Performance Enhancement of Boost Converter Fed Permanent Magnet Synchronous Machine

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Abstract: The renewable energy 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 vehicles like electric aircraft, electric truck, electric space 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.

Key words: PID controller, boost converter, automotive, electric vehicle.

1. Introduction:

PMSM are used for the traction application of electric vehicles. 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 [1]. 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 [2]. The bridge inverter is used to convert dc supply to ac supply. The input voltage and output voltage mainly depends on specific device. To solve this problem this inverter can able to control the speed of the synchronous machine [3]. Square wave is suitable for low sensitive applications. Permanent magnet synchronous machine starts to rotate by using inverter ac supply. The proposed method is simulated and hardware is implemented [4].

2. Block Diagram:

Figure: 1. Block Diagram of Operation
3. Operation:

A 230V DC voltage is fed to boost converter. 230 V is boosted to 457.6 V by the working of boost converter. Input side of the inductor has the value of 200e-6 H. In that inductor resists the input current Dis-continuous and continuous conduction mode is the two modes of operation on boost converter [5-6].

![Circuit Diagram of Boost Converter](image)

**Figure: 2. Circuit Diagram of Boost Converter**

3.1. Continuous Conduction Mode:

In this mode, never goes to zero value of inductor current.

**Case 1: ON mode**

No current passes across the diode while switch is in ON condition. Finally inductor current while switch ON mode equation then,

\[
\Delta I_{LON} = \frac{1}{L} \int_0^{DT} E_1 \, dt = \frac{DT}{L} E_1 \quad \text{.....(1)}
\]

**Case 2: OFF mode**

Diode will short circuited while switch in OFF condition. Switch is un-energizing and the inductor discharges the energy as well as diode discharges the energy and given to the load and output power [7].

Current through the inductor equation is given as

\[
\Delta I_{LOFF} = \int_0^{DT} \frac{(E_1 - E_0) \, dt}{L} = \frac{(E_i - E_o)(1 - D)T}{L} \quad \text{.....(2)}
\]

3.2. Dis-Continuous Conduction Mode:

In this mode, the current through inductor goes to zero [5].

\[
I = \frac{E DT - E D}{2L} = \frac{E_i D^2 T}{2L(E_s - E_i)} \quad \text{.....(3)}
\]

\[
\frac{E_s}{E_i} = 1 + \frac{E D^2 T}{2L I_s} \quad \text{.....(4)}
\]
\[
\frac{E_c}{E_i} = \frac{1 + \sqrt{1 + \frac{4D^2}{K}}}{2} 
\] ..(5)

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

\[E_c = \text{Output voltage of the converter}\]
\[E_i = \text{Input voltage of the converter}\]
\[L = \text{Inductance of the converter}\]

4. Inverter Design:

Thus, the inverter topology used is a bridge inverter energy conserved and utilized efficiently [8]. Gate pulse is given by means of feedback network [7]. Thus, it is necessary to determine the look-up table logic for each and every phase voltage coordinating each other [8]. 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[9-10].

Figure: 3. Lookup Table and Gate Sequence
4.1. Decoder:

This module implements the following truth table:

| ha | hb | hc | emf_a | emf_b | emf_c |
|----|----|----|-------|-------|-------|
| 0  | 0  | 1  | 0     | -1    | +1    |
| 0  | 0  | 0  | 1     | 0     | 0     |
| 0  | 0  | 1  | -1    | +1    | 0     |
| 0  | 0  | 0  | 0     | +1    | -1    |
| 1  | 0  | 0  | +1    | 0     | -1    |
| 1  | 0  | 0  | -1    | +1    | 0     |
| 0  | 1  | 0  | 0     | 0     | +1    |
| 0  | 0  | 1  | +1    | -1    | 0     |
| 1  | 1  | 0  | 0     | 0     | 0     |

Figure: 4. Decoder logic for inverter
Figure 5. Waveform of gate pulse for inverter

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

5. PID Controller:

Calculated the values of error and compare the measured value and value of error [11-12]. On comparing the set value the measured value is more nominal. The proportional, integral and derivative get summed to determine the output of PID controller. The equation is given as follows,

\[ u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de(t)}{dt} \]  

…… (6)

Here,

\( K_p \) = Proportional gain

\( K_i \) = integral gain

\( K_d \) = derivative gain

\( e(t) \) = error

The transfer function of PID controller is

\[ L(s) = K_p + \frac{K_i}{s} + K_d s \]  

…… (7)

| GAIN VALUE OF PID CONTROLLER |
|-----------------------------|
| \( K_p \)                  | 0.0001 |
| \( K_i \)                  | 0.8   |
| \( K_d \)                  | 0     |

Table 1 Specifications Of PID controller
6. Specification:

| S.NO | COMPONENTS       |                  | RATING      |
|------|-----------------|-----------------|-------------|
| 1    | DC VOLTAGE      | Input voltage   | 230 V       |
|      |                 | Inductor        | 200 mH      |
| 2    | Boost Converter | Capacitor       | 50 µF       |
|      |                 | Resistor        | 20 Ω        |
| 3    | PMSM            | Output Voltage  | 457.6 V     |
|      |                 | Output current  | 24.75 A     |
|      |                 | Output voltage  | 237.7 V     |
|      |                 | Speed of rotor  | 5000 RPM    |
|      |                 | Torque          | 105 N-m     |
|      |                 | Current of stator | 120 A   |

7. Result Analysis:

The model of boost converter fed PMSM is performed in MATLAB/Simulink software [13-14]. The consequence of boost converter gives information of output voltage [15-16]. During simulation output voltage gets doubled when compared to input voltage [17]. After simulation output voltage of the converter is higher than input voltage and it gives higher efficiency of 96%. No controller is used in this converter topology [18-20].

![Figure 6. shows motor speed at 5000 RPM.](image)
7. Conclusion:

As Proposed 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 motor speed can reach about the settle time of 0.2s. The Proposed work 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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