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FUZZY CONTROLLER BASED OPTIMIZATION OF SPEED RESPONSEWITH LABVIEW

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Abstract-*Speed control of DC Motor is vital in manyapplications. In this paper, an effort has been made to control thespeed of the DC motor using fuzzy logic control (FLC) based onLabVIEW (Laboratory Virtual Instrument EngineeringWorkbench) program. LabVIEW provides a graphicalprogramming environment suited for high-level or system-leveldesign. The fuzzy logic controller designed to apply the requiredcontrol voltage that sent to dc motor based on fuzzy rule base ofmotor speed error (e) and change of speed error (Ce). In thispaper results of FLC, PI and PID Controller are compared. Thesimulation results demonstrate that the response of DC motorwith FLC show a satisfactory well damped control performance*.

INTRODUCTION

The DC motors have been popular in the industry control area for a long time, because they have many goodcharacteristics, for example: high start torque characteristic, highresponse performance, easier to be linear control etc. There aredifferent control approaches which depend on the differentperformance of motors. The basic property of DC motor is thatspeed can be adjusted by varying the terminal voltage. Therefore,the DC motor control is riper than other kinds of motors. ClassicControl has proven for a long time to be good enough to handlecontrol tasks on system control; however its implementationrelies on an exact mathematical model of the plant to becontrolled and not simple mathematical operations. The fuzzylogic, unlike conventional logic system, is able to modelinaccurate or imprecise models. The fuzzy logic approach offersa simpler, quicker and more reliable solution that is clearadvantage over conventional techniques. Fuzzy logic may beviewed as form of set theory. When compared to theconventional controller, the main advantage of fuzzy logic is thatno mathematical modelling is required. Since the controller rulesare especially based on the knowledge of the system behaviour and experience of the control engineer, the FLC requires lesscomplex mathematical modelling than classical controller does.LabVIEW is better for control applications and MATLAB isbetter for data manipulation. LabVIEW is the graphicaldevelopment environment for creating flexible and scalable test,measurement, and control applications rapidly and at minimalcost.

SYSTEM DESCRIPTION

DC MOTOR MATHEMATICAL MODEL - DC motor system is a separately excited DC motor, which is often used to the velocity tuning and the position adjustment. The equivalent circuit of the DC motor using the armature voltage control method [8] is
shown in Figure 1:

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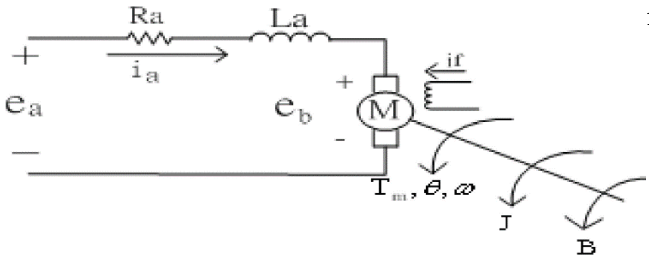


Figure 1: Equivalent circuit of the DC motor.

Where

R_a : Armature resistance (3.3Ω)
L_a : Armature inductance (0.00464H)
i_a : Armature current (A)
i_f : Field current (A)
e_a : Input voltage (V)
e_b : Back electromotive force (EMF) (V)
T_m : Motor torque (Nm)
ω : An angular velocity of rotor (rad/s)
J : rotor inertia (9.64E-6kgm^2)
B : Friction constant (1.8E-6Nms/rad)
K_b : EMF constant (0.028Vs/rad)
K_T : Torque constant (0.028Nm/A)

Because the back EMF e_b is proportional to speed ω directly, hence

$$e_b(t) = K_b \frac{d\theta(t)}{dt} = K_b \omega(t) \tag{1}$$

Making use of the KCL voltage law we can get

$$e_a(t) = R_a i_a(t) + L_a \frac{di_a(t)}{dt} + e_b(t) \tag{2}$$

From Newton law, the motor torque can obtain

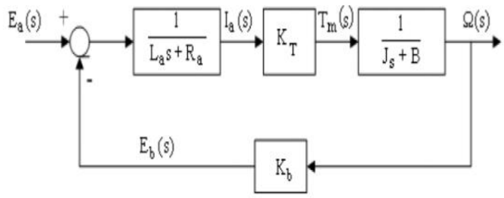
Taking Laplace transform, the above equations can be Formulatedas follows:

$$E_b(s) = K_b \Omega(s) \tag{4}$$

$$E_a(s) = (R_a + L_a s) I_a(s) + E_b(s) \tag{5}$$

$$T_m(s) = B\Omega(s) + Js\Omega(s) = K_T I_a(s) \tag{6}$$

The DC motor armature control system functional block diagram from equations (4) to (6) is shown in Figure 2:



