DESIGN AND SIMULATION ANALYSIS OF ELECTRIC AND HYBRID ELECTRIC VEHICLE DRIVES CONTROLLED BY SWITCHED CAPACITOR VOLTAGE BOOST CONVERTER

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ABSTRACT

This study provides a switched-capacitor (SC) voltage boost converter and related control strategies to accomplish the goals. SC converters are capable of tasks that a regular or boost VSI is unable to do because they combine the primary converter circuit to the power supply with a

switchedcapacitor circuit. Energy density was increased by a factor of two, prices were cut in half, and the size of the linear modulation zone was doubled by getting rid of the enormous inductor from the boost dc-dc stage and the big filtering capacitor. The SC converter can switch between direct current (dc), alternating current (ac), and ac-dc power. Control and operation of a bidirectional synchronous converter (SC) for dc-ac and ac-dc power conversion in electric vehicles and hybrid electric vehicles.

INDEX TERMS: switched capacitor (SC), Boost Converter, Electric Vehicle Drives, voltage-source inverter (VSI).

I. INTRODUCTION

Ultimately, the authors came to the conclusion that a rapid adoption scenario of EVs will occur. By 2042, In the United States, it is predicted that by 2040, 93% (290 million) of all automobiles would be electric. Those manufacturers who still depend on internal combustion engines and haven't made the conversion to EVs will confront their "Kodak moment" shortly. In an ideal world, EV adoption would be swift would be contingent on how quickly EVs would surpass conventionally powered vehicles in terms of mileage and cost. Potential advances in electric vehicle technology may be broken down into three main areas: technologies related to batteries, driverless cars, and power electronics. As for the third group, the drive train is an extremely important power conversion unit. The enhanced drive train allows for a more compact design, a faster speed/torque dynamic, and more efficient battery use. As a result of its dependability, a VSI with or without a boost stage that can invert voltage between two levels is used in the majority of currently available EVs [2][3]. Investigating the constraints of VSIs is one way to address the potential for enhancing the EV power train. It is the nature of VSIs to function as buck converters. As a result, whether the input is direct current (dc) or alternating current (ac), the dc-link voltage must be higher. When the available dc voltage is low, a dcdc boost converter is required to provide the required alternating current voltage [4]. Figure 1(a) displays a typical commercial traction electric drive system in which a

battery feeds power directly to a two-level inverter; Figure 1(b) depicts an alternate configuration in which a dc-dc boost stage is utilized to link a battery to an inverter [5]. The inverter is less stressed in the first design, when the battery is connected directly to the dc-bus; however, this technique employs a high-priced battery with several series-connected cells in order to provide the necessary dc-link voltage [6].The delayed charge equalization speed posed by a series connection of battery cells [7]. Another issue with series connections is that the voltage drops when a single bad cell is removed. It is required to disconnect the whole series row of batteries from the dc- connector in order to avoid creating a connect with additional successive rows of healthy cells to form a short circuit. The first is specific to extended range EVs. (with huge batteries), such as Tesla's (75 to 100 kWh) [8]. Specifically, Fig.1(a second)'s arrangement is employed in

