Switched-Capacitor Voltage Boost Converter for Electric and Hybrid Electric Vehicle Drives

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Abstract

DC-AC and DC-DC power conversion can be accomplished using a SC voltage boost converter, which is described in this article along with the control mechanisms that go along with it. To provide characteristics not attainable with ordinary voltage-source inverters (VSIs) or boost voltage source inverters, the SC converter incorporates a switched capacitor circuit into the primary converter architecture (VSI). In addition, the linear modulation area has been doubled and the big filtering capacitor has been eliminated, resulting in a higher energy density and reduced price. Direct current to direct current, direct current to direct current, and direct current to direct current are all examples of power conversions that can benefit from the SC converter concept. A bidirectional SC converter is used as an example to demonstrate the basics of operation and control.

INDEX TERMS: switched capacitor (SC), voltage-source inverter (VSI), photovoltaic (PV), Maximum power point tracking (MPPT), hybrid electric vehicles (HEVs)

1. Introduction

The authors came to the conclusion that electric vehicles are likely to undergo a rapid period of adaptation. Ninety-three percent (290 million) of all vehicles in the United States will be electric by that year [1]. A Kodak moment will soon arrive for automakers that fail to make the switch to electric vehicles (EVs). A perfect world would see electric vehicles take off as quickly as possible if they could outperform internal combustion-powered vehicles in terms of both mileage and cost. Battery chemistry, self-driving vehicles, and power electronic units are all areas where EV technology has the potential to advance. When it comes to the final category, the drive train is is a crucial component of any power system Reduced in size, speed/torque dynamic is improved and battery power is better utilised as a result of the improved drive train. With or without a boost stage, the two-level voltage source inverter (VSI) is used in most existing EVs because of its reliability. Explore the limitations of VSIs to improve the EV powertrain's performance. Because of this, VSIs must be used as converters. The dc-link voltage must therefore be higher than the dc or ac input voltage.

When the provided dc voltage is insufficient to generate the requisite ac voltage, an additional dc-dc boost converter is required [4]. The most common commercial traction electric drive system configuration uses a battery-powered two-level inverter; the second most popular configuration uses an inverter with an intermediate dc-dc boost stage, as shown in Fig. 1(a) [5]. In order to get a dc-link voltage [6], a big battery with a large number of cells in series is required, even if the inverter side of the battery is not stressed. [7] Due to the sluggish charge equalization speed, series battery connections provide a problem. Consequently, the isolation of one damaged cell results in a voltage drop throughout the entire series. To avoid short circuits with other non-faulty series rows of cells, disconnect the complete series row of batteries. Tesla (75-100 kWh) and other long-range electric vehicles employ only the first option. Electric cars (HEVs and PEVs) with batteries ranging from 5 to 50 kWh can be found (PHEVs). To establish the machine's current and voltage restrictions, you need to know how well it can dissipate heat. A dc-dc boost converter can be used to broaden the range of constant torque [9]. However, despite its greater working voltage, the density of the 1200V SiC-current MOSFET is comparable to the 600V Si-due IGBT's [10]. By using high-voltage motors with SiCMOSFETs [11], semiconductor die area is reduced by a factor of two. [10] Peak losses are reduced by a factor of four due to the reduced peak current. It is possible to considerably reduce cooling system weight and size while simultaneously increasing EV range due to the direct correlation between power loss and cooling system capacity.. Figure 1(a) depicts a conventional boost stage that falls short of ideal performance. Due to the need for a large inductor due to the dc-dc converter's power rating matching the battery pack's power. An expensive and heavy component is the inductor. Furthermore, the losses in the copper and core of the inductor increase with the inductor's size. When boosting a high voltage ratio, the boost converter must operate at a high duty cycle with a poor efficiency [12]. Partial efficiency is reduced because the ac losses, switching losses and ac magnetic losses, all depend on voltage but are almost independent of current. High duty cycles, which increase the rms current applied to the bus capacitance, can have an impact on the size and cost of the bus capacitor [11]. Using the SC converter and associated control approaches, the constraints of traditional drive trains are overcome in this work. An example of a SC converter design is depicted in Figure 1(b). Switched capacitor circuits and the inverter are one and the same thing. Switching the capacitors in the circuit creates a multi-leveled dc-link voltage. The suggested switched capacitor circuit, which differs from standard designs, does not require a reverse blocking diode or a large filtering capacitor on the load side. It is possible to regulate the output current and voltage when the inverter and switched capacitor stages are controlled together. The remainder of the paper is organized as follows: Converter described in section II, followed by the Proposed system in section III, In Section IV describes the simulation results and section V ends with some concluding remarks.

