# Electrical Vehicle Powered by BLDC Motor

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**Abstract: The best alternative for e mobility is electric-based transportation. The importance for electrical transportation increasing rapidly throughout the world due to the decrease in conventional fuels like petrol and diesel. In India, still, most of the transportation is using the conventional I.C. engine vehicles only. According to the surveys, it may take five to ten more years to replace all the existing vehicles with electric vehicles.**

**An electric vehicle or drive train requires several subsystems such as the battery, charging circuit, motor drive, converters, and other controlling circuits. Out of all the subsystems, the vital system in a vehicle is the electrical motor used in the electrical vehicle design. Several motors are available such as a three-phase induction motor, synchronous motor, reluctance motor, and brushless D.C. motor.**

**Out of all the motors, the more suitable motor for electric vehicle applications is the BLDC motor, which provides high torque under starting and running conditions. Hence, the vehicle will be effective by employing the BLDC motor. In this project, the model of the BLDC based electric vehicle is created, and the output waveforms are presented. The model of the vehicle is created in MATLAB/SIMULINK. The vehicle is operated under various conditions. The output waveforms of various subsystems are obtained.**

**Keywords: BLDC Motor, Electrical Vehicle, D.C Motor, Drive Train.**

## 1.INTRODUCTION

In recent years, the emphasis on electric vehicles is increasing rapidly. There are several reasons for it. Few among are the increase in pollution caused bythe conventional I.C. engines, reduction in the fuel availability, etc.

It can be observed that the usage of electric vehicles worldwide is increasing. From 2010 to 2020, there is an enormous increase in the number of electric vehicles under operation.

Millions of vehicles will be coming onto the roads every day and every year. The European countries, America, and other developed countries are mostly adopting electric vehicles only. Most developing countries also aim to increase the number of electric vehicles where ever there is a possibility. The lack of promising technologies is also one reason for the slight slow increase in electric vehicles in developing countries.

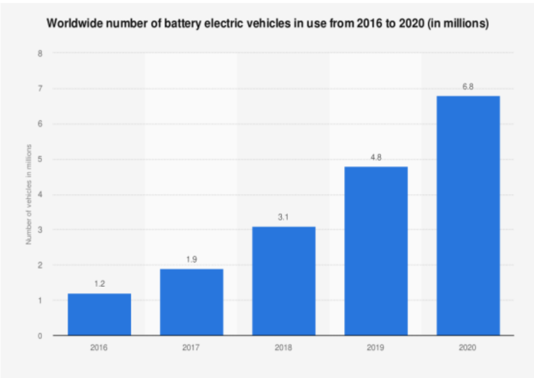



Fig.1 world-wide number of battery vehicles

There is a rapid increment in electric vehicles worldwide, which is 1.2 million vehicles in 2016 to 7 million electrical vehicles in 2020. This shows the interest of the world in electric transportation.

### 1.1 Electrical Vehicles:

The first electrical vehicle was used in the year 1881. The electric vehicle concept is not very new, but the developments in the vehicle sectors are not much in the 1980s. The below figure shows the various parts and subsystems in the electric vehicle.

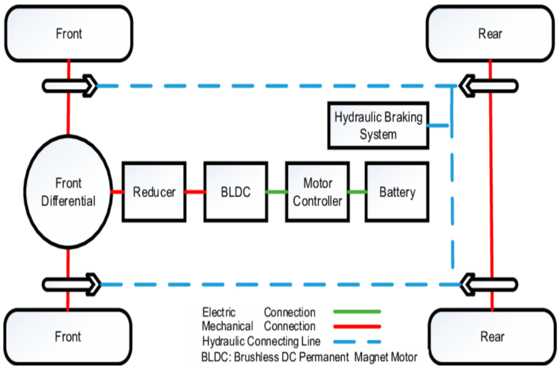



Fig. 2 Electrical vehicle structure

1.2 Battery Vehicles:

A rechargeable battery is fixed in the electric vehicle. This will supply power to the motor. In between the motor and the battery, several power converters will be used. This type of vehicle is the simplest form of an electric vehicle. These types of vehicles are presently running on roads in India. As of today, most of the electric vehicles we see are battery-operated electric vehicles only.

