Introduction to BLDC Motors

Exploring Construction, Principles, and Applications

P.Mouni Rishitha
Power Engineering
234102110

Pexels

Introduction:

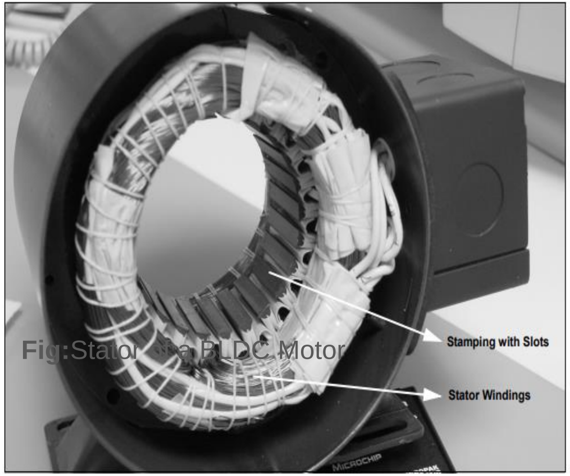


Fig:BLDC Motor

- Brushless Direct Current (BLDC) motors are one of the motor types rapidly gaining popularity. BLDC motors are used in industries such as Appliances, Automotive, Aerospace, Consumer, Medical, Industrial Automation Equipment and Instrumentation.

- As the name implies, BLDC motors do not use brushes for commutation; instead, they are electronically commutated.

P. Yedamale, "Brushless DC (BLDC) motor fundamentals", *Microchip Technology Inc.*, no. AN885, 2003.

Introduction:

Fig: Low Voltage - BLDC Motor

- Forty-eight volts, or less voltage rated motors are used in automotive, robotics, small arm movements and so on.

- Motors with 100 volts, or higher ratings, are used in appliances, automation and in industrial applications.

Figure taken from Domel company's website

Pexels

P. Yedamale, "Brushless DC (BLDC) motor fundamentals", *Microchip Technology Inc.*, no. AN885, 2003.

Advantages

BLDC motors have many advantages over brushed DC motors and induction motors

- Better speed versus torque characteristics
- High dynamic response
- High efficiency
- Long operating life
- Noiseless operation
- Higher speed ranges

P. Yedamale, "Brushless DC (BLDC) motor fundamentals", *Microchip Technology Inc.*, no. AN885, 2003.

Pexels

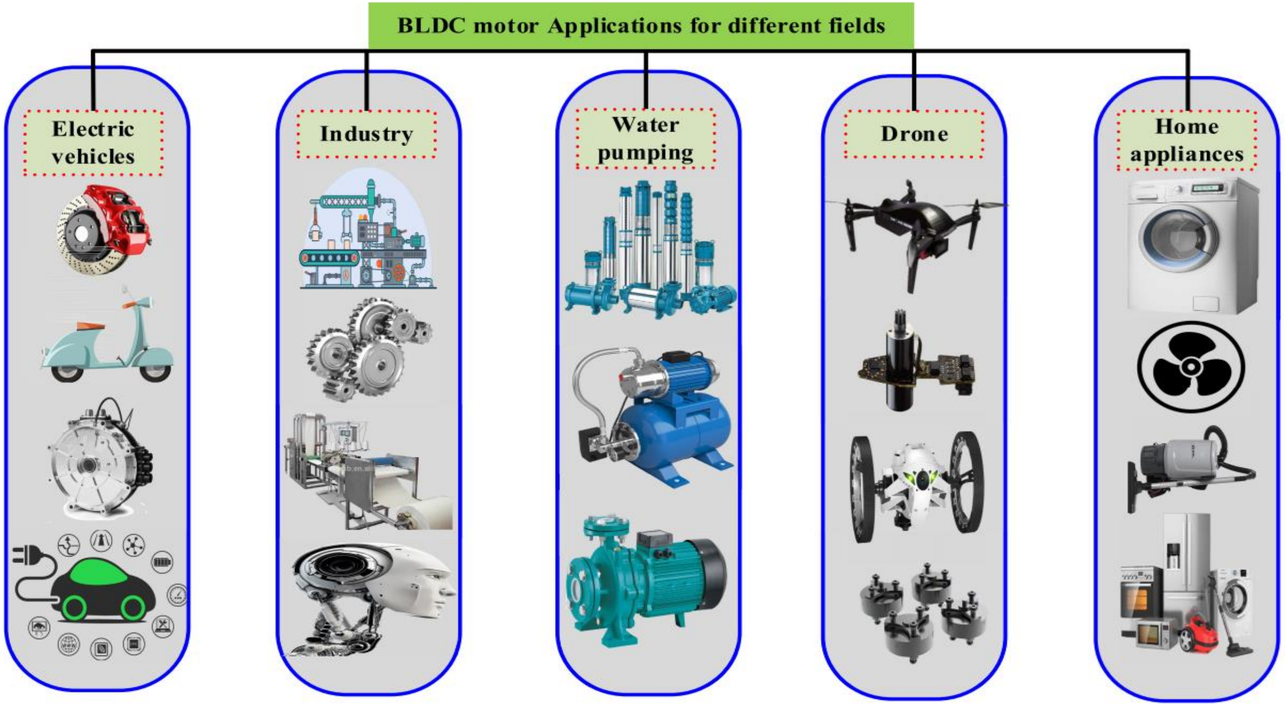


Fig: Applications of BLDC motors in diverse sector.

Mohanraj, R. Aruldavid, R. Verma, K. Sathiyasekar, A. B. Barnawi, B. Chokkalingam, and L. Mihet-Popa, ‘‘A review of BLDC motor: State of art, advanced control techniques, and applications,’’ IEEE Access, vol. 10, pp. 54833–54869, 2022, doi: 10.1109/ACCESS.2022.3175011.

Pexels

BLDC Motors: Standards and Quotation Considerations

Item #	Motor Frame Size	Number of Poles	Rated Voltage	Rated Torque	Rated Speed	Rated Power	Peak Current
☐ FH6PE40H-D3	61 x 61 mm 2.4 x 2.4 in	14	24 V	200 mN·m 28 oz·in	2000 r/min	40 W	10 A
☐ FH6PE40R-D3	61 x 61 mm 2.4 x 2.4 in	14	24 V	200 mN·m 28 oz·in	2000 r/min	40 W	10 A
☐ FH6PF20H-D3	61 x 61 mm 2.4 x 2.4 in	14	24 V	98 mN·m 14 oz·in	2000 r/min	20 W	7 A
☐ FH6PF20R-D3	61 x 61 mm 2.4 x 2.4 in	14	24 V	98 mN·m 14 oz·in	2000 r/min	20 W	9 A
☐ FH6S20H-D3	61 x 61 mm 2.4 x 2.4 in	14	24 V	98 mN·m 14 oz·in	2000 r/min	20 W	7 A
☐ FH6S20R-D3	61 x 61 mm 2.4 x 2.4 in	14	24 V	98 mN·m 14 oz·in	2000 r/min	20 W	9 A
☐ FH6S40H-D3	61 x 61 mm 2.4 x 2.4 in	14	24 V	200 mN·m 28 oz·in	2000 r/min	40 W	10 A
☐ FH6S40R-D3	61 x 61 mm 2.4 x 2.4 in	14	24 V	200 mN·m 28 oz·in	2000 r/min	40 W	10 A
☐ FHD620HD3	61 x 61 mm 2.4 x 2.4 in	14	24 V	98 mN·m 14 oz·in	2000 r/min	20 W	7 A

Fig: From Elinco International, Inc. Japanese Products Corp.