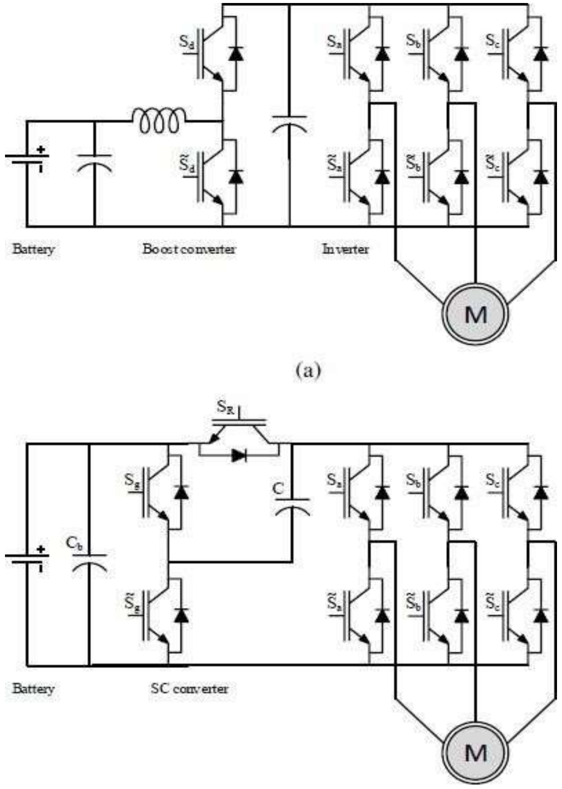


Figure 1: The schematics of (a) the traditional inverter converter architecture, as well as (b) hybrid electric cars (HEVs) and plug-in HEVs (PHEVs) with switchedcapacitor voltage boost converters, with battery energy ratings ranging from 5 to 50 kWh

The heat dissipation capacity of the machine sets the upper limit on the current it can handle, while the voltage level of the dc-link sets the upper limit on the machine's operating voltage. The constant torque area may be maintained for a longer distance by utilising a dc-dc boost converter [9]. Because SiC-MOSFETs have higher current density than Si-IGBTs, a 1200V SiC-MOSFET can produce the same amount of current as a 600V SiIGBT [10]. This gain is realised by the use of SiCMOSFETs [11] in place of conventional high-voltage motors, which halves the footprint of the semiconductor die. If you increase the voltage, you may reduce the peak current and hence the peak losses by a factor of two [10]. Reduced power loss may result in a smaller and lighter cooling system and a longer range for electric vehicles. Fig. 1(a) depicts a typical boost step, however this design has certain flaws. Having a big inductor is necessary since the dc-dc converter's power rating must be equal to that of the battery pack. The inductor is a cumbersome and expensive piece of equipment. The copper and core losses of an inductor grow in proportion to its physical size. For high duty cycles, which are necessary when the voltage ratio is significant, the boost converter's efficiency declines considerably [9]. Because alternating since current losses (switching loss and alternating magnetic loss) decrease partial power efficiency, they are voltage-dependent but virtually currentindependent. The size and cost of the bus capacitor are affected by the duty cycle because of the rms current provided to the capacitor. This study introduces the switched-capacitor voltage boost (SC) converter and related control strategies as a means of ameliorating the aforementioned drawbacks of conventional drive trains. Using the SC converter seen in Fig. 1 is strongly advised. may be implemented (b). The inverter and switched capacitor circuit work together to generate the integrated circuit. To provide a voltage gradient across the dc connection, a switched capacitor circuit is employed. As a result, The suggested switched-capacitor circuit differs from the usual one by eliminating the reverse blocking diode and the big filtering capacitor on the load side. Together, the inverter and the switched capacitor are controlled centrally to achieve the desired output current and voltage regulation.

II. METHODOLOGY

DC to DC converter

A "DC-to-DC converter" is an electrical circuit that changes the voltage of a direct current source. This sort of power converter is available.

Cell phones, laptops, and other portable electronic gadgets that rely on batteries cannot function without DC to DC converters. Many of these electrical gadgets have many sub-circuits, each of which requires a distinct voltage level (sometimes higher or lower than the battery voltage, and possibly even negative voltage). When a battery's energy stores are exhausted, its voltage drops. By using a DC-to-DC converter and a battery with a varying voltage, it's possible to generate several, precisely regulated voltages eliminating the need for several batteries to power different components of the device.

Switched-mode conversion

Inverter-type Electronics It is possible to convert between different DC voltage levels with the use of DC to DC converters. These circuits, like switched-mode power supplies, convert putting a DC voltage across an inductor or transformer for some time (usually between 100 kHz and 5 MHz) to induce current flow and magnetically store energy, and then cutting off this voltage to transfer the stored energy to the voltage output. The output voltage may be controlled independently of the current demand by varying the on/off ratio. This technique of conversion is more efficient in terms of as much as 95% less energy as linear voltage conversion wastes energy through dissipation. The efficiency gained in this way is useful for extending the life of battery-powered gadgets. The highfrequency electrical noise that switching converters produce is a downside that requires filtering in some situations.