II. CONVERTER

DC to DC converter

DC-to-DC converters are circuits that convert direct current sources from one voltage to another in electronics engineering. This piece focuses on a specific subset of power converters. Power is provided by DC to DC converters in portable electronic devices, such as cell phones and laptop computers. In many of these electrical gadgets, there are several sub-circuits, and each of these sub-circuits demands a different voltage level than the battery can deliver (sometimes higher or lower than the battery voltage, and possibly even negative voltage). As the battery's stored power is drained, its voltage drops. The result is that instead of using several batteries for each individual component, a single battery may power various portions of the gadget.

Circuit analysis

Operating principle

It's the inductor's ability to resist current changes that powers the boost converter. When charged, it acts like a resistor and stores energy; when discharged, it acts like a source of energy (somewhat like a battery). Because the rate of change of current, not the charging voltage, determines the voltage it generates during discharge, it is possible to have different input and output voltages.

Fig.1: Boost converter schematic

III. PROPOSED SYSTEM

Proposed Circuit diagram

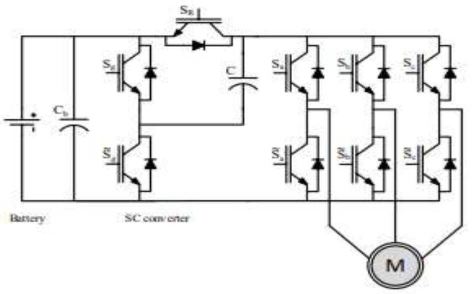

Fig.2: Switched capacitor Voltage Boost Converter

PROPOSED TOPOLOGY

- This project tries to overcome the constraints of existing drivetrains by using the SC converter and associated control methods.
- To construct a single circuit, an inverter and a switch-capacitor circuit are utilised together.
- Switched capacitor circuits allow for multiple dc-link voltage levels.
- The suggested switched-capacitor circuit does not include a big filtering capacitor or a reverse blocking diode on the load side.
- Regulated output current and voltage can be achieved by integrating the control of the inverter and the switched capacitor stages.

Boost converter

- We've all run into where a somewhat higher voltage is required than what our power sources are able to give. Because we only have a 9-volt battery, we can't use it. We could also have a 3.3V supply if our chip requires 5V, or vice versa. Furthermore, the current draw is generally quite good in most cases as well.
- When we get to the point where we ask ourselves, "Can we convert one DC voltage to another?"

- Fortunately, the answer is yes. Converting from one DC voltage to another is technically possible, but the procedures necessitate some ingenuity on the part of the user.
- DC to AC conversion is not necessary, nor is it intended to be. As a result of the many steps involved. This is a useful life lesson: anything that requires too many steps is inefficient.
- Switch mode DC-DC converters are here to stay!
- They're known as switch mode because of the rapid switching of a semiconductor switch.

Switched capacitor boost voltage

Capacitors can now supply power to loads when the switches are closed and the right-hand side has been shorted out from the left-hand side. Because of the blocking diode, the capacitor cannot be discharged through the switch during this time.

SPEED CONTROL

- Voltage amplitude affects the speed of the motor. PWM is used to change the applied signal's amplitude.
- PWM is used to drive the transistors on the higher side of the circuit. The speed of the motor can be controlled by controlling the duty cycle of the PWM signal, which affects the voltage applied to the motor.

TORQUE CONTROL

- In order to control torque, you can change the magnetic flux in the device. Magnetic flux, on the other hand, is directly proportional to the current flowing through the coils. Thus, the torque of a motor can be controlled by controlling the current.

