Sliding Mode Controller for Electric Vehicles based on Switched Boost Converter

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Abstract. This paper proposes electric vehicle energy conversion of DC-DC by using switched capacitor step-up converter and the implemented system's control techniques. In this system, the proposed switched boost capacitor converter is interfaced with a power source, attaining high power gain that could not be achieved by the existing systems like VSI and boost converter. In this proposed system, the large inductor is ignored and the capacitor that used for filtering purpose. Because of this, the system is directed to low cost and high density. The switched capacitor regulated converter is applicable for all the power conversion such as dc-ac, dc-dc. In this paper, the proposed Sliding mode controller (SMC) controls the BLDC motor in the vehicle's inverter. The proposed system results are obtained and verified using MATLAB/Simulink.

Keywords: BLDC Motor, SM controller, boost switch converter, and speed control

1. Introduction

In the perfect future, the rapid transition of an electric vehicle depends on how rapidly the EVs can outperform the internal combustion powered vehicles' mileage and price. EV technology's future development falls roughly into electronic devices, battery system and driving with autonomous. To improve the drive train results reduced size, torque dynamics and increased battery power consumption [1]. As for the last group, the drive train is one of the most important power conversion systems. Because of its reliability, most current EVs use a boost or step-up converter with an inverter. An analysis of the shortcomings of VSIs will tackle the opportunities to develop the EV power train.

VSIs are fundamental converters to bucks. Hence, the dc-link voltage must be higher than the voltage of the dc or ac input [2]. The main configurations are widely used for the electric drive organization: the first is a battery driving a two-level inverter directly. In this, the battery is interfaced with the DC bus bar to provide power for the inverter [3]. The series battery cell relation presents a challenge in terms of the slow rate of equalization of the charge. Besides, the insulation of one defective in series arrangement contributes to a decrease in voltage.

In this paper, switched boost converter is proposed to achieve high voltage gain and high efficiency [4]. The hybrid electric vehicles are using drives to achieve high efficiency with better reliability. This conversion system is controlled by the pulse width modulation technique to achieve the high DC link voltage at the end of a switched boost converter system. The voltage source inverter is used the non-linear control method of sliding mode controller for the machine connected inverter system [5]. Because power loss directly translates into the cooling system's efficiency, a substantial diminution in the size and increase in the EV range has accomplished.
2. Proposed System
In this system, the sliding mode controller (SMC) is used for voltage source inverter for providing both charging and discharging operation of the proposed switched boost converter system [6]. The DC supply is given to the BLDC motor and the voltage source inverter and the power conversion of switched boost converter, which is used to achieve high DC link voltage at the inverter's input.

In this proposed system, the drive is controlled by the SMC regulator. It is utilized to provide efficient, robust control for a dynamic and complex system that is working depends on the varying conditions. The large inductor is ignored, and a capacitor that used for filtering purpose is shown in Figure 1. The SMC controller based proposed BLDC drive is controlled, and the PWM signals are provided to the high gain switched boost converter. The inverter's feedback voltage is fed to the proposed SM controller to generate switching signals for the power switching devices used in VSI [7]. The pulse generation leads the BLDC motor operating performance through the voltage and current control.

3. Sliding mode controller
In this proposed system, the drive is controlled by the SMC regulator. It is utilized to provide efficient, robust control for a dynamic and complex system that is working depends on the varying conditions [8]. The proposed control of SMC based system is shown in Figure 2. This control method is efficiently maintaining system performance with consistent and better stability. The SMC surface is derived as,

$$\sigma(x) = \left( \frac{d}{dt} + \lambda \right)^{r-1} (x^* - x)$$

The sliding mode controller architecture involves choosing the sliding base, as well as the control rules [9]. If the system states reach the sliding phase, the mechanism's dynamics are defined by the chosen sliding surface and are robust to all the disruptions and variations in the parameters. Because SMC refers to the first-order method, the SMC uses the noise-sensitive acceleration signal [10]. The status of such switching signals is defined by the direction of the rotor, the error in speed and the winding currents. The inverter's magnitude and frequency of the output voltage depend on the switching signals produced by the control hysteresis [11].
The sliding mode control (SMC) is utilized in the grid converter to control the powers [12]. The SMC control is proposed to achieve stability in the operation regions of both non-minimum and minimum phases [13]. In this method, the chattering cannot be eliminated, and SMC is based on switching signals.

4. Simulation and Results
Figure 3 shows that the proposed BLDC drive based on the voltage source inverter SMC control simulation for speed and torque range control. The DC supply is given as an input source 12V. The given input source is fed to propose switched boost converter, which consists of the reduced amount of active components that improve the source voltage and ensures the constant DC link voltage. The Pulse Width Modulation control is used to propose a converter power switch of conversion side, which means DC-DC conversion [14]. In the Simulink model of the proposed system contains the DC source for switched boost converter, which has a switching device and is controlled by the pulse generator. The PWM signals are generated using the pulse generator block, which has a 0.5 switching pulse of MOSFET [15], and the output of the converter is stored in DC link voltage. The below part of the model is representing the proposed controller design.
The duty cycle of the MOSFET power switch is 0.5. The six power switches of the inverter side are controlled by using the proposed back emf estimation method. According to this method can be controlled the speed of the drive and torque range. The waveforms for the input voltage, DC bus voltage, inverter voltage, and drive speed are shown in the following figures.

The input supply voltage for the given input source is 12V as shown in below Figure 4, and the supply voltage is after improved by the DC-DC switched converter, as shown in fig. 5.

![Figure 3: Proposed System Simulation](image)

![Figure 4: Proposed System Input Voltage](image)
The inverter output is shown in Figure 6, the output of the proposed inverter is before using the LC filter. Figure 7 illustrates the drive stator current and the motor drive stator current is 8.5 A.

The proposed system’s speed is controlled, and the speed of the BLDC motor is 610 revolution per minute (RPM). The motor speed is settled quickly through SMC controller. The settling time of the proposed system is 0.2 sec. The ripples also reduced. Figure 8 is showing that the BLDC drive speed, which is controlled and settled quickly. In this, the response time is reduced with the controlled speed response of the BLDC motor performed by the control of the proposed controller of SMC.
5. Conclusion

In this paper, the BLDC drive based on switched boost converter is designed with the sliding mode control is proposed. The speed of the drive can be regulated using with proposed controllers. The drive speed and efficiency are improved, and the dc supply voltage is improved by boosting the switching converter. The results are verified and examined in MATLAB/Simulink, and it shows that motor torque range and speed enlargement. The speed of the drive is achieved 610 rpm with the help of planned control technique. The period of the response in BLDC drive speed is 0.2 sec. The voltage boosting method and the efficiency of this proposed method are high while compared with traditional systems. The proposed system results are obtained successfully using Simulink model and show the output of the input voltage, the output of the BLDC motor speed which controlled using sliding mode system, stator current of motor winding, and the inverter output.
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