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JESIT 179 1–12

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Journal of Electrical Systems and Information Technology xxx (2017) xxx–xxx

www.elsevier.com/locate/jesit

Theoretical analysis and real time implementation of a classical controller with intelligent properties

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Received 9 February 2017; received in revised form 22 August 2017; accepted 9 December 2017

Abstract

This paper presents theoretical analysis and experimental implementation of a classical controller with intelligent properties. The controller has constant parameters, but it performs as an intelligent controller. The controller design mimics the fuzzy logic controller in a classical form and combines the advantages of classical controllers and properties of intelligent controllers. The designed controller parameters force the controlled variable to behave such as a first order system with a desired time constant. DC motor practical system is used to demonstrate the effectiveness of the presented controller. Root locus and frequency response using Bode diagram are used to help the design of the controller parameters. Simulation and experimental results verify the high performance of the presented controller.

Keywords: Classical controller; DC motor; Root locus; Frequency response; Arduino microcontroller

1. Introduction

Q4 DC motors, especially separately excited DC motors are controllable over a wide range with stable and linear characteristics. Therefore, they are still used in the industries for both constant speed and constant load operations (Abhinav and Sheel, 2012; Sheel et al., 2010). Many literatures apply different controllers for both speed control and position control of the DC motor. Although proportional (P) speed controller is simple, it produces a steady-state error in case of first order type systems (Das et al., 2015; Tunyasrirut et al., 1999; Ming and Yu, 2012; Cui et al., 2006). Bharatiraja et al. (2016) use a Lab VIEW controller as a single software environment for simulation and real time

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Peer review under the responsibility of Electronics Research Institute (ERI).

ELSEVIER Production and hosting by Elsevier

https://doi.org/10.1016/j.jesit.2017.12.001

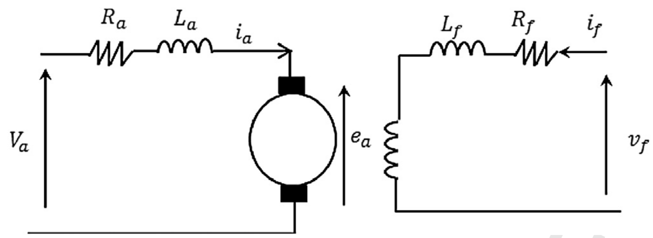

Fig. 1. DC motor model.

implementation of DC motor speed control. The built-in controller is a conventional PI controller. Both proportional integral (PI) and proportional integral derivative (PID) controllers eliminate the steady state errors but changes in system parameters deteriorates the system performance. In addition the PI controller response is usually slow and the controller may cause oscillations and overshoot especially in case of improper design of P and I parameters.

On the other hand, artificial intelligent controllers such as fuzzy logic controllers (FLCs) and, neural network controllers (ANN) are considered as adaptive controllers (Nath et al., 2015; Antar et al., 2013; Al-Hamouz and Al-Duwaish, 1998; Chang and Chung, 2005; Thepsatom et al., 2006; Muruganandam and Madheswaran, 2009; Pavankumar et al., 2010; Rajeswari et al., 2011; Ben John Stephen and Ruban Devaprakash, 2011). FLC is well known and widely employed for power electronics speed drives due to its flexibility (Abdelkarim et al., 2012; Suman and Giri, 2016). In addition, FLC is intuitive knowledge base design. FLCs overcome the main two disadvantages of classical PI controllers, the sensitivity of parameters variations and slow response. Manual tuning and look up table are the main drawbacks of FLCs. These drawbacks mean that FLCs are not perfect solutions for all applications. As listed in the literature, most researches when applying FLCs for DC and AC drives, they compare the performance of FLCs with classical controllers to validate the intelligence nature of FLCs over classical controller's performance such as Das et al. (2015), Tunyasrirut et al. (1999), Cui et al. (2006), Thepsatom et al. (2006), Pavankumar et al. (2010) and Rajeswari et al. (2011).

To achieve the intelligent advantage of FLC and the implementation simplicity of classical controllers at the same time, this paper presents a classical intelligent controller for separately excited DC motor drives.

In Salem (2008) a theoretical study of a classical controller with intelligent properties was introduced. In that theoretical study, the controller is used to control the speed of three phase induction motor and the controller parameters were calculated to provide a motor speed with a certain damped response and a full load torque rejection with a predefined maximum speed dip. This paper presents the application of the controller in Salem (2008) on a separately excited DC Motor. In the present paper, the controller parameters are calculated in different way in which the transfer function of the controlled system (the system and controller) is transferred to a first order system where the calculated controller parameters determine the controlled system time constant. The controller has two loops; the outer loop controls the motor speed and gives armature reference current which is utilized as an input to the inner loop that in turn maintains the armature current within a specified range.

2. DC motor model

Fig. 1 shows the separately excited DC motor model which is considered in this paper. Generally the motor has two separate winding, they are armature and field windings. The armature winding is represented as a resistor R_a, inductance Q5 L_a, and back emf (e_a), while the field winding is represented as a resistor R_f and inductance L_f. The equations of the motor are given by:

$$v_a = R_a i_a + L_a \frac{di_a}{dt} + e_a \tag{1}$$

$$v_f = R_f i_f + L_f \frac{di_f}{dt} \tag{2}$$

$$e_a = k i_f \omega \tag{3}$$

Please cite this article in press as: Hendawi, E., et al., Theoretical analysis and real time implementation of a classical controller with intelligent properties. J. Electr. Syst. Inform. Technol. (2017), https://dx.doi.org/10.1016/j.jesit.2017.12.001