Switched-Capacitor Voltage Boost Converter for Electric Vehicle Drives

Kabilesh K , Deepan Kumar C , Austin S ,

Sri Ramakrishna Engineering College.

Abstract—This article presents a Switched-Capacitor (SC) voltage boost converter and its control methods for implementing dc-ac and ac-dc power conversion. This Switched-Capacitor Converter uses switched capacitor instead of inductor as used in traditional voltage source inverter to increase and decrease voltage from battery of any dc or ac source. This Switched-Capacitor converter has many advantages over traditional voltage source inverter such as less cost and losses due to the absence of inductor in this Switched-Capacitor converter. It also reduces the size of the converter due to the absence of inductor coil. It also doubled 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. This converter can be used of ac-ac, dc-dc, ac-dc and dc-ac.

I. INTRODUCTION

The usage of electric goods are increasing exponentially in day to day life. And we are using electric energy in form of both ac and dc in daily life in different application which requires different voltage ranges. But we are receiving the power in a constant voltages. Here we use converters to increase or decrease voltage and current and we also can convert ac to dc or dc to ac power supply. In world the primary energy consumption is 58 kWh per day per person. So the efficiency of the electric converters we are using must be more efficient. The traditional Voltage source converters, boost and buck converters have inductor which is very large and due to which more power is lost as heat.

There are two configuration we are using currently, one is battery directly connected to 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. The series connection of battery cells poses a challenge in terms of the slow charge equalization speed. 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 dclink to avoid a short circuit with other non-faulty series rows of cells.

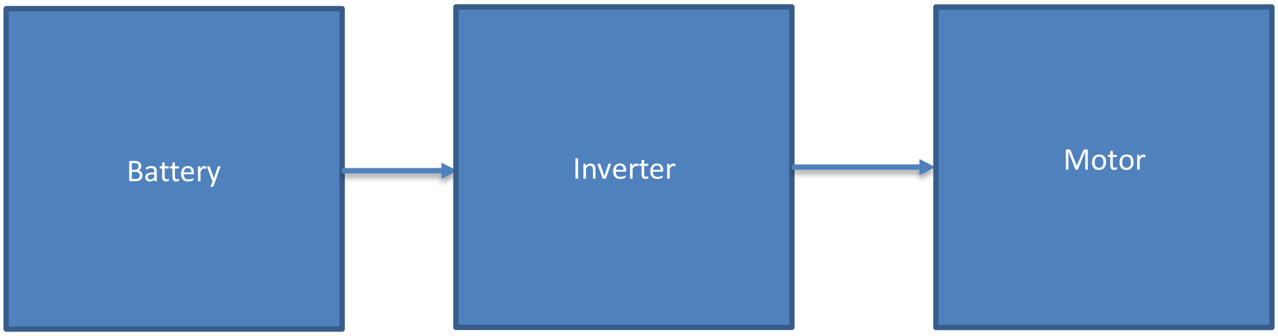


Fig 1 Configuration one

The second configuration is that we use a dc-dc converted between battery and dc-bus so we don't need to use an bigger expensive battery. 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 . 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.

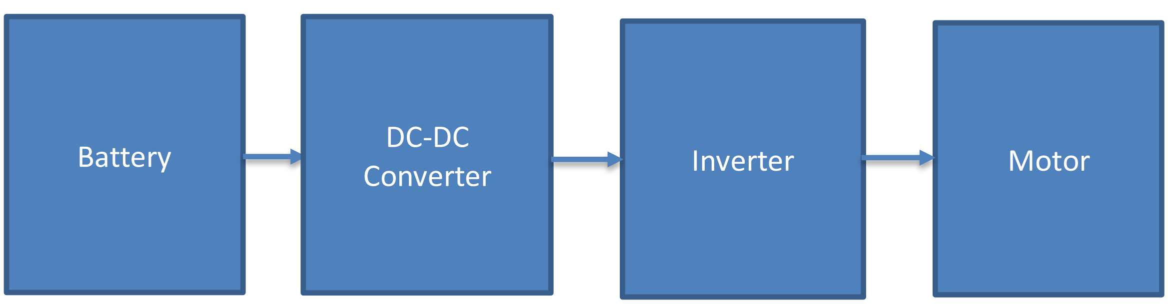


Fig 2 Configuration two

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 05 | May - 2022 Impact Factor: 7.185 ISSN: 2582-3930