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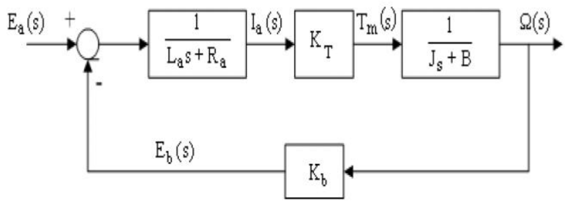

Figure 2: DC motor armature control system functional block diagram.

The transfer function of DC motor speed with respect to the input voltage can be written as follows [11],

$$G(s) = \frac{\Omega(s)}{E_a(s)} = \frac{K_T}{(L_a s + R_a)(Js + B) + K_b K_T} \tag{7}$$

$$= \frac{0.028}{(4.47296 \times 10^{-8})S^2 + 3.18204\ 10^{-5}S + 0.00078994} \tag{8}$$

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PID CONTROLLER DESCRIPTION AND DESIGN

The development of PID control theories has already been from 60 years. PID control has been one of the control system designmethod of the longest history. However, this method is stillextensively used . PID controller is mainly to adjust anappropriate proportional gain (KP), integral gain (KI), anddifferential gain (KD) to achieve the optimal control performance.These functions have been enough to the most control processes.

The PID controller system block diagram is shown in Figure 3:

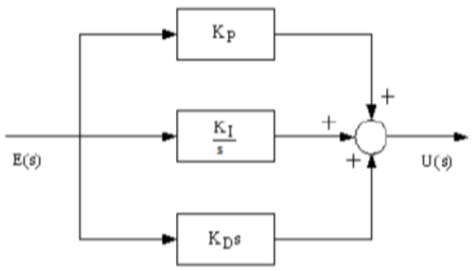

Figure 3: PID controller system block diagram.

The relationship between the input e(t) and output u(t) can b formulated in the following,

$$U(t) = K_P e(t) + K_I \int_0^t e(t)dt + K_D \frac{de(t)}{dt}$$ (9

The transfer function is expressed as follows,

$$C(s) = K_P + \frac{K_I}{s} + K_D s = \frac{U(s)}{E(s)}$$ (10

The PID DC motor speed control system block diagram is show in Figure 4:

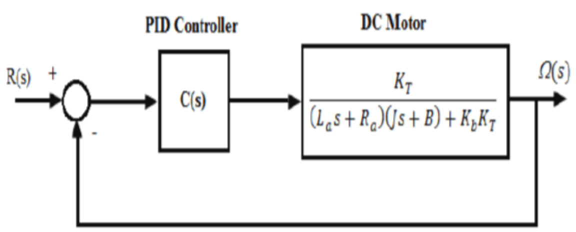

Figure 4: PID DC motor speed control system block diagram

The closed loop transfer function of DC motor speed control system expresses as follows,

$$G(s) = \frac{(K_P + \frac{K_I}{s} + K_D s)\frac{K_T}{(L_a s + R_a)(Js + B) + K_b K_T}}{1 + (K_P + \frac{K_I}{s} + K_D s)\frac{K_T}{(L_a s + R_a)(Js + B) + K_b K_T}} \quad (11)$$

$$= \frac{(K_D s^2 + K_P s + K_I)K_T}{L_a J s^3 + (R_a J + BL_a + K_D)s^2 + (R_a B + K_b K_T + K_P)s + K_b K_T} \quad (12)$$

Ziegler- Nichols is a type of continuous cycling method forcontroller tuning. The term continuous cycling refers to acontinuous oscillation with constant amplitude and is based on the trial-and-error procedure of changing the proportional gain(Kp).Kpis increased from small value till the point at which thesystem goes to unstable. Thus the gain at which system startsoscillating is noted as ultimate gain (Ku) and period ofoscillations is ultimate time period (Pu). It allows us to use theultimate gain value, Ku, and the ultimate period of oscillation(pu) to calculate Kp, Ki,andKd . These two parameters,Ku and Puare used to find the loop-tuning constants of the controller (P,PI, or PID) using the formula tabulated in Table I:

