Adaptive Fuzzy Based Controller in Electric Standing WheelChairs for Physically Disabled

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***Abstract*—Deformations are always challenging. Humans are always keen in making their lives easier; especially to comfort the disabled ones. Nowadays their mobility device, Wheelchair has been transformed to 'smart' mode. Even now so many modifications and experiments are taking place to make it into smarter one. This paper proposes a new electric standing wheel chair topology controlled by a adaptive fuzzy PID controller. Adaptive fuzzy logic PID controller has incorporated in Brushless DC motor having specific characteristic features like high efficiency, torque and robustness which further results in efficient adaptive and speed control characteristics. To study the effectiveness of the system, simulation is carried out in MATLAB/Simulink environment and the obtained results clarify the efficient speed control of the proposed electric standing wheel chair system.**

Keywords—Electric Standing Wheelchair,Brushless DC Motor,Fuzzy Logic Controller,Adaptive Fuzzy PID controller

I. Introduction

Wheelchairs had become an inevitable element in physically disabled human routines. Manually operated wheelchairs had been advanced to smart electric powered systems so that the transportation is made easier. Advances in power electronics and embedded systems led to the interventions to explore new novel methods to provide user friendly and efficient vehicles for the purpose. The projected population of smart powered wheelchair users of 1.4 to 2.1 million represents 61 to 91% of effective utilization of these devices conveying safer and reliable operation.

Brushless DC Motors (BLDCM), which has wider applications in industrial, robotic as well as in vehicles, prevails with their intrinsic advantages such as high torque, less maintenance, low volume and thereby yielding high efficiency[1]. The permanent magnets mounted in the inner core are free with the rotor losses contributing enhanced efficiency features. Only drawback to this type motor is that it will be affected by the non linear load disturbances. The voltage present in the stator windings which are trapezoidally wounded are termed as back emf and it is providing trapezoidal back EMF waveforms .In comparison to the Induction motor, BLDCM has lower inertia and it does not experience slip and thereby constitutes faster dynamic response. The electronic commutation employed in this motor replaces the mechanical commutation effectively and it supplies current to motor windings through the electronic switching patterns. The drawbacks of mechanical commutation such as sparking and wearing out problems of brush and commutator arrangement can be easily excluded through this manner[2]. Hall sensors, which are placed on the non driving end basically relies on hall effect and it helps in determining rotor position by giving out low or high signals when the rotor magnetic poles pass nearby to the sensors.

It has been estimated that hundred million people in this world suffer with walking disabilities. Denied this most basic means of mobility, some crawl on ground subjecting themselves to dangerous, unsanitary conditions in order to maintain their independence. Others spend most of their lives with isolation, confined to a single room and dependent upon family members to help in their most basic needs. Thus the applications of smart electric wheelchairs become predominant working under with different control strategies. Various speed control methods can be incorporated with BLDC motor such as fuzzy controller, PI as well as PID controller[3][7].Fuzzy, which is an extension of multivalued logic relates to classes of objects with unsharp boundaries in which member is a matter of degree. Fuzzy controllers have the ability to effectively control parameters and it is simple to calculate. It mainly depends upon range so that the output can be confined to specified ranges.

II. SPEED CONTROL SYSTEM OF BLDC MOTOR

Despite of PWM control ,various control strategies as well as techniques is getting familiarized with BLDC motor. Speed control plays an eminent role in the case of every motors for industrial applications along with automotive fields.
Fig. 1 shows the complete block diagram for the speed control of three phase BLDC Motor. For the control of BLDC motor mainly two control loops are used. The inner loop synchronizes the inverter gates signals with the electromotive forces whereas the by varying the DC bus voltage outer loop controls the motor's speed. Three phase power converter is used to drive the BLDC motor. By means of three Hall sensors, which is mounted on the stator part determines the switching sequence of the MOSFET switches which in turn determines the rotor position[4].

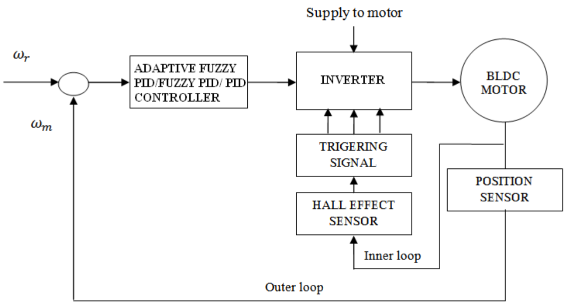

Fig. 1. Block Diagram of speed control of BLDC Motor

The decoder block generates vector signal of back EMF after determining the Hall sensor information and the sign of reference current which further produced by the reference current generator. Table I shows the method for calculating back EMF for Clockwise of motion and the gate logic to transform electromagnetic forces to the gate signals and it is given by Table II.

