Tracking Dynamic System Based on Developing BLDC Motor Model

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Abstract

Brushless direct current (BLDC) permanent magnet machines are used in a wide range of applications due to their multiple advantages. It is important to develop stable drivers that meet the specific performance target of the application. It is extremely important to choose closed-loop parameters in case of multiple loops to control the BLDC motor. Most control systems work on the paths of dynamic targets in an area that needs certain types of motors to meet a set of goals, the most important of which is accuracy. Various soft computing technologies are currently being used to improve the response of control systems (BLDC) motors to build models using MATLAB software and Simulink space. This paper describes tracking a specific dynamic object by developing the BLDC motor model responsible for tracking purposes by designing a specific mechanism. A new intelligent control unit designed with a new theory (hall sensor) was used to solve the problem of tracking nonlinear dynamic systems. The proposed model showed good simulation results to track the position and speed of the dynamic object.

INTRODUCTION

A BLDC motor is used in a wide range of applications in machines and equipment that require small size, precision, durability, and low cost at the same time [1]. BLDC motors, also known as electronic commutated motors, are synchronous motors fed with direct current by an integrated commutated supply circuit which produces an alternating current signal to drive the motor. The rotor of a BLDC motor is often a permanent magnet synchronous motor. BLDC motors can be described as stepper motors, however, the term stepper motors tend to refer to motors specifically designed to operate in a model in which the motor stops at a specific angular position. The BLDC motor uses to improve the speed performance of the system by using position, speed, and current feedback loops are adopted in the control structure [2]. Use the BLDC motor to operate the pump is a simple process of pumping solar water in harsh conditions due to its reliability, high efficiency, small size, high torque, and lower noise compared to the induction motor of the same type [3]. The performance variables for brushless motors are Kv and Km [2]–[5].

METHODOLOGY

In this paper, MATLAB software and SIMULINK space are used to solve, simulate, check and study the performance of the motor under different conditions. MATLAB software allows engineers to develop a high-level graphical language control application algorithm for data flow and signal flow diagrams. The SIMULINK toolbox contains several libraries whose components can be included in block diagram graphs.

PROBLEM FORMULATION

The main objective of this paper is to develop the BLDC motor model in dynamic control systems that require high accuracy using focus and feedback to solve the problem of the nonlinear model and get the best response and the least error.

SYSTEM MODEL AND SIMULATION

This paper deals with the development of the BLDC motor model in dynamic control systems that require high accuracy using two feed-backs using different controllers. The first type of controller was used to control the position of the dynamic signal and was used for this purpose, the neuro-fuzzy controller, which showed a high possibility of tracking dynamic signals, the second type of controller is the PID controller that was used to control the speed of the motor, this type of controller is the best in tracking the speed of the motors. The best response was obtained with the lowest error rate. The neuro-fuzzy controller is widely used nowadays. It is an automatic control and a self-acting mechanism that controls the position according to the desired behavior. Fig. 1 shows the block diagram of the proposed model control system. The input to the neuro-fuzzy console is the error in the position signal between the reference value and the actual value. The advantages of the neuro-fuzzy controller are quick response, a short transition process, flexibility, and ease of calculation. The controller used in the model to track the reference position signal provides improved stability, good response, simple control, and an accurate result [6]–[8].

