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PMSM Motor Control by Efficient DC – DC Boost Converter Topology for EV Application

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Abstract: The Electromotive vehicles plays a vital role in various fields like electronic and automotive applications. This paper presents the Permanent Magnet Synchronous Machine (PMSM) which is fed by boost converter. A wide range of dc voltage is fed to bridge inverter by boost converter which in turn controls the speed of PMSM. Boost converter is used to boost up the input voltage. An electric vehicle may be powered through a shaft of the motor to run the various electric vehicle like electric aircraft, electrictruck, electricspace craft, electric locomotive etc. In this paper by using converter topologies increase the performance of the motor speed. The performance of the proposed system is verified using MATLAB/Simulink and presented results demonstrate the performance and analysis of the system to provide high speed by using PID controller.

Keywords: Automotive, Boost converter, Electric vehicle, PID controller.

I. Introduction

PMSM are used for the traction application of an electric vehicles [2]. It is normally used for high effective and high performance motors. In PMSM the field excitation is presumed by permanent magnets and it can provoke torque at zero speed. The load is driven by PMSM through a bridge inverter which is fed by boost converter. In order to reduce the PMSM's energy consumption, it can able to improve the forbearance mileage of electromotive vehicles [3]. The bridge inverter is used to convert dc supply to ac supply. The input voltage and output voltage mainly depends on specific device. This inverter can able to control the speed of the synchronous machine [5]. Square wave is suitable for low sensitive applications. Permanent magnet synchronous machine starts to rotate by using inverter ac supply [4].

II. Block Diagram

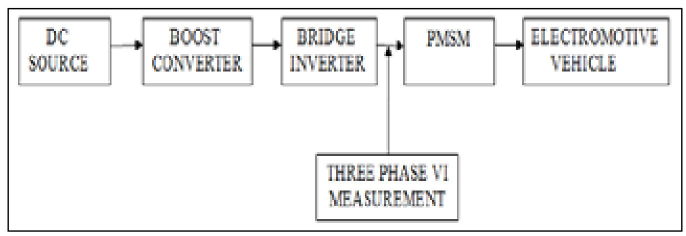

Fig. 1: Operational Block Diagram

III. Operation

A 230 V DC voltage is fed to boost converter. The working principle of boost converter is to boost the input voltage from 230 V to 457.6 V. Input side of the inductor has the value of 200e-6 H. In that inductor resists the input current [6].

The boost converter can be operated in two modes namely Continuous conduction mode and Discontinuous conduction mode.

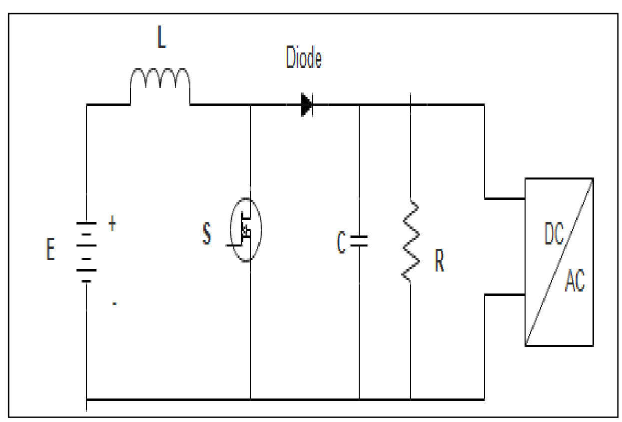

Fig. 2: Boost Converter Circuit

A. Continuous Conduction Mode

In continuous conduction mode, the current through inductor never goes to zero.

- *Case I: ON Mode*

When switch is in ON condition, diode will be open circuited. Switch is energizing and the inductor gets charges. No current passes across the diode.

Current through the inductor at the end of the switching ON mode equation is given as,

$$\Delta I_{LOn} = \frac{1}{L}\int_{0}^{DT} E_i dt = \frac{DT}{L}E_i \qquad \ldots(1)$$

- *Case II: OFF Mode*

When switch is in OFF condition, diode will be short circuited. Switch is unenergizing and the inductor discharges the energy as well as diode discharges the energy and given to the load.

