National Conference on Emerging Trends in Computer, Electrical & Electronics (ETCEE-2015)
International Journal of Advance Engineering and Research Development (IJAERD)
e-ISSN: 2348 - 4470 , print-ISSN:2348-6406,Impact Factor:3.134

Simulation of Modular Multilevel Capacitor Clamped DC to DC Converter for Bi-directional Power Flow Control

Kelvin M. Manavar[1], SureshKumar B. Tank[2], Prof. Nitin H. Adroja[3]

[1,2] P.G. Student, [3]Assistant Professor

[1,2,3] *Department of Electrical Engineering, Atmiya Institute of Technology and Science, Rajkot*

[1]kelvinmanavar@gmail.com
[2]suresh90pe@gmail.com
[3]nhadroja@aits.edu.in

***Abstract*— A multilevel modular capacitor clamped dc–dc converter for bi-directional power flow is presented in this paper. This topology is based on capacitive energy transfer mechanism. It is having with advantages features over conventional dc–dc converters. In this we have used 5 level MMCCC for bidirectional power flow control having features like bidirectional power flow control, redundancy, reduces voltage stress on switches, high efficiency, reliability, applicable to high power application, reduced design cost, improved voltage regulation. So it is the modular structure. In this power transfer is done through capacitor only and having better component utilization than other converters. By connecting number of modules in cascade pattern power rating of prototype can be increased. In this paper, topology is designed in which three operations are performed like down conversion, up conversion and bidirectional power flow through unidirectional switches.**

***Keywords*— Conventional converter, Bi-directional dc-dc capacitor clamped converter, Hybrid automotive system, Bi-directional power flow control, multilevel converter.**

I. INTRODUCTION

The modularity in power electronic circuits is becoming a very important issue in power electronics research.[1] Using modularity, it is possible to simplify the analysis of many power electronic circuits and additional improvements such as better efficiency or good performance can be obtained in an easier way. The purpose of this dissertation work is to introduce some modularity in power electronic dc-dc converters. The recent development in hybrid automobile industry has created a massive requirement for many power electronic converters. That there will be a big demand of power for the dc appliances in future automobile and the standard 14 V bus will not be suitable to supply the power requirements for those dc loads. In this, a 42V/14V bus system named as "42V Power Net" was proposed several years ago. In this system, there will be two voltage buses in the electrical system of a vehicle. In this case bi-directional converter will manage power flow between two buses.[2] The development of a compact, high efficiency dc-dc converter can introduce several modifications to the overall automobile design. The overall performance of the bi-directional dc-dc converter will decide if the 42V/14V dual bus system will be a successful and cost effective solution for the future automobiles. Especially in automotive applications where high ambient temperature (~200°C) is present, conventional dc-dc converters with magnetic elements can be very inefficient, and dc-dc converters with bulky inductors can suffer from limited space issue. Here we know that classical dc-dc converters suffer from limited efficiency at partial loads, and the maximum efficiency is achieved at full load. Thus, inductive energy transfer mechanism is not advantageous. In this converter the mechanism of capacitive energy transfer is used. So high efficiency can be achieved with bidirectional power flow control.[3] Conventional dc-dc converter can not operate at high frequency because at high frequency size of inductor increases. Transistors used in these classical converters experience high voltage stress. To find alternative solution converters based on capacitive energy transfer were proposed known as capacitor clamped converter.[4, 5] It gives reduced voltage and current stress.

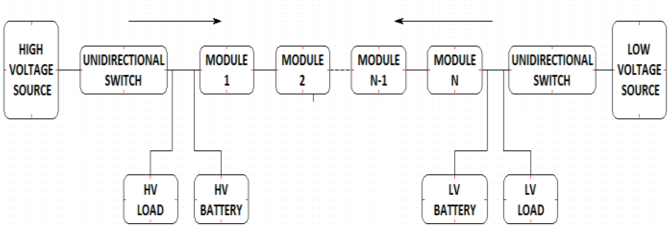

Figure 1 Block diagram of the proposed topology

In above block diagram there is multilevel modular capacitor clamped dc to dc converter is placed between high voltage side and low voltage side to control the power from both sides of voltage sources or batteries. Basically bidirectional power flow depends on ratio of battery voltages on both sides of MMCCC. If ratio of battery voltage is greater than conversion ratio then power flow from high side to low side. If ratio of battery voltages is less than conversion ratio then power flows from low side to high side. Here MMCCC is chosen for 5 level conversions. So total number of modules are 4. In fact, For N level conversion N-1 Modules required.

