

An Efficient Hybrid System for Speed Control of Brushless DC Motor

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Abstract - The conventional control techniques cannot fulfill the most important needs to optimize dynamic systems, electronic circuits, and industrial processes. Brushless DC motors (BLDC) find wide applications in industries due to their high power density and ease of control. These motors are generally controlled using a three phase power semiconductor bridge. For starting and providing proper commutation sequence to turn on the power devices in the inverter bridge the rotor position sensors are required. Based on the rotor position, the power devices are commutated sequentially every 60 degrees. To achieve desired level of performance the motor requires suitable speed controllers. In case of motors, usually speed control is achieved by using Proportional (P), Proportional integral (PI), PID & fuzzy logic (FL) controller. According to new proposed approach speed control of BLDC motor drive and analysis using hybrid PID-fuzzy logic controller to carry off the weakness of fuzzy logic controller (Steady-state error) and PID controller(Overshoots, Undershoots). The proposed hybrid PID-fuzzy logic controller is evaluated via computer simulation using MATLAB simulator.

Key Words: Brushless DC Motor (BLDC), Proportional Integral (PI), Fuzzy Logic Controller (FLC), MATLAB.

1. INTRODUCTION

Brushless dc (BLDC) motors are preferred as small horsepower control motors due to their high efficiency, silent operation, compact volume, long operating life, high speed response, high output power, reliability, and low maintenance. However, the problems are encountered in these motor for variable speed operation. Over last decades, continuing technology development in power semiconductors, microprocessors, adjustable speed drivers control schemes and permanent-magnet brushless electric motor production have been combined to enable reliable, cost-effective solution for a broad range of adjustable speed applications. Household appliances are expected to be one of fastest-growing end-product market for electronic motor drivers over the next five years. The major appliances include clothes washers, room air conditioners, refrigerators, vacuum cleaners, freezers, etc. Household appliance have traditionally relied on historical classic electric motor technologies such as single phase AC induction, including split phase, capacitor-start, capacitor-

run types and universal motor. These classic motors typically are operated at constant-speed directly from main AC power without considering the efficiency. Consumers now demand for lower energy costs, better performance, reduced acoustic noise, and more convenience features. Those traditional technologies cannot provide the solutions.

2. BLDC Motor Applications

BLDC motors find applications in every segment of the market. Some of the applications are described below:

- i) Consumer: PC cooling fans, washing machine, vacuum cleaner, air conditioner, refrigerator, toys.
- ii) Medical: artificial heart, microscopes, centrifuges, dental surgical tools, organ transport pump system.
- iii) Automobile: automotive applications, electric and hybrid vehicle etc.

We can categorize the BLDC motor control into three major types such as

- a) Constant load
- b) Varying loads
- c) Positioning applications

a) Constant Loads

For single-speed applications, induction motors are more suitable, but if the speed has to be maintained with the variation in load, then because of the flat speed-torque curve of BLDC motor, BLDC motors are a good fit for such applications.

b) Varying Loads

BLDC motors become a more suitable fit for such applications because variable speed induction motors will also need an additional controller, thus adding to system cost.

c) Positioning Applications

BLDC motors used in Position control application require more complex controller, optical encoders or High resolution resolvers to calculate speed of motor, two or more closed loop are operated simultaneously.

3. BLDC Motor Drive control scheme

Brushless DC motor known as permanent magnet synchronous motor or may be described as electronically commuted motor which do not have brushes, which means their rotor and stator runs at same frequency that are powered with direct current (DC) inverter/switching power supply, which is build up by using a universal bridge.

