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Design of Speed Control of BLDC Motor Using Back EMF Method

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Abstract— This paper presents a sensorless speed control technique for Brushless DC (BLDC) motors using back electromotive force (B-EMF) method. Traditional speed control methods for BLDC motors rely on position sensors, adding complexity and cost to the system. The proposed sensor less approach leverages the B-EMF signal which is generated by the motor to estimate rotor position and control the motor speed without need for additional sensors. The methodology involves acquiring the back EMF signal, processing it using signal processing techniques and implementing a suitable control algorithm. A controller-based platform is utilized for signal acquisition, processing, and generating control signals. The advantages of this sensor less speed control method include cost reduction, enhanced reliability and simplified design. Obtained results shows the effectiveness of proposed method, showcasing accurate speed control without use of the position sensors. This paper contributes in developing the sensor less control method of BLDC motors speed and opens avenues for further exploration in motor control applications.

Index Terms— BLDC motor, Back EMF, Speed Control, Sensor less

I. INTRODUCTION

Controlling the speed of Brushless DC (BLDC) motors plays an important role in various industrial and consumer applications. BLDC motor has several advantages over the traditional motors, such as high efficiency, compact size, and low maintenance requirements. To optimize its performance and meet specific application, precise controlling the speed becomes essential. BLDC motors have permanent magnets on a rotor and multiple stator windings. When stator is energized with current, it creates a rotating magnetic field that causes motor rotation. The spinning rotor creates a back EMF in the stator windings. [1]

BLDC motors offer advantages over induction and DC motors, such as high duty density, no copper losses in a rotor, and mechanical switching elements are absent, resulting in robust and compact structures. They are preferred for their easy maintenance, efficiency, and simpler control in low power operation. A BLDC motor requires a constant DC source and inverter. Trapezoidal EMF profile motor require six rotor positions for the inverter to function. Inverter requires accurate gate signals based on rotor position. [2]-[3]

The main advantages of BLDC motor are they have higher efficiency, reliability, and reduced acoustic noise without brushes. Smaller, lighter, and improved dynamic response with better speed and torque characteristics. Extended speed range and longer lifespan. [4].

Traditionally, BLDC motors have been controlled using position sensors such as hall effect sensor or encoders, to provide feedback on the position of the rotor. However, Hall sensors are known to be affected by temperature changes and harsh conditions. This could cause performance degradation [5]. Additionally, Hall sensors may take up significant space in limited volume applications. The sensors should be installed with high precision and also adds complexity, increases cost, and introduces potential points of failure in the system. Therefore, there has been a growing interest in developing a speed control technique without any sensors for BLDC motors. [6] By eliminating the need for these sensors, sensor less control methods offer cost-effective solutions with improved reliability and reduced system complexity.

There is various [7] Sensor less speed control techniques available for BLDC motors, including the back electromotive force (EMF) method, voltage model-based methods, current model-based methods and observer-based methods. Each method utilizes different principles and algorithms to estimate the position of rotor and control the motor speed. Among these techniques, the Back EMF method has gained significant attention because of its simplicity and effectiveness. The Back EMF [8] is a voltage signal induced in the unpowered motor windings when the rotor rotates. By analyzing the Back EMF waveform, it is possible to estimate the position of the rotor and consequently control the motor's speed. Back EMF method eliminates the need for additional sensors and provides a cost-effective approach to sensor less speed control. This method amplifies the voltage difference between terminals to detect the initial rotor position and trigger the switching devices for desired acceleration of BLDC motor.

The BLDC motor equation includes the non-linear B-EMF term, which provides position and speed data in real time. B-EMF observer have been designed using the motor's terminal current and dc bus voltage [9]. This paper aims to explore sensor less speed control of BLDC motors using B-EMF method. The proposed approach involves extracting and processing the back EMF signal using advanced techniques and employing a control algorithm to determine rotor position and control motor speed accurately. The advantages of this method include reduced system complexity, cost-effectiveness, improved reliability, and robustness against environmental factors. These advantages make it an attractive option for various applications, such as electric vehicles, industrial automation, robotics and renewable energy system.

Further the paper is organized as follows: Section II give the mathematical modelling of the BLDC motor, Section III shows the methodology followed by Section IV which is the simulation and results followed by conclusion and references.

