Volume I, issue I. October 2021

TRANSIENT PERFORMANCE OF DC MOTOR MODEL FOR WATER PUMP USING FUZZY LOGIC CONTROLLER

Effiong, E. E[1], Edem, B.E[2], Akpama, E. J.[3]
[1,2,3]Electrical/Electronic Department Cross River University of Technology, Calabar/Nigeria
e.effiong43@yahoo.com

ABSTRACT

This paper evaluates the performance of a separately excited direct current motor (SEDCM) closed loop system for water pumping using an armature voltage-controlled motor scheme. The direct current motor is fed by the PV module as a DC voltage source, and the water pump speed is the output. The conventional Proportional-Integral-Derivative (PID) controller and the fuzzy logic controller (FLC) are designed in MATLAB/SIMULINK software. The FLC was developed based on the Mamdani architecture with the centroid defuzzification method. The controller evaluates speed errors in order to track the reference step input voltage. The dynamic behavior of the motor in terms of transient response, such as settling time and peak overshoot, for both the FLC and PID controllers were evaluated as the simulation results were analyzed and compared. It was discovered that FLC offers better performance with a fast dynamic response than conventional PID controllers. The robustness of the controllers was tested with disturbance as well as variable load conditions.

Key Words: Fuzzy logic controller, SEDCM, PID controller, PV module

1 INTRODUCTION

The direct current (DC) motors are extensively used in industrial and domestic appliances. DC motors are efficient, reliable and controllable in an aspect of speed control. The high-performance DC motor drives in factories are used more often due to its excellent electrical characteristics such as high a starting torque, high response performance. They are widely used in for steel rolling mills, cutting tool, robotic manipulators, guided vehicles, overhead cranes, electric traction, electric train, home appliances and other speed and position applications [1]. DC motors are considered as adjustable speed machine due to accurate speed control, controllable torque and high reliability. Separately excited DC motor (SEDCM) is suitable for variable speed drives application. As voltage is supplied directly to the field winding of the motor. Basically, there are three speed control techniques used commonly; Field resistance control, Armature resistance control and armature voltage control method. In armature-controlled Dc drive, the speed is directly proportional to applied armature voltage of the DC motor. So, for armature-controlled DC motor, the motor is controllable over wide range through proper adjustment of terminal voltage [2].

Feedback control loop is indispensable for the desired and better performance of the system. However, the feedback system has slow response. To obtain fast dynamic response, many control strategies have been developed in various feedback control system whose aim is to achieve precise and quick tracking of reference speed with minimal overshoot, little or no steady state error. PID (proportional -Integral-Derivative) controller have become very popular in industrial control applications due to simple model, robustness, high reliability and elimination of steady state error. However, the optimization and tunning task of these conventional controllers (PI, PD, PID) is very difficult and time consuming mainly under varying load condition [1]. There have been so many schemes for speed control of separately excitedly motor such as PI, PID, Fuzzy logic controller, Artificial intelligence technique, optimal Linear Quadratic Regulator (LQR) control etc. since all control systems suffer from problems related to undesirable overshoot, longer settling time, vibrations and stability while going from one state to another state. As real-world systems are non-linear, making accurate modelling difficult and costly [3]. In Usoro I. H et al paper presents a study of impact of fuzzy logic controller and PID controller in the control performance of an industrial type DC motor, from the simulated results and comparison FLC speed controlled-DC motor perform better than PID speed-controlled DC motor due to absence of undesirable overshoot, faster settling time and robustness when load is applied.[4]

In Effiong, E.E et al paper presents the design of scalar control of induction machine using fuzzy logic controller, from the simulation result, it was observed that FLC performs better than conventional PI controller as FLC [5]. showed fast transient response with shorter settling time, zero overshoot and robustness in change in load condition with almost zero steady state error. In Kumar.S. B et al paper presents comparison of performance of PID and FLC in speed control of Dc motor using MATLAB/SIMULINK environment, the simulation result shows that FLC gives better response compared to PI and PID controller. Combination of different motors that are mostly used for water pump application. Motors are used to convert mechanical energy from electrical energy.

This motor has an adequate solution for drinking water supplies in rural areas as well as grid connected areas. the output of PV panel is connected to the boost type DC to DC converter [6][7]. it increases the output voltage level of solar panel and DC link capacitor maintains it at constant DC level. This constant DC voltage acts as an input voltage to DC motor.

In this paper, model of SEDCM speed control system is fed with dc voltage by PV module and the motor rotates water pump being the load, with Fuzzy logic controller (FLC) designed for speed control using Mamdani Fuzzy Inference System (FIS) with 49 rule base. The PID controller is also incorporated in MATLAB/SIMULINK software for comparison of the motor speed transient response when using the two controllers.