Pexels

https://www.e-jpc.com/brushless-dc-motors/

BLDC Motor Type	Speed Range (RPM)	Torque Range (Nm)	Power Range (Watts)	Cost Range (INR)
Low-end	1000-3000	0.1-0.5	50-200	1000-5000
Medium-range	3000-6000	0.5-1.5	200-500	5000-15000
High-performance	6000-12000	1.5-5	500-1500	15000-50000
Industrial-grade	12000+	5+	1500+	50000+

Speed Range (RPM): Indicates the operational speed range of the motor.

Torque Range (Nm): Shows the torque output range of the motor.

Power Range (Watts): Represents the power output range of the motor.

Cost Range (INR): Provides an estimated cost range in Indian Rupees for each type of BLDC motor, considering general market prices.

Pexels

Stator

Sinusoidal Back EMF

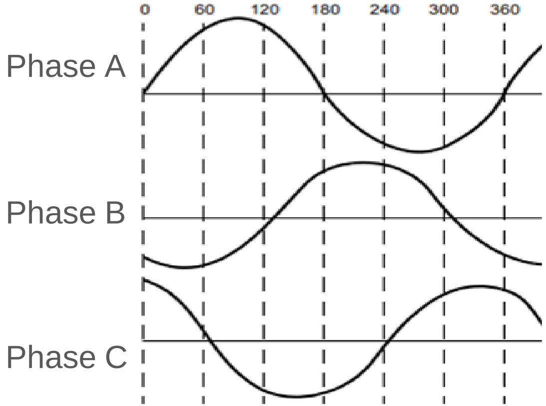


Fig: Sinusoidal Back EMF of BLDC Motor

There are two types of stator windings variants:

- trapezoidal
- sinusoidal motors.

This differentiation is made on the basis of the interconnection of coils in the stator windings to give the different types of back Electromotive Force (EMF).

P. Yedamale, "Brushless DC (BLDC) motor fundamentals", *Microchip Technology Inc.*, no. AN885, 2003.

Stator

Trapezoidal Back EMF

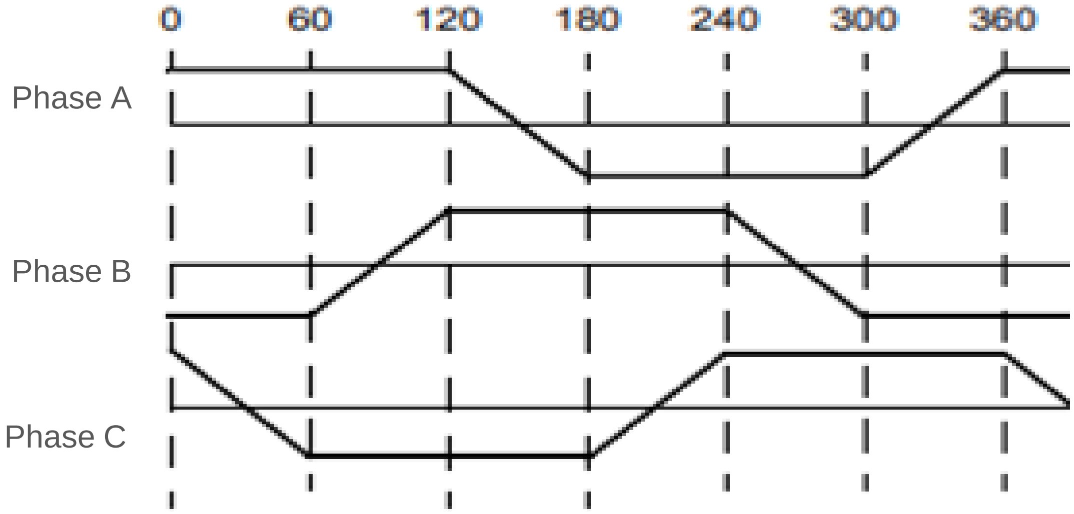
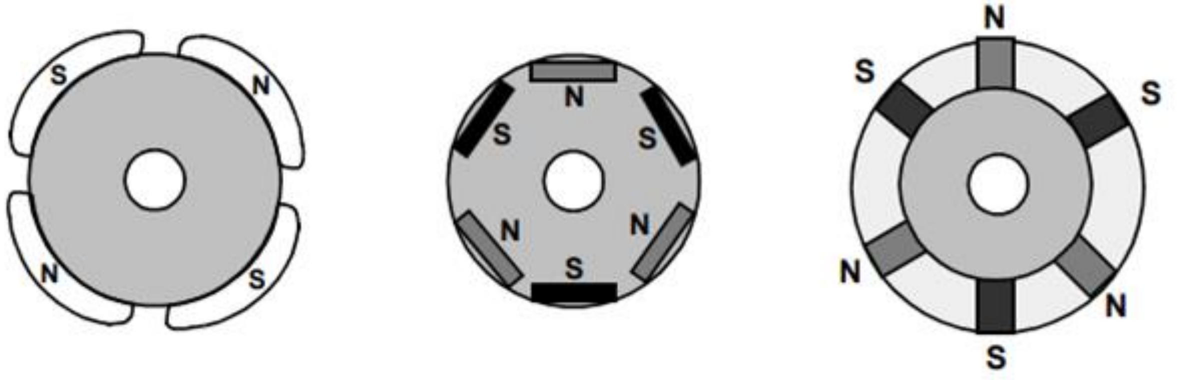


Fig: Trapezoidal Back EMF of BLDC Motor

P. Yedamale, "Brushless DC (BLDC) motor fundamentals", *Microchip Technology Inc.*, no. AN885, 2003.

Rotor

The rotor is made of permanent magnet and can vary from two to eight pole pairs with alternate North (N) and South (S) poles.