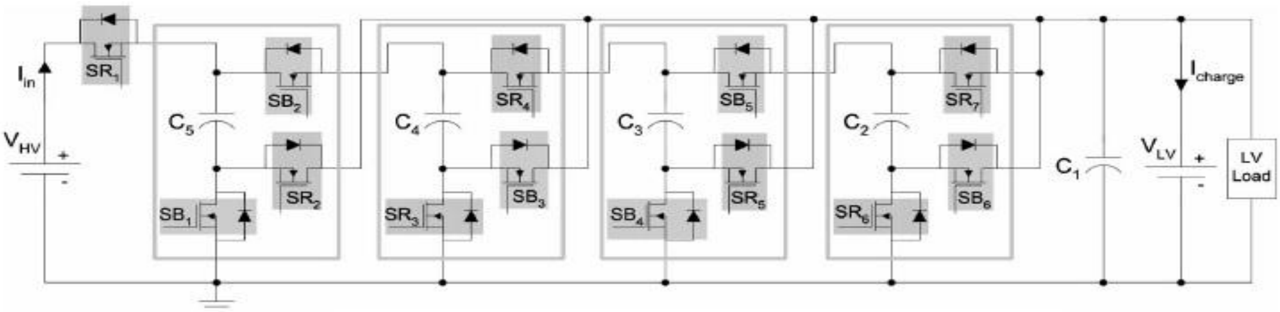

Figure 2 Five level MMCCC

Here for bidirectional power flow control we have connected unidirectional switch at both sides. So it can connect high voltage source to MMCCC and load as well as low voltage source to MMCCC and load. Low voltage and high voltage batteries connected to both sides. So when power is transferring from low voltage source to high side at that time high voltage battery is charging and vice-versa. It will supply power to load in absence of source.

II. THE NEW TOPOLOGY

The five level multilevel modular capacitor clamped dc-dc converter shown in figure 2. It has unique modular structure and can be designed to achieve any conversion ratio. [6]

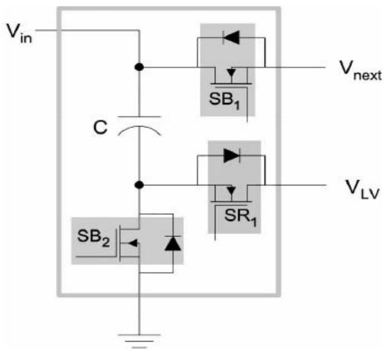

Figure 3 Unique Modular Block

Each modular block has one capacitor and three transistors. A modular block is shown in figure 3. Terminal V_{in} is connected to either HV battery or output of previous stage. V_{next} is connected to input of next stage. V_{LV} is connected to low voltage battery positive terminal.

Figure 2 was designed to manage power flow between two different dc buses having voltage V_{HV} and V_{LV}. However, this converter would also work as a conventional dc-dc converter with one source connected at one end and a load at the other end. The present design has 4 modules that produce a CR of 5. For N level converter N-1 modules are required. Switches SR1 to SR7 are operated at the same time to achieve state 1. In the same way, switches SB1 to SB6 are operated simultaneously to make the steady-state conditions. [7]

