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Synthesis of Guaranteed Stability Regions of a Nonstationary Nonlinear System with a Fuzzy Controller

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Abstract

The paper proposes a method for constructing guaranteed regions of stability of nonstationary nonlinear systems on the plane of parameters of a fuzzy PID controller. It is shown that this method allows to determine the full stability areas, which are significantly larger than the areas determined by classical methods (frequency circle criterion, quadratic Lyapunov functions). This improvement is achieved by using the algorithm for constructing spline Lyapunov functions. This type of Lyapunov functions is based on the necessary and sufficient conditions of stability, while the classical methods are only sufficient conditions of stability. In this regard, on the basis of the proposed method, it is possible to calculate the maximum sizes of the sectors in which the nonlinear characteristics in the channels of the fuzzy PID controller should be located. Examples of the synthesis of fuzzy P, PI, PID controllers for a nonstationary control object of the third order are given. Numerical experiments show that the expansion of the boundaries of nonlinear characteristics allows to improve the accuracy in the steady state, and also to almost double the speed of the automatic control system with a nonstationary object. The advantages over linear controllers are demonstrated. The proposed method guarantees the stability inside the calculated stability regions for any character of the change in the nonstationary parameter, as well as for any character of the change in the nonlinear characteristics in the corresponding sectors.

Keywords: Nonstationary Nonlinear System; Stability Regions; Lyapunov Functions; Circle Criteria; Spine Functions; PID Controllers; Fuzzy Logic; Adaptive Systems.

1. Introduction

In recent decades, there has been a rapid increase in interest in the study of control systems for nonstationary objects. This is due to the fact that with the help of nonstationary models it is possible to describe rather complex technological objects in industry [1]. To achieve the required values of accuracy and speed of such a systems, artificial intelligence technologies are used in practice [2]. However, the analysis of the stability of intelligent control systems of nonstationary objects is a difficult task. On the other hand, the use of active controllers represents a perspective way of isolating the structure from earthquake-induced vibrations [3]. Since there are many uncertain parameters in the buildings and system coefficients are varying in the time, methods of absolute stability theory are proposed for control system synthesis [4].

As part of solving the problem of the stability of systems with nonstationary nonlinear elements, algorithms for constructing special Lyapunov functions were developed in [5-7]. These algorithms are based on the necessary and sufficient conditions for absolute stability [8-10], which makes it possible to identify guaranteed (full) regions of stability in the system parameter space. This has a practical importance in the design of fuzzy control systems in which fuzzy controllers perform nonlinear transformations that ensure the improvement of the quality characteristics of automatic control system (ACS) [11]. In this connection, the problem arises of determining the permissible sector inside of which

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