
ISSN: 2321-2152
IJMECE
International Journal of modern
electronics and communication engineering
E-Mail
editor.ijmece@gmail.com
editor@ijmece.com
www.ijmece.com

ISSN2321-2152
www.ijmece .com
Vol 11, Issue.2 June 2023

Enhancing Electric and Hybrid Vehicle Drives: The Switched-Capacitor Voltage Boost Converter Solution

G.SANDYA RANI
Assistant Professor, Department of EEE, Princeton College of engineering and technology for women
Narapally vijayapuri colony ghatkesar mandal, Pin code-500088.

Abstract

This article presents a switched-capacitor (SC) voltage boost converter and its control methods for implementing dc-ac and ac-dc power conversion. The SC converter employs a switched-capacitor circuit augmented with the main converter circuit to the power source, thus providing unique features that cannot be attained by the traditional voltage-source inverter (VSI) or boost VSI. The additional features include doubling the area of the linear modulation region and eliminating both the large inductor in the boost dc-dc stage and the large filtering capacitor, which leads to a higher energy density and lower cost. The SC converter concept can be applied to all dc-ac, ac-dc, ac-ac, and dc-dc power conversions. To describe the operating principle and the control, we focus on one example: a bidirectional SC converter for dc-ac and ac-dc power conversion in electric and hybrid electric vehicles.

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

1. Introduction

the authors concluded that a fast adaptation scenario for electric vehicles is likely to happen. By 2042, around 93% (290 million) of all vehicles in the U.S. will be electric [1]. At that time, the internal combustion-based automakers that fail to transition to electric cars (EVs) will soon have a Kodak moment. In ideal world, the fast adaptation of EVs depends on how fast the EVs will outperform the internal combustion-based cars in mileage and price. The potential development of EV technology falls broadly into three categories: battery chemistry, autonomous driving, and the power electronic units. With regard to the last category, one of the most critical power conversion units is the drive train. The improvement of the drive train results in size reduction, fast speed/torque dynamic, and better utilization of battery power. Most of the existing EVs utilize a two-level voltage source inverter (VSI) with or without boost stage due to its reliability [2][3]. The opportunities to improve the EV power train can be addressed by exploring the limitations of VSIs. VSIs are inherently buck converters. Therefore, the dc-link voltage has to be higher than the dc or ac input voltage.

For applications where the available dc voltage is limited, an additional dc-dc boost converter is needed to obtain the desirable ac voltage [4]. For the commercial traction electric drive system, two configurations are commonly used: the first one is a battery directly powering a two-level inverter; the second one is a battery connected to the inverter with an intermediate dc-dc boost stage as shown in Fig. 1(a) [5]. The first configuration of a battery directly connected to the dc-bus offers minimum stress on the inverter side, but it requires an expensive battery with a large number of cells in series to achieve the necessary dc-link voltage [6]. The series connection of battery cells poses a challenge in terms of the slow charge equalization speed [7]. Furthermore, the isolation of one faulty cell in the series connection leads to a voltage drop in the overall series connection. In this case, the entire series row of batteries needs to be disconnected from the dc-link to avoid a short circuit with other non-faulty series rows of cells. The first configuration is seen only in extended-range electric vehicles (with large batteries) such as Tesla (75 to 100 kWh) [8]. Hybrid electric vehicles (HEVs) and plug-in HEVs (PHEVs) where the battery energy rating ranges from 5 to 50 kWh. While the current limit in the machine is dependent on its ability to dissipate the heat, the voltage limit is dependent on the dc-link voltage level. Therefore, using a dc-dc boost converter extends the constant torque region [9]. Owing to the superior current density characteristics of the SiC-MOSFET compared to the Si-IGBT, the current density of the 1200V SiC-MOSFET is similar to the current density of the lower voltage 600V Si-IGBT [10]. This advantage leads to a reduction in semiconductor die area by a factor of two, and this is accomplished by utilizing high-voltage motors and SiCMOSFETs [11]. Furthermore, the reduced current peak at a higher voltage leads to smaller peak losses by a factor of four [11]. Since power loss translates directly into cooling system capacity, a significant reduction in cooling system size and weight, as well as an improvement in EV range, can be achieved. The conventional boost stage depicted in Fig. 1(a) is not quite perfect. The power rating of the dc-dc converter must match the battery pack power, leading to a proportionally large inductor. The inductor is a heavy and costly component. Furthermore, the inductor copper and core losses increase proportionally with the size of the inductor. When boosted by a high-voltage ratio, the boost converter must operate with a high duty cycle where the efficiency is relatively low [12]. The partial power efficiency is also reduced, because the ac losses (switching loss and ac magnetic loss) depend on voltage but are nearly independent of current. At high duty cycles, the rms current applied to the bus capacitor is also quite high, which impacts the size and cost of the capacitor [11]. To overcome the above limitations of the traditional drive trains, this paper presents the switched-capacitor voltage boost (SC) converter and its control methods. Fig. 1(b) shows one version of the proposed SC converter. It employs a switched capacitor circuit with the inverter to form a unified circuit. The switched capacitor circuit is used to create a multi-leveled dc-link voltage. Therefore, the proposed switched-capacitor circuit differs from the conventional one by not having the reverse blocking diode at the load side or the large filtering capacitor. The regulation of the output current and voltage is realized by unified control of both the inverter and the switched-capacitor stages.

