Synthesis of PID Controller for the Automatic Control System with Imposed Performance based on the Multi-Objective Genetic Algorithm

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***Abstract*—This paper presents an improved algorithm for tuning of the proportional-integral-derivative controller, according to the maximum stability degree criterion with implementation the optimization procedure, based on the multi-objective genetic algorithm. According to the maximum stability degree criterion, the tuning parameters of the typical controllers can be calculated by the given analytical expressions that depends on the value of maximum stability degree. Based on these analytical expressions, it is presented the implementation of the multi-objective genetic algorithm, that permits to calculate the tuning parameters, which offers to the control system the settled range of performance. The fitness function is settled based on the imposed performance to the control system as overshoot, settling time, rise time. The proposed algorithm was verified by the computer simulation and there are presented some case studies. The case study was done for the situation when the control object is approximated with model of object with second order inertia with/without time delay, and model of object with third order inertia.**

Keywords*—PID controller; multi-objective genetic algorithm; imposed performance; fitness function

I. Introduction

Proportional integral derivative (PID) controllers have a large applicability in different industrial applications, due to its simplicity, good robustness and performance that they offer to the automatic control systems. PID controllers, become the standard of industrial feedback control for more than 65 years, but they face problem of finding the tuning parameters and nowadays [1-3]. Essential reason of the unsatisfactory results in synthesis the control algorithm is related to the reason that a lot of proposed tuning methods are limited to very restricted conditions on the control object, presence of the time delay, variation of the control object parameters and to solve this problem nowadays are widely used the optimization approaches for synthesis the typical controllers [4]. In this way, the problem of synthesis the controllers can be presented as an optimization problem of certain performance measures of the controlled systems and a useful algorithm for solving such problem is the genetic algorithm (GA) and other evolutionary algorithms [11-13].

Genetic algorithm has been deployed for multi-objective control design in case of imposed performance to the automatic control system, that permits to generate the optimal solutions, that enables user to perform trade-off study under imposed performance [14]. In this way, the multi-objective optimization investigates a set of solutions, where each of which asure the fitness function at an acceptable level [9, 10].

In [5, 6], it is presented the algorithm for synthesis the controller PID and its variations to the model of objects with inertia and time delay, by the maximum stability degree (MSD) criterion. According to this algorithm, the values of the tuning parameters can be calculated in dependence of the maximum stability degree of the system, known parameters of the control object and imaginary part of the complex dominant root.

In this paper, the MSD criterion was proposed to be improved, namely the calculation procedure of the tuning parameters, in the case when there are imposed performance as overshoot, settling time, rise time for the automatic control system and to use the multi objective genetic algorithm, that permits to set the different objective functions and introducing methods to promote solution diversity.

II. Synthesis of the Control Algorithm

The automatic control system consists from the typical controller $H_R(s)$ and the control object described by the transfer function with inertia and time delay:

$$H_F(s) = \frac{k \exp(-\tau s)}{a_0 s^r + a_1 s^{r-1} + \ldots + a_{r-1} s + a_r}, \tag{1}$$

where k is the transfer coefficient of the control object; τ - time delay; a_i, $i=0,\ldots,r$ – parameters of the control object; r - the order of the object model.

The controller is described by the following transfer function: