the integral variable structure controller needs less computer calculation time than adaptation of the PID controller.