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Design of Intelligent Adaptive Controller for DC Motor Speed Analysis

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***Abstract*—The conversion of electrical energy to mechanical motion is done by motors. Among them the Direct Current powered motors i.e.,DC motor has wide verity of industrial applications. Irrespective to the disturbances in plant it must maintain the required speed. There are different types of conventional controllers available to maintain satisfactory performance of the motor. P,PI,PID, MRAC are some among them. Here analysis of DC motor speed is done with conventional adaptive controller and fuzzy based adaptive controller using MATLAB Simulink. It is found that Fuzzy being intelligent controller MRFAC provide a stable output to the system with low overshoot.**

***Index Terms*—P, PI, PID, MRAC, MRFAC, Fuzzy**

I. INTRODUCTION

In day today life we come across many situations where electrical energy is converted to mechanical motion. Here arises the significance of a motor. Their applications are diverse fans, blowers, pump, household applications, disk drive etc. Motor can either be powered using an AC source or by DC source. In this work the speed analysis of separately excited DC motor is done. DC motor has verity of application in Industrial area. It is necessary for a DC motor to maintain required speed. Due to the disturbances in the plant speed may vary. In order to control and maintain the desired performance we use controllers PI, PID are the conventional controllers used. But they are not good for parameter change. So, we go for adaptive controllers MRAC is an adaptive controller where desired performance is expressed in terms of reference model. In MRFAC fuzzy logic is used where the intelligent Fuzzy controller gives better performance.

II. MATHEMATICAL MODEL OF DC MOTOR

The Speed of a DC motor can be controlled by two ways by varying armature voltage or by varying the field. Here armature controlled separately Excited DC motor is considered, where the field current is kept constant and armature voltage is varied to control the speed of the motor. Fig.1 shows electrical equivalent circuit of DC motor.

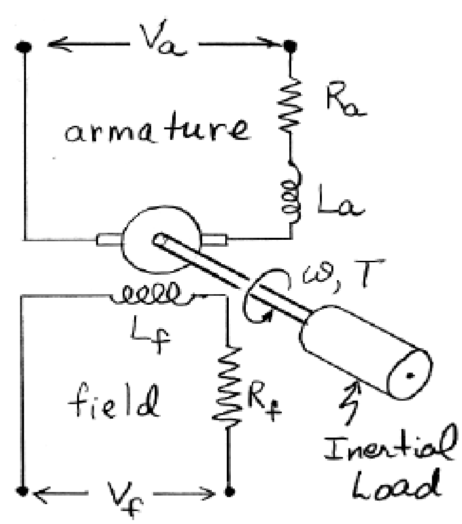

Fig.1. Electrical Equivalent Circuit Diagram of DC motor.

TABLE I
PARAMETERS OF DC MOTOR

Symbol	Parameter	Unit
Ra	Armature Resistance	Ω
Eb	Back emf	V
θ	Angular displacement of Shaft	rad
La	Armature Inductance	H
Va	Armature Voltage	V
Rf	Field resistance	Ω
Lf	Field Inductance	H
Vf	Field Voltage	V
ω	Angular Velocity	rad/sec
T	Torque	N-m
J	Moment of Inertia of Motor & Load	Kg-m2/rad
B	Frictional Coefficient of Motor & Load	N-m/(rad/sec)
Kt	Torque constant	V/(rad/sec)

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Kb	Back emf constant	N-m/A

Considering the electrical equivalent circuit of armature and by applying Kirchhoff's voltage law the armature voltage can be written as:

$$iaRa + La\frac{dia}{dt} + Eb = Va \quad (1)$$

$$Eb \propto \frac{d\theta}{dt} \quad (2)$$

Back emf of DC Machine is proportional to angular velocity of the shaft. Applying this to equation (1) it can be modified as:

$$iaRa + La\frac{dia}{dt} + Kb\frac{d\theta}{dt} = Va \quad (3)$$

The differential equation for the mechanical system of motor is given by:

