

Fuzzy Logic Controller Implementation on Separately Excited DC-Motor

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Abstract: Various industrial and domestic applications such as automotive, aerospace, appliances and many others are electrically driven. Conventional methods of motor control had failed to produce desired performance of DC-motor due the system parameters variation and load changes. The Fuzzy-Logic-controller is one of the controllers that can handle non-linear system. This project is aimed to control the speed of a separately-excited DC-motor using fuzzy logic control. The system is simulated on MATLAB-Simulink and implemented on ARDUINO Uno development board.

Keywords: Fuzzy-logic-controller, DC-motor, Separately-excited, DC motor drives

1. Introduction

DC-motors are widely used in many applications such as electric vehicles, electrical train, milling machine and other robotic system. DC-motors speed controller is carried out by means of voltage control in 1981 (C.C.Chan, 1987). Driven with specific controllers and functions, it has been seen as highly reliable, flexible and lowcost type of machine (Namazov, 2010). DC-motors are available in few types mainly the conventional brushes-commutator based DC-motor, permanent magnet based DC-motor and stepper mechanism based DC-motor.

Separately-excited is one of a technique to operate brushes-commutator based DC-motor where both field and armature are excited by different power sources. Therefore, the field and armature can be independently adjusted to control the motor mechanical output such as speed and torque.

Fuzzy-logic-controller (FLC) had extensively used in research and industrial applications (Li & Tso, 2010). This system is functioning by following the instructions of human learning. MATLAB/Simulink is used to simulate the control system and implemented using ARDUINO Uno microcontroller development board.

2. Methodology

The overall system hardware setup are as illustrated in Figure 1. 5-Vdc voltage supply is boost to the setting voltage as required for the speed control. This voltage is applied to the armature sides of the motor windings while the field is excited using variable power supply. For experimental purpose, this field supplied voltage are set as fixed variable. Generic switch-mode boost converter topology are implemented. Infrared proximity sensor is used to detect the shaft motion and through that the mechanical speed are encoded. The actual speed are compared with the setting speed.

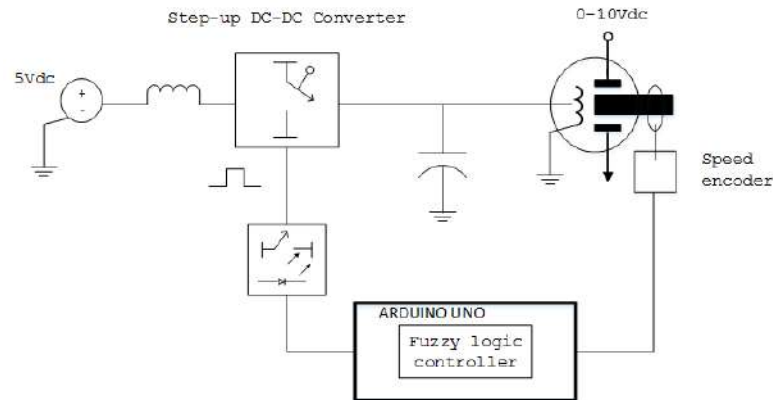


Figure 1. The hardware setup.

Fuzzy logic controller are developed to generate FIS file from the toolbox. Triangular or trapezoidal shape is used as fuzzy sets. The system has two inputs named 'error' and 'change of error' and the output 'control'. This model is then converted to C-codes and uploaded to ARDUINO Uno board microcontroller. Mechanical speed of 1-horse power DC-motor are observed and analysis are made.