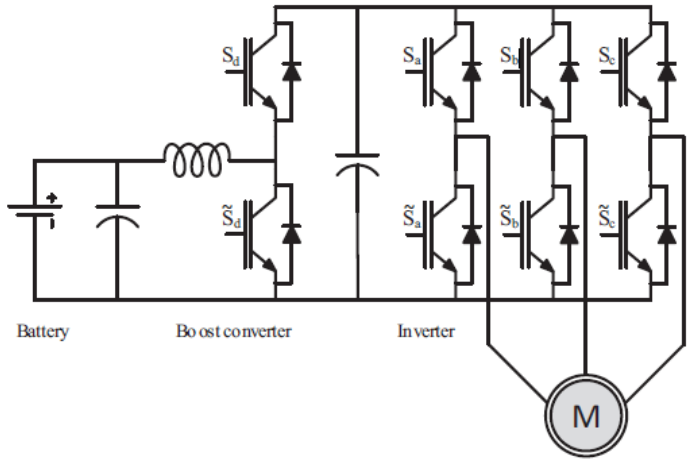


Fig 3 Existing System

To overcome this disadvantage and some extra features we can use Switched-Capacitor converters in order to be efficient. It employs a switchedcapacitor 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.

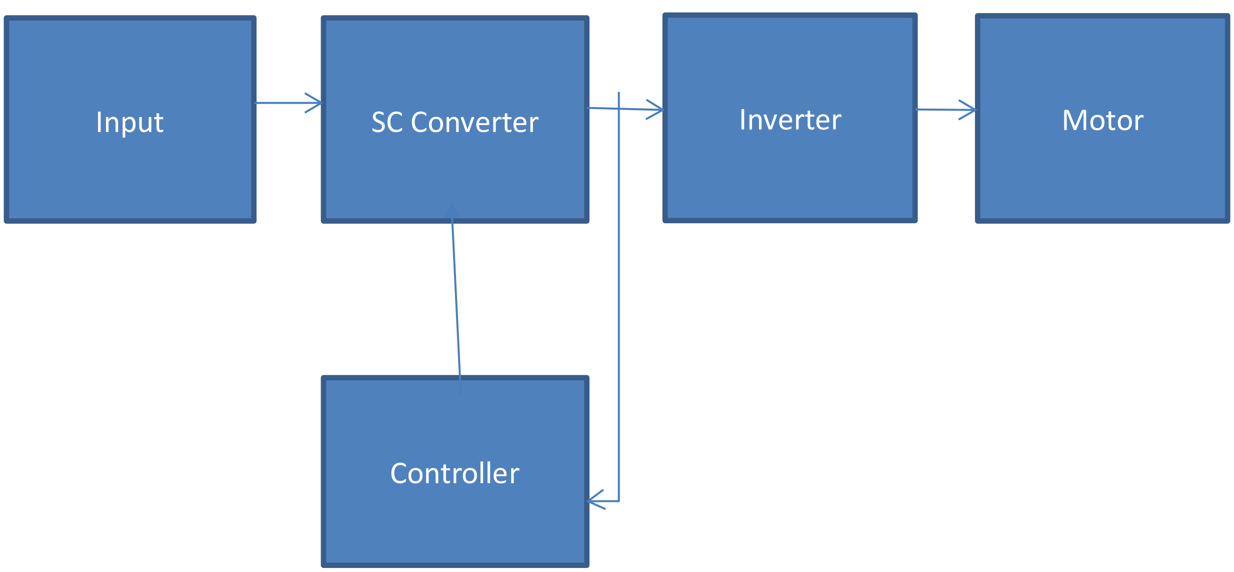


Fig 4 Proposed System

II. CALCULATION

Capacitor charging condition:

$V_{bat} = V_{cap} = V_i$

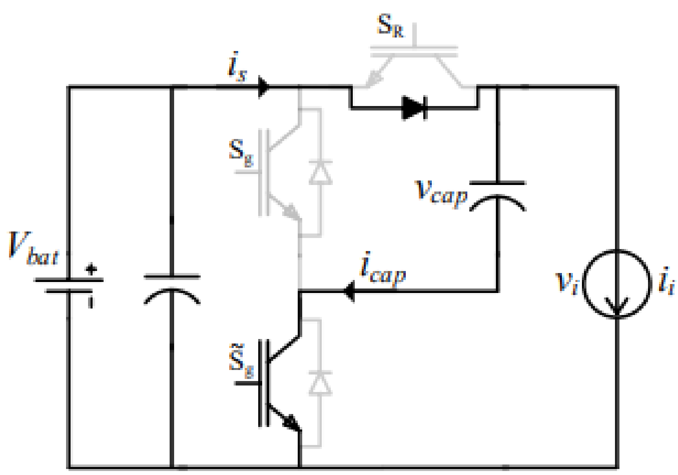


Fig 5 Charging Condition

Here the Switch S_R and S_g are open and the capacitor V_{cap} is being charged. Now the voltage of V_{bat}, V_{cap} and V_i are equal.