Controller	K_p	τ_I	τ_D
P	$0.5K_u$	∞	0
PI	$0.45K_u$	$\frac{P_u}{1.2}$	0
PID	$0.6K_u$	$\frac{P_u}{2}$	$\frac{P_u}{8}$

Table I: for Ziegler Nichols parameters

Then according to Z-N tuning rule, by using ultimate gain and ultimate period P, PI, PID gains K_P, K_I and K_D obtained using relation $K_I = K_P/\tau_I$ and $K_D = K_P * \tau_D$ [14] for DC motor is shown in Table II:

Controller	K_P	K_I	K_D
P	0.5542	0	0
PI	0.4987	85.5540	0
PID	0.6650	190.011	0.0005819

Table II: Simulated results for Ziegler Nichols.

PID controller transfer function for DC motor using Ziegler Nichols tuning method is shown in Equation 13.

$$U(s) / E(s) = \frac{0.0005819S^2 + 0.66504S + 190.0114}{S} \quad (13)$$

FUZZY LOGIC

The term "Fuzzy Logic" was introduced by Lofti A. Zadeh in the year 1965. Fuzzy Logic is a many valued logic relative to binary logic. Binary logic mainly deals with only two values i.e. 0's and 1's whereas the Fuzzy Logic is concerned about the intermediate values also i.e. between 0's and 1's. Fuzzy Logic is a rule based algorithm is used where the exact mathematical model of the system is not known. It converts the rules which are in the form of human languages into mathematical equivalents. The beauty of the Fuzzy Logic is that it mimics human thinking, and adds a common sense element to the control strategy . Figure 1 shows a generalized Fuzzy Logic controller consists of 1. Fuzzification module (Fuzzifier) 2. Rule base and Inference engine (Database) 3. Defuzzification module (DE fuzzifier)

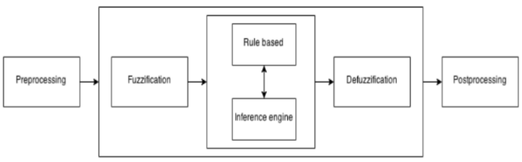

Fig -1: Block diagram of a Fuzzy controller

Fuzzification is the process of assigning suitable linguistic variables for the crisp input data, consists of membership functions that are obtained from the inputs and outputs of the system. The knowledge-base consists of a collection of rules that describe the control strategy. These rules are evaluated by an inference mechanism. The rules commonly used are the IF- THEN rules. The defuzzification is the process of aggregation of the linguistic information as well as an inference process to convert output linguistic variables to crisp output by various methods such as centre of area, max of means etc. Pre-processing The inputs are most often hard or crisp measurement from some measuring equipment rather than linguistic. A pre-processor conditions of measurements before enter the controller. Post processing: The postprocessing block often contains an output gain that can be tuned and also become as an integrator. An expert operator develops flexible control mechanism using words like "suitable, notvery suitable, high, little high and much Although the classiccontrollers dependon the accuracy of the system model and parameters,FLC uses different strategies for motor speed control. Basically, FLC process is based on experiences and linguistic definitions instead of system model. It is not required to know exact system model to design FLC. In addition to this, if there is not enough knowledge about control process, FLC may not give satisfactory results.

IMPLEMENTATION OF PI CONTROLLER ON COMPACTRIO

The only difference between Fuzzy Logic controller and PI controller is that a FPGA PID is available in the compact RIO has been used to generate the PWM signal corresponding to the error. The gain constant of proportional Kp is 4 and KI is 0.05 Sec is obtained by tuning.