Voltage and current waveforms (Boost Converter)

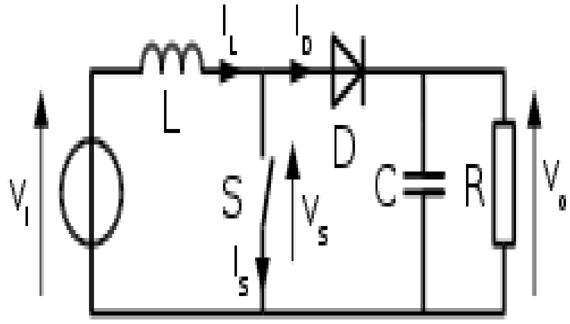
Power converters having a DC voltage differential between the input and output are known as boost converters or step-up converters. It's a type of SMPS that has at least one energy storage component and two semiconductor switches (a diode and a transistor). The converter's output is often filtered using capacitors (and maybe inductors) to smooth out the voltage.

Operating principle

The inductor's natural inclination to resist fluctuations in current is the fundamental idea behind the boost converter. It functions as a load and absorbs energy (similar to a resistor) when charging, and a source of energy during discharging (somewhat like a battery). During the discharge phase, the voltage it generates is proportional to the rate of change of current rather than the charging voltage, permitting a broad selection of input and output voltages.

Figure 2: Boost converter schematic

In a boost converter, the two possible setups are selected via the switch S. A Boost converter operates on a simple premise of two states:



- When the switch S (shown in Figure 3) is in its "On" position, current through the inductor rises.
- When the switch is in its open "Off" position, current in the inductor can only flow through the flyback diode D, the capacitor C, and the load R. What this does is charge the capacitor with the power that has

been building up in the device while it has been in its On state.

- As can be seen in Figure 4, the input current is identical to the inductor current. This means there is no abrupt transition like in a buck converter, and the input filter can be less stringent.