Capacitor discharging condition:

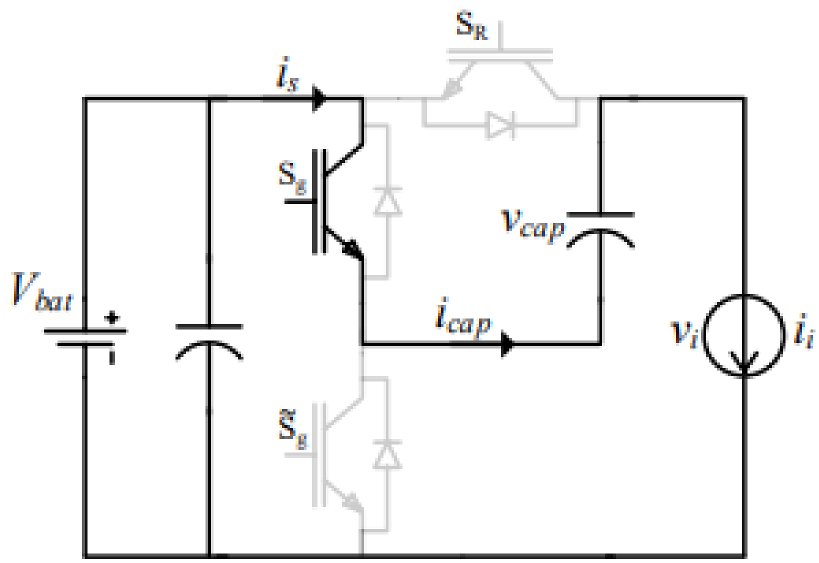


Fig 6 Discharging Condition

Here the Switch S_g is colsed and the capacitor V_{cap} is discharged. Now the voltage of