A. *Switching Scheme*

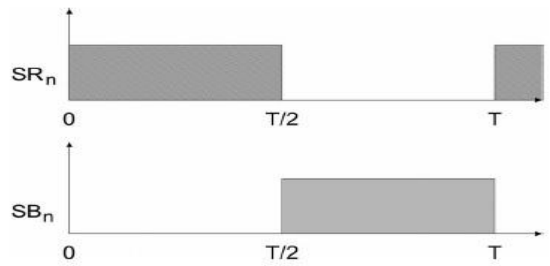

Figure 4 Switching scheme for triggering gate

TABLE I
CHARGE-DISCHARGE OPERATION OF CAPACITORS

Sub intervals	Operations
1	VHV→ C5↑ + C1↑ C4↓ → C3↑ + C1↑ C2↓ → C1↑
2	C5↓ → C4↑ + C1↑ C3↓ → C2↑ + C1↑

As shown in figure 2, during first sub-interval C_5 is being charged from V_{HV} through the output circuit. In the second sub-interval, C_5 will transfer the charge to C_4 through the output circuit. During the third sub-interval, C_4 releases energy to C_3 through the output circuit. However, during this third sub-interval, the charging operation of the first sub interval like C_5 is charged from V_{HV} through the output circuit can be performed without perturbing the operation of the entire circuit. Thus in this stage, two operations are performed at the same time, and C_5 is charged for the second time through the output circuit. During the fourth sub-interval, the same operation of second sub-interval can be performed. In addition, C_3 can transfer energy to C_2 through the output circuit without perturbing the entire operation. Thus, two operations can take place at the same time. All the sub-intervals are the initialization steps where all the capacitors are being charged and ready to transfer to the steady state operating conditions. In the fifth stage, C_5 is again energized from V_{HV} and C_4 transfers' energy to C_3. C_2 was charged in the previous stage, and now it transfers the energy to the output circuit.