II. MATHEMATICAL MODELLING OF BRUSHLESS DC MOTOR

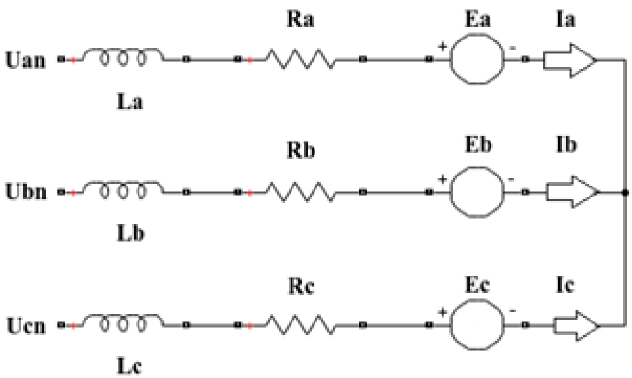

Fig 1. BLDC motor Equivalent circuit diagram

$U = RI + \rho(LI) + E$ (1)

Where,

U – Phase Voltage Vector, $U= [U_{an} U_{bn} U_{cn}]^T$;

R – Stator Winding Resistance, $R=\begin{bmatrix} Ra & 0 & 0 \\ 0 & Rb & 0 \\ 0 & 0 & Rc \end{bmatrix}$;

I – Phase Current Vector, $I=[I_a\ I_b\ I_c]^T$;

ρ- Differential Operator;

L – Inductance matrix $L=\begin{bmatrix} Laa & 0 & 0 \\ 0 & Lbb & 0 \\ 0 & 0 & Lcc \end{bmatrix}$;

E - Back EMF vector $E=[E_a\ E_b\ E_c]^T$;

Electromagnetic Power, $P_e= E_a I_a+ E_b I_b+ E_c I_c$ (2)

(2) → Power transferred to rotor

Electromagnetic Power is converted to kinetic energy by eliminating the losses (mechanical & stray)

$P_e= T_e\ \Omega_m$ (3)

Considering equations (2), (3) we get

Torque, $T_e = \frac{E_a I_a + E_b I_b + E_c I_c}{\Omega_m}$ (4)

Where,

T_e- Electromagnetic torque

Ω_m- Mechanical angular velocity of the rotation

Considering, Phase-C to be De-energized and Phase-B to be ground while, Phase-A to be connected to positive terminal of Dc supply.

Using V_{LL} dependency of neural voltage will be eliminated. Therefore,

$U_{ab}= RI_{ab}+L(\ \rho I_{ab})+ E_{ab}$ (5)

Applying Laplace Transform for (5) we get

$U_{ab}(s)= RI_{ab}(s)+LsI_{ab}(s)+ E_{ab}(s)$ (6)

III. METHODOLOGY

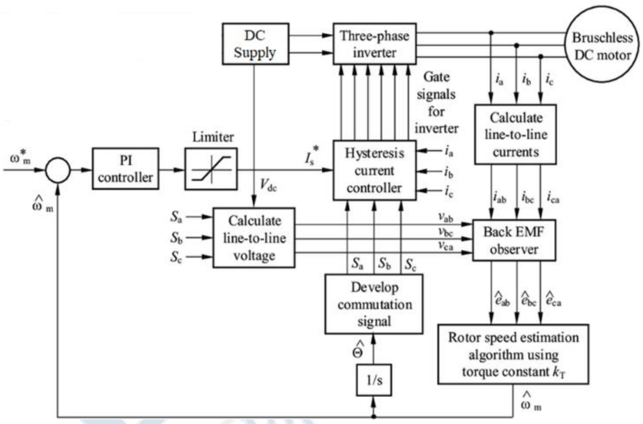

Fig 2. Speed control functional block diagram of BLDC Motor

This paper proposed speed control algorithm for BLDC motor using B-EMF observer. As we can observe from Fig 2., consist a B-EMF observer which is used to find the speed and position, back EMF obtained is directly proportional to speed of motor and also can be employed as a feedback signal for speed control. Since the BLDC motor's back-EMF cannot be detected directly, it is calculated by a comparator using a zero-crossing detection technique, and a sensor less technique is employed to control speed. To control speed effectively a PI controller is employed. Current control loop is implemented to regulate the motor's phase currents. This is done using techniques such as Proportional-Integral (PI) control. The loop of the current control makes sure that the motor currents are maintained at the desired levels. Similarly, voltage control loop is designed to adjust the motor's applied voltage on the basis of an estimated back EMF and a desired speed reference. voltage control loop adjusts the motor's input voltage to achieve the desired speed.

