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# Importance of DC-DC Converter for PMBLDC Motor Drive of an Electric Vehicle

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**Abstract—***As the demand of an efficient electric vehicle is increasing, the overall design parameters should be efficient. A Permanent Magnet Brushless Direct Current (PMBLDC) motor is the obvious option for an electric vehicle for its efficiency and higher starting torque. A conventional controller for a PMBLDC motor uses the Pulse Width Modulation (PWM) driven inverter. This paper compares two methodology in which, one is conventional and the other uses a dc-dc converter before the conventional inverter drive. The dc-dc converter is beneficial for both, the motor and drive as it helps to reduce the effects voltage stress in the windings (dv/dt), and torque quality at the output, increasing its life as well as the efficiency of an overall system.*

## 1. INTRODUCTION

Since the cost of fossil fuels is gradually increasing day by day as well as government policy is also towards the minimization of atmospheric pollution, it is mandatory for the human being to concentrate more on designing a hybrid vehicle powered by rechargeable batteries with an efficient technique. Advances in battery technology and significant improvements in electrical motor efficiency have made electric vehicles an attractive alternative, especially for short distance commuting. The applications for daily uses are being modified with the latest technologies with the best efficiencies. In today's market there is availability of various hybrid technologies like gasoline-electric hybrid, gasoline-hydraulic hybrid vehicles with the improved efficiency than the conventional internal-combustion (IC) engine vehicles [4]. Our past was about the 'power', whereas now is towards the 'efficiency'. The same is adopted by the automobile sector, which is having a significant growth in betterment of electric vehicles (EVs) because the advantages against gasoline vehicles. Electric vehicles are powered by the battery banks, which is one of the greatest advantages of EVs' and also an expensive element. Most of the EVs' uses permanent magnet brushless dc (PMBLDC) motors having better starting torque and better dynamic response than induction motor (IM) [5]. Recent researches on vector control and direct torque control techniques makes IM a better option than PMBLDC motor for larger load.

The electric powered vehicle uses PMBLDC motor, which is most effective option and with good dynamic control like shunt DC motor. The work presented in this paper deals with understanding the importance of a dc-dc converter requirement to control the motor although the inverter can control the motor speed itself, the working of the PMBLDC motor and reason to choose this particular motor. The simulation of a tentative designed buck converter to control a PMBLDC motor drive is shown. The buck converter is used to vary the speed of the motor, which is controlled by changing the duty cycle of the buck converter from 0-95%, which will vary the dc link voltage supplied to the motor.

## 2. SYSTEM DISCRIPTION

### 2.1. Block Diagram of Overall System

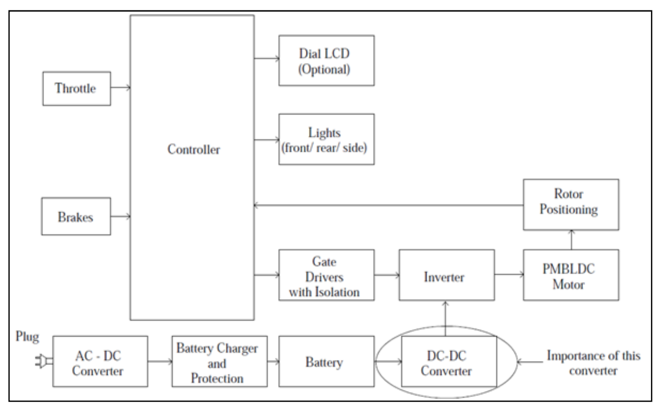


**Fig. 1: Overall System Block Diagram**

Fig 1 shows the overall electric vehicle system with all the accessories it could carry i.e. lights, speed dial, battery charge indication, charging circuit, batteries, dc-dc converter, throttle, brakes, inverter and the PMBLDC motor. In the presented work only the dc-dc converter, inverter, PMBLDC motor drive will be discussed. This block diagram is of a pure electric vehicle; no other form of hybridization (with gasoline or any other) is included in the system.