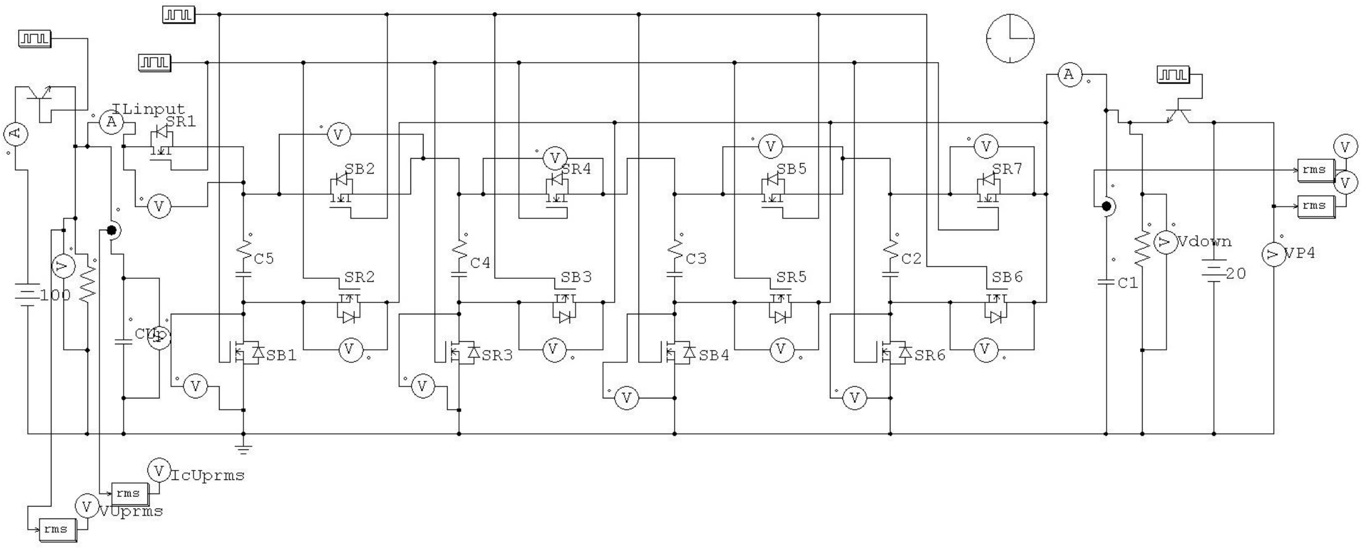

Figure 5 Simulation diagram for five level MMCCC

Thus, two operations can take place at the same time. The operations shown in fourth sub-interval are repeated again in the sixth step. These two steps shown in sub-interval fifth and sixth are the steady state operations of the converter. Once all the capacitors are charged after the initialization stage, the circuit enters into steady state and state 1 and state 2 will be repeated in every clock cycle. Here transistors experiences maximum voltage stresses 2 V_{LV} and minimum V_{LV}.

III. SIMULATION

A 600 watt prototype is designed with MMCCC for bidirectional power flow control mechanism as shown in figure 5. Capacitors are of equal valued.

TABLE II

PROTOTYPE SPECIFICATION

Prototype	600 W
V_{HV}	100 V
V_{LV}	20 V
On state resistance of MOSFET	52 m Ω
ESR of Capacitor	0.1 Ω
Load at higher voltage side	100 Ω
Load at lower voltage side	1 Ω
Capacitor	1000 µf
Switching frequency	10 KHz

IV. RESULT WAVEFORMS

Average output voltage for down conversion is 18.67V, input current stress is 5.38A and capacitor charging current 4.92A as shown in figure 6. During Up conversion process output voltage remain 97.88V, input current stress 5.04A and average capacitor charging current is 1A as shown in figure 7. During bi-directional power flow for some interval LV source is isolated and getting output voltage 18.67V at that time HV source is supplying to LV load and LV Battery through down conversion and for another interval HV source is isolated and LV source supplying to HV load and HV battery during this interval up conversion process done as shown in figure 8. Now upper three switches of the individual modules experience voltage stress 2 V_{LV} as shown in figure 9 and another switches experiences V_{LV} as shown in figure 10.

