Journal of Electronics and Informatics (ISSN: 2582-3825)
www.irojournals.com/iroei/

Sensor Less BLDC Drive System for Conveyor Applications

Akash T.[1], Balachandar A.[2], Harither M.[3], Madan M.[4], Thulasi Raman S.[5], Gunasekaran S.[6]

Department of Electrical and Electronics Engineering, Coimbatore Institute of Technology, Coimbatore, India

E-mail: [1]akashthirumurugan116@gmail.com, [2]abala3393@gmail.com, [3]ms.harither2002@gmail.com, [4]madhan2303student@gmail.com, [5]thulasiramansri@gmail.com, [6]gunasekaran.s@cit.edu.in

Abstract

The research aims to design and implement a sensorless Brushless DC (BLDC) motor optimized for conveyor applications. Typically, BLDC motors rely on sensors for rotor position detection to determine the rotor's location, which can increase system complexity and maintenance costs, among other drawbacks. This research explores the application of sensorless techniques, specifically back electromotive force (back-EMF) detection, to estimate the rotor position without the need for physical sensors. The proposed system comprises a step-down transformer, a bridge rectifier, an electronic commutator, and an STM32F103C8T6 microcontroller. By integrating advanced control algorithms, this system seeks to improve the efficiency, reliability, and cost-effectiveness of conveyor operations. The designed hardware for the sensorless BLDC drive system will be tested and verified for its robustness under various load conditions, demonstrating its potential applicability in industrial conveyor systems.

Keywords: BLDC motor, STM Microcontroller, Electronic commutator, Back EMF.

1. Introduction

The research, entitled "Sensorless BLDC Drive System for Conveyor Applications," presents a novel approach to motor control that eliminates the need for traditional rotor position sensors. Brushless DC (BLDC) motors are widely utilized in industrial conveyor applications due to their efficiency, reliability, and low maintenance requirements [1-4]. However, the conventional use of Hall-effect sensors for rotor position detection in these motors increases

DOI: https://doi.org/10.36548/jei.2025.1.004
Received: 18.02.2025, received in revised form: 20.03.2025, accepted: 07.04.2025, published: 16.04.2025

system complexity, cost, and the likelihood of failure [5,6]. This research proposes a sensorless control method based on Back-EMF detection to enhance system robustness while reducing costs. The system is implemented using an STM32F103C8T6 microcontroller, an electronic commutator, and power electronic devices, enabling precise motor control and efficient operation. The proposed system has been tested under various load conditions and demonstrates a cost-effective and dependable solution for industrial automation [7-10]

2. Proposed System

2.1 Overview of the System

The proposed solution is a cost-effective, reliable, and efficient drive solution for conveyor systems based on Brushless DC (BLDC) motors. BLDC motors are highly efficient, compact in size, and low in maintenance due to the absence of brushes and commutators. This research eliminates the necessity of traditional sensors, including Hall-effect sensors, used for rotor position detection; instead, it implements sensor less control strategy. This sensor less method uses the back-EMF to identify the rotor position, which reduces the overall complexity and cost of the system and reduces the susceptibility to sensor-related failures.

Automation, robotics, aviation, industrial applications, etc. are among the fields in which the switched reluctance motor finds use. The motor’s speed control is important because of its broad range of applications. High efficiency, increased dependability, affordability, and constructional advantages over other motors are just a few of the motor’s benefits.

2.2 Block Diagram

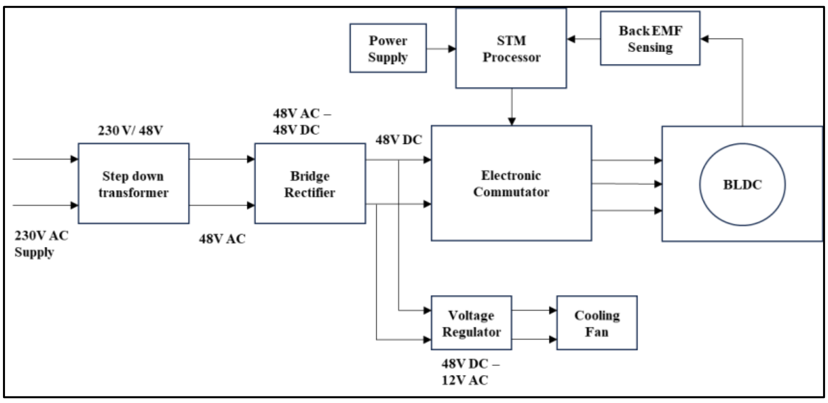

Figure 1. Block Diagram

The input single phase 230V AC Voltage should be step down to 48V AC, which is the rated voltage of the motor. The output of the transformer is AC voltage which should be converted into DC Voltage. It is done by the bridge rectifier. The bridge rectifier converts the input 48V AC to 48V DC. Then this 48V DC is supplied to the motor through the electronic commutator. The electronic commutator operates on the gate pulse received from the STM processor. The STM processor acts as core for the implemented control method. The gate pulse is determined by the back EMF sensed of the BLDC motor. The processor processes the sensed back EMF and determines the phase at which the supply is to be provided. Based on the phase of the motor, the appropriate power electronic switches in the electronic commutator receives the gate pulse. The Figure 1 depicts the block diagram of the proposed sensor less system for BLDC drive system.

