UDC 621.378.001

ANALYSIS OF NON-LINEAR PID CONTROLLER

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The theory of linear control systems has become the most widespread in theoretical works and practical applications. In the synthesis of modern high-quality automatic control systems, various types of linear control devices are widely used - from the simplest universal proportional-integral-differential (PID) algorithms to modal control, analytical design of regulators.

Synthesis of nonlinear control algorithms is developed only for a particular class of systems. Nevertheless, many studies have shown that in many cases the use of nonlinear control laws can significantly improve the parameters of the system being designed. Separately, it is worth mentioning the successful attempts to use fuzzy, neural and hybrid algorithms, which are also non-linear systems in the control of technological processes. There are especially a lot of studies on the use of nonlinear systems and special algorithms to improve the PID algorithm [1-2]. A comparative analysis of the most popular nonlinear methods was carried out in the work [2].

The use of nonlinear transformations in the formation of control actions is hindered by the complexity of the mathematical proof of stability and robustness. For the practical use of new management solutions, it is very important to have simple methods of setting up the system.

The experience of modelling and practical application of nonlinear correcting devices has shown their high efficiency. An important advantage of the non-linear correction device is that they are successfully combined with linear algorithms.

When searching for settings of nonlinear PID-algorithms, methods of numerical minimization of integral quality criteria are popular: ISE; IAE, ITAE, USQR, UABS

In the paper, it was shown [2] that simulation time can affect the values of the regulator settings. This is due to the choice of a digital method for solving a differential equation, as well as accuracy in simulation systems as Matlab. This is not important for practical tasks, but when forming conclusions when comparing algorithms it should be considered very carefully. As the choice of *tf*, the time of the transient process of the system with or without feedback can serve.

When searching for settings, you can increase the stability margin, reduce overshoots if you modify the ITAE and ISE criteria [3].

$$\int_0^{tf} t^N |e(t)| dt \to \min \text{ and } \int_0^{tf} t^N e(t)^2 dt \to \min$$

where N – 1, 2, 3 … . $e(t)$ – the error at the input of the system; $u(t)$ – the control signal; tf – the simulation time.

PID algorithm is one of the most universal algorithms for maintaining technological parameters. But at the same time there are objects of management and circumstances, when it does not show the best qualities. First of all, these are the objects with a restriction on the control action and objects with a long delay time.

The choice of non-linear functions that can be used to improve the PID controller is quite large. Uniquely for each object, you can pick the best function from the point of view of certain qualities, but the optimization process may require too much time and costs. In addition, it should be borne in mind that when managing technological processes it is difficult to meet an object with unchanged parameters during operation.

The preliminary searches, as well as the orientation toward applied application of the results, made it possible to confine the study of the piecewise linear characteristic and the logarithmic characteristic

$$\Box\, \mu = sign(err)\ln\left(\left(1+\alpha|err|\right)-\left(1+\alpha\right)\right),$$

where α – is the coefficient of curvature.

As the object of investigation, a transfer characteristic of the form

$$W_O = \frac{k_O}{T^2 p^2 + 2zTp + 1}\exp(-\tau p),$$

where k_O – the gain of the object; T – the time constant; s – the Laplace operator; z – the oscillation coefficient; τ – the delay value, which allows to cover a wide class of process control objects.

The use of non-linear characteristics for PID and PI-regulators at certain values of τ and z of the object provides an improvement of the integral criterion by more than two times. At the same time, other parameters of the transient process were improving.

When the gain factor is changed by 10% in one direction or another, the deterioration in the quality of the regulation is comparable or less in comparison with the performance of a classical PID or PI controller. Characteristics like piecewise linear, and logarithmic have the potential to improve the quality of PID regulation.

Reference

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