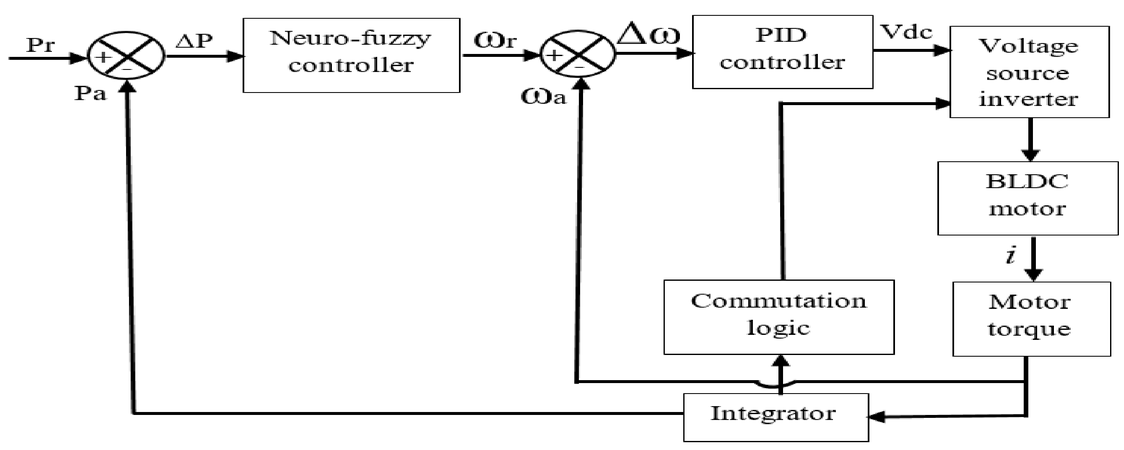

Figure 1. Block diagram of the proposed model.

BLDC MOTOR MODEL

The BLDC motor is called an electronic commutated motor. The rotor is brushless and in part, electronic commutation is performed. The stator magnetic circuit is usually made of sheet steel. The phase coils of the stator are inserted into the slots as shown in fig. 2. The permanent magnet's magnetization and displacement in the rotor are set to produce a trapezoidal back-EMF (induced voltage in the stator winding owing to rotor movement). This allows a rectangular-shaped three-phase voltage system to create a rotational field with low torque ripples.

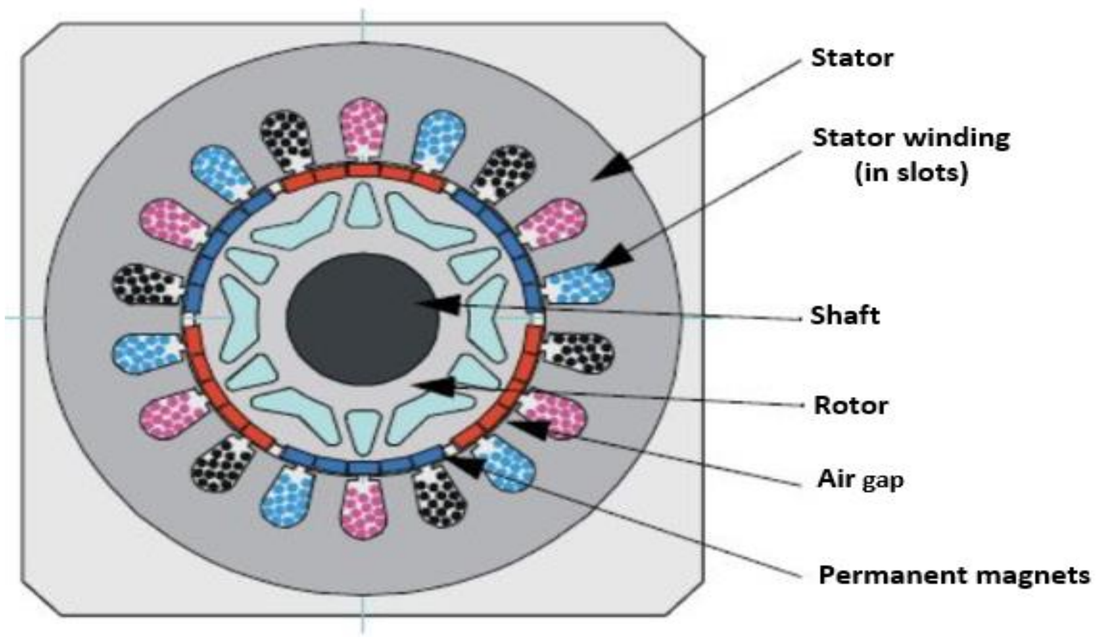

Figure 2. A BLDC motor cross-section

The equation for the terminal voltage of a BLDC motor can be represented as in equation (1) and derived as state-space equations and simulated in the MATLAB toolbox:

$$\begin{cases} V_a = R_a I_a + L_a \frac{di_a}{dt} + M_{ac} \frac{di_b}{dt} + M_{bc} \frac{di_c}{dt} + e_a, \\ V_b = R_b I_b + L_b \frac{di_b}{dt} + M_{ac} \frac{di_a}{dt} + M_{bc} \frac{di_c}{dt} + e_b, \\ V_c = R_c I_c + L_c \frac{di_c}{dt} + M_{ac} \frac{di_b}{dt} + M_{bc} \frac{di_a}{dt} + e_c, \end{cases} \quad (1)$$

Where $R_{a,b,c}$ is the equal resistance per phase, $L_{a,b,c}$ is the equal inductance per phase, and M_{ac} and M_{bc} are mutual inductance. For BLDC motor net effect value will be Zero. i_a, i_b, and i_c are stator current/phase. V_a, V_b, and V_c are the winding phase voltage.

Equations (2) and (3) determine the electromagnetic force (EMF) and motor parameters torque of a BLDC motor with a trapezoidal shape, where C_0 and C_v are friction torques in static and dynamic situations, respectively, and T_l is the motor's load torque. Equation (4) illustrates the final output power is developed by the motor.

$$\begin{cases} e_a = f_a(\theta) Ke\omega \\ e_b = f_b(\theta) Ke\omega \\ e_c = f_c(\theta Ke\omega \end{cases} \quad (2)$$

$$T_e = T_1 - C_0 - C_v \quad (3)$$

$$P = T_e * \omega \quad (4)$$

SIMULATION RESULTS

The simulation model developed to track the dynamic signals of the BLDC motor is obtained in MATLAB Simulink. Fig. 3 and fig. 4 show the tracking position and speed mode respectively.

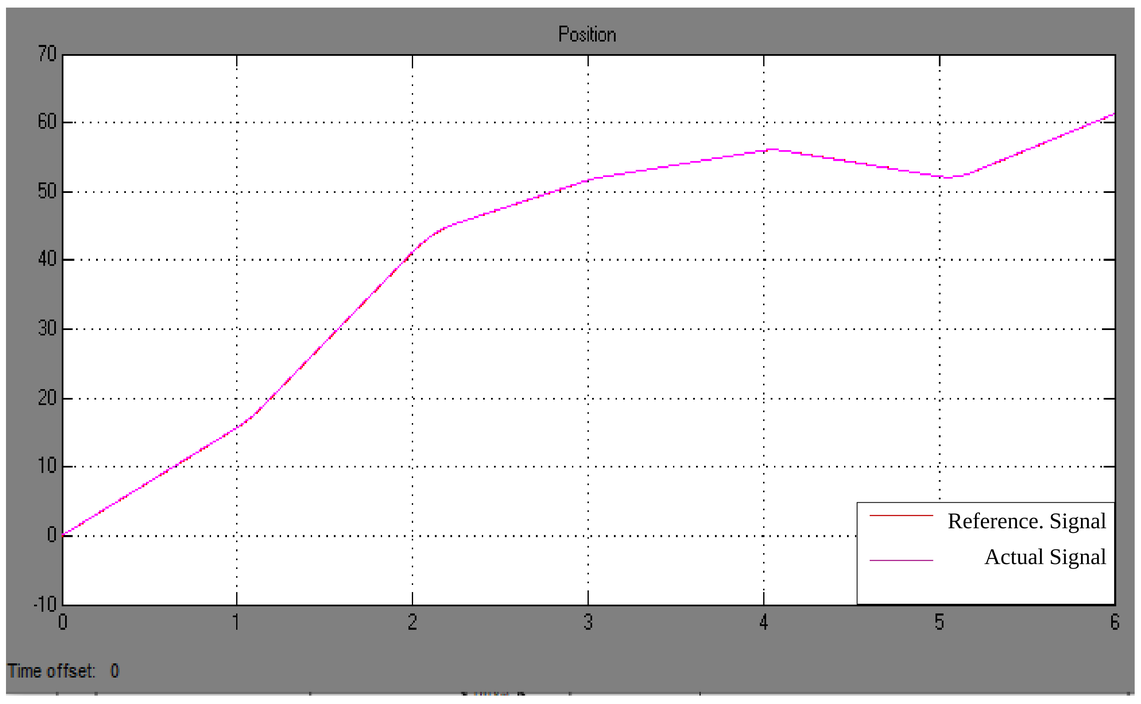

Figure . 3 Normal mode position tracking result.