Current through the inductor equation is given as:

$$\Delta I_{LOff} = \int_{DT}^{T}\frac{(E_i - E_o)dt}{L} = \frac{(E_i - E_o)(1-D)T}{L} \qquad \ldots(2)$$

B. Discontinuous Conduction Mode

In discontinuous conduction mode, the current through inductor goes to zero.

$$\frac{E_i DT}{2L}\cdot\frac{E_i D}{E_o - E_i} = \frac{E_i^2 D^2 T}{2L(E_o - E_i)} \qquad \ldots(3)$$

$$\frac{E_o}{E_i} = 1 + \frac{E_i D^2 T}{2LI_o} \qquad \ldots(4)$$

$$\frac{E_o}{E_i} - \frac{1+\sqrt{1+\frac{4D^2}{K}}}{2} \qquad \ldots(5)$$

Where,

$K = \frac{2L}{RT}$ [1]

E_o = Ouput voltage of the converter

E_i = Input voltage of the converter

L = Inductance of the converter

IV. Inverter Design

Thus, the inverter topology used is a bridge inverter. Gate pulse are given by means of feedback network. Thus, its necessary for us to have look up table logic for each and every phase voltage coordinating each other [9].

The gate sequence is produced by using relational operators suggesting the proper logic pattern. The six logic on and off period is controlling the operation the phase and line voltage of the system [10].