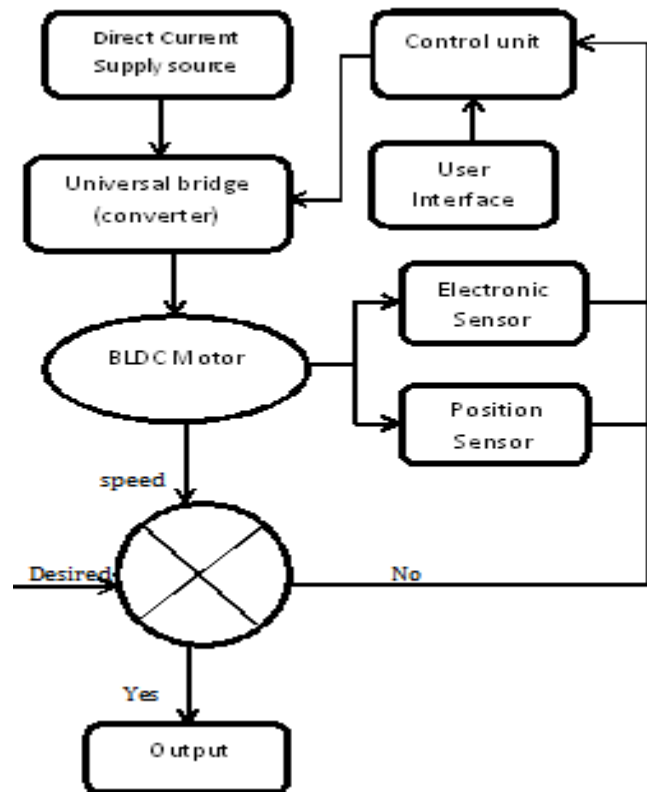


Figure -1: Block diagram of BL DC Motor Control scheme

The basic block diagram of BLDC Motor control consist power converter, permanent magnet- synchronous machine (PMSM) sensors, and control algorithm. Three phase inverter transforms power from the source to the PMSM which in turn converts electrical energy to mechanical energy. BLDC motor has rotor position sensors controlled by the command signals, the command signal may be classified as torque, voltage, and speed command and so on. The type of the BLDC motor is determined by the structure of the control algorithms due to which there are two main types voltage source and current source based drives. Permanent magnet synchronous machine with either sinusoidal or non-sinusoidal back-emf waveforms is used by both voltage source and current source based drive. The speed control is obtained by using either PI controller or by using Fuzzy Logic controller.

4. PI Speed Control Of BLDC Motor

Figure 2 describes the basic building blocks of the PMBLDC Motor drive. The drive consists of speed controller, reference current generator, PWM current controller, position sensor, the motor and IGBT based current controlled voltage source

inverter (CC-VSI). The speed of the motor is compared with its reference value and the speed error is processed in proportional integral (PI) speed controller.

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

$\omega_m(t)$ Is compared with the reference speed ω_{ref} and the resulting error is estimated at the nth sampling instant as.

$$T_{ref}(t) = T_{ref}(t - 1) + K_p[e(t) - e(t - 1)] + K_I e(t)$$

Where K_p, K_I the gains of PI are speeds controllers.

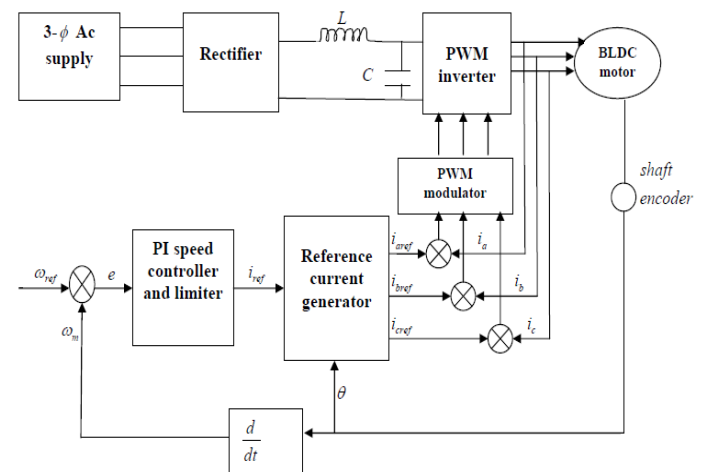


Figure-2: PI Speed Controller of the BLDCM Drive.

Following Characteristics of PID controller are given as.

CL Response	Rise Time	Over Shoot	Setting Time	Steady-State error
Kp	Decrease	Increase	Small Changes	Decrease
Ki	Decrease	Increase	Increase	Eliminate
Kd	Small Changes	Decrease	Decrease	No Changes

In this P accounts for present value of error, I accounts for past value of error, D accounts for future value of error. Some application may require only one or two terms to provide the appropriate system control. This is achieved by setting the other parameter to zero. A PID controller will be called as a PI, PD, P & I controller in the absence of respective control actions. These are no accurate but each depends upon each other (Kp, Ki, Kd) changing one of them can change the effect of other two.

5. Methodology

According to new proposed approach speed control of BLDC motor drive and analysis using hybrid PID- fuzzy logic controller. There are following steps as follow as:

Step 1: Design BLDC motor in Simulink.

- Step 2:** Apply PI based controller for BLDC motor.
- Step 3:** Select input as ruler membership function.
- Step 4:** Generate number of fuzzy ruler for PI based controller.
- Step 5:** Introduce fuzzy ruler fuzzification and apply for control operation.
- Step 6:** Calculate Impulse Response, Amplitude Response and Speed Fluctuation.