1.3 Hybrid vehicles:

Hybrid vehicles use two or more power sources. This means they employ a conventional I.C. engine along with the battery system with an electric motor.

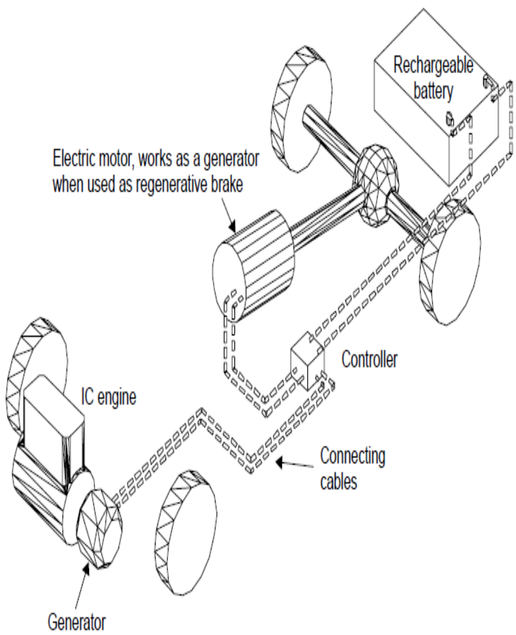



Fig.3 Series hybrid vehicle layout.

## 2. LITERATURE REVIEW

In this section, the related work that is available in past literature is presented. This will give a good insight into the work to be continued in the present and future. Several research papers are available related to the present work. Some of those essential papers are considered here, and the work done is presented in this section.

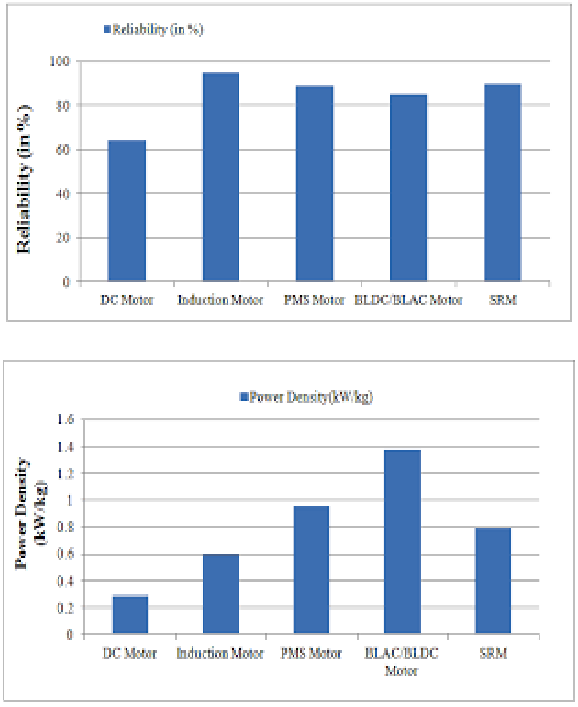



Fig. 4 :Comparison of various motors for E.V. applications.

The above table shows the comparison of various motors that can be used for electric vehicle applications. The comparison is made in terms of power density and reliability. From the above table, it can be seen that the BLDC motor is more suitable than other machines for vehicle applications.

## 3. MODELLING OF BLDC MOTOR

In this section, all the aspects related to the BLDC motor are presented. The construction, operation, losses, operating characteristics, torque issues, control methods, and machine modeling are included here.

These machines consist of trapezoidal-shaped back emf, which are easy to control compared to the other motors. Hence, these machines became famous for the applications of electric vehicles.

3.1 Construction and Operation of BLDC Motor:

The construction of the BLDC motor is similar to the A.C. induction motor. This motor is also simple in construction and easy to control.