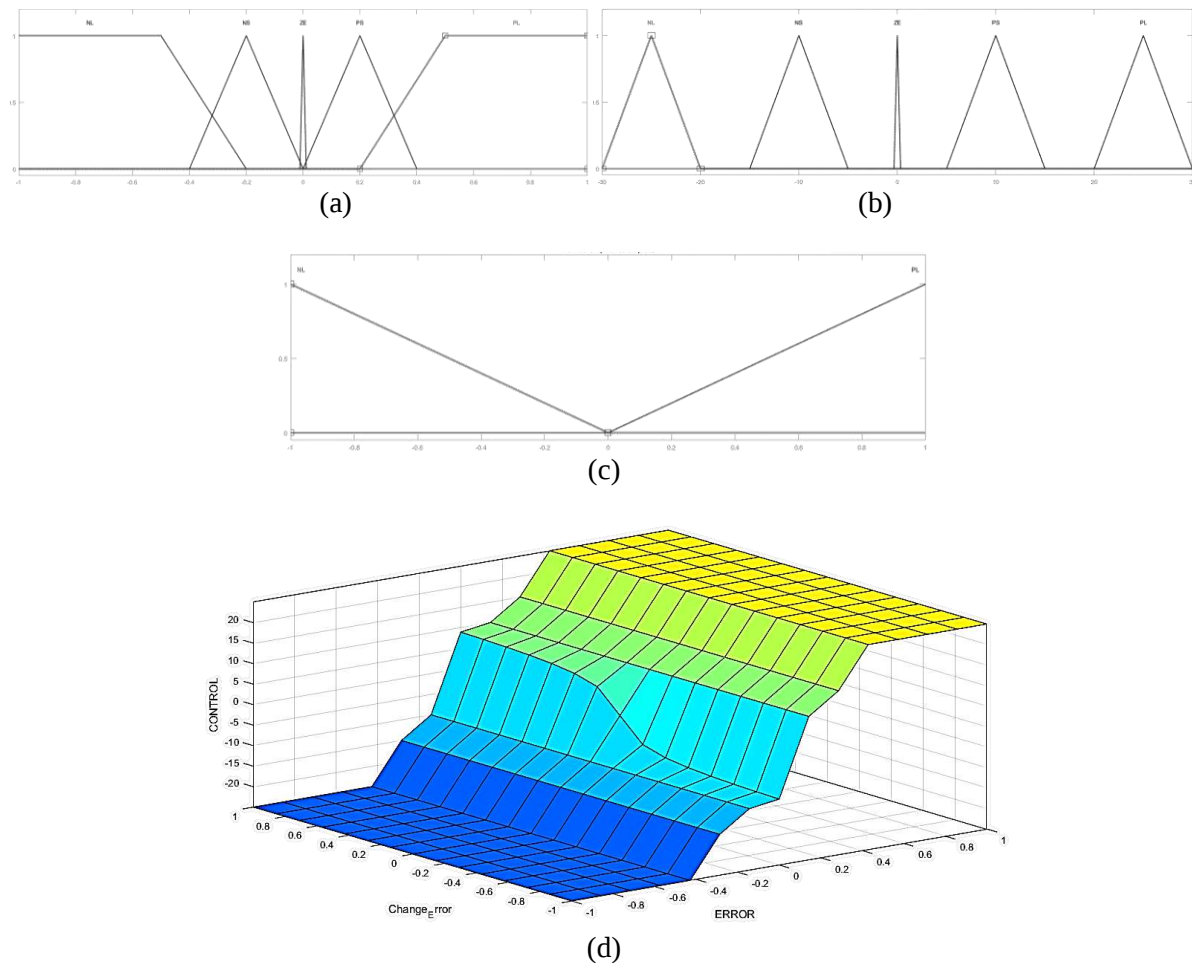
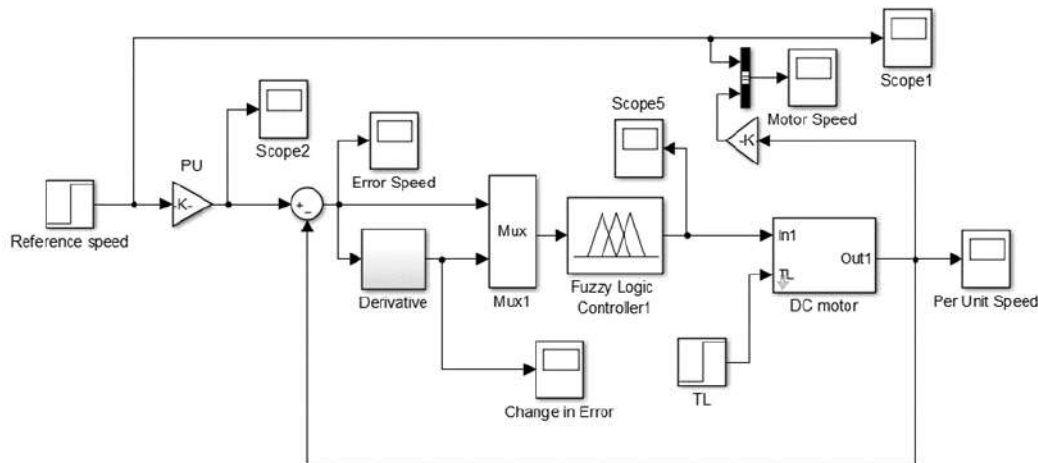