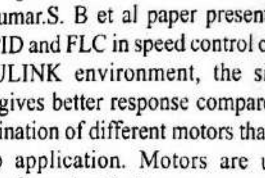

Fig 1 DC motor Pump [9]

II DESIGN METHODOLOGY

(A) Fuzzy logic controller

Input linguistic variable

The reference speed or command speed value is 1800 rpm. The two input variables to FLC are

(a) Speed error (e)

(b) Change in error or derivative of speed error (Δe).

The speed error is expressed as;

$$e = \omega_{ref} - \omega_m \qquad (1)$$

$$\Delta e = \frac{de}{dt} \qquad (2)$$

ω_{sl}.

The controller output called change in control is

(B) Rule base if then statements

TABLE I: Fuzzy rule base table for output (w_{d}) of FLC

e/Δe	NB	NM	NS	Z	PS	PM	PB
NB	NVB	NVB	NB	NBM	NM	NS	Z
NM	NVB	NB	NBM	NM	NS	Z	PS
NS	NB	NBM	NM	NS	Z	PS	PM
Z	NBM	NM	NS	Z	PS	PM	PBM
PS	NM	NS	Z	PS	PM	PBM	PB
PM	NS	Z	PS	PM	PBM	PB	PVB
PB	Z	PS	PM	PBM	PB	PVB	PVB

The 49 IF-THEN statement of the rule base according to table I for the design of Fuzzy cover a whole universe of discourse logic controller (FLC).

Parameters	Values	Units
Armature resistance (Ra)	4.0	Ohms (Ω)
Armature inductance (La)	0.3	Henry (H)
Torque constant (Kt)	0.24	N-m/A
Back emf constant (Kb)	0.24	V/(rad/sec)
Rated speed (N_m)	2400	Revolutions per minute (rpm)
Moment of inertia (J)	0.0043	kg.m2
Frictional coefficient (B)	0.0011	N-m/(rad/sec)
Input Voltage (Va)	12	Volts (V)

The transfer function of the SEDCM model is given as

$$G = \frac{Kt}{(sJ + B)\ (sLa + Ra) + KbKt}$$

By substituting the machine data in table II into (3), The motor transfer function of speed to armature voltage is

$$G = \frac{186}{S^2 + 13.59S + 48.06} \qquad (4)$$

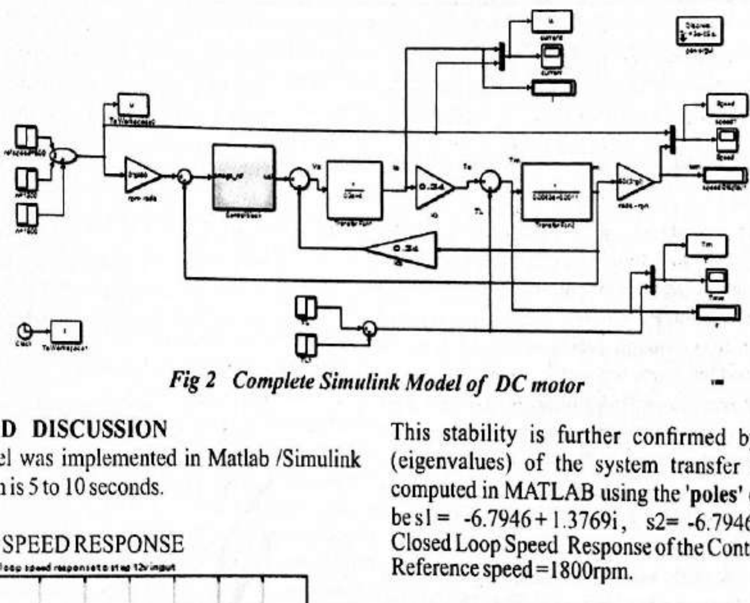

Fig 2 Complete Simulink Model of DC motor

III. RESULTS AND DISCUSSION

The SIMULINK model was implemented in Matlab /Simulink and simulation duration is 5 to 10 seconds.

(1) OPEN LOOP SPEED RESPONSE

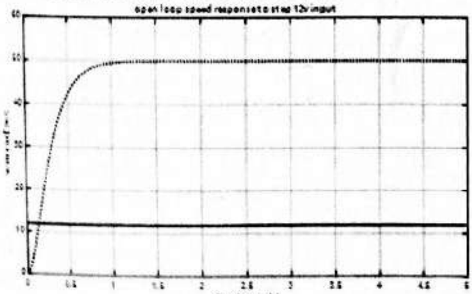

Fig 3: Open loop speed response the motor

Figure 3, shows Open-loop step response of the system without any Controller, it is observed that the DC motor speed increases continuously as time increases to 50.0 rad/s (477.8 rpm) after 0.91sec and it stabilized when step 12volt is supplied to input. With settling time of 0.91 sec and zero overshoot from step input reference level. DC motor system is stable in open loop operation.

This stability is further confirmed by the negative poles (eigenvalues) of the system transfer function in (4) were computed in MATLAB using the **'poles'** command and found to be s1 = -6.7946+1.3769i, s2= -6.7946-1.3769i.

