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Fault-Tolerant Fuzzy Gain-Adaptive PID Control for a 2 DOF Helicopter (TRMS System)

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International Scientific Research and Experimental Development

Istanbul, Turkey

Authorized Signature

April 21-22, 2015

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***Abstract*—**In this paper, a Fault-Tolerant control of 2 DOF Helicopter (TRMS System) Based on Fuzzy Gain-Adaptive PID is presented. In particular, the introduction part of the paper presents a Fault-Tolerant Control (FTC), the first part of this paper presents a description of the mathematical model of TRMS, an adaptive PID controller is proposed for fault-tolerant control of a TRMS helicopter system in the presence of actuator faults, A fuzzy inference scheme is used to tune in real-time the controller gains, The proposed adaptive PID controller is compared with the conventional PID. The obtained results show the effectiveness of the proposed method.

***Keywords*—**Fuzzy control, Gain-adaptive PID, Helicopter model, PID control, TRMS System.

I. Introduction

FAULT-TOLERANT CONTROL (FTC) is a relatively new idea that makes possible to develop a control feedback that allows keeping the required system performance in the case of faults [1]. The control strategy can be perceived fault tolerant when there is an adaptation mechanism that changes the control law in the case of faults. Another solution is to use hardware redundancy in sensors and/or actuators. In general, FTC systems are classified into two distinct classes [2]: passive and active. In passive FTC [3] [4], controllers are designed to be robust against a set of presumed faults, therefore there is no need for fault detection. In the contrast to passive ones, active FTC schemes, react to system components faults actively by reconfiguring control actions, and by doing so the system stability and acceptable performance is maintained.

Due to the complicated nonlinearity and the high coupling effect between two propellers, the control problem of the (TRMS) has been considered as a challenging research topic [5].

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PID (Proportional - Integral - Derivative) controllers are the most familiar controller in the society of automation and control, due to their simple structure and wide variety of usage. These kinds of controllers are classified into two main categories in terms of parameters selection strategies. In the first group, controller gains are fixed during operation while in the second group, gains change based on the operating conditions. In the first group, gains are tuned by the designer and remain invariable during the operation. One of the most familiar methods for choosing control gains in this group is Ziegler-Nichols method [6].

In most applications, due to structural changes the controlled system may lose its effectiveness, therefore the PID gains need to be continuously retuned during the system life span.

To reduce the effort of retuning the gains and also in order to increase system's performance, in the second group of controllers, the gains are adapted online. A number of methods have been proposed in the literature for PID gain scheduling [7] a stable gain-scheduling PID controller is developed based on grid point concept for nonlinear systems. Different gain scheduling methods were studied and compared [8], [9] a new PID scheme is proposed in which the controller gains were scheduled by a fuzzy inference scheme.

Many method and research works in this domain in [10], [11], [12]. A particle group optimization method is used in [10] to design membership functions of fuzzy PID controller. In [13], an accumulated genetic algorithm is proposed which learns the parameters and number of fuzzy rules in the fuzzy PID controller.

An adaptive fuzzy PID using neural wavelet network is presented in [14], an intelligent control scheme using a fuzzy switching mechanism, grey prediction and genetic algorithm (GA) in [15]. The interested readers can find a brief review of different fuzzy PID structures in [16].

The remainder of this paper is organized as follows. The model of the TRMS is described in Section II. The Fuzzy Gain Adaptive PID (FGAPID) strategy is designed in Section III. Section IV presents the simulation results to demonstrate the effectiveness of the FTC Controller. Concluding remarks are provided in Section VI.