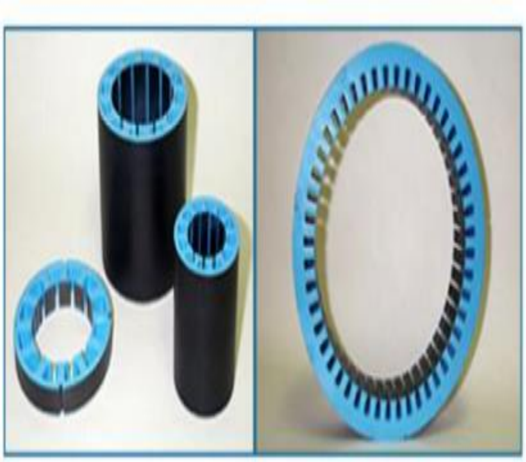


Fig. 5 Slots in the stator

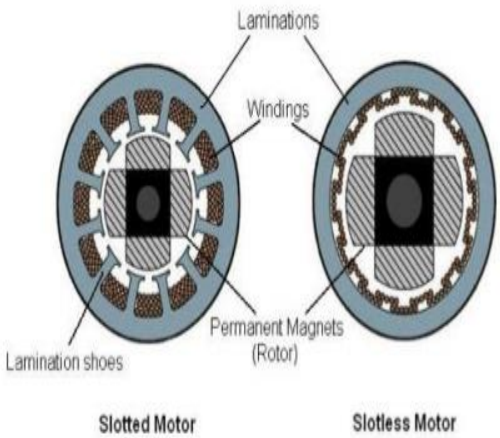



Fig. 6 Two types of stators.

The BLDC consists of the following parts

- Stator
- Rotor

The stator can be either with slots or without any slots. Laminated steel is used in the design of the stator to increase the magnetic flux density.

Fig.7. 4 pole/ 8 pole rotor.

The above figure shows the rotor structure with permanent magnets in a BLDC motor. It can be with any number of poles depending on the rating of the machine. Here, the four-pole and the eight-pole rotor are shown in the figure.

The operation of the BLDC motor takes place electronically. Continuous energization of stator windings is necessary for the rotation of the rotor in BLDC. For this, it requires the estimation of rotor position. The more accurate position sensing method will give more accurate control of the motor. That's why the rotor position estimation plays a vital role in the operation of the BLDC motor.

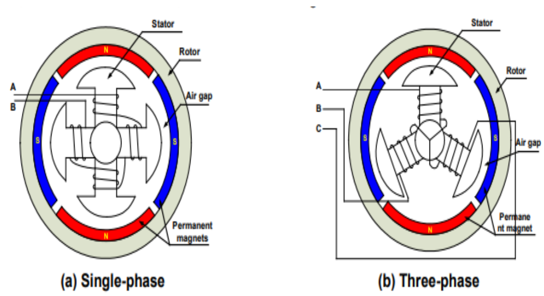



Fig. 8: Single phase and Three phase Stator connections in BLDC Motor.

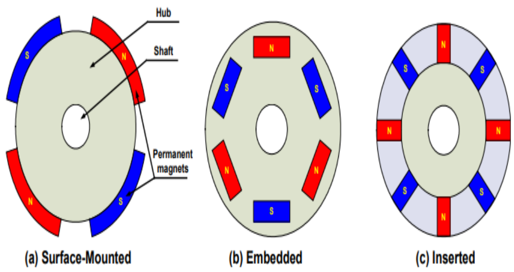



Fig. 9 Rotor Magnets in BLDC Motor.

### 3.2 Torque – Speed Characteristics of BLDC Motor:

Characteristics of the motor are vital parameters to choose the motor for a specific application. The characteristics must match with the particular application for the smooth operation of the vehicle.

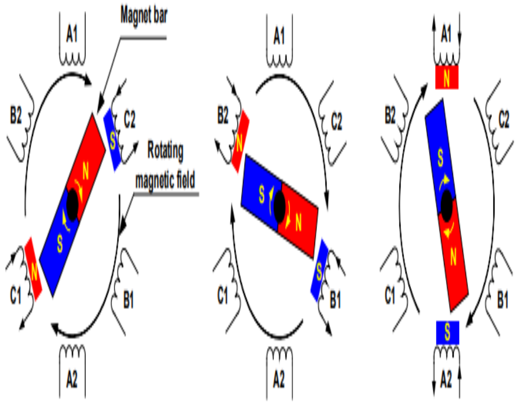



Fig. 10: Rotor at various positions.