Along with these blocks the protective equipment, to ensure the safer operation is also implemented in the designed hardware. The protective equipment includes glass fuses at the input of the transformer, blade fuses at the output of the transformer, at the output of the bridge rectifier and at the output of the electronic commutator. The heat sinks and cooler fans are also provided to avoid overheating in the hardware.

2.3 Back EMF Sensing

Back-EMF detection methods estimate rotor position using the voltage induced in the unenergized winding. Zero-crossing detection and extended Back-EMF modelling were evaluated. The advantages are Simple, cost-effective, and highly accurate at moderate to high speeds that exceed 3000 RPM. After a comprehensive analysis, the Back-EMF Zero-Crossing detection method was chosen as the most suitable technique for the 48V, 3000 RPM BLDC motor. This method balances simplicity, cost-effectiveness, and accuracy, making it ideal for applications primarily operating at moderate speeds.

3. Mathematical Modelling

The model of the armature winding of the BLDC motor can be expressed as:

$$V_a = R_a I_a + L\frac{dI_a}{dt} + e_a \tag{1}$$

$$V_b = R_b I_b + L\frac{dI_b}{dt} + e_b \tag{2}$$

$$V_c = R_c I_c + L\frac{dI_c}{dt} + e_c \quad (3)$$

It can be expressed in the compact matrix form also,

$$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \begin{bmatrix} R+\rho L & 0 & 0 \\ 0 & R+\rho L & 0 \\ 0 & 0 & R+\rho L \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix}$$

$$L_a = L_b = L_c = L = L_S - M$$

where,

L_s – armature self-inductance

M – Mutual inductance

The expression of back emf can be expressed as follows,

$$e_a(t) = k_E * \phi(\theta) * \omega(t) \quad (4)$$

$$e_b(t) = k_E * \phi\left(\theta - \frac{2\pi}{3}\right) * \omega(t) \quad (5)$$

$$e_C(t) = k_E * \phi\left(\theta + \frac{2\pi}{3}\right) * \omega(t) \quad (6)$$

where k_E is the back emf constant and ω is the mechanical speed of the motor. The permanent magnet also influences produced torques due to the trapezoidal flux linkage. The torque produced can be expressed as,

$$T_E = \frac{(e_a i_a + e_b i_b + e_c i_c)}{\omega} \quad (7)$$

where T_E is the resultant torque produced by the motor, which can be obtained from the following expressions,

$$T_a(t) = k_{T^*} \phi(\theta) * \omega(t) \quad (8)$$

$$T_b(t) = k_T * \phi\left(\theta - \frac{2\pi}{3}\right) * \omega(t) \quad (9)$$

$$T_C(t) = k_T * \phi\left(\theta + \frac{2\pi}{3}\right) * \omega(t) \quad (10)$$

ISSN: 2582-3825

where k_T is the torque constant.

$$T_E = T_a(t) + T_b(t) + T_c(t) \tag{11}$$

The angular motion of the motor can be written as follows:

$$T_e(t) - T_L(t) = J\frac{d\omega(t)}{dt} + B * \omega(t) \tag{12}$$

4. Simulation and Output

In the simulation using MATLAB the reference speed is fed to the error generation block and the speed of the motor is fed to the block by the feedback circuitry. In normal BLDC motors the rotor position is sensed by the hall effect sensors and they provide the position feedback to determine the rotor's angle position for commutation. This signal helps to represent the phase currents and back EMF of the motor winding.

These signals are fed to monitoring and control units for proper motor operation. In our simulation we used the PID Controller, which process the error between the reference speed and actual rotor speed, The output of the controller is used to generate gate signals for the power switches in the inverter. The inverter converts DC supply to AC voltage to drive the 3phases of the BLDC motor.