$$J\frac{d\theta}{dt} + B\frac{d\theta}{dt} = T \quad (4)$$

$$T \propto ia \quad (5)$$

$$J\frac{d\theta}{dt} + B\frac{d\theta}{dt} = Kt\ ia \quad (6)$$

Equations (1) to (6) shows the derivation of transfer function of a DC Motor by considering the electrical and mechanical equivalent circuits. Torque of DC Motor is proportional to the product of flux and current. Here since the flux is constant, so the torque is proportional to armature current alone.By taking Laplace transform and rearranging the equation we get transfer function of armature controlled DC motor as:

$$G(s) = \frac{Kt}{(Ra+Las)(Js+B)+Kt\,Kb} \quad (7)$$

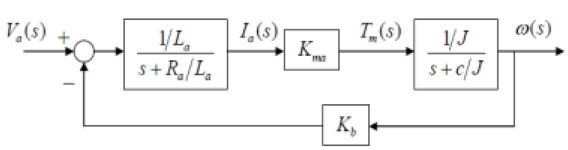

Fig. 2. Mathematical Model of DC motor.

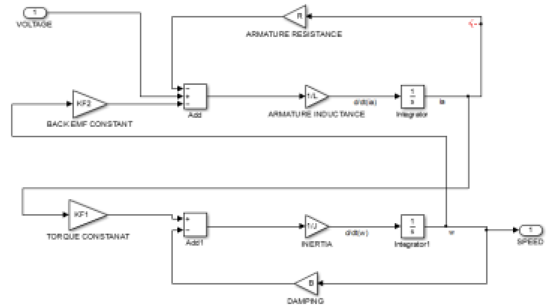

Fig. 3. Simulink Model of DC motor.

III. CONVENTIONAL CONTROLLERS

P,PI, PID are the conventional controllers. P is the proportional controller which produces the output signal which is proportional to error. P controller reduces the Steady State error by increasing gain. K_p is the gain of the controller it amplifies the error signal and increases the loop gain. PI is the proportional plus Integral controller. Advantage of both modes can be obtained in this controller.It cannot eliminate oscillations and reduce rise time. K_p is the proportional gain and K_i is the integral gain. Proportional–Integral–Derivative controller (PID controller) is a control loop feedback mechanism. Mainly used in industrial control systems. PID controller correct the error between a measured process variable and a desired set point. It is done by calculating and then outputting a corrective action that can adjust the process accordingly. The PID controller calculation has three separate parameters; the Proportional, the Integral and Derivative values. Proportional value determines the reaction to the current error. Integral determines the reaction based on the sum of recent errors. Derivative determines the reaction to the rate at which the error has been changing. Christo Ananth et al.[4] discussed about E-plane and H-plane patterns which forms the basis of Microwave Engineering principles.

TABLE II
ZIEGLER NICHOLAS TUNED VALUES

	Kp	Ki	Kd
P	2.24	-	-
PI	2	9.4	--
PID	2.7	21	0.0864

Tuning of the conventional controllers is done using Ziegler Nicholas Tuning Method. The calculated values are given in the table II and the implementation of controllers to system is show in Fig.4

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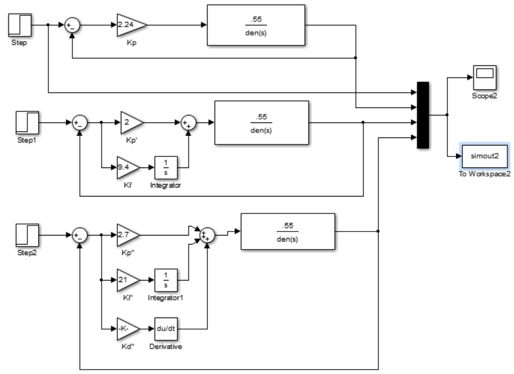

Fig. 4. P, PI, PID Controller Implementation.

IV. MODEL REFERENCE ADAPTIVE CONTROLLER

In Adaptive Controllers, their behavior is adjusted on-line per the property change of controlled process. The factor that make an Adaptive controller different from the conventional controller is the presence of adjustment mechanism. In order to maintain the system stability proper adaptation mechanism has to be synthesized. In Model Reference Adaptive Controller as the name says the model output will be the desired performance of the system. Degree of stability of the system is determined by the model.

