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Nonlinear Response Control of DC Motor Using Hardware Implemented Fuzzy Logic Controller

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***Abstract* - Fuzzy logic is a superset of Boolean logic which has been extended to handle the concept of partial truth values between "completely true" and "completely false". It is the logic basic modes of reasoning which are approximate rather than exact. Fuzzy logic replicates human knowledge into control logic. The actuators having wast application in industries and also in automation anywhere. The actuators are controlled depending upon the process parameters known as inputs, output, and variables. To control any actuator-based system there are various controllers are designed like Proportional controller, integral controllers, derivative controllers and also integrated controllers. Most of time the computers are used to control the whole system or PID control unit, but the artificial intelligence which means the fuzzy can also be implemented on computer using various software. Here we proposed a hardware implementation for fuzzy logic controller to control actuators which we here used is the DC motor to control its speed.**

***Index Terms* - Actuators, automation, controllers, derivative controllers, Fuzzy logic, human knowledge, integral controllers, Proportional controller, reasoning.**

I.INTRODUCTION

Due to their advantages over other conventional motors, such as better speed and torque characteristics, better dynamic response, high efficiency, no need for excitation current, no noise operation and high weight to torque ratio, relatively low cost [1], permanent magnet DC (PMDC) motors have started to be used in many applications including wiper blades, heater, air conditioners and personal computer, in recent years.
To control the speed of a PMDC motor different methods of control are used [1]:
1. The classic PID controller.
2. Advanced controller (adaptive and improving).
3. Intelligent controller (fuzzy and neural).

In recent years, a variety of control techniques have been combined to improve the overall performance of the PMDC motor. The aim of this paper is to verify the performance of an artificial intelligence control method, Fuzzy, based on low-cost hardware (Arduino) [4], to be connected in a real-time.
In the past decade, fuzzy logic control techniques have been tested in a simulation environment (such as MATLAB simulation models) to control nonlinear systems or plants in real-time. However, when evaluating the system performance based on these test results of the simulation model, it is impossible to consider all real time disturbances in an actual system. In that case, the actual system performance and the optimum efficiency will be completely different from the simulation test results.

II. FUZZYLOGIC AND DC MOTOR

The Fuzzy logic controller consists of four blocks, fuzzifier, fuzzy inferencing engine, knowledge base and a defuzzifier as shown [7]. The input variables of Fuzzy controller are the error eN and error change ecN, and the output of the fuzzy controller is UfN.

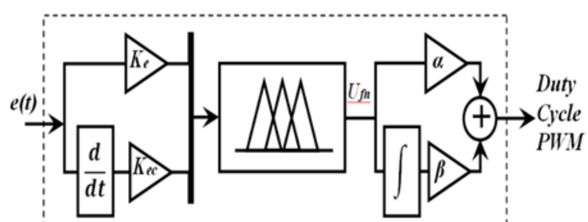


Fig.‖ A basic Block diagram of fuzzy logic controller.
A DC motor is any of a class of electrical machines that converts direct current electrical power into mechanical power. The most common types rely on the forces produced by magnetic fields. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic, to periodically

change the direction of current flow in part of the motor. Most types produce rotary motion; a linear motor directly produces force and motion in a straight line. Fig. 3 represented a DC motor.

Fig.2 A DC gear motor JHONSON made

III. BLOCK DIAGRAM AND HARDWARE SELCTION FOR PROPOSED MODEL

The Fuzzy Logic Controller used has two inputs (error and change in error) and has a single output that is given as Control Input to the desired plant. First, the membership function of the FLC is optimized by using hit and trial method using MATLAB. After optimization, it was found out that after fuzzification and de-fuzzification, the crisp output that we were getting had its range between -7 to 7. But the Digital Microcontroller operates in the TTL of 0V to 5V. So, inside the code, the crisp value was
converted to the required range.

The data from the optimized membership functions were used in writing the C++ code. The C++ code was converted to Arduino language and was burned in the microcontroller present in the Arduino hardware. The required debugging was done and the final PWM output was seen through a DSO. The PWM output from the hardware was then compared with the PWM output that was found out by simulating in MATLAB.