$V_{bat} + V_{cap} = V_i,$

as V_{bat} and V_{cap} are equal,

$V_{bat} = V_{cap}$,

$2V_{bat} = V_i,$

III. CIRCUIT DIAGRAM

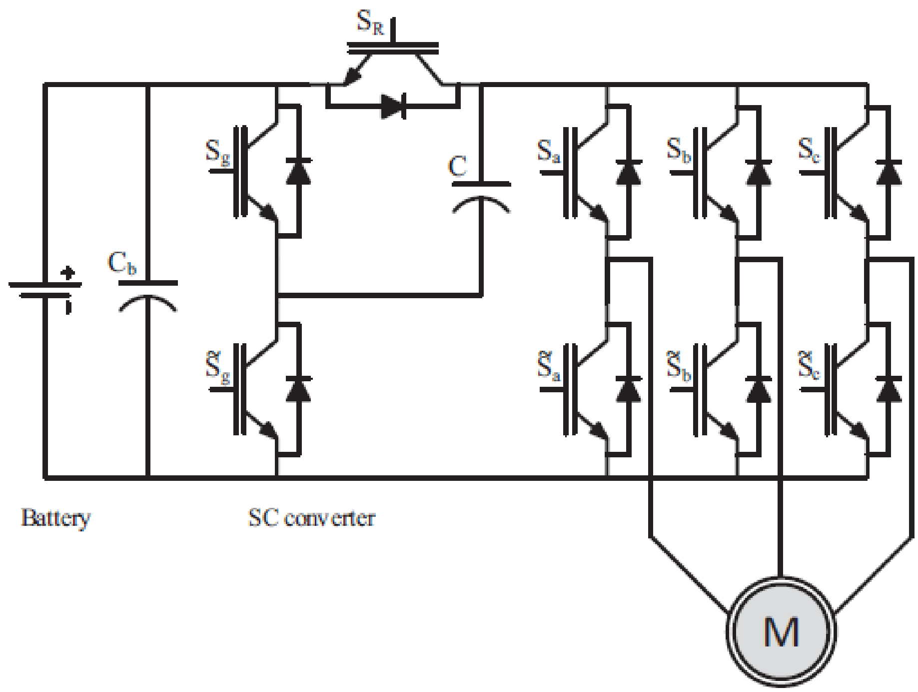


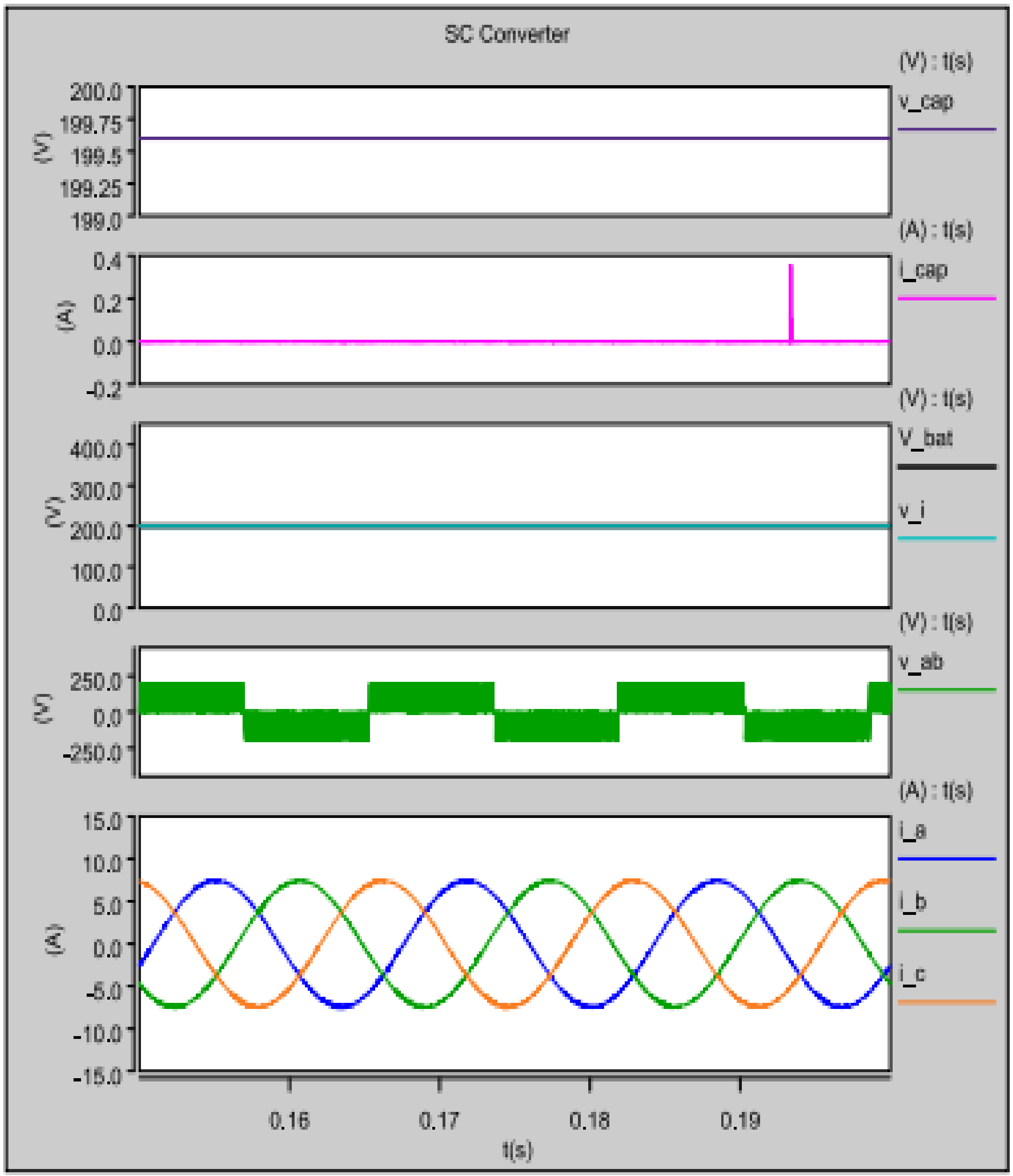
Fig 7 Proposed System

IV. SIMULATION RESULTS

To verify the proposed method, first figure shows the simulation output of the circuit with abstemious mode, $M_i = 0.5$ and $A = 0$ and the second figure shows the simulation result of the circuit with gluttonous mode, $M_i = 0.5$ and $A = 0.5$. In both cases, $V_{bat} = 200$.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 05 | May - 2022 Impact Factor: 7.185 ISSN: 2582-3930

Fig 8 Simulation Output of SC Converter with abstemious mode, $M_i = 0.5$ and A = 0