Closed Loop Speed Response of the Controllers Reference speed=1800rpm.

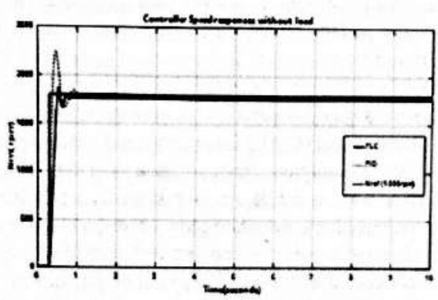

Fig 4: Speed response of the controllers without Load

From response in figure 4 &5, Fuzzy logic controller shows better transient characteristics than PID controller as it shows almost zero overshoot, however, FLC has minimal steady state error while PID has zero steady state error.

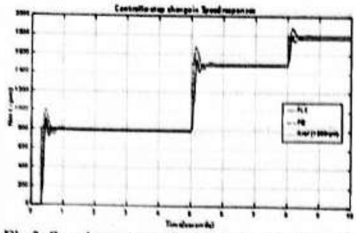

Fig 5: Speed response of controllers with change in reference speed (Nm=800- 1500-1800 rpm)

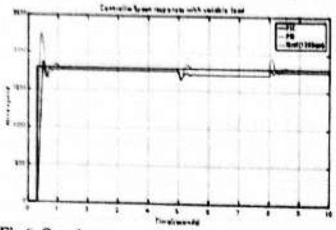

Fig 6: Speed response with change in applied load

Fig 7: Torque response at variable load condition

Fig. 6 the torque response with a load 2Nm, it is observed that, the speed decreases, and the Fuzzy logic controller shows better robustness as it tracks the reference speed to reject the disturbance.

TABLE III: Performance indices for controllers

Controllers	Settling time(sec)	Rise time (Sec)	Peak time(sec)	Peak Overshoot (%)	Steady state error
FLC	0.82	0.43	0.54	3.2	2
PID	1.23	0.34	0.46	24.8	0

From table III, FLC have better transient behaviour than conventional PID controller as it showed less settling time, very little overshoot and negligible steady state error.
PID gain values are: **Kp** = 2.0, **Ki** = 25.0, **Kd** = 0.1

IV CONCLUSION

This paper successfully present performance evaluation of Direct current motor (SEDCM) closed loop speed control system for water pumping using armature voltage-controlled scheme. The Dc motor has input source from PV module and it output is speed that drives water pump. The dynamic behaviour of the motor in term of transient response such as settling time and peak overshoot for both Fuzzy Logic controller (FLC) and PID controller were evaluated as the simulation results were analyzed and compared. It was discovered That FLC offer better performance of the motor with fast dynamic response than conventional PID controller.

The FLC offer better robustness and fast transient response with perturbation like change in applied load condition. This shows that dc motor powered by PV module can efficiently replace the ac motor.

REFERENCES

[1] M. R. Khan, A. A. Khan, U. Ghazali, "Speed Control of DC Motor under Varying Load Using PID Controller". *International Journal of Engineering (IJE),* Volume (9): Issue (3), pp 38-48, 2015.

[2] U. Kumar, D. Dohare, "Separately Excited DC Motor Speed control of using various Tuning Conventional Controllers", *Int'nal Research Journal of Engineering and Technology (IRJET)*, Volume: 02 Issue: 08, pp496-499, Nov-2015.

[3] R. Dwivedi, D. Dohare, "PID Conventional Controller and LQR Optimal controller for Speed analysis of DC Motor: A Comparative Study", Int'al Research Journal of Engineering and Technology (IRJET), Volume: 02 Issue: 08, pp508-511, Nov-2015.

[4] I. H. Usoro, U.T. Itaketo and M. A. Umoren. "Control of a Dc Motor using Fuzzy logic control Algorithm", Nigerian Journal of Technology (NIJOTECH) vol.36.No2, pp 594-602, April 2017.

[5] E.E. Effiong, E.J. Akpama, I. E. Omini, and R. U. Ezenwosu, "Scalar control of induction machine speed using fuzzy logic controller", global journal of engineering science and researches, Emmanuel, 7(12), pp1-11. December 2020.

[6] P. Sharma, A.S. Sindekar 'Suitability and comparison of electrical motors for water pump application', International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 5, Issue 3, pp1356-1362, March 2016.

[7] S.B. Kumar, M. H. Ali, Anshu Sinha, 'Design and Simulation of Speed Control of DC Motor by Fuzzy Logic Technique with Matlab/Simulink', International Journal of Scientific and Research Publications. Volume 4, Issue 7, pp1-4 July 2014.

[8] A. Mokeddem, A. Midoun, N. Ziani1, D. Kadri and S. Hiadsi, 'Test and Analysis of a Photovoltaic DC-Motor Pumping System', Conference Paper · January 2008.

[9] https://www.chinataifu.com