Circular core with magnets on the periphery

Circular core with rectangular magnets embedded in the rotor

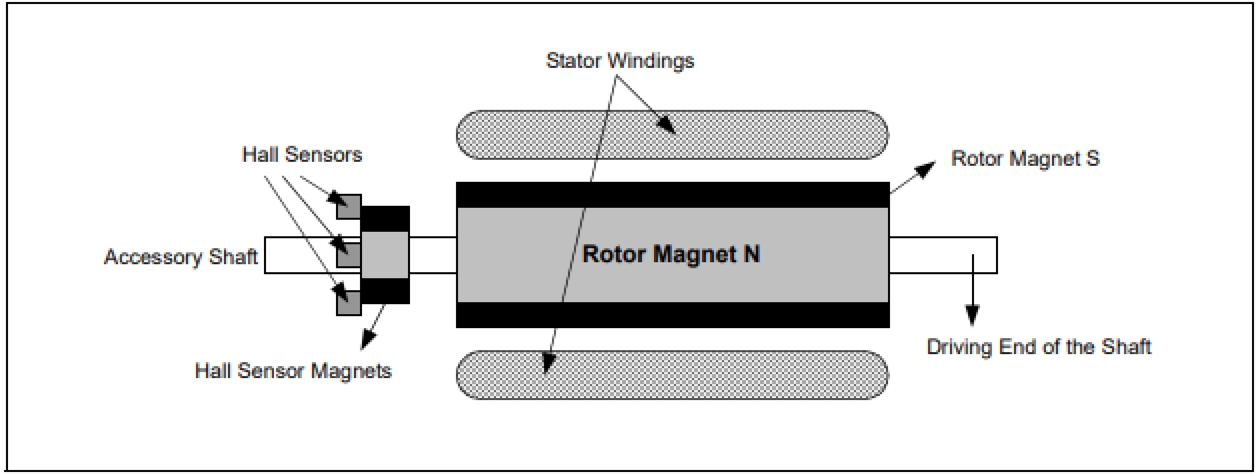
Circular core with rectangular magnets inserted into the rotor core

Fig: Types Of Rotors in BLDC Motor

P. Yedamale, "Brushless DC (BLDC) motor fundamentals", *Microchip Technology Inc.*, no. AN885, 2003.

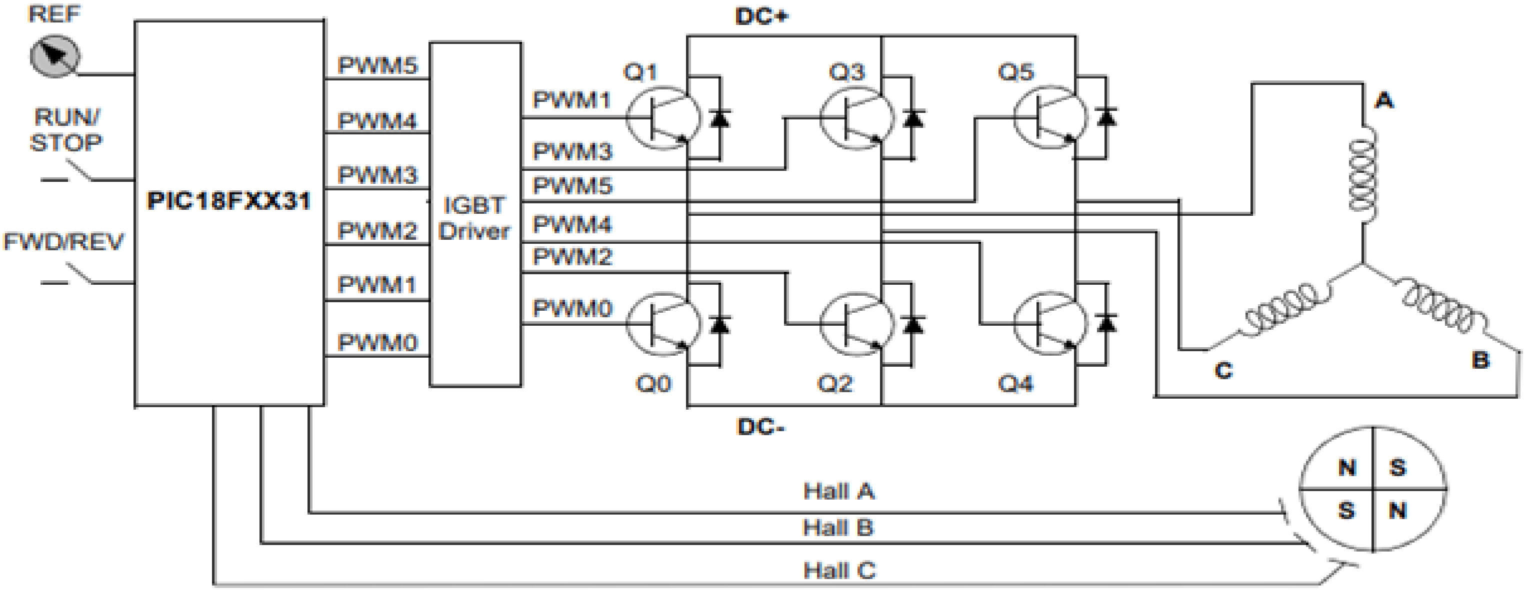
BLDC MOTOR TRANSVERSE SECTION

The Hall sensors require a power supply. The voltage may range from 4 volts to 24 volts. Required current can range from 5 to 15 milliAmps.



P. Yedamale, "Brushless DC (BLDC) motor fundamentals", *Microchip Technology Inc.*, no. AN885, 2003.

BASIC CIRCUIT DIAGRAM:



P. Yedamale, "Brushless DC (BLDC) motor fundamentals", *Microchip Technology Inc.*, no. AN885, 2003.

BASIC CIRCUIT DIAGRAM:

Sequence	Hall Sensor Input	Active PWMs	Phase Current (ABC)
1	100	PWM1(Q1), PWM4(Q4)	DC+ (A), Off (B), DC- (C)
2	110	PWM1(Q1), PWM2(Q2)	DC+ (A), DC- (B), Off (C)
3	010	PWM5(Q5), PWM2(Q2)	Off (A), DC- (B), DC+ (C)
4	011	PWM5(Q5), PWM0(Q0)	DC- (A), Off (B), DC+ (C)
5	001	PWM3(Q3), PWM0(Q0)	DC- (A), DC+ (B), Off (C)
6	101	PWM3(Q3), PWM4(Q4)	Off (A), DC+ (B), DC- (C)

T. Nama, A. K. Gogoi, and P. Tripathy, “Application of a smart hall effect sensor system for 3-phase bldc drives,” in 2017 IEEE International Symposium on Robotics and Intelligent Sensors (IRIS), 2017, pp. 208– 212.

