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DESIGN, PERFORMANCE, AND STABILITY ANALYSIS OF A FORMULA-BASED FUZZY PI CONTROLLER

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Abstract. *In this paper, a new formula-based fuzzy proportional-integral (FPI) controller is proposed. This controller is based on the conventional proportional-integral (PI) controller. The proposed FPI controller has a linear structure similar to that of the conventional controller, and the operation of the proposed controller is based on analytical formulas. The structure is designed by using three membership functions as input variables and five membership functions as output variables. Thus, the proposed controller is a discrete-time fuzzy version of the conventional PI controller. For performing stability analysis, sufficient conditions for the bounded-input bounded-output (BIBO) stability of overall closed-loop control are derived by using the small gain theorem. The performance of the FPI controller in setpoint tracking, disturbance rejection, and noise suppression is evaluated. Computer simulations of the control of the outlet flow concentration of a nonlinear non-thermic catalytic continuous stirred-tank reactor (CSTR) were performed by using the National Instrument^{TM} software LabVIEW^{TM}; the simulation results obtained for the proposed FPI controller and its counterpart fuzzy PI (NI_FPI) controller using Fuzzy Logic toolkit were compared. The performance of the proposed formula-based FPI controller is considerably better than that of the NI_FPI controller. Our simulation results demonstrate the effectiveness of the proposed FPI controller.*
Keywords: PID, PI, Fuzzy PI controller, CSTR, BIBO stability

1. **Introduction.** Classical proportional-integral-derivative (PID) controllers are extremely important in process industries and widely used in industry in many forms such as pneumatics, hydraulics and electronics. A statistical study shows that PID controllers are used in more than 90% of the modern industries. This is because of their low cost, inexpensive maintenance, simplicity of operation, ease of design, and effectiveness for most processes [1-4]. In general, the classical PID controller cannot provide good solutions for higher-order processes involving time delay, nonlinearity, and poorly defined dynamics. When a process becomes too complex to be described by analytical models, it cannot be efficiently controlled by conventional approaches. To overcome these difficulties, various types of modified PID controllers such as autotuning and adaptive PID controllers have been developed recently [3-7]. Further, a nonconventional type of PID controller in which fuzzy logic is employed has been designed and simulated for this purpose [3,8-10]. Fuzzy logic has emerged as a popular tool used by scientists and researchers to enhance the capabilities of the classical PID controller.

Chen et al. designed fuzzy PI/PD/PID controllers, and compared these controllers with the conventional controllers. They designed the structure of fuzzy controllers, with simple analytical formulas as the final results. For fuzzification, they used two fuzzy sets as the input variables and three fuzzy sets as the output variables. They also considered