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

In electronics engineering, a DC-to-DC converter is a circuit which converts a source of direct current from one voltage to another. It is a class of power converter. DC to DC converters are important in portable electronic devices such as cellular phones and laptop computers, which are supplied with power from batteries. Such electronic devices often contain several sub-circuits with each sub-circuit requiring a unique voltage level different than that supplied by the battery (sometimes higher or lower than the battery voltage, and possibly even negative voltage). Additionally, the battery voltage declines as its stored power is drained. DC to DC converters offer a method of generating multiple controlled voltages from a single variable battery voltage, thereby saving space instead of using multiple batteries to supply different parts of the device.

Circuit analysis

Operating principle

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. When being charged it acts as a load and absorbs energy (somewhat like a resistor), when being discharged, it acts as an energy source (somewhat like a battery). The voltage it produces during the discharge phase is related to the rate of change of current, and not to the original charging voltage, thus allowing different input and output voltages.

Fig.1: Boost converter schematic

III. PROPOSED SYSTEM

Proposed Circuit diagram

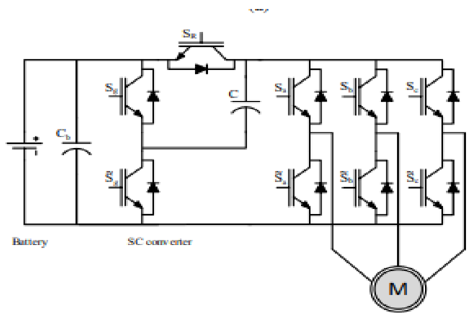

Fig.2: Switched capacitor Voltage Boost Converter

PROPOSED TOPOLOGY

- To overcome the above limitations of the traditional drive trains, this project presents the switched-capacitor voltage boost (SC) converter and its control methods.
- It employs a switched capacitor circuit with the inverter to form a unified circuit.
- The switched capacitor circuit is used to create a multi-leveled dc-link voltage.
- The proposed switched-capacitor circuit differs from the conventional one by not having the reverse blocking diode at the load side or the large filtering capacitor.
- The regulation of the output current and voltage is realized by unified control of both the inverter and the switched-capacitor stages

Boost converter

- We've all come across pesky situations where we need a slightly higher voltage than our power supplies can provide. We need 12 volts but have only a 9 volt battery. Or maybe we have a 3.3V supply when our chip needs 5V. That too, in most cases, the current draw is quite decent.
- Eventually, we ask ourselves the question, is it possible to convert one DC voltage to another?
- Lucky for us, the answer is yes. It is possible to convert one DC voltage to another, however the methods are a slightly on the clever side.
- And no, it does not involve the conversion of DC to AC and back again. As it involves too many steps. Anything that has too many steps is inefficient; this is a good life lesson too.
- Enter the world of switch mode DC-DC converters!
- They're called switch mode because there's usually a semiconductor switch that turns on and off very rapidly.

Switched capacitor boost voltage

When the switch is then closed and the right-hand side is shorted out from the left-hand side, the capacitor is therefore able to provide the voltage and energy to the load. During this time, the blocking diode prevents the capacitor from discharging through the switch.