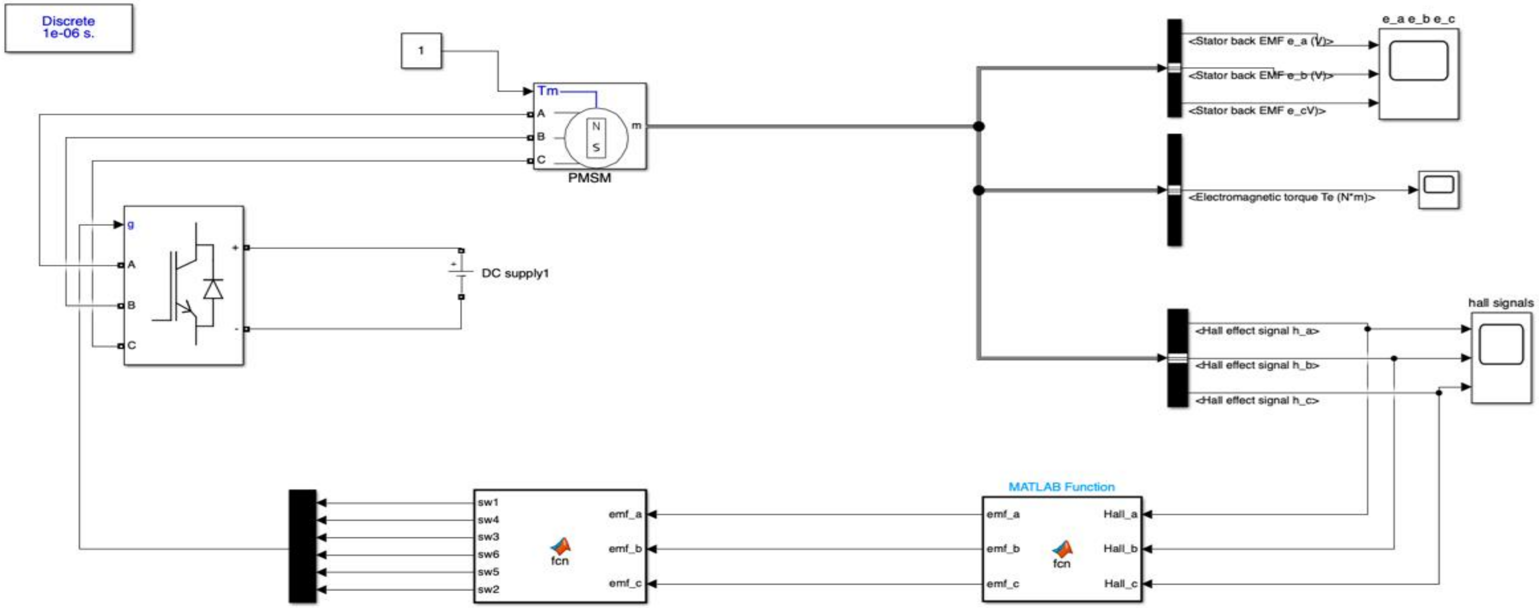
Pexels

SIMULATIONS:

Parameter	Value
Type	BLDC
Continuous Power Rating	1 KW
Input Voltage	48 V DC
Rated Current	21 Amps
Rated Torque	3.2 N.m
Viscous damping coefficient B	0.002 [N.m/(rad/sec)]
Moment of inertia J	0.004 [kg.m2]
Stator Phase Resistance	4 mΩ
Stator Phase Inductance	23 μH

Pexels

SIMULATIONS:
Trapezoidal Commutation



Pexels

SIMULATIONS:

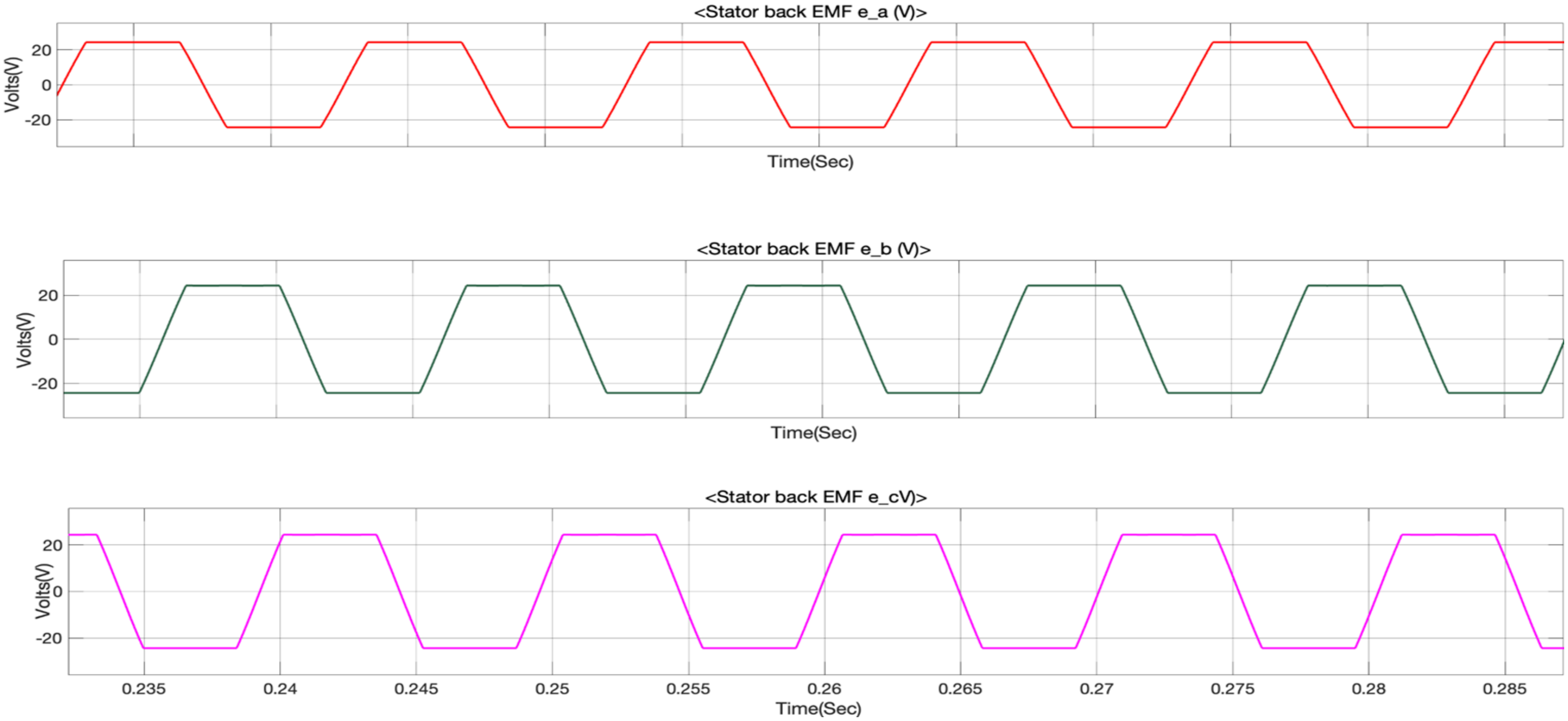


Fig: **BACK EMF**

Pexels

SIMULATIONS:

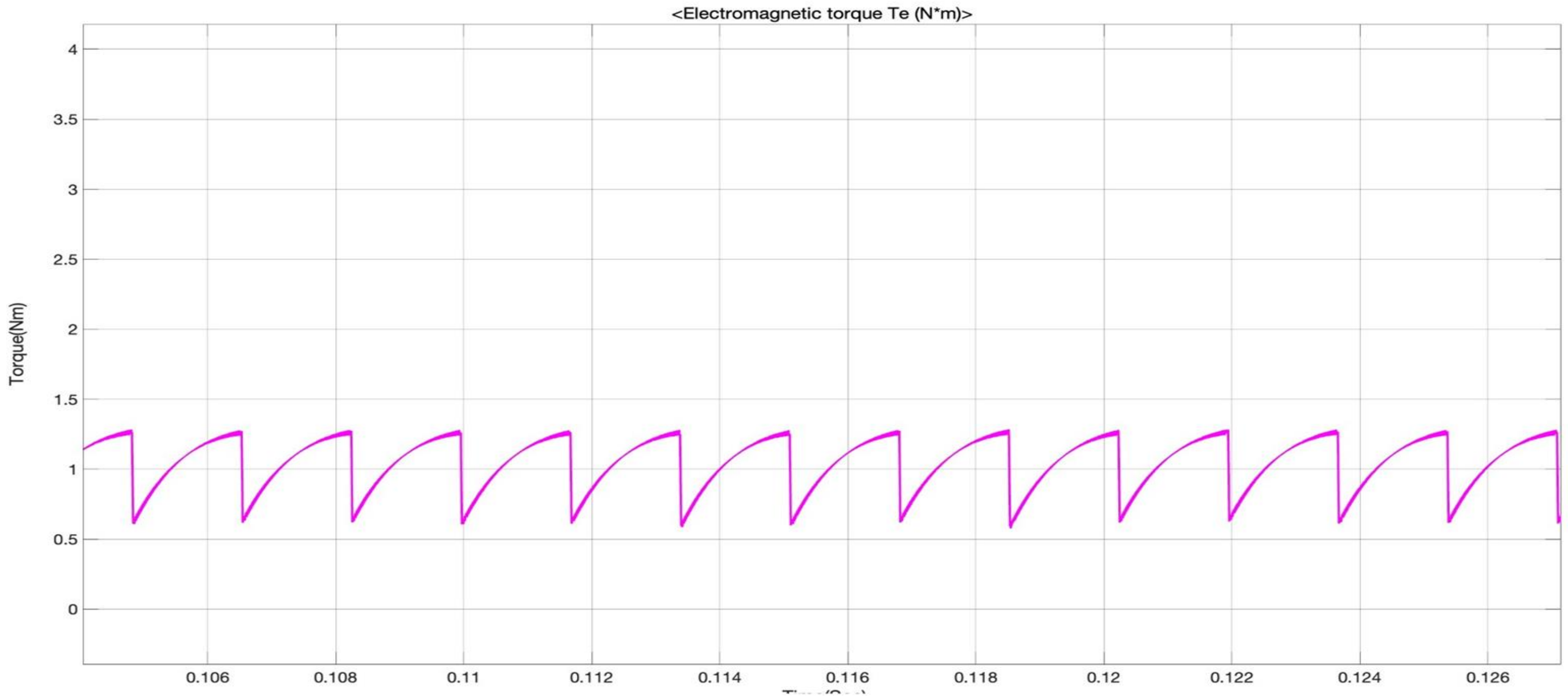


Fig: **OUTPUT TORQUE**

Pexels

SIMULATIONS:Trapezoidal

Each phase current is either positive, negative, or zero during each 60-degree interval.

Advantages of Trapezoidal Control:

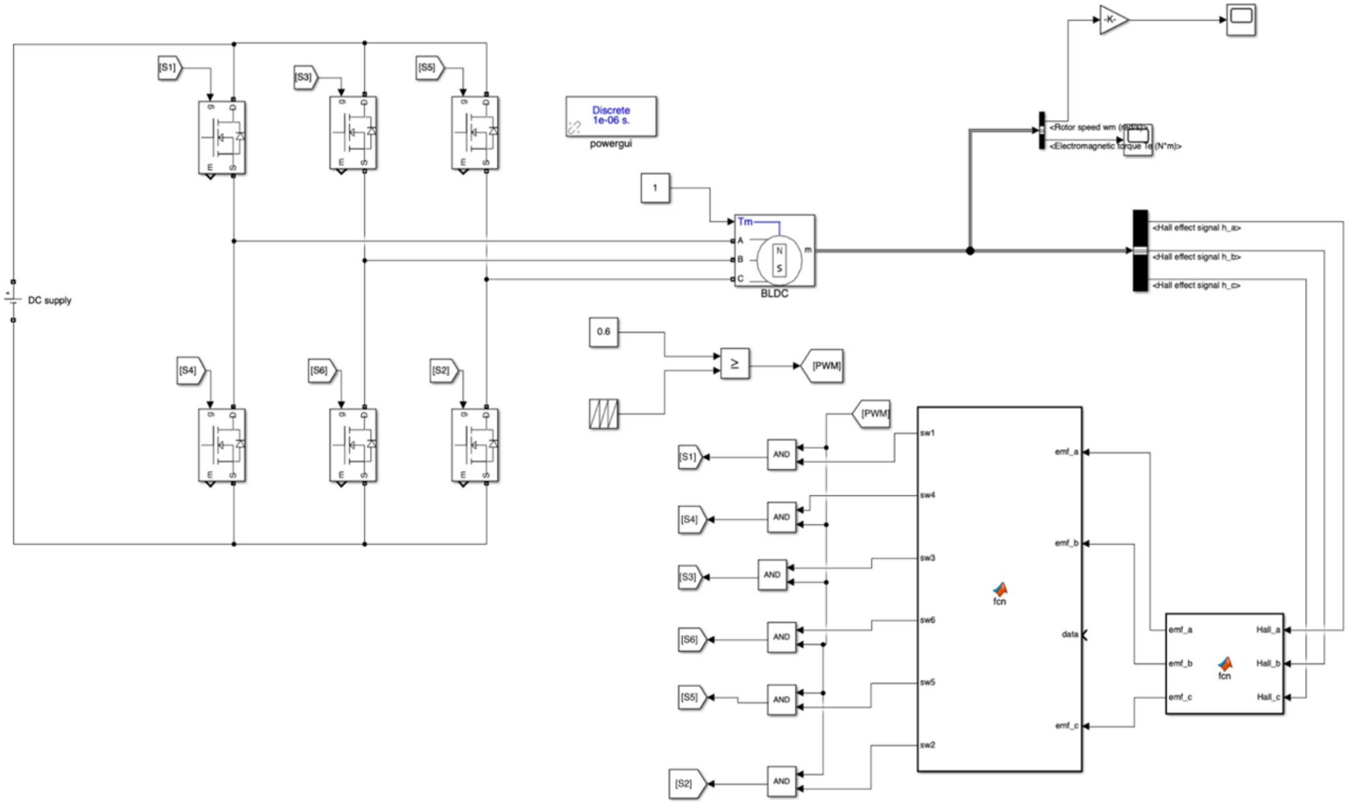
- Low cost
- Simple implementation
- Supports high-speed operation
- Efficient high torque delivery due to maximum allowable voltage application