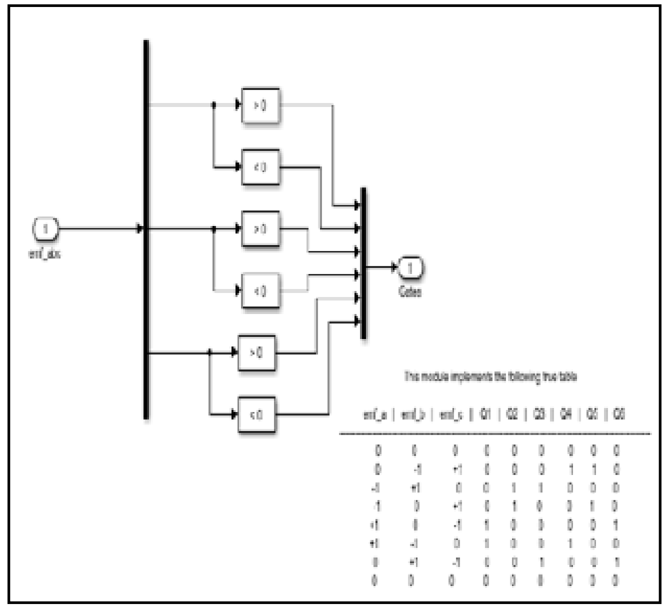

Fig. 3: Lookup Table and Gate Sequence

A. Decoder

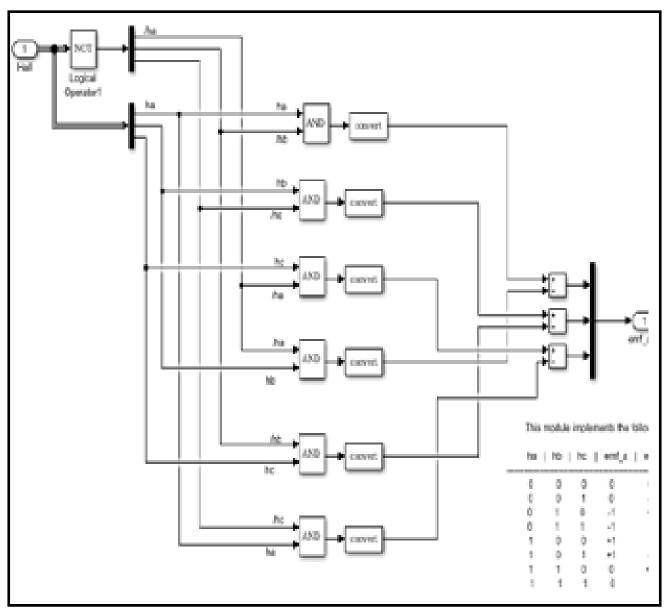

Fig. 4: Decoder Logic for Inverter

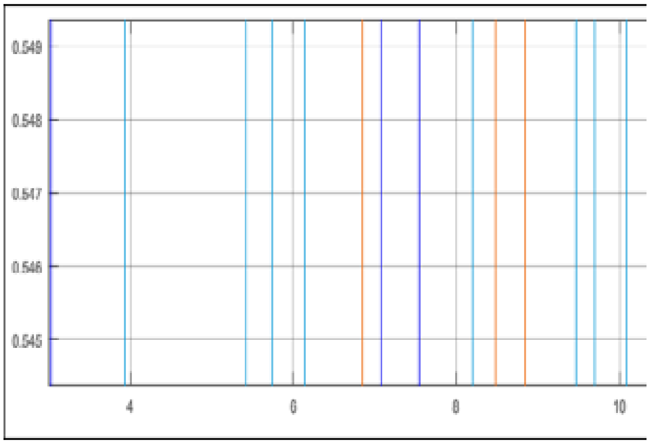

Fig. 5: Waveform of Gate Pulse for Inverter

The above Fig. 5 represents the gate pulse used for controlling the firing angle of inverter.

V. PID Controller

This controller calculates the error value as the difference between a set value and measured value. On comparing the set value the measured value is more nominal [8]. The proportional, integral and derivative get summed to determine the output of PID controller. The equation is given as follows,

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de(t)}{dt} \quad \ldots(6)$$

Where,

K_p = proportional gain

K_i = integral gain

K_d = derivative gain

$e(t)$ = error

The transfer function of PID controller is

$$L(s) = K_p + \frac{K_i}{s} + K_d s \quad \ldots(7)$$

The values of proportional, integral and derivative gain are as follows:

Table I: Specification Detail of PID Controller

Gain Value of PID Controller	
K_p	0.0001
K_i	0.8
K_d	0

A. Specification

Table II: Specification Detail of Converter and PMSM

Sr. No.	Components		Rating
01	DC Source	Input Voltage	230 V
02	Converter	Inductance	200e-6 H
		Capacitance	50e-6 F
		Resistance	20 ohm
		Output Voltage	457.6 V
		Output Current	24.75 A
03	Permanent magnet synchronous machine	Output Voltage	237.7 V
		Rotor Speed	5000 RPM
		Torque	105 N-m
		Stator Current	120 A

VI. Result Analysis

The model of boost converter fed PMSM is performed in MATLAB/Simulink software [7]. The consequence of the boost converter gives the information of output voltage [11]. During simulation the output voltage gets doubled when compared to input voltage. After simulation output voltage of the converter is higher than input voltage and it gives higher efficiency of 96% [3]. No controller is used in this converter topology.

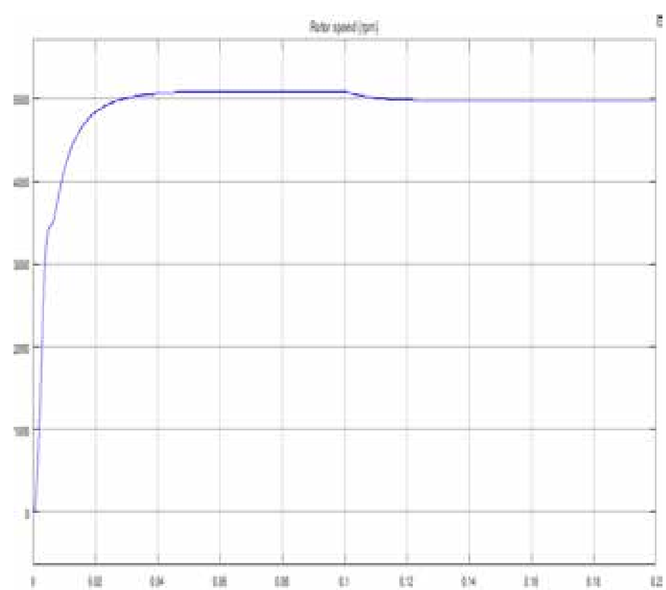

Fig. 6: Waveform of Rotor Speed

The above Fig. 6 represents the speed of the motor which is measured at 5000 RPM.