TABLE I. CLOCKWISE ROTATION

Hall sensor A	Hall sensor B	Hall sensor c	EMF A	EMF B	EMF C
0	0	0	0	0	0
0	0	1	0	-1	1
0	1	0	-1	1	0
0	1	1	-1	0	1
1	0	0	1	0	-1
1	0	1	1	-1	0
1	1	0	0	1	-1
1	1	1	0	0	0

Hall sensors are based on Hall effect which implies that when a conductor is placed in a magnetic field, it experience a transverse force such that the charge carriers tends to align in either sides of conductor creating a potential difference .These sensors are place in 120^0 apart and thereby rotor information are achieved and corresponding switching is obtained as in Table II

TABLE II. GATE LOGIC

EMF A	EMF B	EMF C	Q1	Q2	Q3	Q4	Q5	Q6
0	0	0	0	0	0	0	0	0
0	-1	1	0	0	0	1	1	0
-1	1	0	0	1	1	0	0	0
-1	0	1	0	1	0	0	1	0
1	0	-1	1	0	0	0	0	1
1	-1	0	1	0	0	1	0	0
0	1	-1	0	0	1	0	0	1
0	0	0	0	0	0	0	0	0

III. CONTROLLER CIRCUIT

Adaptive Fuzzy PID controller is used to control the BLDC motor and it is based on two inputs and three outputs. The overall structure of Simulink model adopted for controlling the speed of electrical standing wheelchair is shown in Fig. 2. In Fuzzy PID controller have three outputs which are Kp, Ki and Kd.

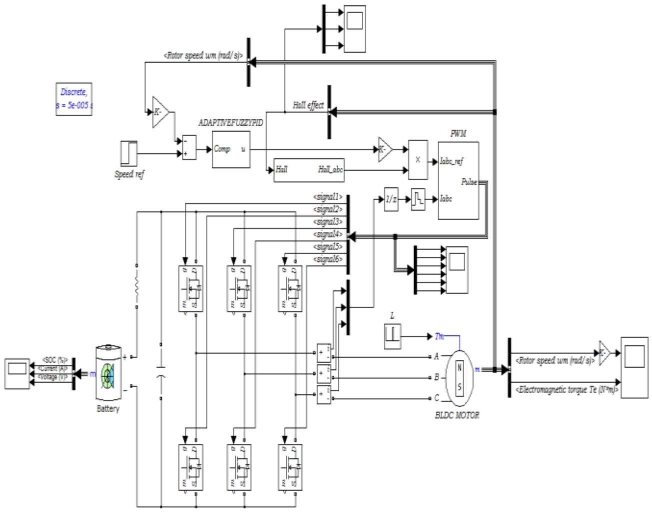

Fig. 2. Simulink model for speed control of BLDC Motor

The Simulink model consists of three phase converter sourced by battery, hall sensor, and adaptive fuzzy PID controller which drives the BLDC motor. A DC supply from the battery is given to the system such that a capacitor is connected for further voltage regulation. As the motor speed depends on voltage, firing pulses are given to the inverter side. The current measurements are taken from the inverter side and given to motor.
Fig.3 shows the adaptive fuzzy PID controller Simulink model. Error speed (E) and Change in error speed (CE) is taken as fuzzy control input and fuzzy outputs are given by ΔKp, ΔKi, and ΔKd [5] [6]. It is given as the equation below.

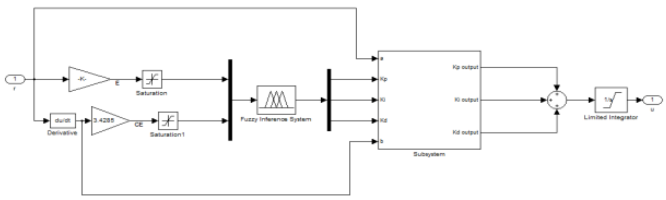

Fig. 3. Adaptive Fuzzy PID Controller

$$\Delta Kp = Kp.\Delta Kp^1 \quad (1)$$
$$\Delta Ki = Ki.\Delta Kp^1 \quad (2)$$
$$\Delta Kd = Kd.\Delta Kp^1 \quad (3)$$

Linguistic variable which implies inputs and output has been classified as: NB, NM , NS, Z, PS, PM, PB. Inputs are normalized in the interval of [-3,3] and output ΔKp in the interval [-1,1], ΔKp in interval[-1,1] and ΔKp in interval[-0.005,0.005]. Mamdani fuzzy interference reasoning algorithm is used in this paper and ambiguity resolution uses center of gravity method. The output of ΔKp, ΔKi, Δkd can be available via ambiguity resolution.

TABLE III. TABLE OF FUZZY LOGIC

CE / E	NB	NM	NS	Z	PS	PM	PB
NB	PB	PB	PM	PM	PS	PS	Z
NM	PB	PB	PM	PS	PS	Z	NS
NS	PB	PM	PM	PS	Z	NS	NS
Z	PM	PM	PS	Z	NS	NM	NM
PS	PS	PS	Z	NS	NS	NM	NM
PM	PS	Z	NS	NM	NM	NM	NB
PB	Z	NS	NS	NM	NM	NB	NB

Rule table for Fuzzy controller and membership functions are provided such that the control over a wide range is made possible by adaptive fuzzy PID controller. It has high accuracy value when compared to the conventional fuzzy logic controllers.