Figure 2. The fuzzy logic controller memberships (a) Error (b) Control (c) change of error (d) Surface view.

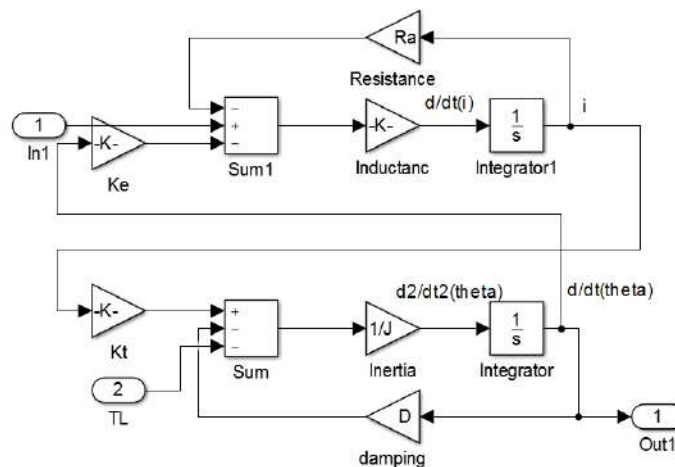
The followings are rules applied in the system:

1. If the error is positive large then the control is positive large.
2. If the error is negative large then the control is negative large.
3. If the error is zero and the change of error is negative large then the control is negative small.
4. If the error is zero and the change of error is positive large then the control is positive small.
5. If the error is negative small then control is negative small.
6. If the error is positive small then the control is positive small.
7. If error is zero then control is zero.

As seen from Figure 3 (a), the reference speed and actual speed (input) are divided with 1500 for crisp value. Speed error are computed and fuzzy rules applied to generate control (output). The output fed to the motor armature winding as the field is fixed. Figure 3(b) illustrates the DC-motor simulation model implemented for this simulation. For actual hardware implementation, the output value is digitalized in form of duty cycle of PWM through ARDUINO Uno board as shown in Figure 3 (c). The PWM is fed to the switch-mode boost converter as illustrates in Figure 1.



(a)



(b)

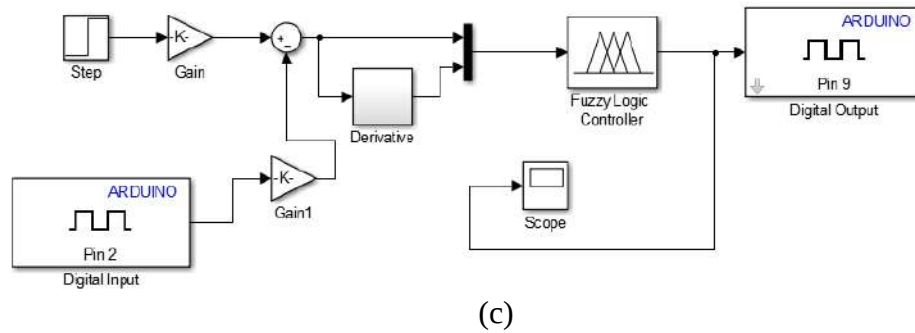


Figure 3. (a) Simulink model of fuzzy logic control implementation on DC-motor (b) Simulink model of DC-Motor (c) The Simulink model that deployed through ARDUINO UNO board.