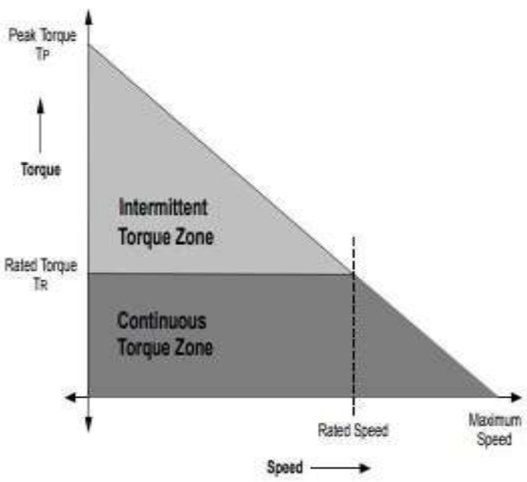

Fig.3: Torque-Speed Characteristics

IV. SIMULATION Results

Simulink

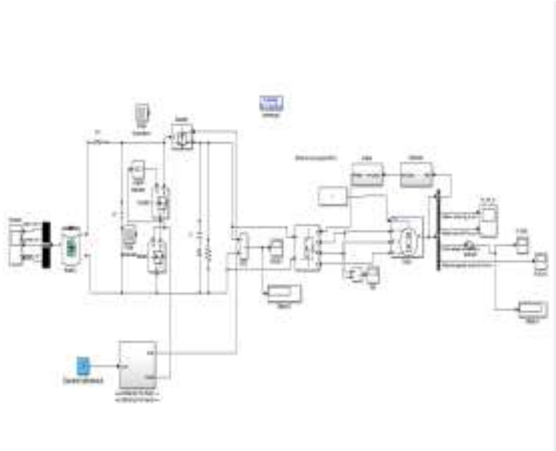

Fig.4: Simulink model of the System with Boost Converter for Electric and Hybrid Electric Vehicle Drives

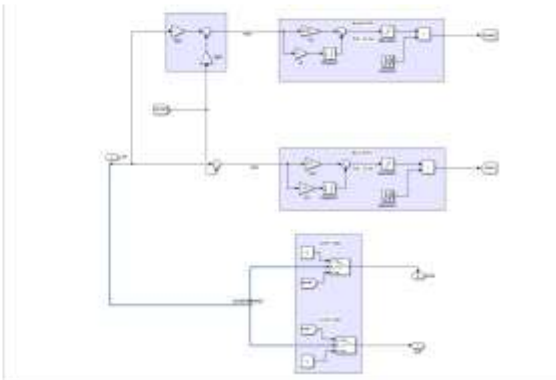

Fig.5: Switched capacitor controller

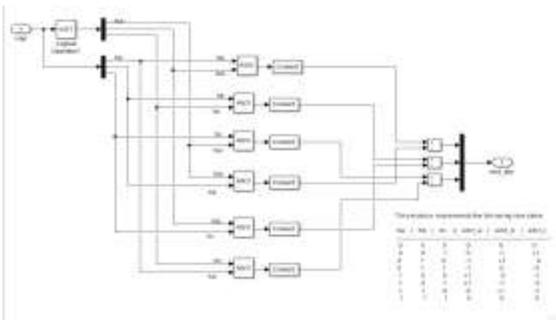

Fig.6: Hall sensor


Fig.7: Switched capacitor output voltage


Fig.8: Motor speed

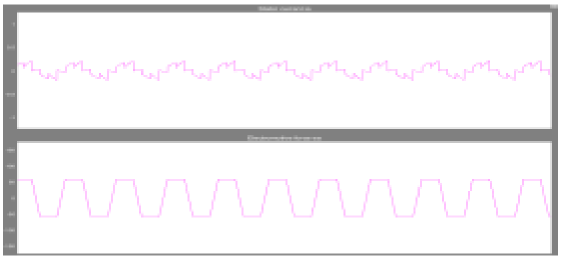
Fig.9: Stator current and back emf

V. Conclusion

An unique SC power converter has been presented in this research for achieving dc-ac and ac-dc power conversion (SC). It has a lot of advantages over the standard VSI or BVSI converters in terms of efficiency and ease of use. Unique to this model, linear modulation is expanded to cover twice as much space. The inductor used to boost voltage is no longer necessary with the SC converter. As a result, higher power density can be achieved because of the use of capacitors alone. Analytical methods are used to determine the maximum voltage drop and minimum charging current of a capacitor. Using the findings of the investigation, it is possible to increase the charging current's power output. In order to develop carrier-based modulation for a new SC converter, the SVPWM's exact switching sequence is used with minimal computational effort. The proposed converter's operating principle and modulation methods have been verified through simulations and experiments. The SC converter has the advantages of fewer components, higher power density, and lower cost. GC micro-inverters with MPPT for photovoltaic applications are discussed in this paper as a low-cost control option. The proposed system will be tested using a macro-model, which will also speed up simulation times. MPPT algorithms can be developed and compared in this manner. To track power points to their maximum potential, a macro-model is used. This macro-model speeds up voltage loop tuning and the design of input filters. It has been proven that the AM and the circuit used for inverter simulations are accurate.

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