The following plot shows the torque-speed characteristics of the BLDC motor

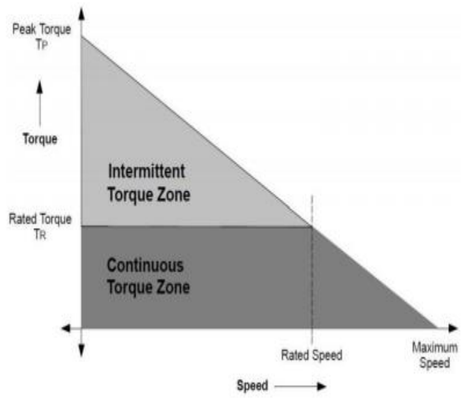



Fig. 11: Torque Speed Characteristics of BLDC Motor.

The above figure shows the torque-speed characteristics of the BLDC motor, which consists of two zones named, intermittent zone and the continuous zone. In the intermittent zone, the magnitude of the torque is high and consistently above the rated torque. In the continuous zone, the torque is near the rated value.

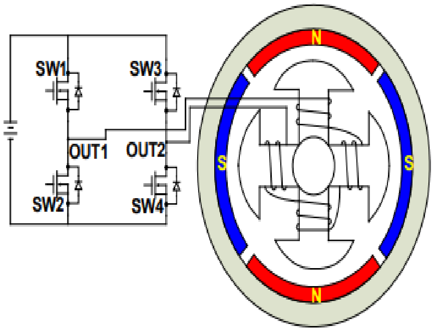



Fig. 12 BLDC with Converter.

This drive requires six phases of position sensing to operate in various regions like constant torque and constant speed. To control the speed, the reference speed will be set, and then the rotor is controlled to obtain the reference speed using the chosen control method.

Various speed control mechanisms are

- FOC (Field Oriented Control) method
- DTC (Direct Torque Control) method
- Hysteresis Control method

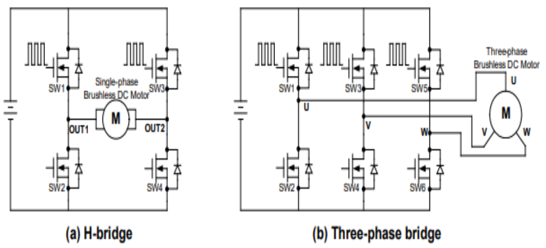



Fig. 13: Driving Circuit for a BLDC motor

The above circuit shows the driver circuit employed in the control and operation of BLDC motor for electrical vehicle applications. A single-phase converter is required for a single-phase motor

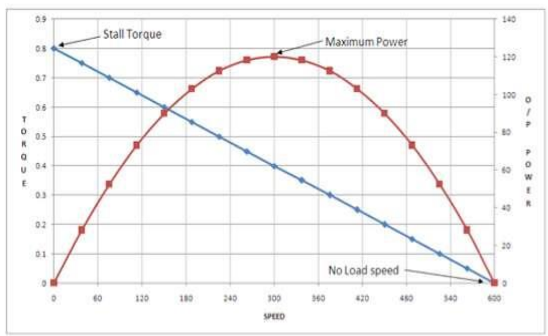



Fig. 14 Speed – Torque – Power Characteristics of BLDC Motor

Specifically, due to the increased demand for electric vehicles, the usage of the BLDC motors for electric vehicle applications is increasing due to their suitability and sound characteristics.

The modelling and control-related aspects of the BLDC motor are presented in this chapter. The detailed modelling and its normalization are also included. Bothe the operation of single-phase, as well as three-phase machines, are considered and presented. The driving circuits are also emphasized.

## 4. CONTROL OF BLDC MOTORS

The Various control methods can be applied for the control of BLDC motors for the electric vehicle application purpose. The single method will not provide all the advantages required for an electric vehicle. There are merits and demerits for every control technique that is employed for BLDC motor control. In this chapter, various control methods that are employed for brushless D.C. motors are presented.

