Tuning the Controller for Object Models with One-Four Poles Using the Polynomial Method

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Abstract: The paper describes the procedure for tuning the controller for models of control objects with first to fourth order inertia and astatism, using the polynomial method with the imposition of damping ratio and settling time of the synthesized system. In the automation of various technical objects, industrial, and technological processes that require automatic control [1, 2], whose dynamics approximate mathematical models described by transfer functions with constant parameters and inertia degrees 1-4 and astatism of the form:

$$H_1(s) = \frac{b_0}{s(a_0 s + a_1)} = \frac{B(s)}{A(s)}, \tag{1}$$

$$H_2(s) = \frac{b_0}{s(a_0 s^2 + a_1 s + a_2)} = \frac{B(s)}{A(s)}, \tag{2}$$

$$H_3(s) = \frac{b_0}{s(a_0 s^3 + a_1 s^2 + a_2 s + a_3)} = \frac{B(s)}{A(s)}, \tag{3}$$

$$H_4(s) = \frac{b_0}{s(a_0 s^4 + a_1 s^3 + a_2 s^2 + a_3 s + a_4)} = \frac{B(s)}{A(s)}. \tag{4}$$

where b_0, a_0, a_1, a_2, a_3, a_4 are the coefficients of the transfer function.

For models (1)-(4), there are methods for tuning the controller such as the pole-zero method, frequency methods, integral criteria method, etc. However, using these methods is accompanied by complex calculations to achieve the desired performance [1, 2].

In the study, the synthesis procedure of the control algorithm for models (1)-(4) using the polynomial method is described, aiming for the synthesized system to exhibit high performance and good robustness.

The transfer functions of the objects (1)-(4) are described in factored form according to the zeros in the left and right half-planes of the complex plane. Based on the required performance specifications for the system, the characteristic polynomial is constructed with two dominant poles and, if necessary, additional real poles allocated as far as possible from the dominant poles to meet the performance criteria of the synthesized system.

Based on the order of the object's model and the conditions for solving the system of algebraic equations, the physical feasibility of the controller and the robustness of the system, the desired characteristic polynomial of the synthesized system is constructed. This polynomial contains two polynomials with unknown coefficients, and the degrees and the unknown polynomials, as well as the degree of the desired polynomial, are calculated. The desired polynomial is equated with the polynomial containing the dominant poles. By equating the coefficients of the same powers of the variable $\boldsymbol{s}$ on both sides of the equality, an algebraic system of equations is obtained, from which the unknown coefficients and polynomials are determined. Based on the stable components of the object's model and the unknown polynomials, the transfer function of the control algorithm is constructed.

The study analyzes the synthesis of the control algorithm for models (1)-(4) using the polynomial method, aiming for the synthesized system to exhibit high performance and good robustness. By examining the results of the controller synthesis for examples of models (1)-(4) with the imposed performance specifications—a damping ratio of 0.707 and a settling time of one second—it is found that:

1.The synthesis of the controller for these types of models is straightforward and involves a low computational effort.

2. The step responses of the systems are aperiodic with high performance and good robustness, and the performance decreases slowly with the increasing order of the model.

References

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