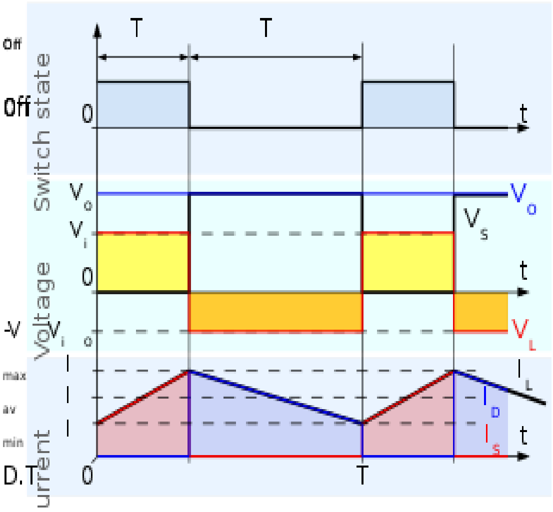


Figure 3: Continuous mode

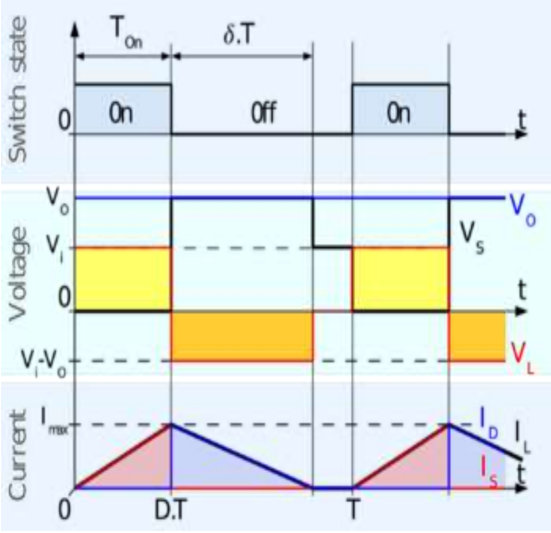


Figure 4: Discontinuous mode

MODELING OF PROPOSED PMBLDCM DRIVE

When put together, these models constitute a comprehensive representation of the planned PFC drive. 1) One such generator is the voltage reference generator, which produces a voltage at the DC link that is proportional to the PMBLDCM's target reference speed. Given that the controller's speed control relies on a precise equivalent DC link voltage reference, this reference is an essential part of the device. 2) The rate limiter, which is introduced into the reference voltage, maintains a steady voltage error (Ve) at the DC link under transient conditions, so enabling the motor current (Idc) to rise gradually. The DC current increase (Idc) in the motor is a function of the rate of voltage rise (Ve) at the DC connection and the equivalent resistance (Req) of the PMBLDC motor at the DC connection. Calculating PMBLDCM requires the rate limiter to consider the rated terminal voltage (VT), the winding resistance per phase (Ra), the maximum permissible motor current per phase (Idc max), and the mechanical time constant (m).

3) Based on the difference between the reference voltage and the detected voltage at the DC link, the proportional and integral (PI) controller voltage controller generates a control signal Ic with proportional gain Kp and integral gain Ki.

4) Using the AC mains voltage as a template and the PI controller's output, a reference current (id*) is created for use at the input of an isolated zeta converter.

5) The current inaccuracy is determined by comparing the measured DC current (id) after DBR to the isolated zeta converter's reference input current (id*) (id). To create the switching signal for the MOSFET in the PFC converter, the current error (id) is compared to a sawtooth carrier waveform (md (t)) at a constant frequency (fs) [8].

6) Hall effect position sensors provide information into the electronic commutator, which then uses that information to determine the switching sequence for the VSI.

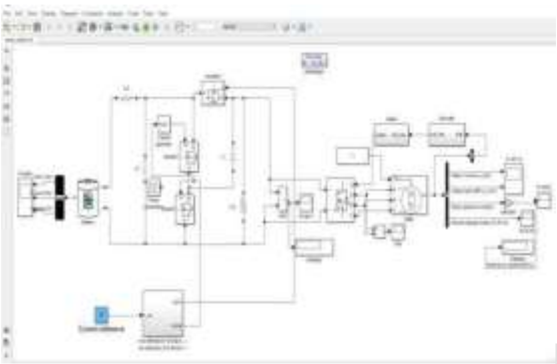
7) The proposed PMBLDCM drive uses insulated-gate bipolar transistors since it works at a lower frequency than the PFC converter (IGBTs). The VSI output is linked to phase 'a' of the

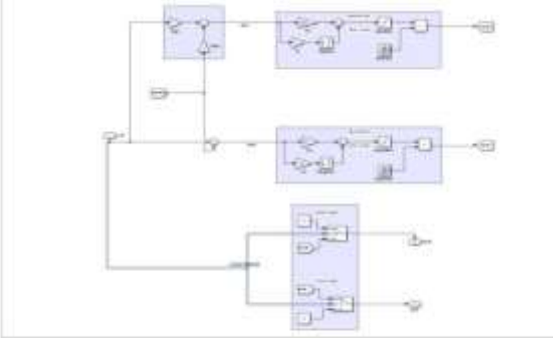
PMBLDC motor using the analogous circuit of a VSI-fed PMBLDCM, where vao, vbo, vco, and vno are the voltages at the virtual halfway of the DC connection, phase 'a,' phase 'b,' phase 'c,' and the neutral point, respectively. Van, vbn, and vcn denote three-phase voltages with regard to the motor's neutral terminal (n). Sa1 and Sa2 can be 1 or 0 to indicate whether VSI IGBTs are "on" or "off." The switching patterns of the VSI's other IGBTs (Sb1, Sb2, Sc1, and Sc2) and the voltages for the other two phases supplying the PMBLDC motor (vbo, vco, vbn, and cn) are created similarly. 8) p is the differential operator (d/dt), ia, ib, and ic are currents, a, b, and c are flux linkages, ean, ebn, and ecn are the alternating and countercurrent back emfs of the PMBLDCM, and R is the motor winding resistance. Ls indicates selfinductance/ph and M mutual inductance/ph. Te = electromagnetic torque, r = motor angular velocity, P = number of poles, Tl = load torque, J = moment of inertia, and B = friction coefficient.