If the synchronous motor is excited by the D.C. supply, it is called the BLDC motor. It requires the exact estimation of the rotor position for its operation. Following are the various configurations in electric vehicles, which require several types of control methods or mechanisms.

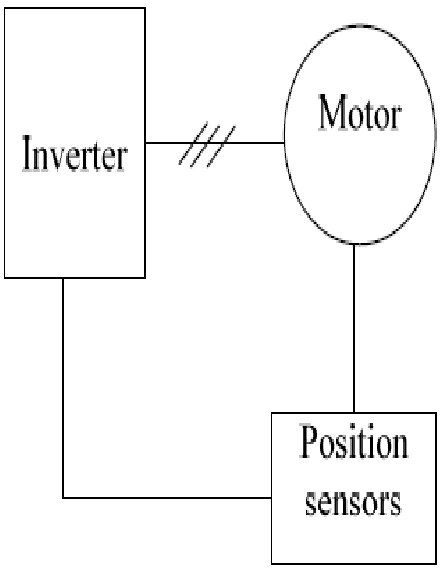



Fig. 15: Block diagram for control BLDC motor.

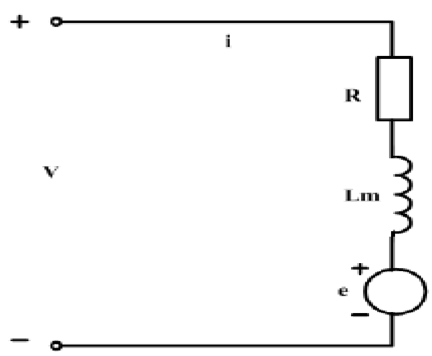



Fig.16: Equivalent circuit of BLDC motor

### 4.1 CSI Based Drive Circuits:

Following are the current source inverter-type driver circuits for the BLDC motor.

- Buck type converter
- Load commutated type converter
- Cuk type converters

The below figures show the configurations of the various current source inverter type driver circuits

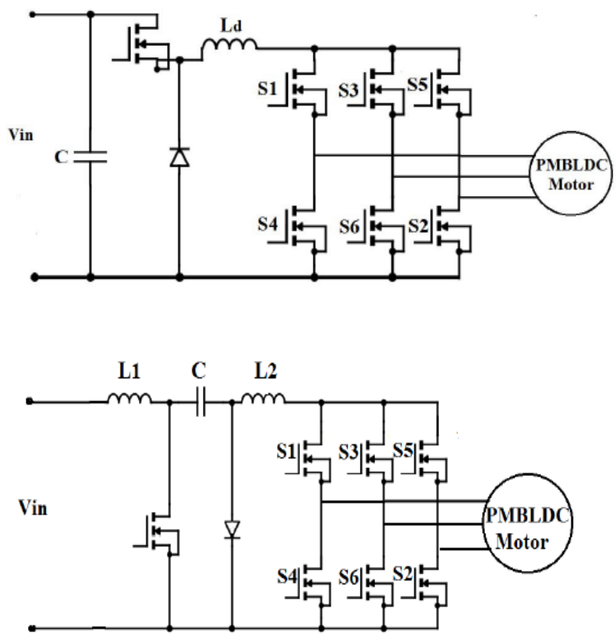



Fig. 17: Buck and cuk type driver circuits.

### 4.2 VSI Based Drive Circuits:

The operation and control of the current source inverter are complex compared to the voltage source converters. The design of voltage source converters is simple, and many control methods are available. Following are the voltage source converter-based driver circuits available for control of the BLDC motor.

- Half-bridge circuits
- Full bridge circuits
- H bridge circuits
- C – Dump circuits
- Four switch-type circuits.

The circuit configurations for every type of driver circuit are shown in the figures below.