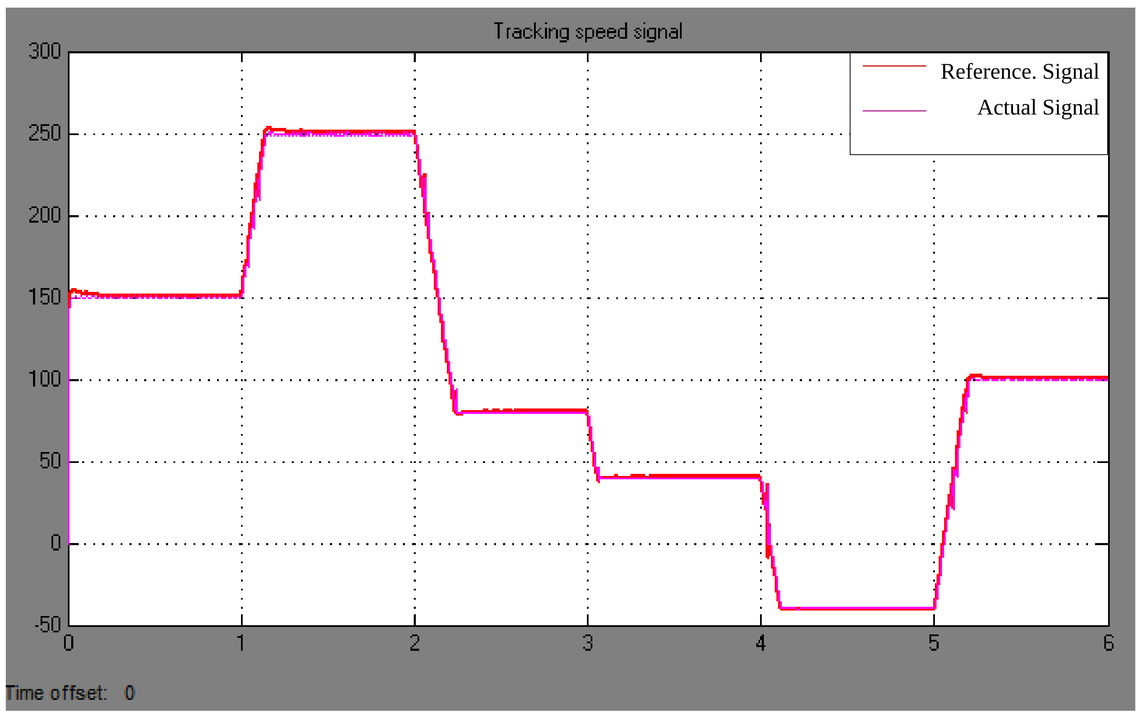

Figure 5. Speed signal for the proposed model.

CONCLUSION

Developing a BLDC motor model with hall sensors to tracking reference position and speed of dynamic systems is carried out. All sub-models used in modeling are derived from all parameters. The developed model of the BLDC motor can be used for dynamic systems such as combustion systems and hot spot tracking of a burning flame. Finally, the results of the tracking for the position and speed of the BLDC motor were carried out, and the significant improvement in the tracking was noticed using the hybrid controllers in the system, with the elimination of the steady-state error, and the lowest rise time and settling time and the reduction of the maximum overshoot to the minimum.

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Biography

Ahmed Abdelrahim received his B.Sc. And Master degree in Electrical Engineering (Control and microprocessor) from Sudan University of Science and Technology in 2003 and 2010 respectively, and Currently his PhD student in NCEPU.