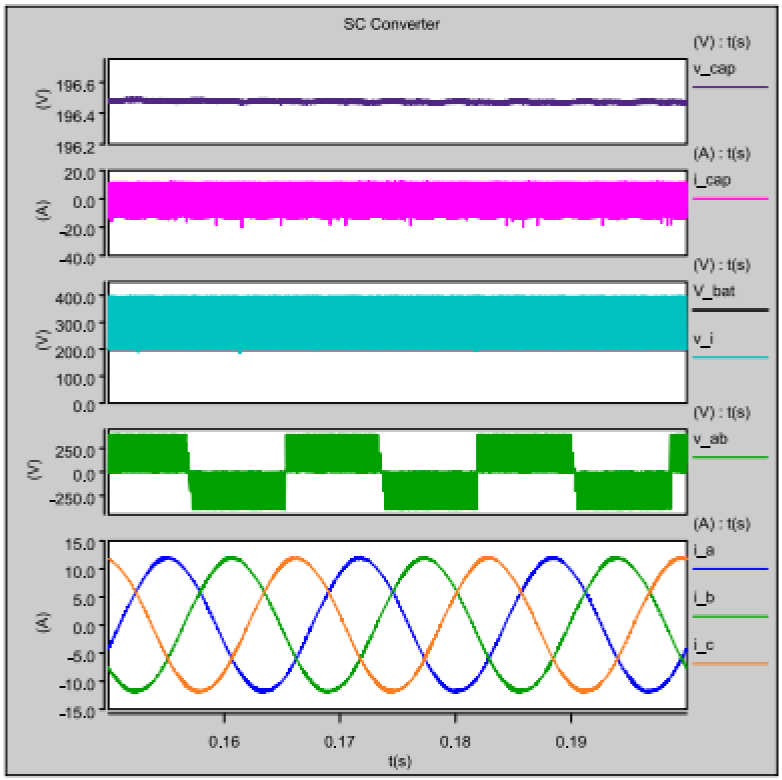


Fig 9 Simulation Output of SC Converter gluttonous mode, M_i = 0.5 and A = 0.5

V. EXPIREMENTAL OUTPUT

To verify the proposed method, first figure shows the simulation output of the circuit with abstemious mode, M_i = 0.5774 and A = 0 and the second figure shows the simulation result of the circuit with gluttonous mode, M_i = 0.5774 and A = 0.5. In both cases, V_{bat} = 100.

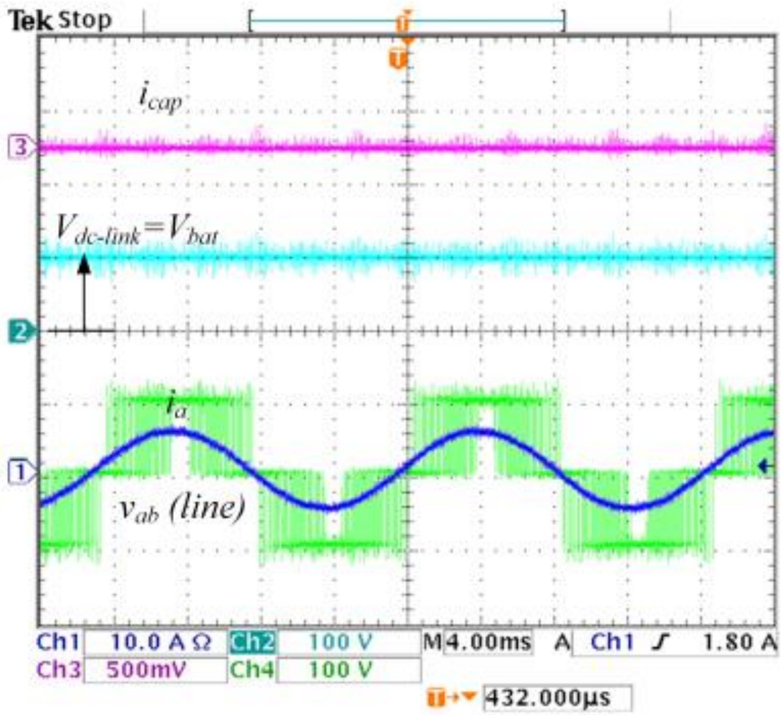


Fig 10 Experimental results of SC Converter with abstemious mode, M_i = 0.5774 and A = 0

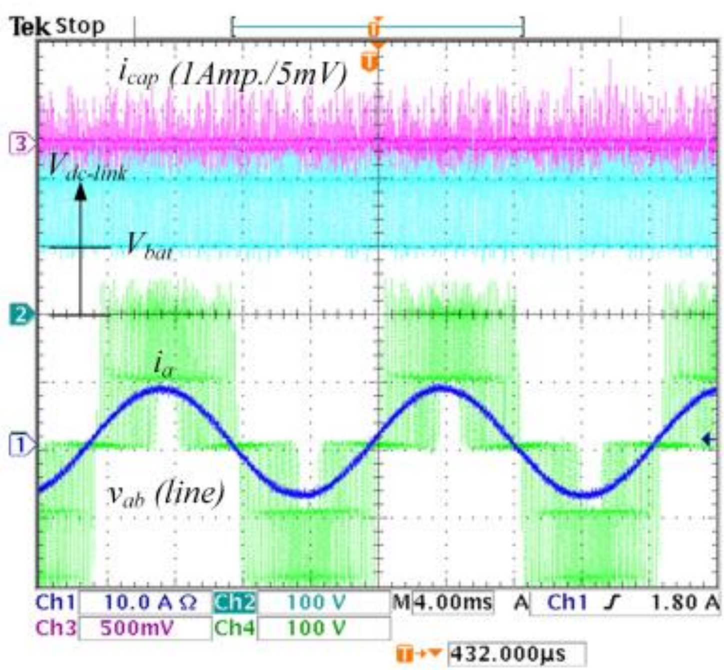


Fig 11 Experimental results of SC Converter gluttonous mode, M_i = 0.5774 and A = 0.5