6. Fuzzy Logic Control of BLDC Motor

The fuzzy logic controller was applied to the speed loop by replacing the classical polarization index (PI) controller. The fuzzy logic controlled BDCM drive system block diagram is shown in Figure 3.

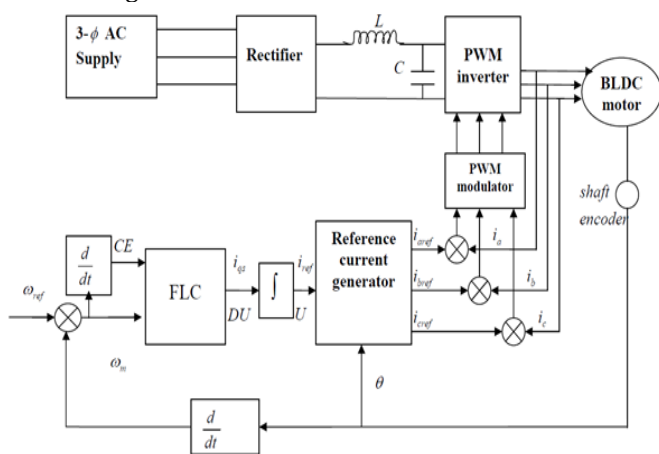


Figure-3: Fuzzy speed control diagram of BLDC motor.

7. Simulated Results

In this section, the proposed algorithm is evaluated via computer simulation using MATLAB simulator. MATLAB stands for MATRIX LABORATORY. It is primarily a tool for matrix computations. MATLAB is a high-level language whose basic data type is matrix that does not requiring dimensioning. There is no compilation and linking as is done in high level languages, such as C. MATLAB has a rich set of plotting capabilities. The graphics are also integrated in MATLAB. Since MATLAB is also a programming environment, a user can extend the functional capabilities of MATLAB by writing new modules. MATLAB has a large collection of toolboxes in a variety of domains. For example communication systems, signal processing, image processing etc. The toolboxes consist of functions that can be used to perform computations in a specific domain. All simulation results are obtained by using fuzzy logic controller, PI controller and hybrid fuzzy logic controller. Figure 4 show line-line voltage variable and stator current.

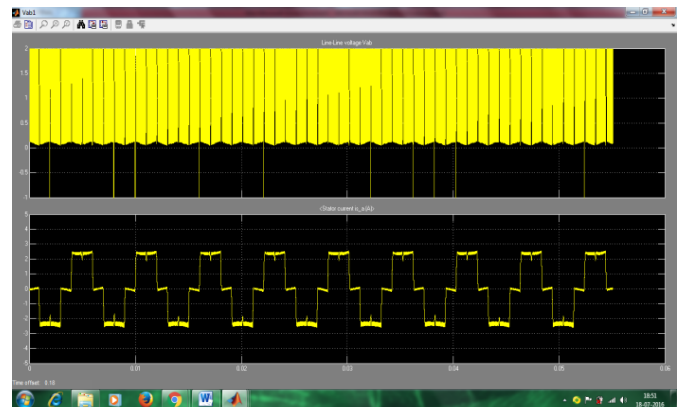


Figure-4: Input Line-Line Voltage variable and stator current.

Figure 5 show output line-line voltage of BLDC control.

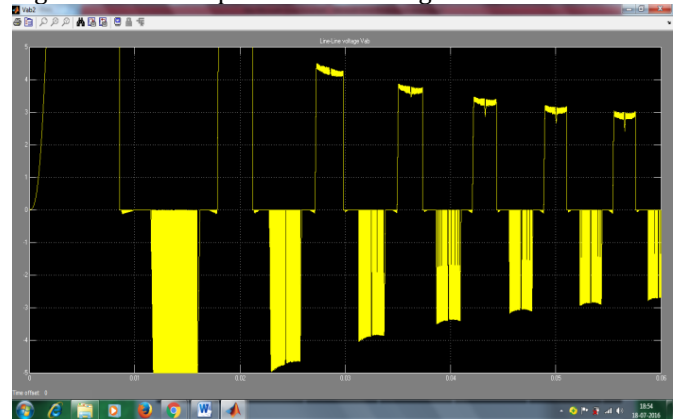


Figure-5: Output Line-Line Voltage for BLDC motor control

Figure 6 show emf variation in proposed model.



Figure-6: Proposed model with emf error variation.