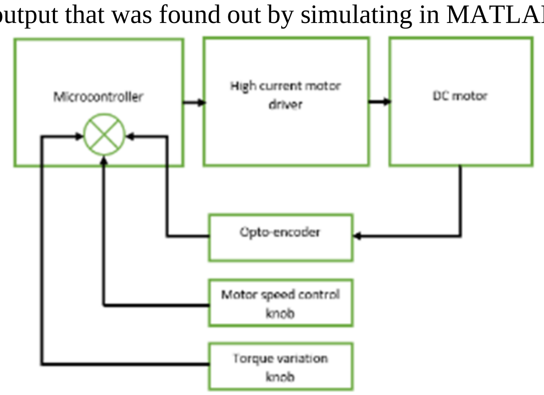


Fig. 3. Block diagram of proposed model

The figure consists of microcontroller that is ARDUINO UNO for implementation purpose and the inputs are motor speed set which comes from 100K pot which is converted in to 0 to 500RPM equivalency. Second input is current speed which is measured using opto-encoder which will encode the rotation of shaft hence the duration of one minute will gives number of count from encoder which can easily converted in to RPM that is feedback element for current speed. The third input is the torque, here the DC motor is used which is having specification as RPM=500, torque=4.4kg, operating voltage=12V which we used. The third input is selected as calibrated torque which can increase or decrease according to load or we can say according to break applied. According to three input parameters the ARDUINO UNO having fuzzy log algorithm or program in it designed by considering input and output and factors will have responded to input parameters and to control the speed it will increase or decrease PWM output. The motor driver which is high current motor driver consist of L298 motor driver IC with 2amps capacity will convert the 5v PWM signals to 12v signals to drive 12v rated motor. By setting speed at particular value the factors affecting speed can be observed in this project.

The working condition model is shown in above figure whereas the desired output we are getting by varying the load knob and set speed knob.

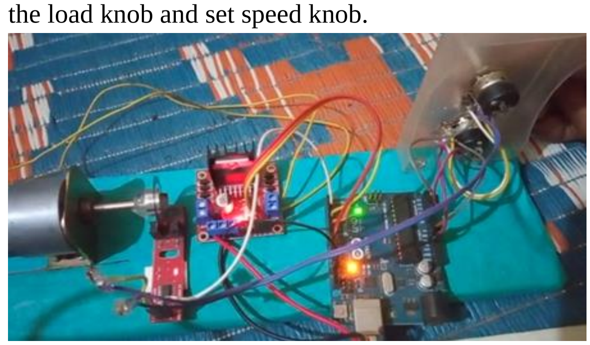
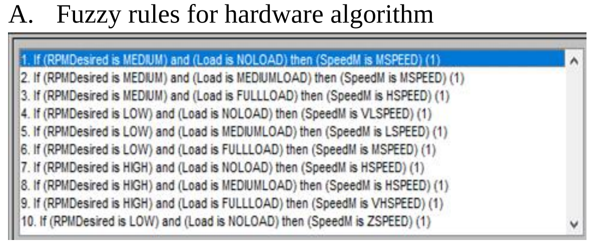


Fig. 4. Proposed model hardware setup

IV. PRESETUP FOR HARDWARE MODULE

A. Fuzzy rules for hardware algorithm



1. If (RPMDesired is MEDIUM) and (Load is NOLOAD) then (SpeedM is MSPEED) (1)
2. If (RPMDesired is MEDIUM) and (Load is MEDIUMLOAD) then (SpeedM is MSPEED) (1)
3. If (RPMDesired is MEDIUM) and (Load is FULLLOAD) then (SpeedM is HSPEED) (1)
4. If (RPMDesired is LOW) and (Load is NOLOAD) then (SpeedM is VLSPEED) (1)
5. If (RPMDesired is LOW) and (Load is MEDIUMLOAD) then (SpeedM is LSPEED) (1)
6. If (RPMDesired is LOW) and (Load is FULLLOAD) then (SpeedM is MSPEED) (1)
7. If (RPMDesired is HIGH) and (Load is NOLOAD) then (SpeedM is HSPEED) (1)
8. If (RPMDesired is HIGH) and (Load is MEDIUMLOAD) then (SpeedM is HSPEED) (1)
9. If (RPMDesired is HIGH) and (Load is FULLLOAD) then (SpeedM is VHSPEED) (1)
10. If (RPMDesired is LOW) and (Load is NOLOAD) then (SpeedM is ZSPEED) (1)

Fig. 5. Fuzzy rules for hardware algorithm

Fuzzy rules are linguistic IF-THEN constructions that have the general form "IF A THEN B" where A and B are (collections of) propositions containing linguistic variables. A is called the premise and B is the consequence of the rule. In effect, the use of linguistic variables and fuzzy IF-THEN rules exploits the tolerance for imprecision and uncertainty. In this respect, fuzzy logic mimics the crucial ability of the human mind to summarize data and focus on decision-relevant information.