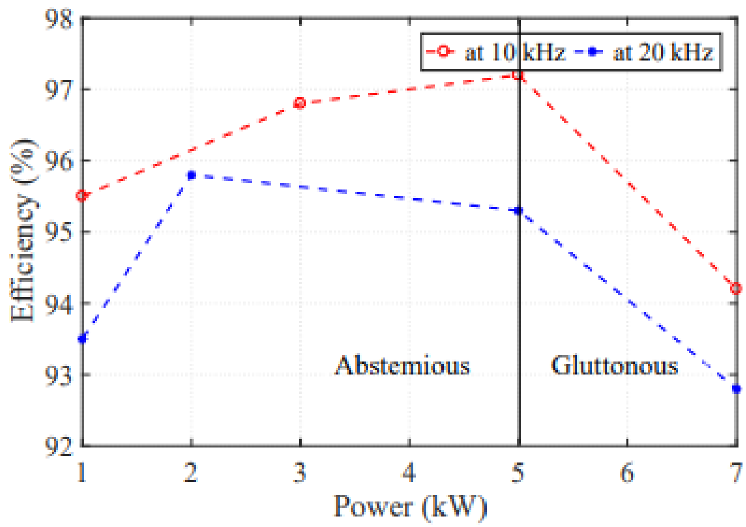


Fig 12 Efficiency of the SC Converter.

VI. HARDWARE SNAPSHOT

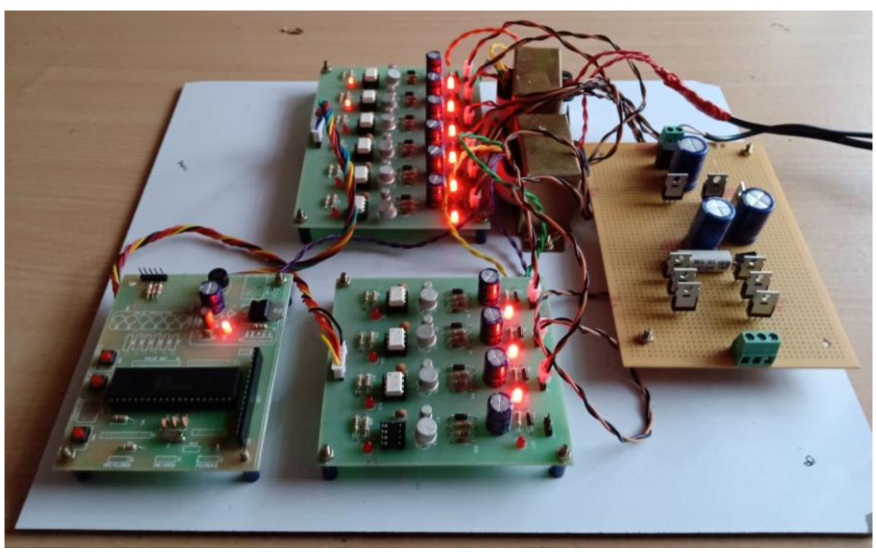


Fig 13 Complete hardware component.