There's a Hysteresis current controller that switches MOSFETs based on the current in the hysteresis current regulator. [9] The inverter's switching states are directly managed by the error. Switching frequency for varying loads and supply voltage changes varies in accordance with the current error.

The estimated back EMF from B-EMF observer is used to calculates the motor speed. The back EMF is related to the speed, so by observing its variations, the speed can be

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estimated. Based on estimated speed, control algorithm is developed. This algorithm adjusts the motor drive voltage or current to be maintained at the desire speed setpoint.

The sensorless control approach motor starting process must be followed. The suggested observer-based strategy uses the globally acknowledged "align and go"[10] process, that will be employed as a startup process for a commercialized sensorless control approach for BLDC motor. By performing a motor phase prior to rotation, rotor align at the specified place in this system. Following that, a rotor rotates in accordance with the specified switching sequence along with increased in speed of rotor. Conventional methods demand a greater speed to initiate the closed-loop operation, to determine precise voltage level in order to determine zero crossing of terminal voltages. Position of rotor can be estimated through Back EMF observer-based method after each 60° revolution of the motor.

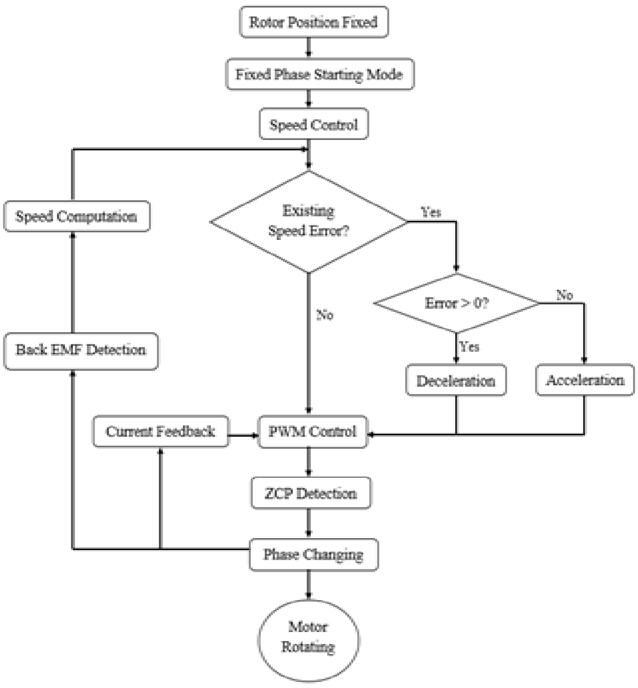

Fig 3. Flow chart of Control Algorithm

IV. SIMULATION AND RESULT

Simulation was done in MATLAB/Simulink using BLDC motor with a parameter of motor mentioned in the Table 1 shown below.

Table 1. BLDC motor parameters used for simulation

Parameters	Value	Unit
No. of Phase	3	
Rated Voltage	12	V
Rated Power	350	W
Rated Torque	0.7	Nm
Rated Speed	2200	rpm

Block diagram of MATLAB/Simulink implementation of the sensor less control of a BLDC motor speed using B-EMF is shown in Fig. 4. Elaboration of controller block is shown in Fig. 5