### 2.2. PMBLDC Motor Drive

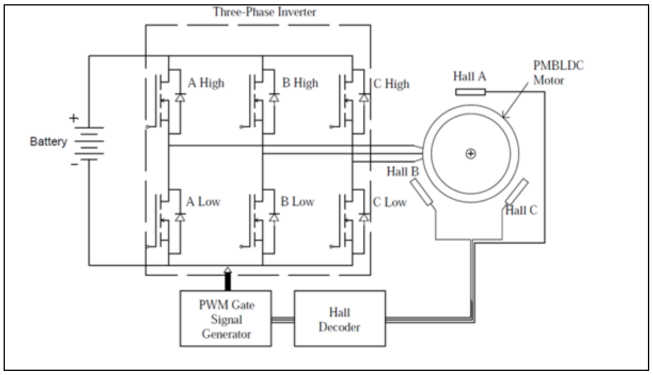


**Fig. 2: Conventional PMBLDC Motor Drive with PWM Gate Driven Inverter**

A PMBLDC motor requires a dc source voltage to be applied to its stator windings in a sequence so as to sustain rotation. This is done by electronic pwm switching using an inverter as shown in fig 2 which is used conventionally[3].

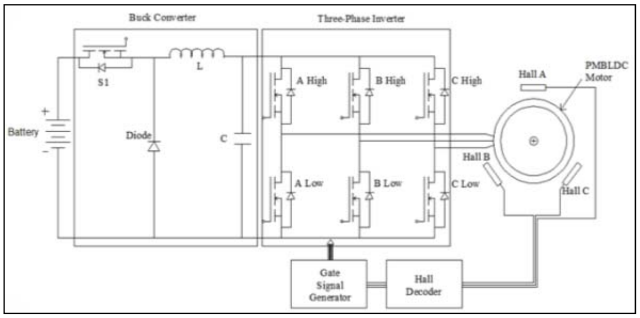


**Fig. 3: PMBLDC Motor Drive with DC-DC Converter**

Presented PMBLDC motor drive is shown in fig 3 which uses a buck converter having one switch (MOSFET or IGBT), driven by acceleration input which varies the duty cycle of the pwm waves to vary the speed of the motor and gives variable output voltage to the input of the three phase inverter, which is supplied to the motor [6].

## 3. ADVANTAGES OF DC-DC CONVERTER

The inverter can be used to convert dc to ac as the output of the inverter is going to be fed to the multi-phase ac armature winding. Inverter is able to do the work of voltage variation as per the acceleration needed, then the question arises that why to use a dc-dc converter. The answer is, linear voltage regulators converts one level of dc to another, typically using a series pass transistor circuit which usually operates in the linear region of its characteristics curve, and thus it cause much higher loss compared to the switching converter. With switching converters, the power semiconductor device operates in either fully on or fully off mode of conduction which operates in the nonlinear 'low voltage drop' region, resulting low conduction loss across the device. As the pwm of the power switch is used to control the power through the dc-dc converter, its efficiency is less dependent on the voltage difference from input to output which allows a wider range of input voltage range and higher efficiency [1,7]. Another reason is that the inverter is operated based on the rotor positioning, so this close loop of position based controlling won't be affected by the variation in the output of dc-dc converter. The rotor positioning and speed control, both the control schemes will be operated independently from each other.

## 4. SIMULATION RESULTS

The simulation is carried out in the MATLAB software. Both the control strategies (with and without dc-dc converter) were simulated keeping all the parameters as: 50V, 5Ah battery nominal voltage and rated capacity respectively and the mechanical torque at output of 2 N.m.

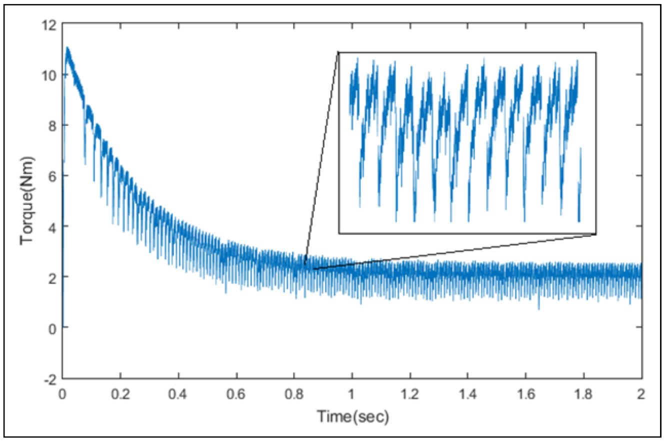


**Fig. 4: Output Torque Without DC-DC Converter**

Fig 4 and fig 5 shows the output torque and the phase voltage $V_{ab}$ respectively of the topology without the dc-dc converter.