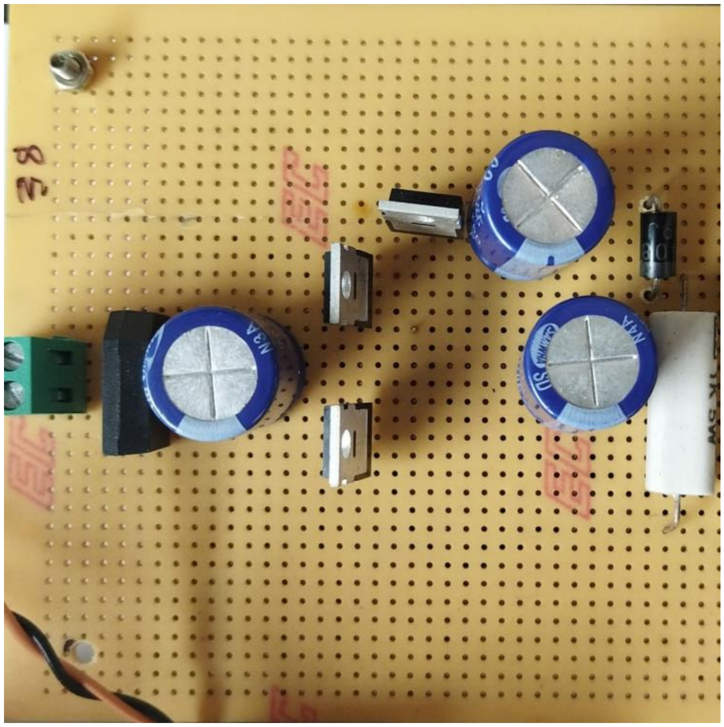


Fig 14 SC Converter

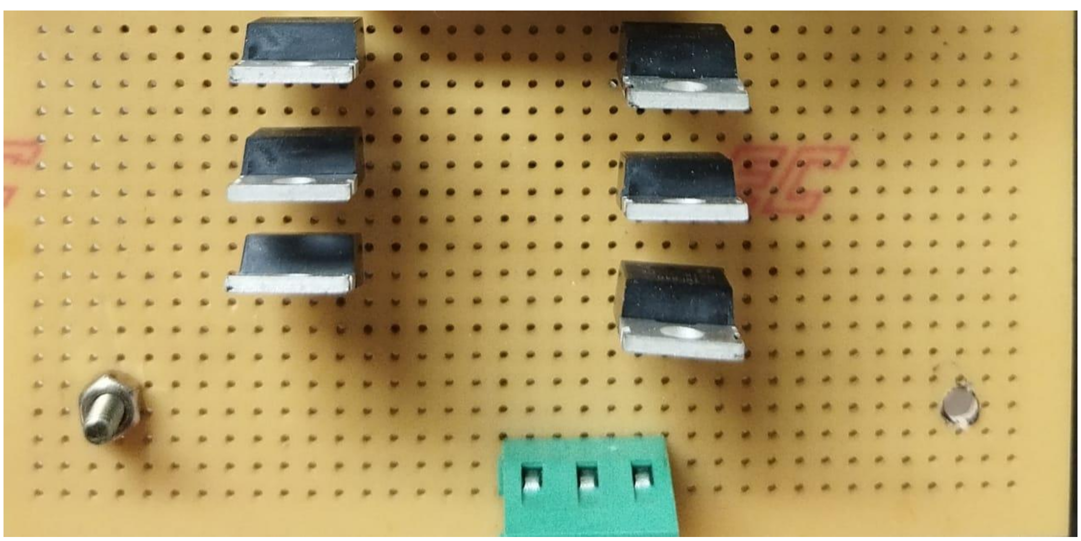


Fig 15 Inverter circuit

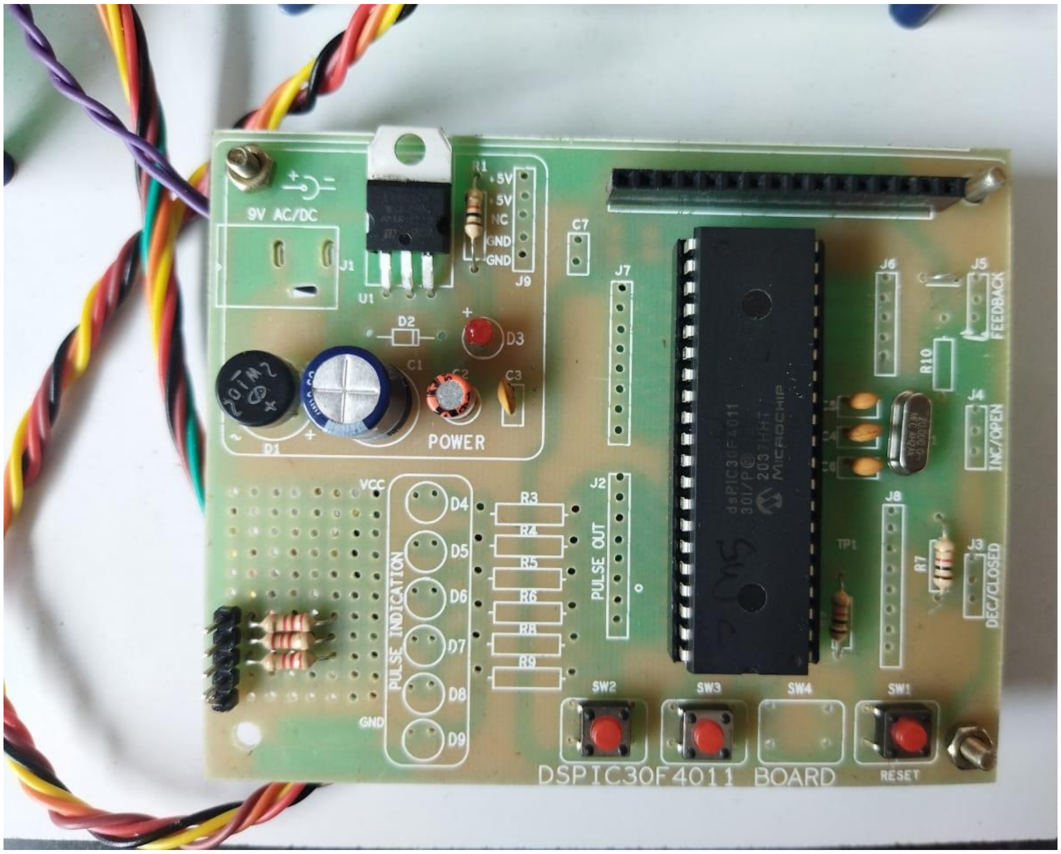


Fig 16 DSPIC Microcontroller

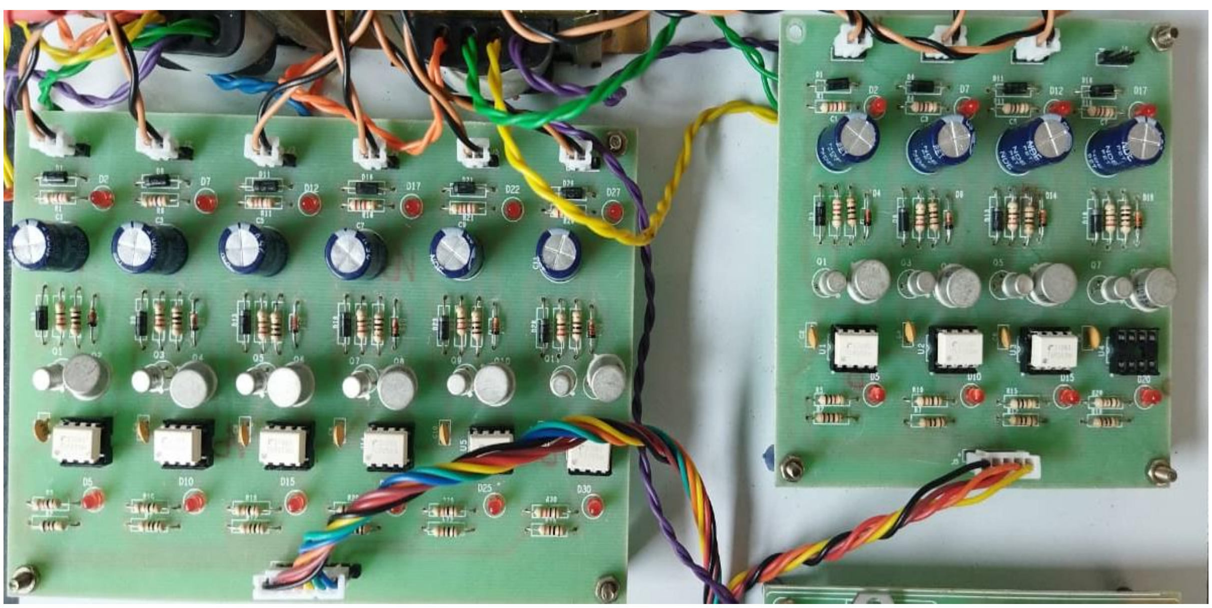


Fig 17 TLP Driver Board

VII. CONCLUSION

Our proposed system 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 behaviour of the charging current, thus allowing the operation at higher power.

The SC converter can boost or buck voltage, minimize component count, increase power density, and reduce cost.

VIII. APPENDIX

FEATURES

Small size

In our proposed system we used Switched-Capacitor instead of dc converter. So, there is no inductor in the circuit, it results in size reduction and weight reduction.

Low Cost

As there is no inductor present in the Switched-Capacitor Circuit. So, it is cost effective.

Reduction in losses due to Inductor

The copper loss of an inductor can be calculated by multiplying the square of the current in the inductor by resistance.

In addition to copper loss, an iron-core coil (inductor) has two iron losses. These are called Hysteresis loss Eddy-Current loss. Hysteresis loss is due to power that is consumed in reversing the magnetic field of the inductor core each time the direction of current in the inductor changes.

Eddy-current loss is due to heating of the core by circulating currents that are induced in the iron core by the magnetic field around the turns of the coil. These currents are called eddy currents and circulate within the iron core only.

IX. REFERENCE

- 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.
- Y. Song and B. Wang, "Survey on Reliability of Power Electronic Systems," in IEEE Transactions on Power Electronics, vol. 28, no. 1, pp. 591-604, Jan. 2013.
- Fang Zheng Peng, "Z-source inverter," in IEEE Transactions on Industry Applications, vol. 39, no. 2, pp. 504-510, March-April 2003.
- W. Qian, H. Cha, F. Z. Peng, and L. M. Tolbert, "55-kW Variable 3X DCDC Converter for Plug-in Hybrid Electric Vehicles," in IEEE Transactions on Power Electronics, vol. 27, no. 4, pp. 1668-1678, April 2012.