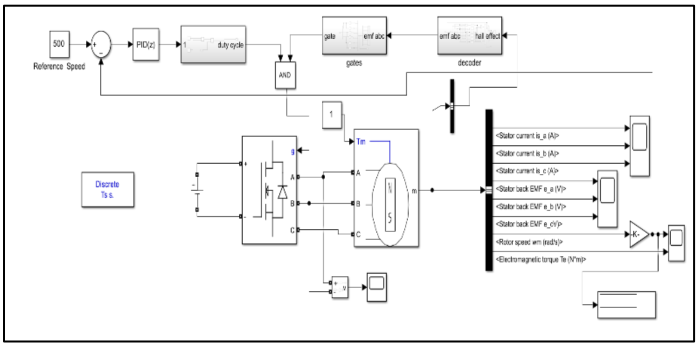

Figure 2. Simulation Diagram

In the simulation (Figure 2) we used Discrete Sampling Time block to indicate a digital sampling mechanism, which discretizes the signals for digital control implementation. In addition to it the AND gate ensures the PWM signals are appropriately conditioned and only passed when all conditions are met. The duty cycle control adjusts the on/off time ratio of the PWM signal to regulate voltage and speed.

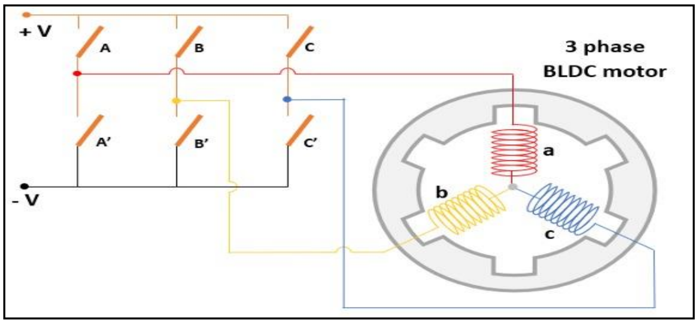

Figure 3. Commutator Diagram

Figure 3 shows a 3-phase BLDC motor connected to a driver circuit comprising six switches (Q1, Q2, Q3, Q4, Q5, Q6). Each phase of the motor (A, B, C) is connected to the corresponding driver switches, forming a bridge configuration. The windings of the motor are marked as a, b, and c, which correspond to phases A, B, and C. Power is supplied from a positive voltage (+V) and a ground (-V). Switches are operated in a sequence to commutate the current in the motor phases, generating a rotating magnetic field.

Table 1. Commutation Sequence

Step	Q1 (A High)	Q2 (A Low)	Q3 (B High)	Q4 (B Low)	Q5 (C High)	Q6 (C Low)	Active Phases	Floating Phase
1	ON	OFF	OFF	ON	OFF	OFF	A → B	C
2	ON	OFF	OFF	OFF	OFF	ON	A → C	B
3	OFF	OFF	ON	OFF	OFF	ON	B → C	A
4	OFF	ON	ON	OFF	OFF	OFF	B → A	C
5	OFF	ON	OFF	OFF	ON	OFF	C → A	B
6	OFF	OFF	OFF	ON	ON	OFF	C → B	A

The Table 1 lists the six steps for commutation in the motor's operation. Q1 to Q6: Represent the states of the switches (ON or OFF)

Active Phases: Indicates which motor phases are energized (e.g., A → B means current flows from phase A to phase B).

Floating Phase: Denotes the motor phase is not involved in the current path for that step.

At any step, two phases are active while one phase floats (not energized). The sequence of switching creates the required rotating field to drive the motor. This control strategy ensures efficient operation with minimal energy loss.

The output waveform of the simulation is shown in the Figure 5. The simulation output shows trapezoidal Back-EMF waveforms for a three-phase BLDC motor, with each phase 120° electrically out of phase. The waveforms are symmetric and consistent in amplitude, indicating uniform winding and proper motor design. Zero-crossing points, where one phase's Back-EMF crosses zero while others are at peak values, are essential for sensor less control techniques like Zero-Crossing Detection. These waveforms validate the motor's suitability for reliable commutation and control.

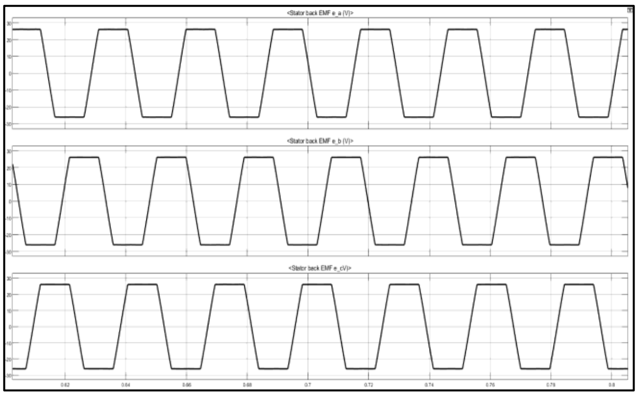

Figure 5. EMF Waveform

5. Discussion

In conveyor systems, sensor less BLDC motors, especially using back EMF sensing, have significant potential as they offer several advantages that are a good fit for such applications. One major advantage is lower system costs, as classic BLDC motors are generally equipped with encoders or Hall sensors to track rotor position, while these components can be bypassed using back EMF sensing. The proposed solution yields lower system costs and lower demand for maintenance, because there are fewer components that wear out. Moreover, since sensor less systems typically do not have mechanical position sensors, they tend to be more reliable and less likely to fail. They are therefore well equipped to survive in hostile surroundings like those common in the mining, manufacturing, or food processing sectors directly, where dust and difficult conditions can impede traditional sensors.