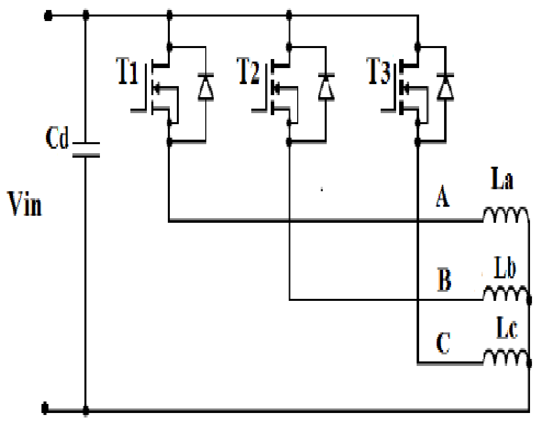



Fig. 18: Half bridge-type driver circuits.

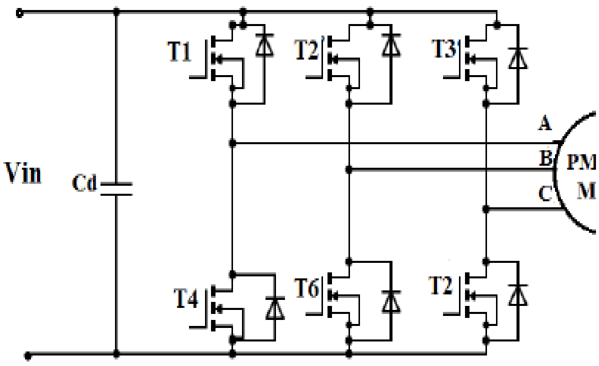



Fig.19: Full Bridge type driver circuits.

The main difference between the half and full-bridge circuits are the number of switches in the Converter. A complete bridge circuit requires converters.

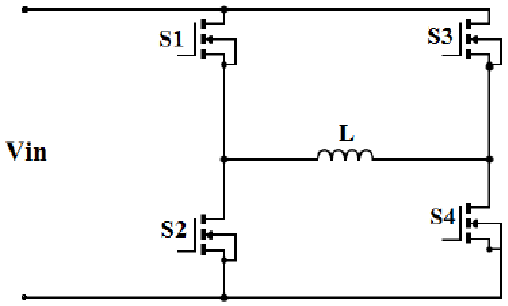



Fig.20: H-Bridge type driver circuits.

Out of all the configurations, the H bridge circuits are straightforward to design, and many control methods can be applied to these circuits. Following are the advantages of the H bridge circuits.

- Good quality voltage
- Low harmonic contents
- Low EMI.
- High-frequency operation.
- High efficiency.

## .5. Simulation Results of BLDC Motor

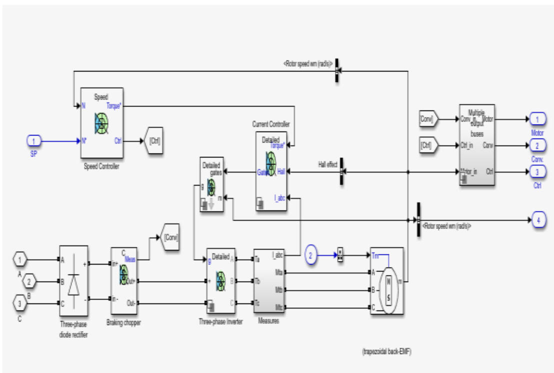


Fig. 21: Complete model of BLDC Motor in SIMULINK.