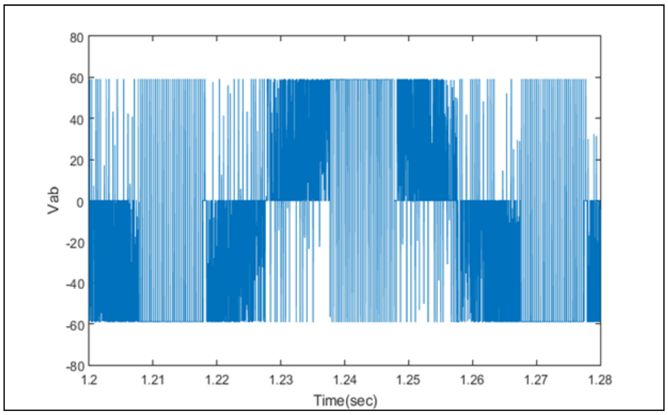


**Fig. 5: Phase Voltage Vab Without DC-DC Converter**

In this topology, the pwm signals are generated based on the rotor positions and the operator, who gives the command for the speed variation needed. These signals are directly given to the switches, which are directly fed by the batteries. The rotor position sensor itself is equipped with its logic sequences which frequently make the gaps in each signals fed to the driver. Thus, we are getting such a high dv/dt and because of these voltage fluctuations, insulation in the motor may breakdown or causes internal damages. The same is the cause for bad torque quality and fluctuation in the speed.

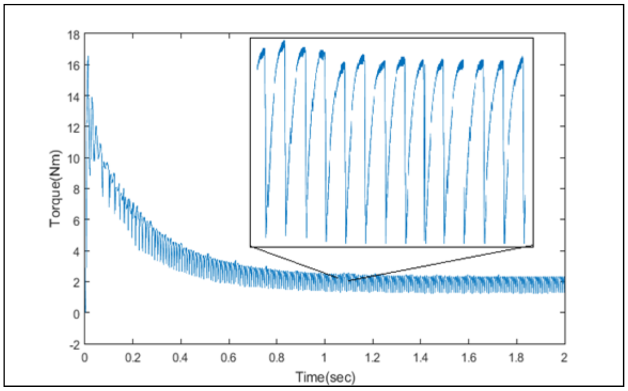


**Fig. 6: Output Torque with DC-DC Converter**

The output torque with dc-dc converter topology is shown in fig 6 in which the torque fluctuation is seen nearly 30% less than the control strategy without the dc-dc converter. While using the same topology, the regulation of voltage (which is directly proportional to speed) is carried out by the switch used in the converter, so that the inverter gets the variable dc voltage in accordance of the operator. In this topology, the close loop of the rotor positioning won't be affected and thus, the phase voltage of the inverter $V_{ab}$ as shown in fig 7.

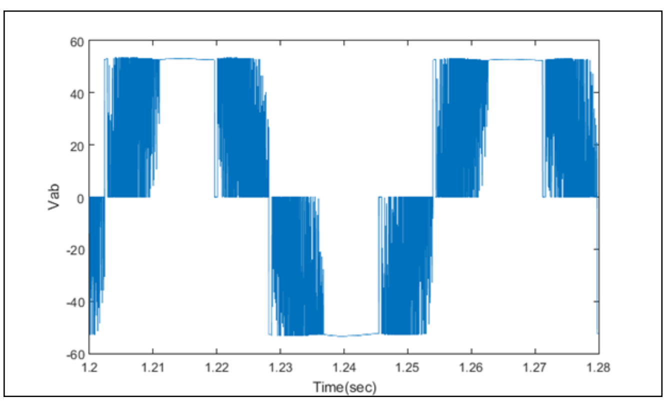


**Fig. 7: Phase Voltage Vab with DC-DC Converter**

## 5. CONCLUSION

In this paper, the comparison between two strategies was carried out, in which the conventional drive was compared with the drive having the buck dc-dc converter before the inverter. By doing so, the torque fluctuations are reduced more than 30% and the effect on the phase voltage $V_{ab}$ can be clearly observed. Using the dc-dc converter, the life of the motor windings (as the voltage stress on the insulation is much less) increases as well as the overall efficiency of the drive also improves. The only disadvantage is that the component count increases as an additional converter in the drive is being used. More utilization of the drive could be done by using the two quadrant dc-dc converter for the regenerative braking purpose by increasing only a switch in the converter and modifying the control scheme.

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