Sensors allows for more smaller and simpler motors, which contributes to reducing the physical size of the motor controller and simplifies wiring, a clear advantage in confined spaces. Sensor less control method allows for smooth and precise speed adjustment, thus it's suitable for conveyor systems where consistency and process synchronization are critical. Fast response time to load changes further improves system performance.

In addition, sensor less BLDC motors typically utilize field-oriented control (FOC), enhancing torque performance and overall efficiency. Programming with programmable logic controllers (PLCs) is easy, further simplifying system control. Sensor less BLDC motors have numerous advantages, but there are challenges, especially in startup conditions and low-speed operation, as back EMF signals are not strong under these conditions. In spite of this, developments in control algorithms are reducing these problems. The uses in conveyor applications are numerous, across industries like material handling, packaging, food processing, pharmaceuticals, and electronics, where efficiency of energy, reliability, and accuracy are essential. Sensor less BLDC motors, by utilizing back EMF sensing, thereby provide a reliable and economic solution to new generation conveyor systems, with considerable benefits in operations.

6. Conclusion

The application of a sensor less BLDC drive system with Back-EMF detection is an effective alternative to traditional sensor-based approaches for conveyor applications. Through the elimination of rotor position sensors, the system realizes cost savings, increased reliability, and reduced design complexity. Experimental findings validate the efficiency of the proposed approach in maintaining smooth and efficient motor operation and accurate speed control. In spite of low-speed operation challenges, improvements in control algorithms can further improve performance. The system developed has great potential for use in industrial automation, material handling, and process industries, opening the door to more efficient and intelligent conveyor systems.

References

[1] W. H.-f. Zhu Bao-peng, "A Novel Back-EMF Zero Crossing Detection," International Journal of Innovative Science, Engineering & Technology , Vol. 4 Issue 4, April 2017 2017. 7-13.

[2] Anand, Aniket, and Bhim Singh. "Dual output cuk converter fed switched reluctance motor drive." In 2016 IEEE 7th Power India International Conference (PIICON), IEEE, 2016. 1-6.

[3] Vas, Peter, A. F. Stronach and M. Neuroth. “DSP-based speed-sensorless vector controlled induction motor drives using AI-based speed estimator and two current sensors.” (1998).

[4] Kumar, Prashant, Devara Vijaya Bhaskar, Ranjan Kumar Behera, and Utkal Ranjan Muduli. "Continuous fast terminal sliding surface-based sensorless speed control of pmbldcm drive." IEEE Transactions on Industrial Electronics 70, no. 10 (2022): 9786-9798.

[5] Li, Qiang, Xiaojing Huang, Jian Li, Guangmin Liu, and Jizhong Tao. "Design of sensorless high speed BLDCM controller for molecular pump." In Journal of Physics: Conference Series, vol. 1654, no. 1, IOP Publishing, 2020. 012039.

[6] Joshi, Dhaval, Dipankar Deb, and Ashutosh K. Giri. "MRAS disturbance observer-based sensorless field-oriented backstepping control of BLDC motor drive." Electrical Engineering 106, no. 5 (2024): 6681-6701.

[7] Awchar, Shivaji Manik, Seema P. Diwan, and Pratik Arlikar. "Advanced technique for speed control of sensor-less bldc motor." In 2018 Fourth International Conference on Computing Communication Control and Automation (ICCUBEA), IEEE, 2018. 1-5.

[8] Akrami, Milad, Ehsan Jamshidpour, Babak Nahid-Mobarakeh, Serge Pierfederici, and Vincent Frick. "Sensorless control methods for BLDC motor drives: A review." IEEE Transactions on Transportation Electrification (2024).

[9] Gamazo-Real, José Carlos, Ernesto Vázquez-Sánchez, and Jaime Gómez-Gil. "Position and speed control of brushless DC motors using sensorless techniques and application trends." sensors 10, no. 7 (2010): 6901-6947.

[10] Kim, T., H. W. Lee, and M. Ehsani. "Position sensorless brushless DC motor/generator drives: review and future trends." *IET Electric Power Applications* 1, no. 4 (2007): 557-564.