Analytical Synthesis Algorithms of the Controllers for the Automatic Control Systems with Maximum Stability Degree and Imposed Performance

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***Abstract*—Elaboration of the analytical algorithms for synthesis of typical controllers P, PD, PI and PID to the objects with arbitrary order of inertia and time delay, using the maximum stability degree criterion is proposed in this paper. The dependencies between dominant roots of the designed system and its dynamical performance were used. There were obtained the analytical expressions for calculation the maximum stability degree of the system and the values of dynamical parameters of typical controllers in dependence of known parameters of the control object and imposed performance: damping degree, oscillation degree, overshoot and settling time. To demonstrate the efficiency of proposed algorithms were analyzed three examples of tuning the typical algorithms to the diverse models of objects with imposed performance of the designed system.**

Keywords — model of object with inertia and time delay; typical control algorithms; control system; maximum stability degree criterion; performance of control system

I. INTRODUCTION

Based on the analysis of bibliographical sources relating to synthesis of controllers was noticed the lack of the simple and effective methods for tuning of the PID controllers to the objects with arbitrary order inertia and time delay, which would ensure the high performance and robustness and the possibility of imposing the desired performance to the system in process of designing [1-9]:

- Analytical methods (Coon, Shedel, the method of the module, the method of the symmetry etc.) are based on the approximation of the dynamic process to the models objects with low order inertia, and do not ensure high performance for the high order control object.
- Graphical-analytical methods (roots locus method, frequency method) offer to the designed system the satisfactory performance, but require a big volume of calculations and graphic designs.
- The experimental tuning methods (Ziegler-Nichols, Chien-Hrones-Reswich, Offerens etc.) are simple in uses, but do not permit to impose the desired performance and the quality of the control are sometimes unsatisfactory and require the further tuning.
- The optimization methods characterize the overall behavior of the control system, and can be applied to the complex model objects, offer high performance of the designed system and the possibility to impose the desired performance, but these method are required big volume of calculations and using of computer-aided design and in some cases the calculation procedure may diverge from the optimal values. This fact involves the difficulties in computing, brings the increase of the time and the necessary resources for the synthesis of the controllers and therefore some impediments in terms of system design - conventional or adaptive.
- The presence of time delay in the model of control objects complicates essential the synthesis procedure of controller, and many synthesis method can not be applied in this case.
- Most of the existence methods, even though some provide the high performance, do not take into account the problem related to the precision of identification and nonlinear behavior of processes and the randomness character of the disturbances that occur during operation and therefore do not provide to the designed system the required robustness.

According to this consideration the purpose of this work is development of the analytical algorithms, in form of the algebraic expressions, for synthesis of PID controller and its variation to the model of objects with inertia and time delay, which would satisfy the following requirements: to be simple in application and require low volume of calculations; do not impose restrictions on the complexity of model objects; to offer to the designed system the high performance and robustness and also permit to impose the desired performance; can be used both for synthesis of the conventional automatic control systems, the automatic systems with auto-tuning and adaptive control systems.

To achieve this goal it was found that one of the perspective ways in this direction is elaboration of the methods, which would establish a direct dependence between performance of the designed automatic control system and tuning parameters of the controller. At the same time, it is also

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