Hardware implementation was done on Super Whirlwind Stepless DC-motor by Nan San Industrial Co., Ltd; 1-horse power DC-motor (Specification shown at Table 1) with setup are as indicated in Figure 4. Infrared proximity switch is used for speed encoding. Two (2) units of ARDUINO Uno boards utilized for speed encoder and FL controller respectively. A MOSFET IRF530N is used as the power electronics switch.

Table 1: Specification of unit under test DC-motor.

0.75KW 1HP			TYPE	DC-1
ROTOR	175V	5.3A	EXC.	200V 0.32A
EFFI	76%		RPM	1750 RPM
DUTY	CONT		INS.	B CLASS
O.L.S	6304zz	6302zz	N.W.	23.5kg
NO.	0308		DATE	2002

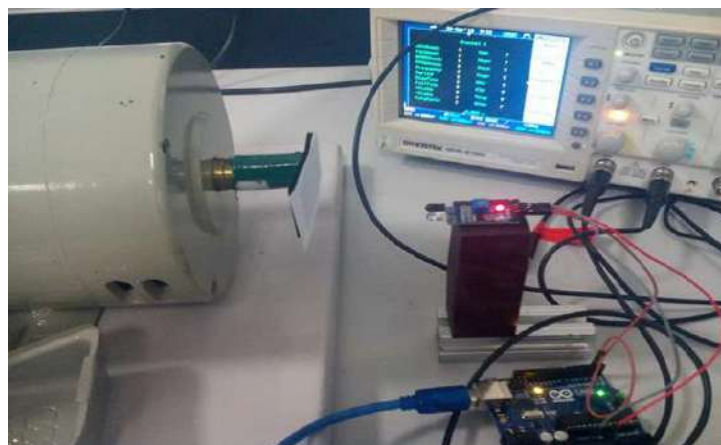


Figure 4. Actual hardware implementation experiment setup.

3. Results and discussion

The system is simulated under normal simulation mode with simulation stop time set to 10s. As result, the system response with overshoot value of 792rpm, final value 786rpm and rise time of 1.89s for the first part of transient state (0 to 800rpm step). For the next step (800 to 1200 rpm), the system behaves similarly to a first order system with settling time of 0.5s. A perturbation has also occurs at $t = 7s$. Figure 4 illustrates the simulation results.