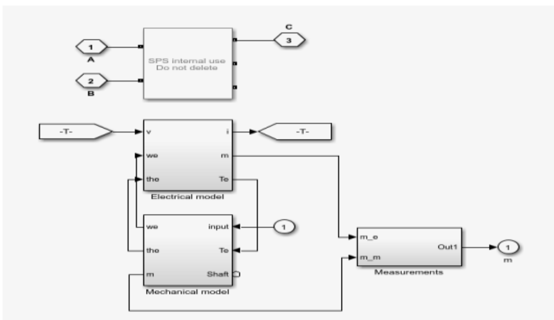
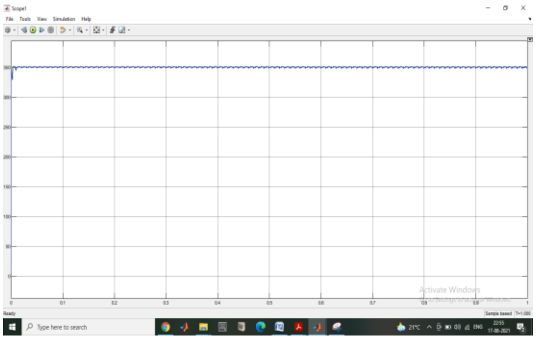
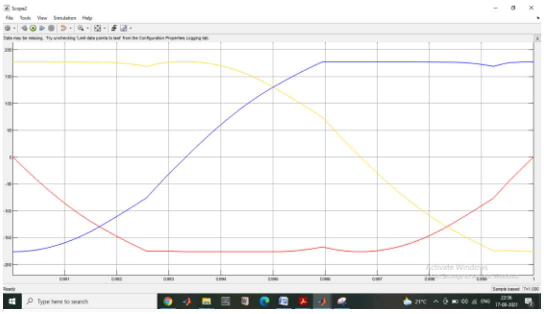



Fig.22: Electrical and Mechanical parameters of BLDC in SIMULINK

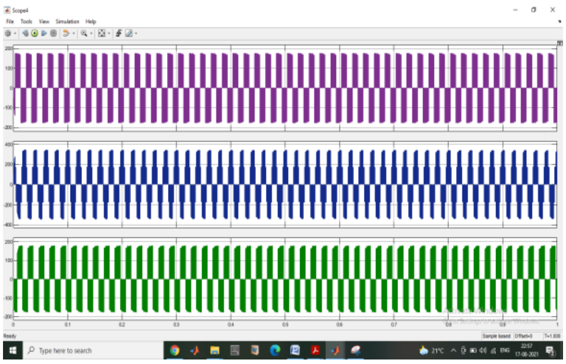
5.1 Output waveforms:



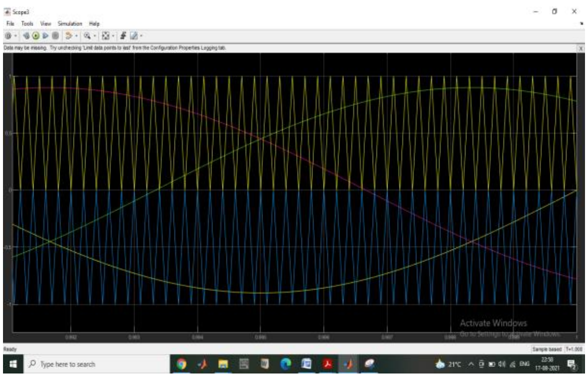
D.C. bus voltage



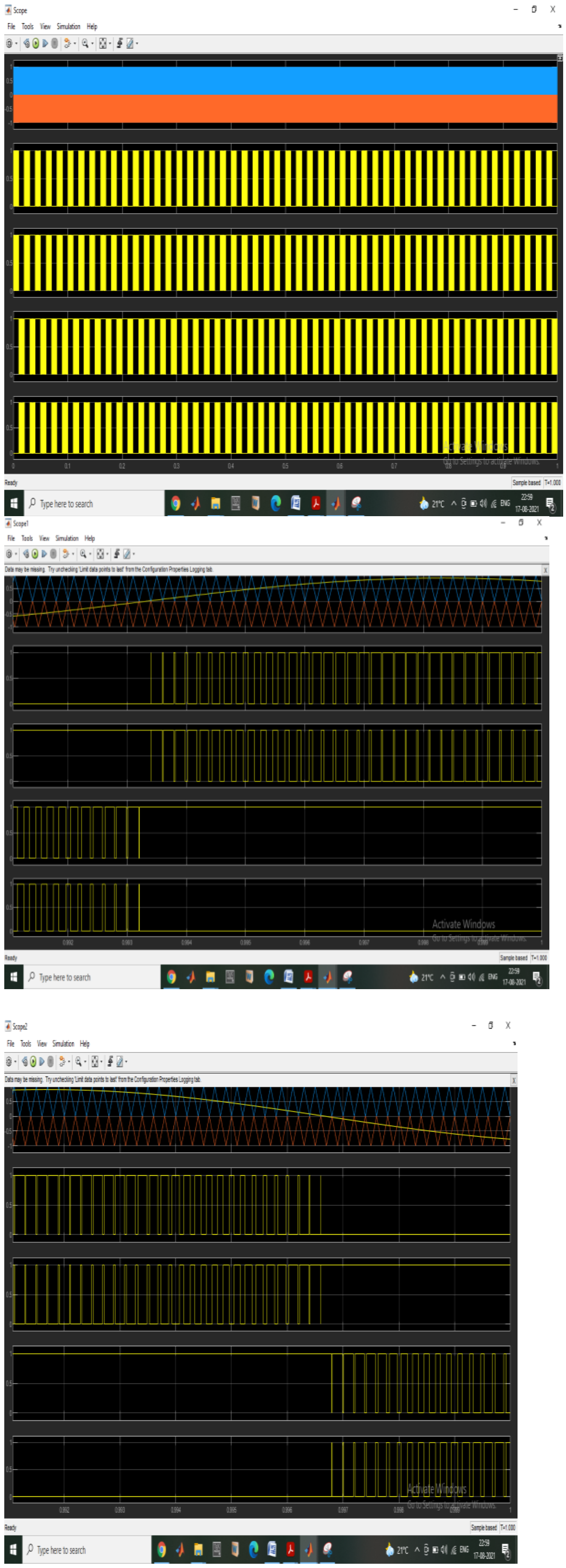
Three-phase voltages



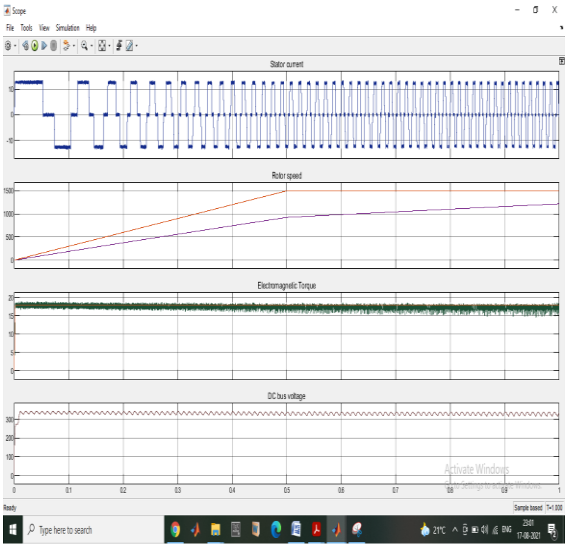
Inverter Output waveforms.



PWM waveform



Gate pulses of three phases.




BLDC motor Current, speed torque, and voltage waveforms.

From the above output waveforms of the BLDC motor, it is clear that the electromagnetic torque produced by the BLDC motor is constant and is ripple-free. This is because of the inverter circuit. As the motor is fed from the inverter's output voltage, the quality of the voltage waveform is good. Hence, the torque produced by the BLDC motor is very smooth.

The current waveform of the motor is also near to sinusoidal; slight distortions are present due to the inductive nature of the motor, which is most common.

## 5.CONCLUSION

The performance of the multi-level inverter fed BLDC motor is analyzed in this work. The inverter fed BLDC motor is simulated in the SIMULINK tool. From the simulation results, it is found that,

- Usage of the multi-level inverter for feeding the inverter improves the torque profile of the BLDC motor.
- The current waveforms of the BLDC motor are near sinusoidal due to the sinusoidal nature of the inverter voltage waveforms.

### 5.1Future Scope

Following aspects of the BLDC motors are not yet fully addressed in this work. Hence these are left as future work of this project.

- Comparison of the performance with other conventional types of inverter fed BLDC drive systems.
- Implementation of DTC for multi-level inverter fed BLDC Drive.
- Implementation of the hybrid controller for the BLDC motor drive.

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