III. STUDY RESULTS

For the evaluation of the proposed control, the system shown in Fig.2 is modeled using MATLAB/SIMULINK simulation environment and the following results are obtained.

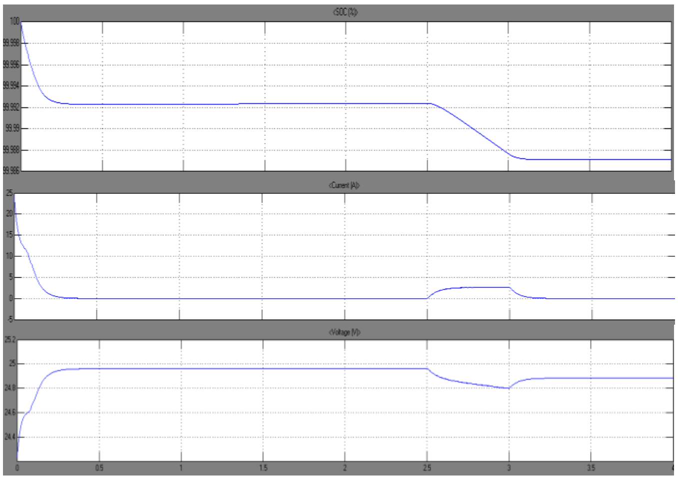

Fig. 4. (a) Battery state of charge (SOC) (b) Battery current (c) Battery voltage

A 24 volt lead acid battery is used in the simulation model as source of power converter. The charging – discharging state of battery is shown in SOC result of battery. Fig 4 (b)- (c) shows the battery current and voltage result.

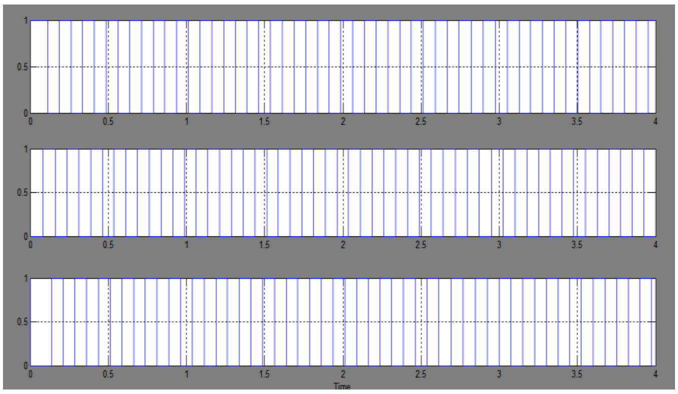

Fig.5. Hall sensor output

The Hall sensors produces output pulses which provides information about rotor position is depicted in Fig5.These three hall sensors are placed 120^0 apart in the stator of BLDC Motor and hence rotations of rotor are sensed and thereby positions are noted.

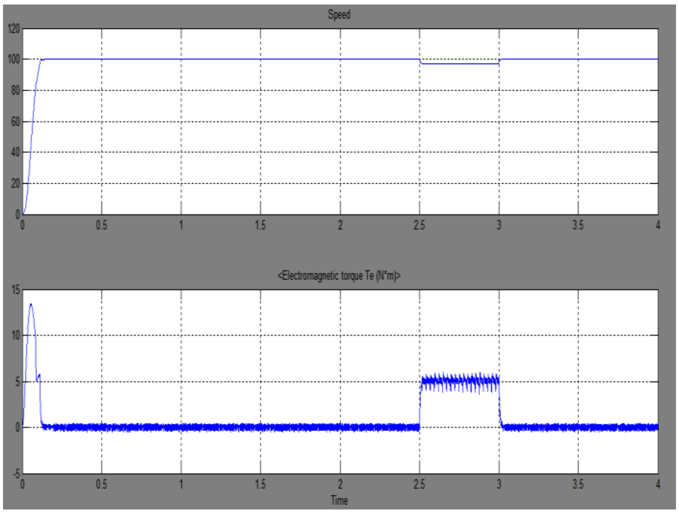

Fig. 6. (a) Speed of BLDC motor (b) Torque of BLDC motor

Here the result fig.6 (a) shows that the speed is kept constant to 100 RPM by using the adaptive fuzzy PID controller. The corresponding electromagnetic torque output is also obtained and it is shown in Fig 6(b).The above results shows that the system works effectively and the proposed controller could be used for any speed control applications.

TABLE IV.

SIMULATION PARAMATERS FOR BLDC MOTOR

Paramters	Value	unit
Terminal Voltage	24	Volts
Terminal Resistance	0.2	Ohms
Terminal Inductance	8.5	mH
Rotor Inertia	0.089	kg m^2
No. of Pole pairs	4	-
Torque constant	1.4	Nm/A

IV.CONCLUSION

The paper proposes an alternative control mechanism which enables the effective speed control for electric standing wheel chair. Using MATLAB/ SIMULINK environment the performance of the proposed controller using adaptive fuzzy PID controller are investigated. The effective study reveals that the proposed controller detects and effectively controls the speed. As future scope, the hardware implementation of electric standing wheel chair controlled by adaptive fuzzy PID controller can be implemented.

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