III. Simulation Results

Figure.7: Hall sensor

Figure.8: Switched capacitor output voltage





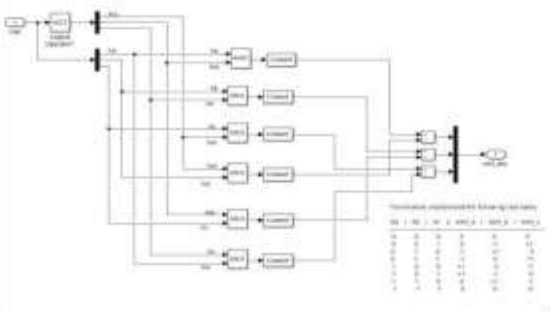


Figure.5:

Simulink

Figure.9: Motor speed

Figure.6: Switched capacitor controller

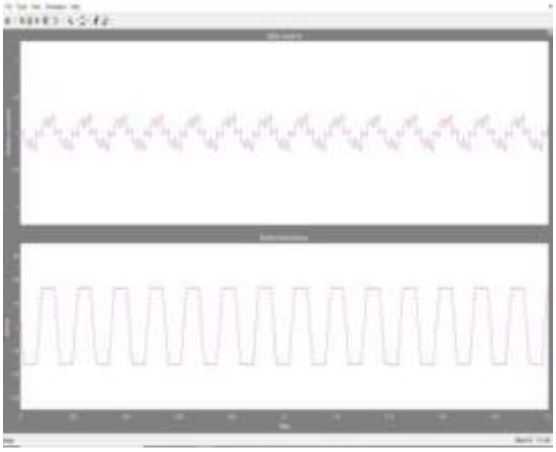


Figure.10: Stator current and back emf

IV. CONCLUSION

In this study, a unique switched-capacitor (SC) converter was presented to achieve both dc-ac and ac-dc power conversion. The SC converter achieves outcomes that a conventional VSI or boost VSI cannot attain by integrating the switched-capacitor circuit with the main converter circuit to the power source. Increasing the size of the linear modulation zone by a factor of two is one of these special characteristics. Using an inductor to increase the voltage is inconvenient and expensive, but not with the SC converter. Rather, it uses only capacitors to boost voltage, resulting in greater power density. It is possible to analytically obtain the formula for highest possible charging current and lowest possible voltage drop across the capacitor. In order to operate at higher power, the analytical results provide light on the design aspects that impact the charging current's behavior. The new SC converter uses a carrier-based modulation approach that is developed It differs from SVPWM in that it uses the same switching sequence but requires somewhat more processing work. Analytic derivations, modelling, and experimental discoveries have confirmed the recommended converter's operating principle and modulation methodologies. In addition to boosting or bucking voltage, the SC converter reduces the number of components, improves power density, and lowers the price. For photovoltaic applications, this research suggests a technique of control for a cheap GC microinverter equipped with maximum power point tracking.

To verify the suggested system and speed up simulation times, a macro-model is presented. This allows for the creation of several MPPT algorithms and the straightforward comparison of their performance. The tuning of the voltage loop and the construction of the input filters required for maximum power point tracking are both sped up by the macro-model. There is experimental confirmation of both the AM and the circuit utilized in the inverter simulations.

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