Figure 7 show the hybrid based error variation in speed

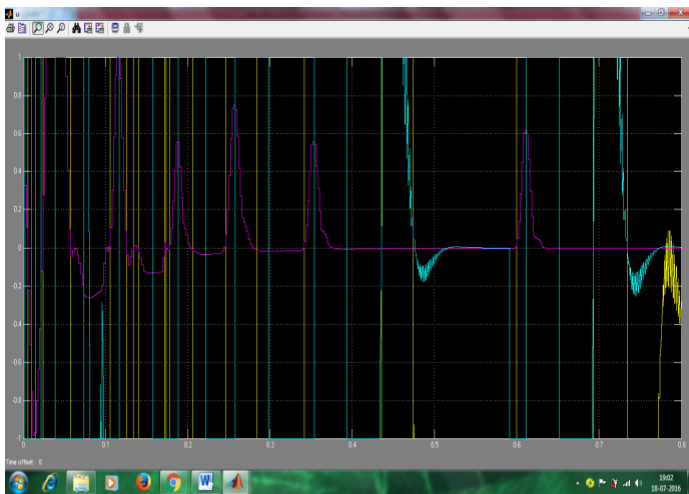


Figure-7: Hybrid based error variation in speed

Figure 8 show current variation in proposed model.

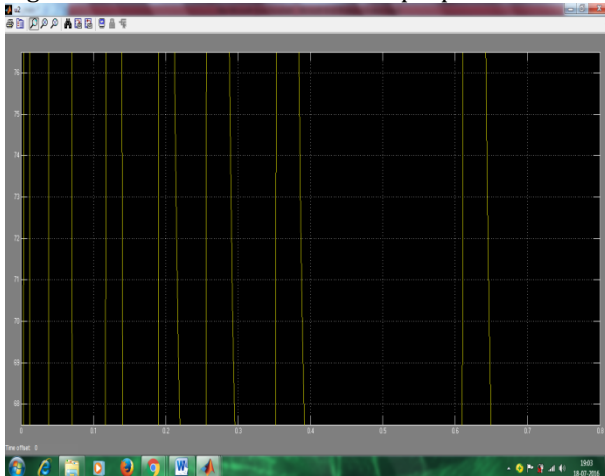


Figure-8: Current variation in proposed model.

Figure 9 show comparison of PID and hybrid on the basis of speed and time.



Figure-9: Comparative analysis of PID and hybrid on the basis of speed and time.

Figure 10 show initial speed variation of BLDC based on fuzzy control.

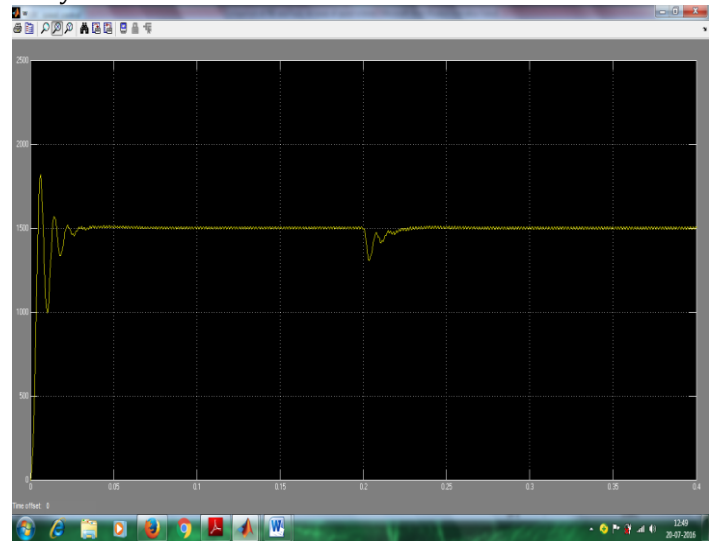


Figure-10: Initial speed variation of BLDC based on fuzzy control.

8. Conclusion

A hybrid fuzzy logic controller (HFLC) has been employed for the speed control of BLDC motor drive and analysis of results of the performance of a fuzzy controller is presented. The modeling and simulation of the complete drive system is described. Effectiveness of the model is established by performance prediction over a wide range of operating conditions. A performance comparison between the hybrid fuzzy logic controller and the conventional PI controller has been carried out by simulation runs confirming the validity and superiority of the fuzzy logic controller for implementing the hybrid fuzzy logic controller is adjusted. The performance of the BLDC drive with reference to PI controller, hybrid fuzzy logic controller and fuzzy logic controller experimental verified with conventional controller. Hybrid fuzzy logic speed controller improved the performance of BLDC Drive of the fuzzy logic speed controller. For further extent of the work, new Artificial Intelligence (AI) technique can also be used for multiple control of BLDC motor.

Appendix

Brushless DC motor: 3-phase, 440 volt, 1600 rpm

Parameter: Stator phase resistance=2.875Ω, Stator phase inductance=8.5mH, Pole pair=4, Load torque=1.8N-m.

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