Disadvantages:

- Torque ripple
- Audible noise

S. G. Maiya, S. Holla, S. Patil, G. Patil, S. Angadi, and A. Raju, “Trapezoidal speed control of bldc motor,” in 2022 International Conference on Smart Generation Computing, Communication and Networking (SMART GENCON), IEEE, 2022, pp. 1–5

PWM Control:



Pexels

PWM Control:

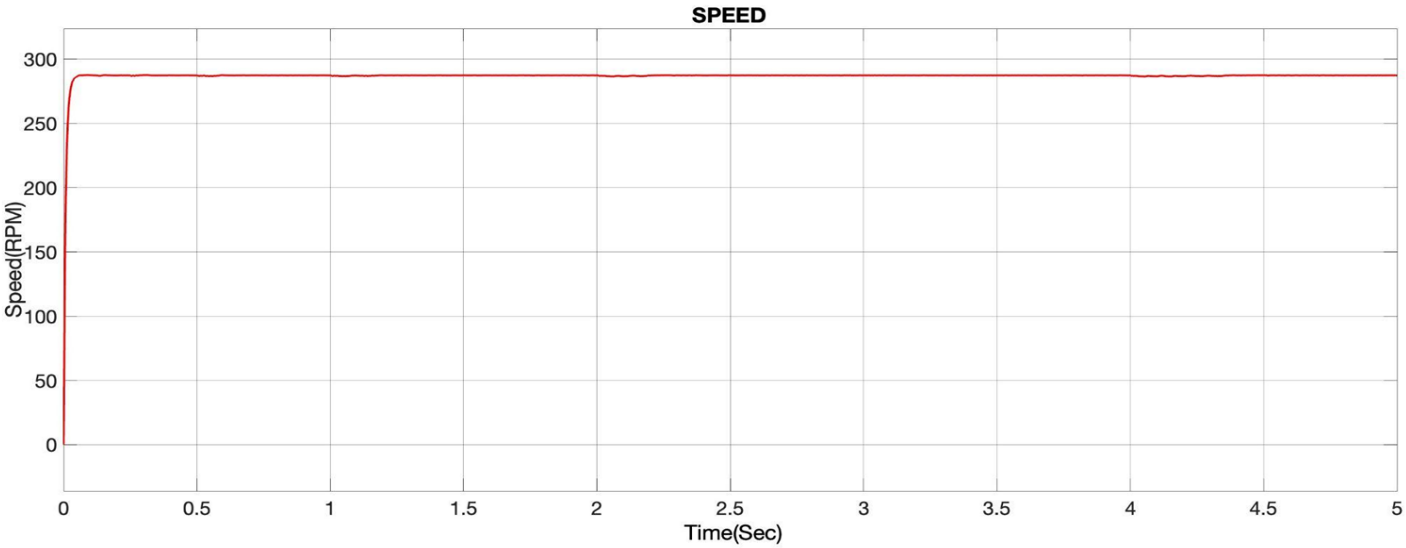


Fig:Duty=0.8

Pexels

PWM Control:

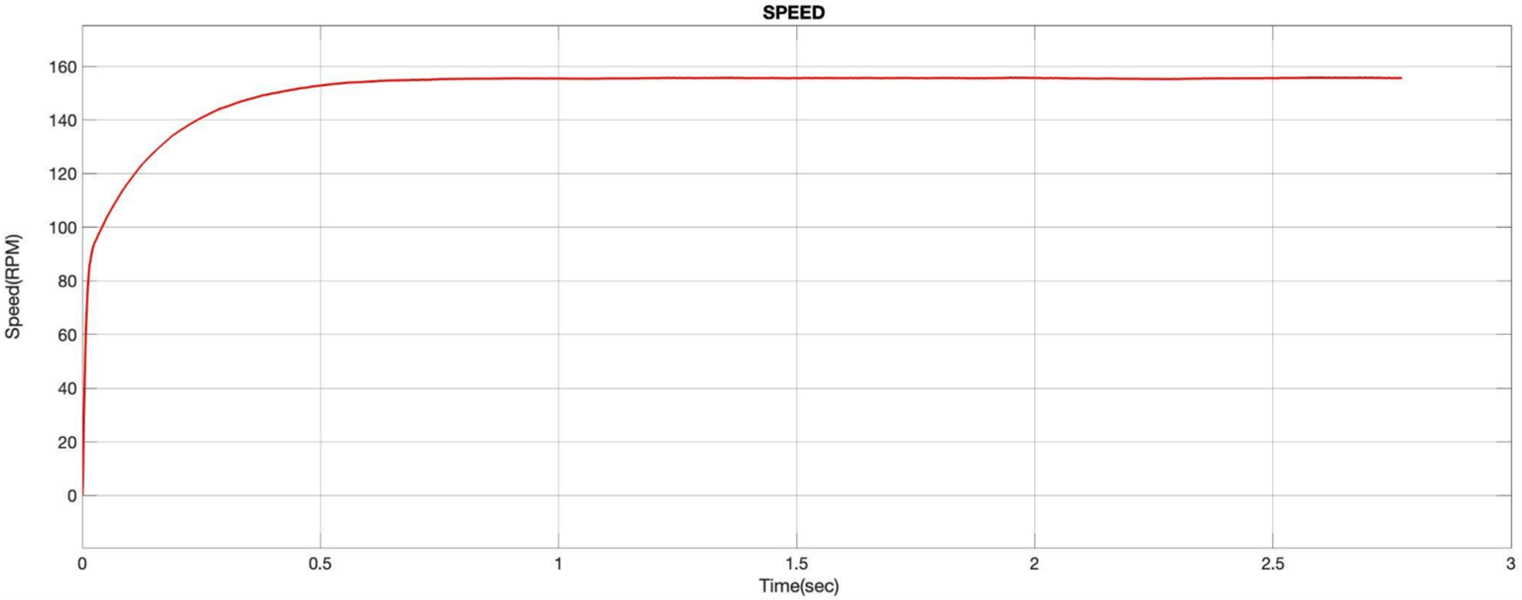


Fig:Duty=0.6

[Pexels](https://www.pexels.com)

PWM Control:

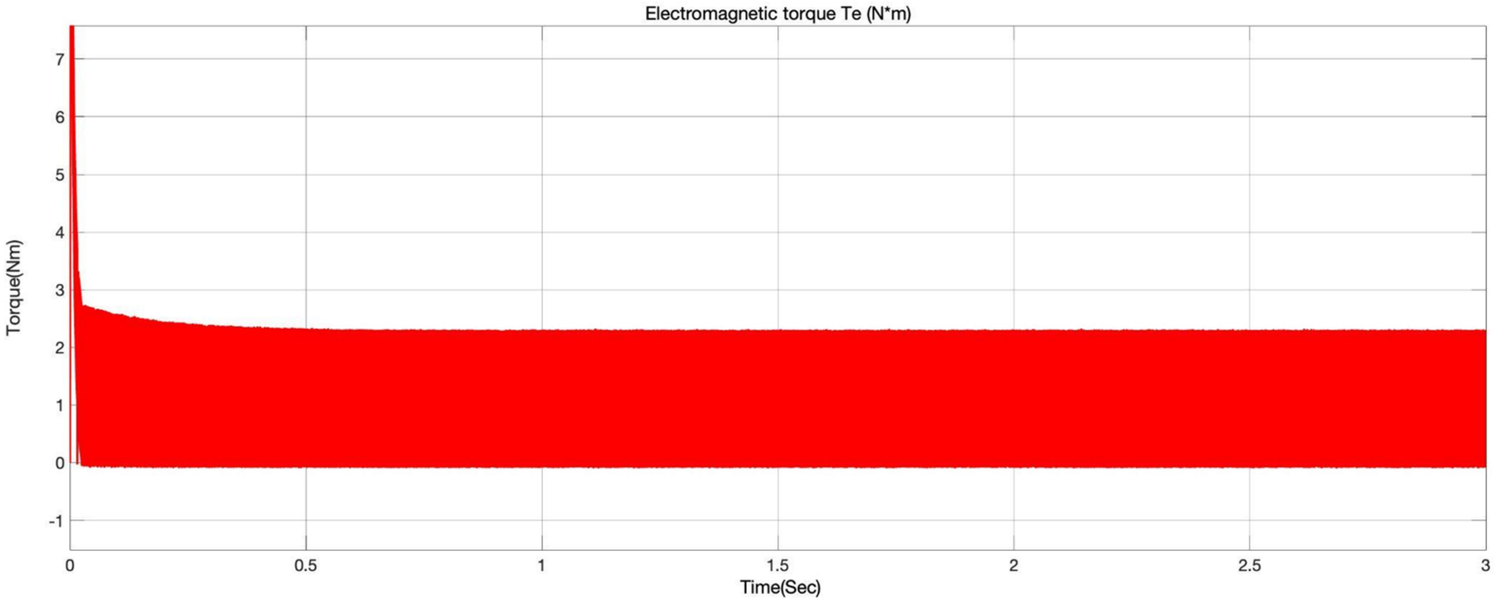


Fig: Torque

[Pexels]

PWM Control:

Advantages:

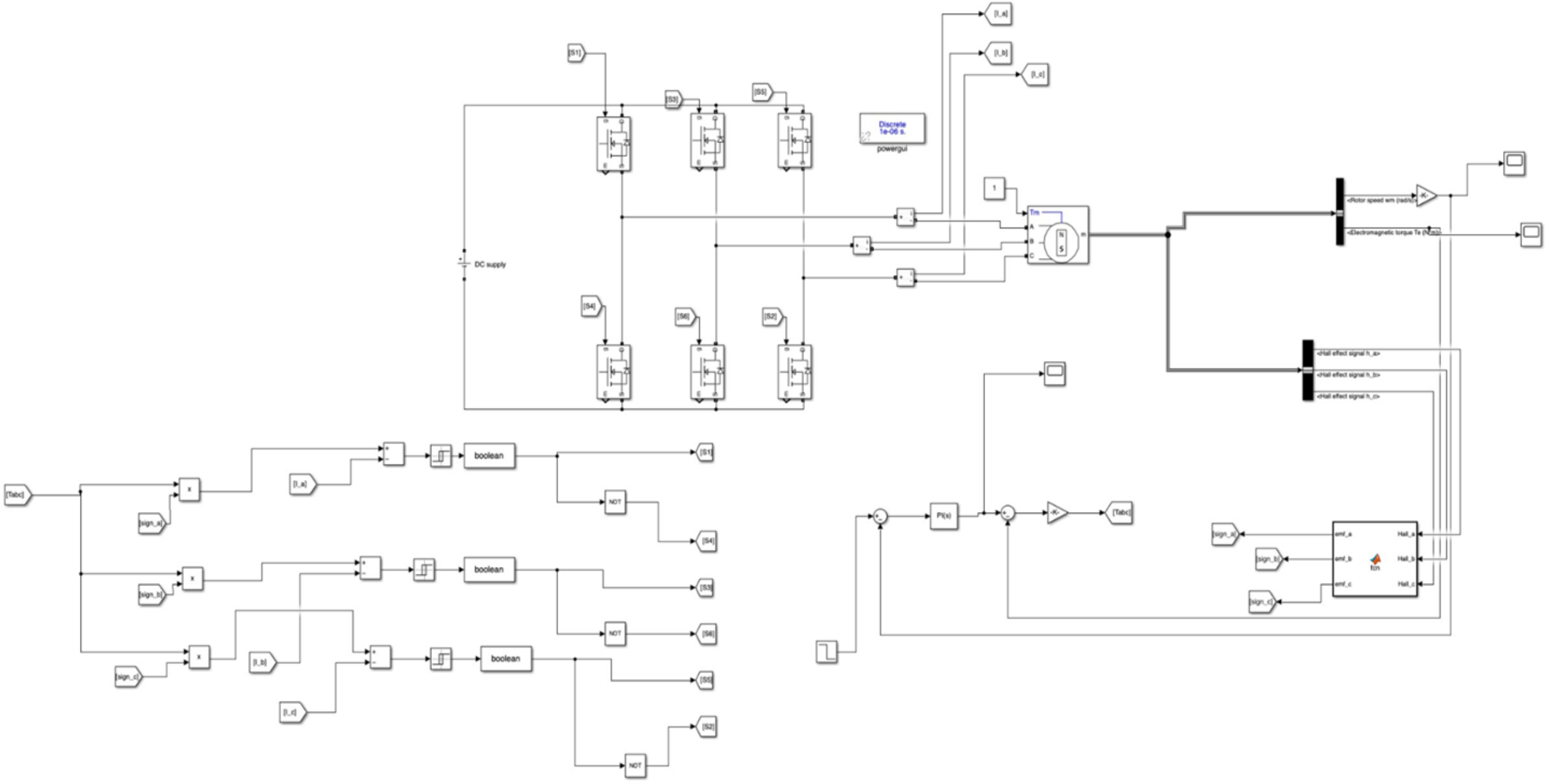
- Low noise
- Easier to implement than FOC

Disadvantages:

- Switching losses
- Poor dynamic load performance
- Lower maximum speed

G. Gupta and M. Sreejeth, “Comparative analysis of Speed control of BLDC motor using PWM and Current Control Techniques,” 2022 IEEE IAS Global Conference on Emerging Technologies, GlobConET 2022, pp. 610–614, 2022, doi: 10.1109/GLOBCONET53749.2022.9872173.