SPEED CONTROL

- Motor speed depends upon the amplitude of the applied voltage. The amplitude of the applied signal is adjusted by using PWM.
- The higher side transistors are driven using PWM. By controlling the duty cycle of the PWM signal, the amplitude of the applied voltage can be controlled, which in turn will control the speed of the motor.

TORQUE CONTROL

- Torque can be controlled by adjusting the magnetic flux. However, magnetic flux is dependent upon the current flowing through the windings. Thus, by controlling current, torque of a motor can be controlled.

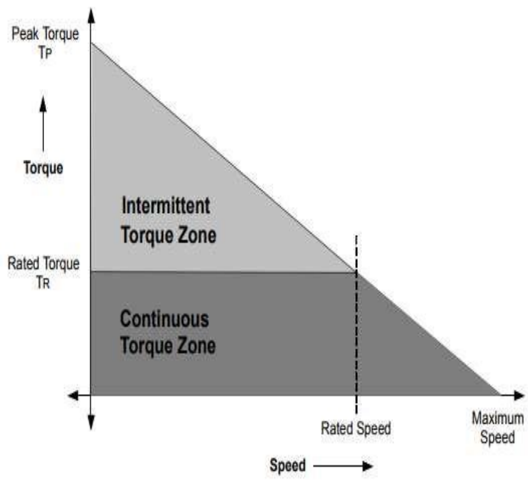

Fig.3: Torque-Speed Characteristics

IV. SIMULATION Results

Simulink

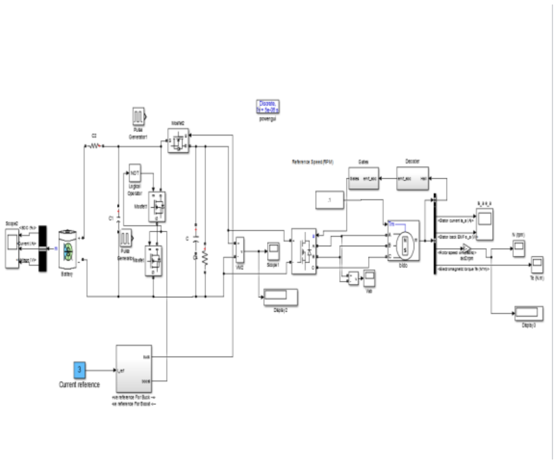

Fig.4: Simulink model of the System with Boost Converter for Electric and Hybrid Electric Vehicle Drives