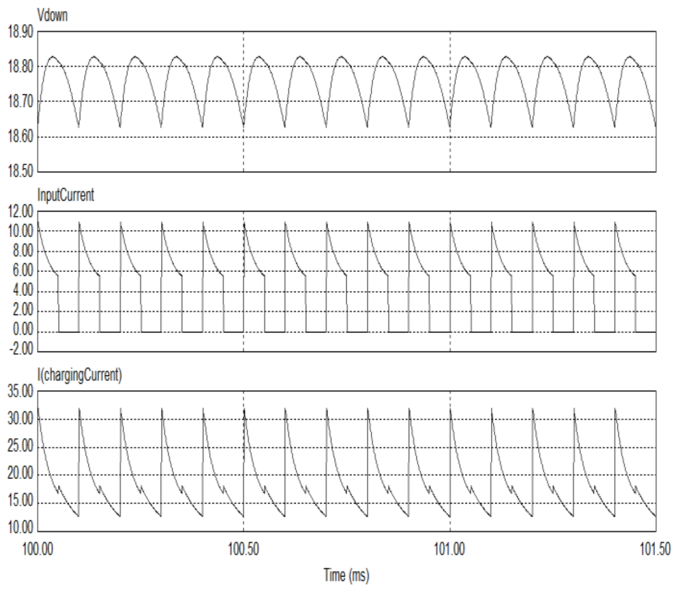

Figure 6 Output voltage, Input and charging current for down conversion

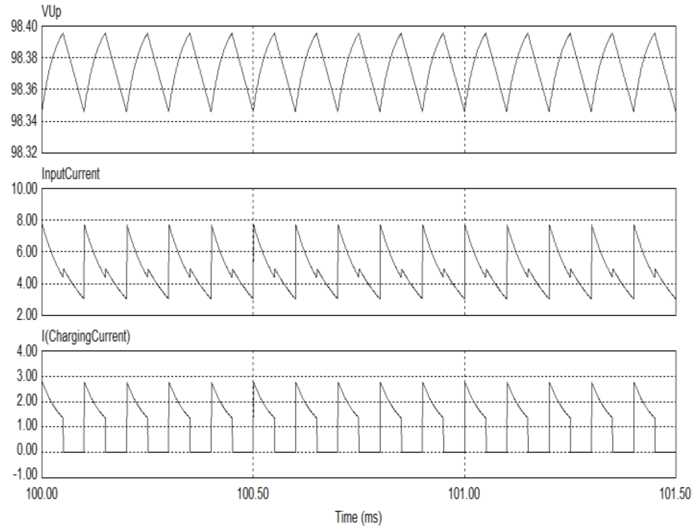

Figure 7 Output voltage, Input and charging current for Up conversion

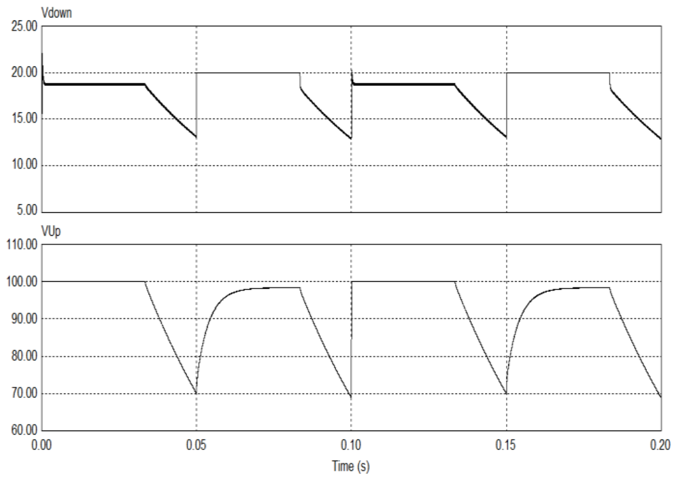

Figure 8 Bi-directional power flow for down and up conversion

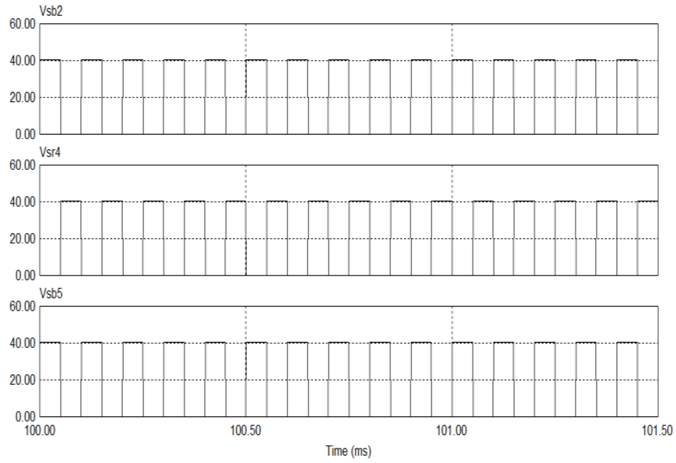

Figure 9 Voltage stress on switches Sb2, Sr4 and Sb5

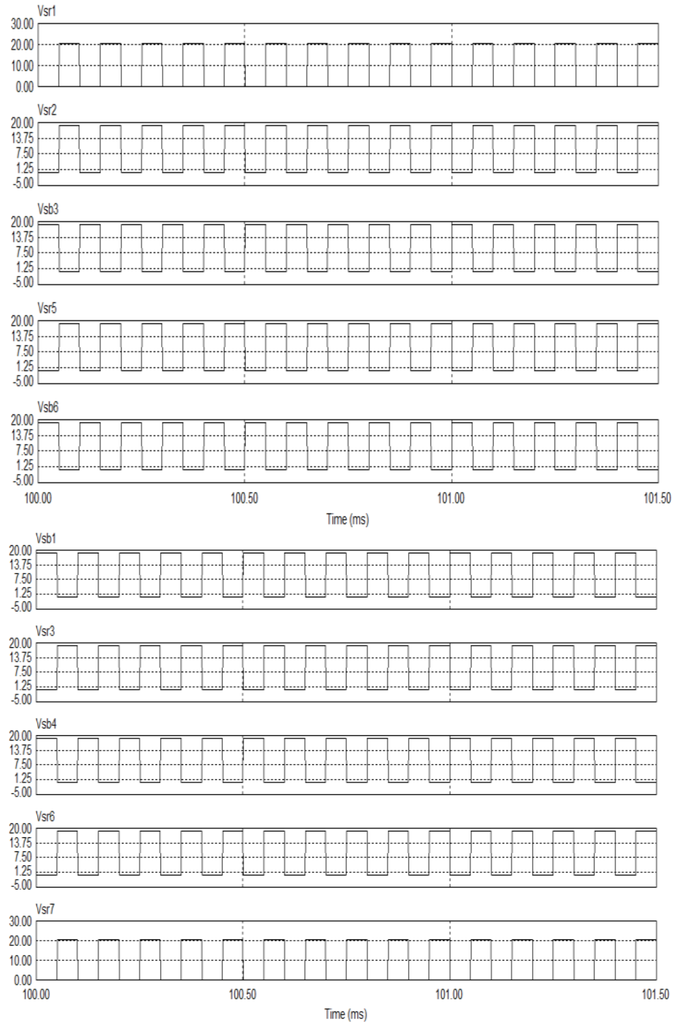

Figure 10 Voltage stress on switches Sr1, Sr2, Sb3, Sr5, Sb6, Sb1, Sr3, Sb4, Sr6, Sr7

V. RESULTS

TABLE III

DOWN CONVERSION MODE

Average charging current of capacitor	4.92 Amp
Average output voltage	18.67 V
Average load current	18.67 Amp
Input Voltage	100 V
Input current	5.38 Amp

TABLE IV

UP CONVERSION MODE

Average charging current of capacitor	1 Amp
Average output voltage	97.88 V
Average Load current	0.98 Amp
Input Voltage	20 V
Input current	5.04 Amp

VI. CONCLUSION

This new topology modular multilevel capacitor clamped dc-dc converter for bi-directional power flow is validated by simulation. Stability performance is achieved by getting average output voltage constant. The modular nature also gives the use of one additional level to establish fault bypassing and bidirectional power flow management. Bi-directional power flow control is done through simulation.