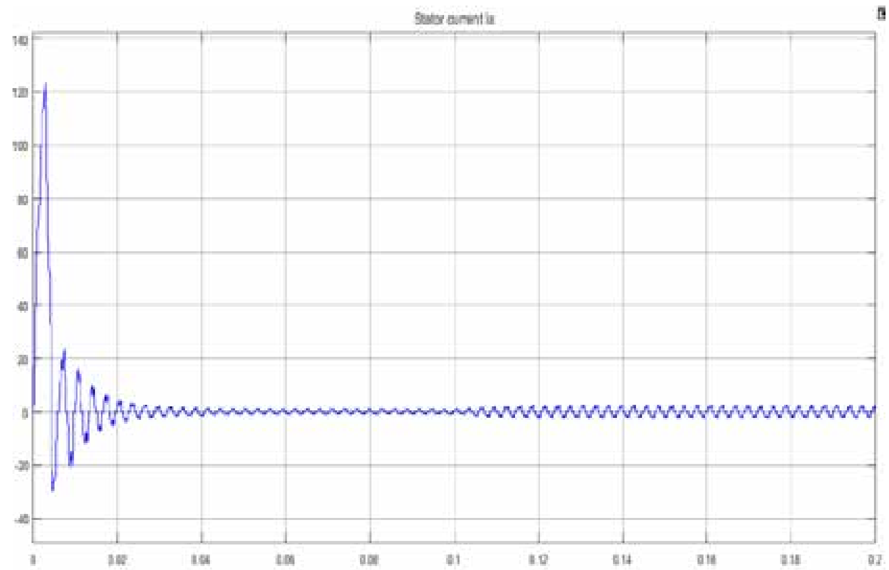

Fig. 7: Waveform of Stator Current

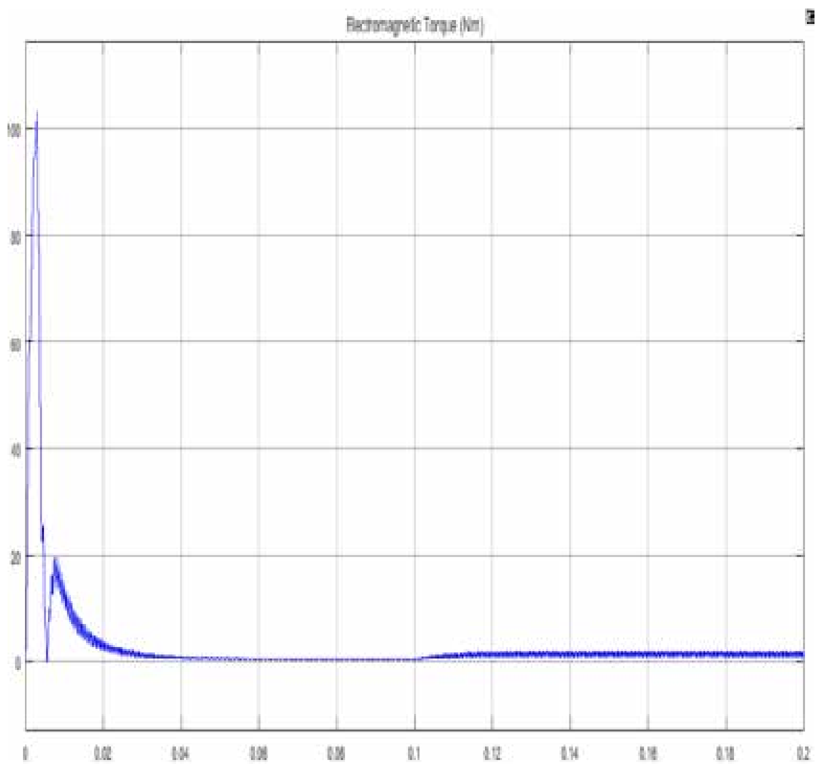

Fig. 8: Waveform of Electromagnetic Torque

The above Fig. 7 represents the current of the stator which is measured at 120 A.

The above fig 9 represents the motor torque which is measured at 105 N-M.

VII. Conclusion

The design and analysis of less noise high voltage boost converter was presented in this paper. The required amount of voltage is fed to the bridge inverter by boost converter which controls the speed of the motor. The settling time to reach the motor speed is about 0.2s. It is mainly used in high voltage applications. Electric vehicles are charged through batteries. The proposed converter design and its performance was observed through simulation and then verified with experimental measurements.

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