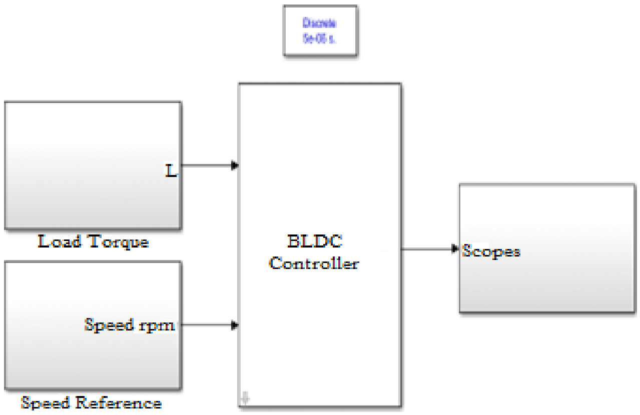

Fig 4. Designed simulation model for controlling BLDC motor speed

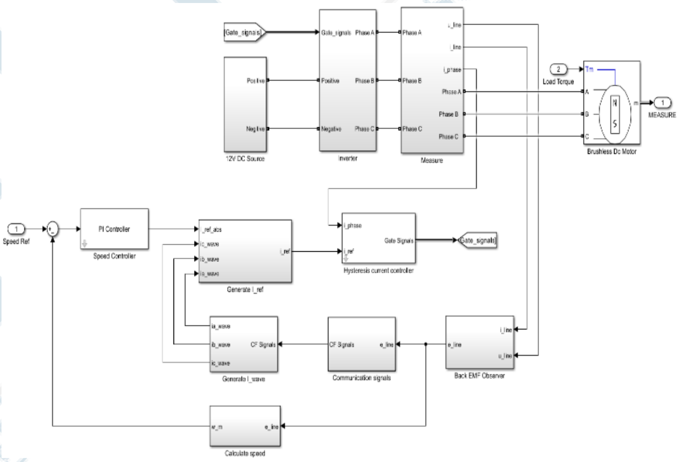

Fig 5. Simulation design of BLDC Sensor less Controller

Simulation waveforms for rotor speed can be seen in Fig 6. where the obtained speed is same as reference speed thus, motor speed is been controlled as per the reference speed. The corresponding load torque and phase current can be seen in Fig 7. and 8. respectively.

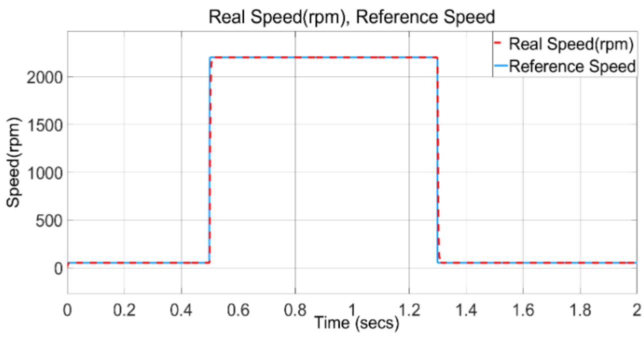

Fig 6. Simulation output of the BLDC motor Rotor Speed (RPM)

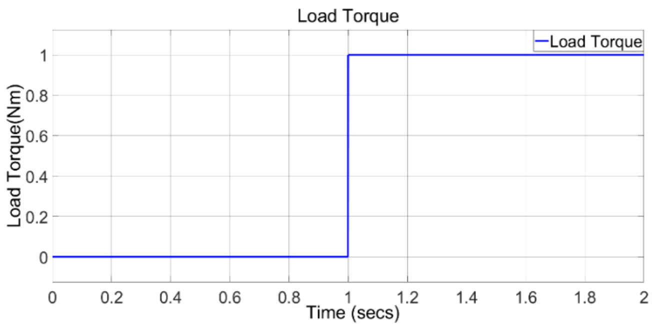

Fig 7. Load Torque (Nm)

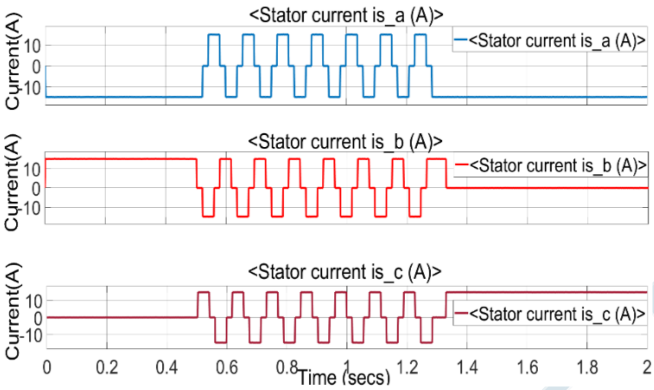

Fig 8. Phase Current(A)