B.Membership function

Fuzzification is the first step in the fuzzy inferencing process. This involves a domain transformation where crisp inputs are transformed into fuzzy inputs. Crisp inputs are exact inputs measured by sensors and passed into the control system for processing, such as temperature, pressure, rpms etc. Each crisp input that is to be processed by the Fuzzy Inference System (FIS) has its own group of membership functions or sets to which they are transformed. This group of membership functions exists within a universe of discourse that holds all relevant values that the crisp input can possess.

V. RESULTS AND DISCUSSION

These results confirmed that the Fuzzy controller demonstrates robustness under various operating conditions and shows a very satisfactory performance.

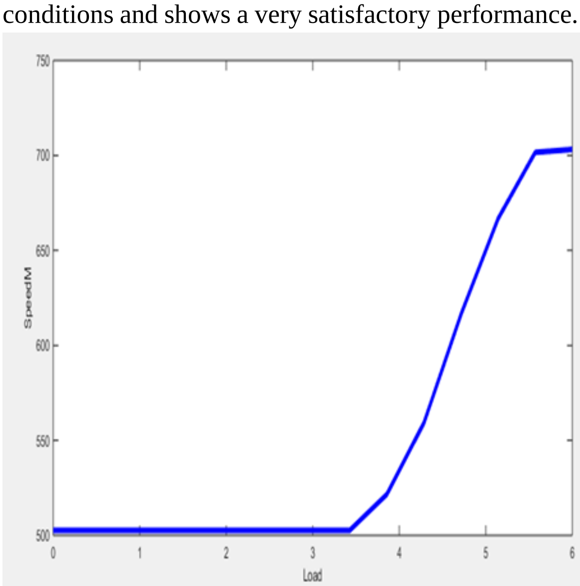


Fig.6. output speed and load plot of proposed system

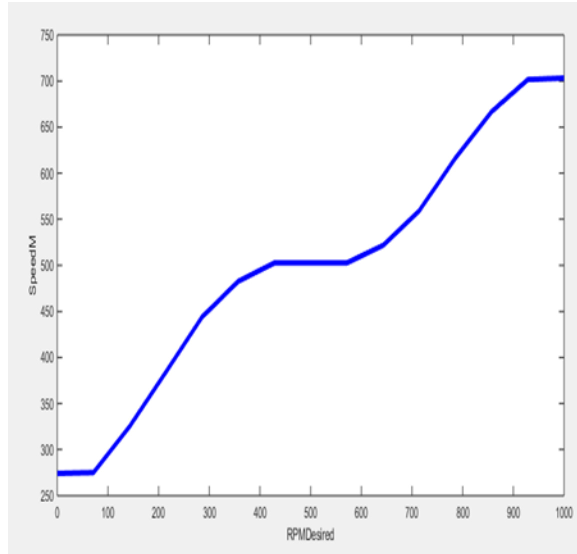


Fig.7. output speed and input speed plot of proposed system

The response of DC motor to the specific controller is obtained in real-time and stored. The stored data are then used to analyze various parameters by plotting the data.

VI. CONCLUSION

The real-time application of fuzzy logic-based controller has implemented successfully and control of DC motor using fuzzy logic showed that the output of the DC motor does not suffer from the overshoot, although, the settling time of fuzzy logic controller. However, there is a steady state error in case of fuzzy control due to the inefficient design of the fuzzy controller, but this is to be believed that by increasing perfection in fuzzy logic controller the steady state error can be reduced. The fuzzy-integral controller has also introduced for the removal of steady state error and the results are inspiring.

The hardware model used in this project is efficient and can be modified using few steps for different application The overall performance of position control of DC motor control using fuzzy logic is appreciable.

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