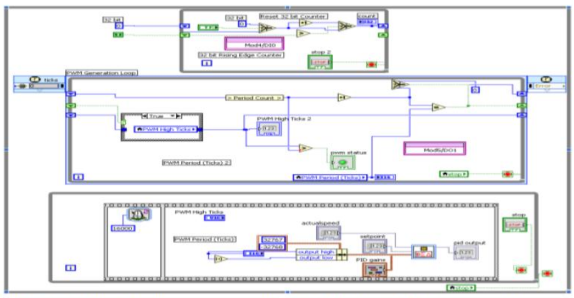

Fig10 Block diagram of FPGA VI of PI Controller

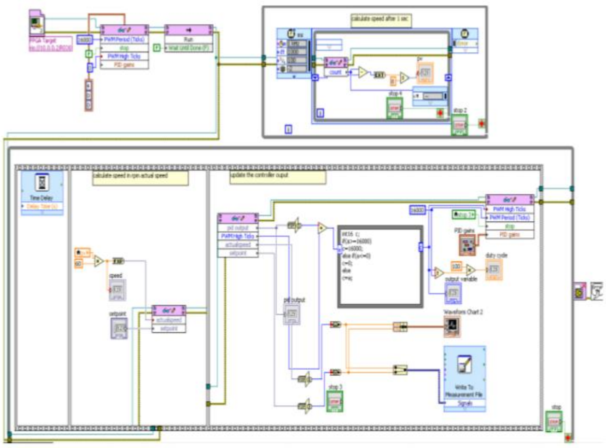

Fig-12 Block diagram of Host VI of PI Controller

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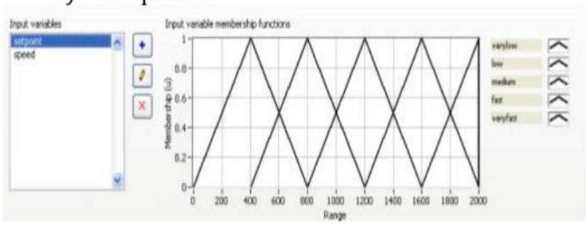
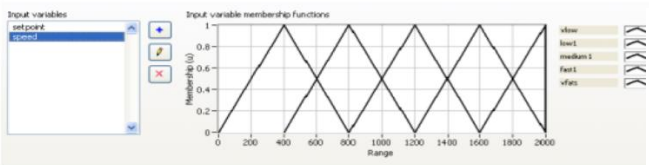
Input Membership Functions

1) Set point:

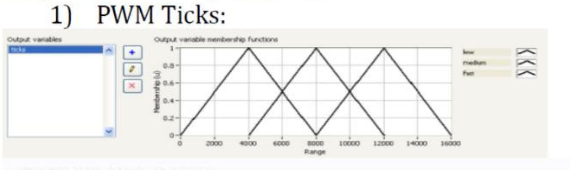


2)speed



Output Membership function:

1) PWM Ticks:



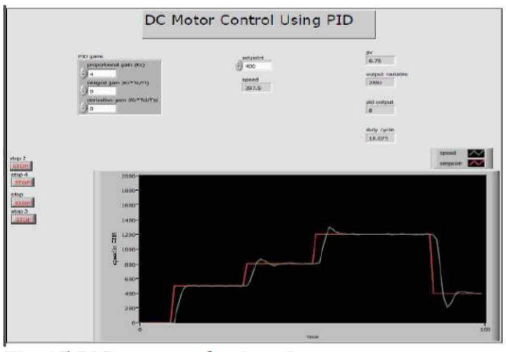


Fig :PI response for step input

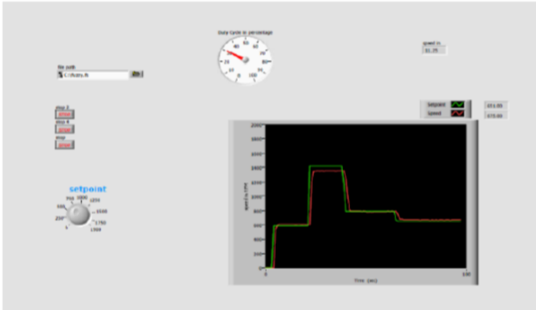


Fig: Fuzzy logic response for step input

RESULST AND CONCLUSION

The results of the Time response parameters of DC motor speed control are calculated using LabVIEW Control system tool box are depicted in Table1. The results shows that speed control of the DC motor using PI controller takes more rising time and oscillations for a step input, whereas Fuzzy Logic control provides the smooth control.

	PI Controller	Fuzzy Logic
Overshoot	28%	1%
Rise Time	1.785 Sec	1.1 Sec
Settling Time	9.45 Sec	3.6 Sec

Table 1