Hysteresis Current Control



Pexels

Hysteresis Current Control

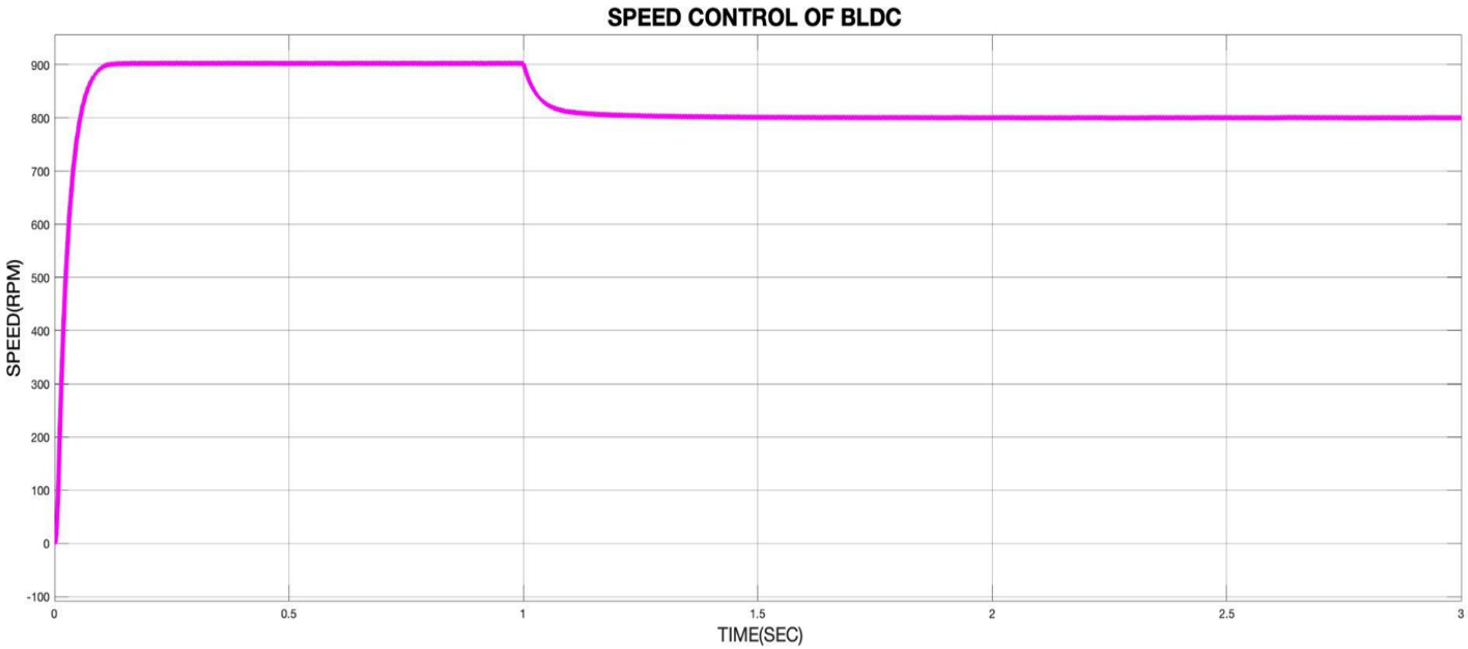


Fig: SPEED

Pexels

Hysteresis Current Control

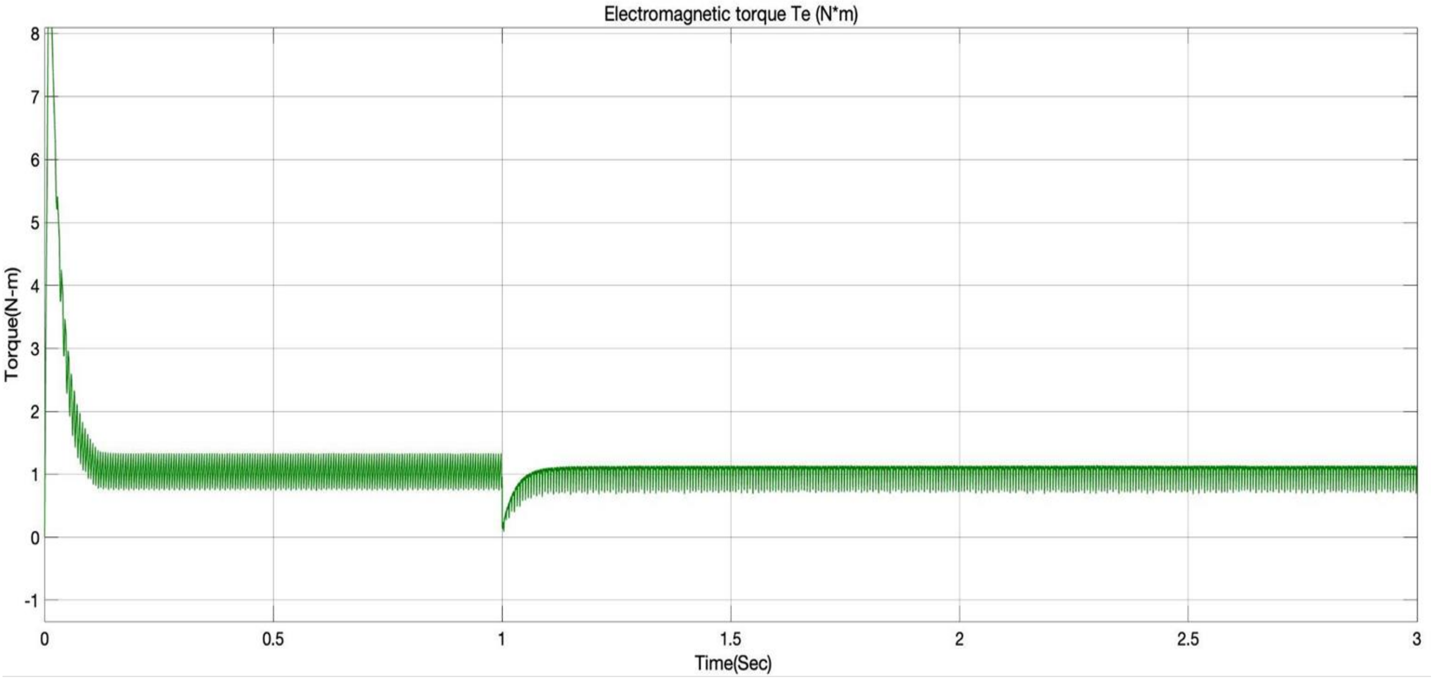


Fig: OUTPUT TORQUE

Pexels

Hysteresis Current Control

Advantages :

- High power output
- Low noise
- Less torque ripple as compared with PWM
- Inherent Overcurrent Protection
- Good motor efficiency

Disadvantages:

- Costly because of Current Sensors
- Complex as compared with PWM

S. K. Chari, R. Dhiman and R. Saxena, "Novel and Robust Hysteresis Current Control Strategies For a BLDC Motor: A Simulation Study and Inverter Design," 2018 2nd IEEE International Conf. on Power Electr., Intelligent Control and Energy Systems (ICPEICES), pp. 841-846, 2018.

Pexels

THANK YOU

Pexels