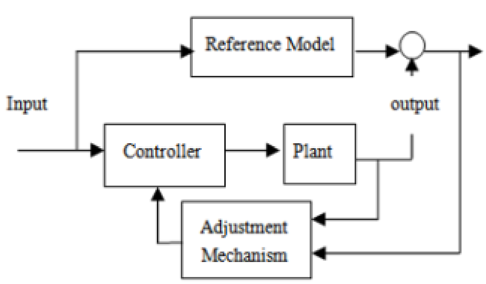

Fig. 5. Block diagram of MRAC

Model Reference Adaptive Controller block diagram representation shown in Fig.5. MRAC is normally a closed loop feedback system which has two loops an inner loop and an outer loop. In ordinary feedback loop, there is a plant and a controller. Other loop is for changing the control parameter. In a typical Model Reference Adaptive Controller, the model output and plant output are compared and the error between them is used to calculate the control parameter. To make the plant output follow the model output and attain desire response the parameters are controlled. For tuning the control parameters MIT Rule is used.

V. FUZZY BASED ADAPTIVE CONTROLLER

In Fuzzy based Adaptive Controller technique, the control mechanism used is fuzzy logic. Fuzzy logic maps input space to output space, using if-then rules.

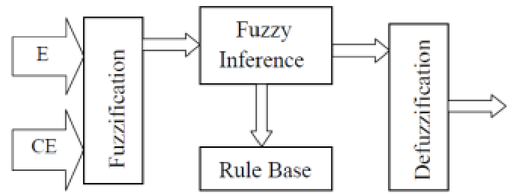

Fig. 6. Block diagram of Fuzzy Logic Controller

Basic block diagram of a Fuzzy Logic Controller in Fig.6. shows a fuzzification block which convert the crisp input to fuzzy value, rule base which contain control rules, Fuzzy Inference, performs fuzzy logic action based on the input given and a defuzzification block which converts fuzzy value back to crisp value.

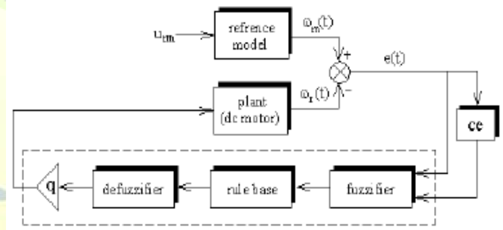

Fig. 7. Block diagram of MRFAC Scheme

Block diagram of Figure.7 shows the MRFAC scheme block. The output of the Plant is compared with a reference model output which is the desired output. The error and the change in error is fed to the fuzzy logic controller. Fuzzy controller controls the plant.

VI. METHODOLOGY

The speed of DC motor needs to be maintained at a constant RPM for various industrial applications There can be chances of various disturbances while different machines and instruments are connected in the grid. Therefore, suitable programmed controller with real time feedback is used for analyzing the error with respect to the reference. based on the controller feedback the speed will be adjusted to obtain the desired performance

The DC motor used in the present study is a separately excited armature controlled DC motor. Suitable transfer functions for the DC motor is inputted into the SIMULINK as motor parameter. The DC motor is controlled by a dedicated controller by conventional method and adaptive method.

In conventional method,the response of proportional(P), Proportional integral(PI) and Proportional integral derivative(PID) are compared. It was observed that PI controller has lesser overshoot and faster settling time than the other two controllers. Hence PI controllers are used for adaptive controller method.PI based MRAC and fuzzy based MRAC controllers are used for further analysis. MRAC is designed based on MIT rule.

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VII. SIMULATION AND RESULTS

Simulation is done with MATLAB Simulink. Step response of conventional controllers P,PI,PID are compared and the performance criteria rise time, percentage overshoot, settling time is calculated.

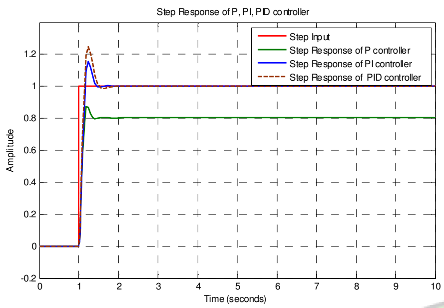

Fig. 8. Step Response of P, PI, PID Controllers

By analyzing the step response of P, PI, PID Controllers in Fig.8, it is found that PI and PID are better than P. Both PI and PID has same rise time, but the percentage overshoot of PI is 16% and of PID is 24.6%. This percentage overshot is not a desirable property and hence PI controller is better in terms of percentage overshoot.