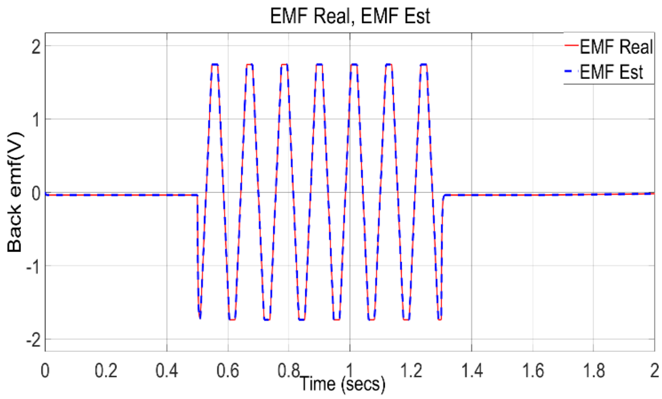

Fig 9. Simulation output of Estimated Back EMF

V. CONCLUSION

This paper presents sensor less approach of controlling the BLDC motor speed using B-EMF observer method. Sensorless method of controlling BLDC motors speed using the B-emf method offers an advantageous approach for motor control. By eliminating the need for external position sensors, the sensor less method reduces system complexity, cost and potential points of failure. Obtained results from the simulation show that the reference and obtained speed is same thereby clearly showing that the proposed system is feasible in controlling BLDC motor speed. The methodology outlined above gives a clear framework for implementing sensor less speed control. By acquiring Back EMF signal, processing it using signal processing techniques and estimating the position of rotor, accurate speed control has been achieved.

REFERENCES

[1]. Hendi Purnata, Muhamad Yusuf, Sugeng Dwi Riyanto "Closed Loop System BLDC Motor for Electric-Bike" 2020 International Conference on Applied Science and Technology (iCAST).

[2]. Shruti Sandip Ghodke, Nikita Bhole, Ajinkya Gokul Shirude "Simulation of BLDC Motor Drive for Ceiling Fan Application" 2021 IEEE Bombay Section Signature Conference (IBSSC).

[3]. Marcel NICOLA, Claudiu-Ionel NICOLA, Dumitru Sacerdoțianu "Sensorless Control of Multi-Motors BLDC using Back-EMF Observer" 8th International Conference on Modern Power Systems (MPS).

[4]. K. Alfoni Jose, Salapu Sai Ganesh, Sirasapalli Sai Kumar, Lokireddy Sunil, Yeddu Aravind Kumar, Karri Kesava "Speed Synchronization of Multiple BLDC Motor Drive using Arduino" 2023 IEEE 8th International Conference for Convergence in Technology (I2CT).

[5]. Tze-Yee Ho, Cong-Khoi Huynh, Yuan-Joan Chen, Cong-Fong Yan "The Design and Implementation of a Sensorless Delta-Connected Brushless Direct Current Motor Drive for Home Appliances". 3rd International Conference on Robotics, Control and Automation Engineering.

[6]. Dimas Arifiyan, Slamet Riyadi "Hardware Implementation of Sensorless BLDC Motor Control To Expand Speed Range" 2019 International seminar on application for technology of information and communication (iSemantic).

[7]. Hardik Khambhadiya and Asheesh Dhaneria" Sensorless control method of 3-phase BLDC motor through Bac-EMF observer" 2021 International Conference on Advances in Electrical, Computing, Communication and Sustainable Technologies (ICAECT).

[8]. Nadia Tadrist, Hocine Zeroug "Sensorless Control with Back EMF Integration Method for E-bike" 2022 International Conference of Advanced Technology in Electronic and Electrical Engineering (ICATEEE).

[9]. C. Shrutika, Sahil Matani, Siddhartho Chaudhuri, Atul Gupta, Shishir Gupta, Navdeep Singh "Back-EMF estimation based sensorless control of Brushless DC motor" 1st International Conference on Power Electronics and Energy (ICPEE-2021).

[10]. Tae-Sung Kim, Byoung-Gun Park, Dong-Myung Lee, Ji-Su Ryu, and Dong-Seok Hyun "A New Approach to Sensorless Control Method for Brushless DC Motors" International Journal of Control Automation and Systems · August 2008.