REFERENCES

[1] John G. Kassakian and David J. Perreault, "*The future of electronics in automobiles*", Proceeding of 2001 International symposium on power semiconductor devices & ICs, Osaka.

[2] L. Tang and G. J. Su, "*An interleaved, reduced component count, multi voltage bus DC/DC converter for fuel cell powered electric vehicle applications*," in *Conf. Rec. IEEE IAS Annu. Meeting*, 2007, pp. 616–621.

[3] Fang Z. Peng, Fan Zhang, and Zhaoming Qian, "*A Magnetic-Less DC-DC Converter for Dual-Voltage Automotive Systems*," *IEEE Trans. of Industry Applications,* vol. 39, no. 2, Mar. 2003, pp. 511-18.

[4] Fang Z. Peng, Fan Zhang, and Zhaoming Qian, "A Novel Compact DC-DC Converter for 42 V Systems", *IEEE/PESC*, pp. 33-38, June 2003.

[5] F. Zhang, L. Du, F. Z. Peng, and Z. Qian, "*A new design method for high-power high-efficiency switched-capacitor DC–DC converters*," *IEEE Trans. Power Electron.*, vol. 23, no. 2, pp. 832–840, Mar. 2008.

[6] F. H. Khan and L. M. Tolbert, "*A multilevel modular capacitor clamped DC–DC converter,*" *IEEE Trans. Ind. Appl.*, vol. 43, no. 6, pp. 1628–1638, Nov. 2007.

[7] F. H. Khan and L. M. Tolbert, "*A 5-kW multilevel DC–DC converter for future hybrid electric and fuel cell automotive applications*," in *Conf. Rec. IEEE IAS Annu. Meeting*, 2007, pp. 628–635.