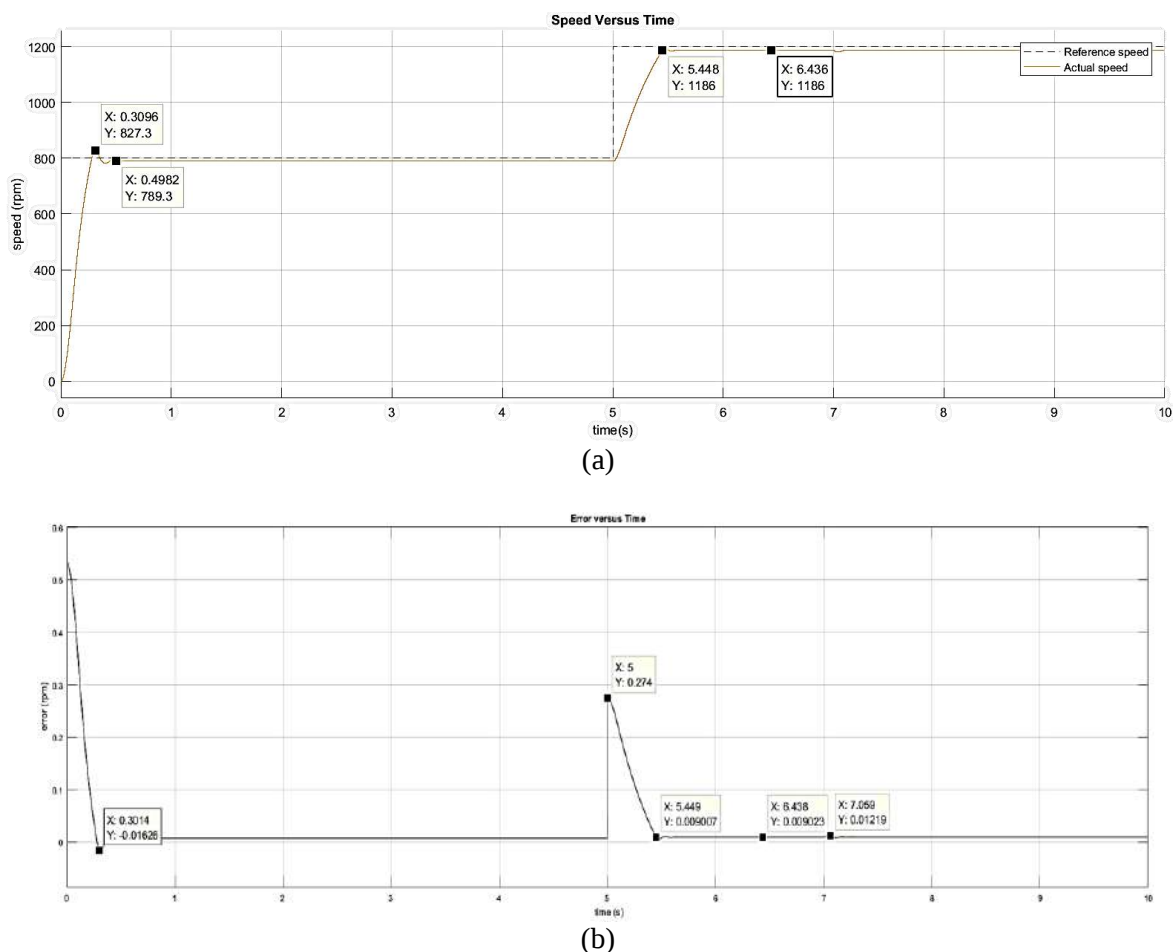


Figure 5. (a) Compare of input and output of fuzzy logic controller (b) Speed error.

Input voltage of fixed 5V is expected to be supplied from solar panel. The switch-mode DC-DC converter circuit is used to accommodate low voltage supplies to the 1-horse power DC-motor (See Table 1 for specification). The use of IR proximity sensor on the other hand is cheaper and effective enough for this speed feedback control purpose as it does not need to be accurately calibrated.

As compared to the result from the work of Azman et. al. (Azman, Aris, Hussain, Samat, & Nazelan, 2017), for step-up step-response simulation, the proposed FLC separately-excited DC-motor behaves similarly. However, the number of rules is reduced from 25 rules to 7 rules. This gives the model several advantages in real implementation on actual processor particularly in lowering computational latency and reducing the size of memory consumption. In order to reduce settling time, overshoot and eliminating unexpected perturbation, the system could be improved with the implementation of a hybrid system; combining both FLC and the conventional PID controller as such done by Namazov, Basturk and Pothi (Namazov & Basturk, 2010; Pothi, 2017).

4. Conclusion

FLC is simpler and easier to be applied and implemented as compared to the conventional PID controller. It does not require designers to acquire the complex mathematical model of the system dynamics. From the step response, the result shows that the speed of separately-excited DC motor could be controlled effectively with FLC. Within the 10s sample of simulation, perturbation has occurred during the steady-state. However, this perturbation is significantly small and therefore is negligible. This developed model is adequately suitable to be applied in many applications that are not highly sensitive to error or could expose hazards to consumers. This system should be sufficiently safe for fan, blower, pump and simple robotic application. Moreover, the system is also practically suitable to be applied for

undergraduate laboratory exercise to expose newbies to FLC and its application in power electronics and motor drives.

Acknowledgments

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