The response of PI settles faster than PID.The settling time for PI is 1.55 seconds and of PID is 1.8 seconds. The better response time and lesser overshoot for PI controller is of significant advantage.

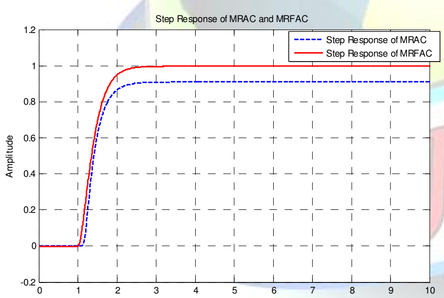

Fig. 9. Step Response of MRAC and MRFAC

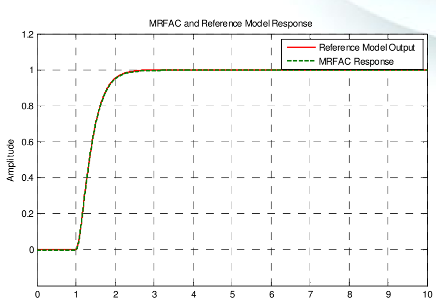

Fig.10. MRFAC and Reference Model Response

Step response of MRFAC and MRAC in Fig 9 gives a clear picture that fuzzy based adaptive controller strictly follow the reference output. MRAC is implemented with PI controller. Percentage Overshoot for both controllers are zero, rise time for MRFAC is 0.7s and for MRAC is 2.2s. MRFAC attains the desired value in 2s. MRFAC response found to follows the desired output.

TABLE III
PERFOMANCE CRITERIA OF STEP RESPONSE

	Rise Time	Percentage overshoot	Settling time
PI	0.11s	16%	1.55s
PID	0.11s	24.60%	1.8s
MRAC	2.2s	0	2s
MRFAC	0.7s	0	2s

VIII. CONCLUSION

Model Reference Adaptive Control and Fuzzy based Adaptive controller has been designed for the speed Analysis of DC motor. Comparing the response of both it is found that the output of fuzzy based adaptive controller follows the model reference output, which is the required response better than normal Adaptive control. Fuzzy based controller gives afast-stable output with low overshoot. By analyzing conventional controllers PI found better than PID hence MRAC is designed with PI controller. For MRAC thus designed if parameters are not adjusted properly the plant output will not follow the model output.Therefore, fuzzy based controller can be consideredenough good for DC motor speed control.

Neural Network of the simulation can be used for further analysis. This method can be further extended for the real-time analysis of speed control in DC motor.

REFERENCES

[1] J.Y.M. Cheung, K.W.E. Cheng, A.S. Kamal, "Motor speed control by using a fuzzy logic model reference adaptive controller", IEEE/PEVSD,pp. 430-435, Sep. 1996

[2] Faa-Jeng Lin, "Fuzzy Adaptive Model-Following Position Control for Ultrasonic Motor", IEEE Trans. on Power Electronics, Vol 38, No. 2, pp. 261-268, March 1997.

[3] Sumit Kumar Sar, Lillie Dewan, "MRAC based PI Controller for Speed Control of D.C Motor Using Lab View", WSEAS Trans. on Systems and Control, Vol. 9, pp. 10-15, 2014

[4] Christo Ananth, S.Esakki Rajavel, S.Allwin Devaraj, M.Suresh Chinnathampy. "RF and Microwave Engineering (Microwave Engineering).", ACES Publishers, Tirunelveli, India, ISBN: 978-81-910-747-5-8, Volume 1,June 2014, pp:1-300.

[5] Ghazanfar Shahgholian, Mojtaba Maghsoodi, Mehdi Mahdavian, Mohammadreza Janghorbani, Manijeh Azadeh, Saeed Farazpey, "Analysis of Speed Control in DC Motor Drive byUsing Fuzzy Control Based on Model ReferenceAdaptive Control", IEEE, 2016.

[6] Tawanda Mushiri, Abigail Mahachi, Charles Mbohwa, "A Model Reference Adaptive Control (MRAC) System for the Pneumatic Valve of the Bottle Washer in Beverages Using Simulink", Procedia Manufacturing, pp.364-373, January 2017