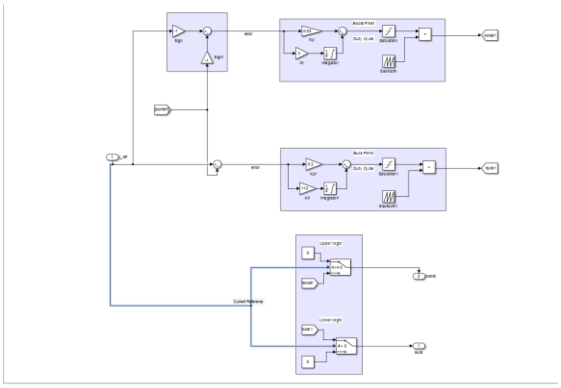

Fig.5: Switched capacitor controller

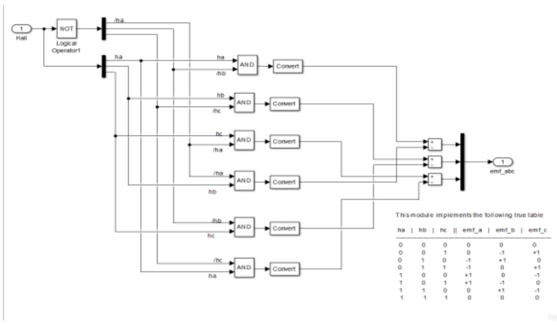

Fig.6: Hall sensor

Fig.7: Switched capacitor output voltage

Fig.8: Motor speed

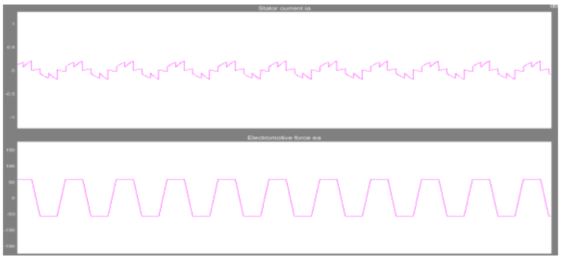

Fig.9: Stator current and back emf

V. Conclusion

This paper has presented a new switched-capacitor power converter (SC) for implementing dc-ac and ac-dc power conversion. The SC converter employs a switched-capacitor circuit augmented with the main converter circuit to the power source, thus providing unique features that cannot be attained by the traditional VSI or boost VSI. One of these unique features is doubling the area of the linear modulation region. The SC converter eliminates the need for the cumbersome and costly inductor to boost the voltage. Instead, it relies on only the capacitors to achieve voltage boost, which allows higher power density. The formulation of the maximum voltage drop across the capacitor and the minimum charging current are analytically derived. The analytical results provide a clear insight into the design elements that affect the behavior of the charging current, thus allowing the operation at higher power. The carrier-based modulation method for the new SC converter is derived from the SVPWM and employs the exact switching sequence of the SVPWM method with minimal computational effort. The analytic derivations, simulation, and experimental results have validated the operating principle and modulation methods of the proposed converter. The SC converter can boost or buck voltage, minimize component count, increase power density, and reduce costThis paper proposes a control method for a low cost GC micro-inverter with MPPT used in photovoltaic applications. A macro-model is proposed in order to testthe proposed system and improve simulation times. In this way different MPPT algorithms can be developed and easily compared. Also, the macro-model speeds-the tuning of the voltage loop and the design of the input filters used for maximum power point tracking. The AM and the circuit used for inverter simulations are validated experimental results.

REFERENCES

[1] Reda Cherif, Fuad Hasanov, and Aditya Pande, “Riding the Energy Transition: Oil Beyond 2040,” IMF Working Papers, May 2017.

[2] Y. Song and B. Wang, “Evaluation Methodology and Control Strategies for Improving Reliability of HEV Power Electronic System,” in IEEE Transactions on Vehicular Technology, vol. 63, no. 8, pp. 3661-3676, Oct. 2014.

[3] Sateesh Devanga Yerra, D Y Kiran Kumar, (2021), “Optimizing DC Microgrid Performance: Improved Energy Management Strategy for Seamless Integration of Electric Vehicle Fast Charging Stations”. NeuroQuantology| June 2021 | Volume 19 | Issue 6 | Page 292-302| doi: 10.48047/nq.2021.19.6.NQ21101.

[4] Sateesh Devanga Yerra, D Y Kiran Kumar, (2019), “Innovative Resonant Inverter Designs for Material Vessel Induction Cooking: A 3-Leg Full-Bridge Approach”. International Journal of Early Childhood Special Education, Pages: 300-307, DOI: 10.48047/INTJECSE/V11I2.670491.

[5] G. M. S. Azevedo, M. C. Cavalcanti, K. C. Oliveira, F. A. S. Neves, Z. D. Lins, "Evaluation of maximum power point tracking methods for grid connected photovoltaic systems," in Proc. IEEE PESC, 2008, pp. 1456-1462.

[6] Norjasmi Bin Abdul Rahman, “Inverter Topologies for Photovoltaic Systems”, Master’s Thesis, Dept. Electrical Engineering, Aalto University School of Science and Technology, Espoo, Finland, 2010.

[7] Tat Luat Nguyen, Kay-Soon Low, "A Global Maximum Power Point Tracking Scheme Employing DIRECT Search Algorithm for Photovoltaic Systems," IEEE Transactions on Industrial Electronics, vol. 57, no. 10, pp. 3456-3467, Oct. 2010.

[8] D. Sera, T. Kerekes, R. Teodorescu, F. Blaabjerg, "Improved MPPT Algorithms for Rapidly Changing Environmental Conditions," in Proc. 12th International Conference on Power Electronics and Motion Control, 2006, pp. 1614-1619.

[9] D. Sera, T. Kerekes, R. Teodorescu, F. Blaabjerg, "Improved MPPT method for rapidly changing environmental conditions," in Proc. IEEE International Symposium on Industrial Electronics, 2006, vol. 2, pp. 1420-1425.

[10] D Y Kiran Kumar, Sateesh Devanga Yerra, (2021), “Enhancing Large-Scale Process Control: Advanced IMC-PI Controller Performance Optimization”. NeuroQuantology | December 2021 | Volume 19 | Issue 12 | Page 690-694| doi: 10.48047/nq.2021.19.12.NQ21271.