ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

A Novel Switched-Capacitor-Based Active-Network Converter (SC-ANC) For High Step-Up Conversion

U.Anusha
M.Tech Student, Power Electronics,
Dept of Electrical and Electronics Engineering,
Sahaja Institute of Technology and Sciences for Women, Karimnagar, Telangana, India.

S.Srividya
Assistant Professor,
Dept of Electrical and Electronics Engineering,
Sahaja Institute of Technology and Sciences for Women, Karimnagar, Telangana, India.

Abstract:

Switched-capacitor (SC) DC-DC power converters are a subset of DC-DC power converters that use a network of switches and capacitors to efficiently convert one voltage to another. Unlike traditional inductor-based DC-DC converters, SC converters do not rely on magnetic energy storage. High voltage gain is required in applications, such as the renewable energy power systems with low input voltage. A high step-up voltage gain active-network converter with switched capacitor technique is proposed in this paper. While they are only capable of a finite number of conversion ratios, SC converters can support a higher power density compared with traditional converters for a given conversion ratio. Finally, through simple control methods, regulation over many magnitudes of output power is possible while maintaining high efficiency.

Key words:

SC-ANC, high voltage gain, DC/DC converter.

Introduction:

Switched-capacitor (SC) DC-DC power converters are a subset of DC-DC power converters, using only switches and capacitors that can efficiently convert one voltage to another. Since SC converters use no inductors, they are ideal for integrated implementations, as common integrated inductors are not suitable for power electronic applications. SC DC-DC converters also exhibit other advantages (and disadvantages) which will be further examined in this paper. A switched-capacitor (SC) DC-DC converter is a power converter which is comprised exclusively of switches and capacitors. In general, an SC converter can have an arbitrary number of ports. Each port can be connected to a voltage source, current source, resistive load, or any other type of circuit.

A converter can be made of any number of series sub-converters, or stages, to expand the conversion ratio range. Additionally, a single-stage SC converter can implement one or several topologies, where the converter is denoted a multi-ratio converter.Each topology corresponds to a particular configuration of switches and capacitors which achieves a particular conversion ratio. By changing the way the switches in a converter are clocked, a converter can be configured into multiple topologies. A converter stage may also implement a number of parallel copies of the topology (or set of topologies), each known as an interleaved phase. By placing these interleaved phases in parallel, and using equally-spaced interleaved clocking, output ripple frequency will be increased and ripple magnitude will be decreased.The non-coupled inductor type can achieve high voltage gain with minimized magnetic components. The voltage conversion ratio of a cascade boost converter is the product of each stage. However, the topology is complex, and the efficiency would deteriorate with a multistage structure. Though the circuit can be improved with less complexity, the switch voltage and current stress are still high.

Various switched-inductor and switched-capacitor structure to extend the voltage gain have been discussed. With the transition in series and parallel connection of the switched inductor, an inherent high voltage gain can be achieved. The switched-inductor-based boost converter is then derived, but the voltage gain is still limited, and the voltage stress of active switch and diode is also high. Based on the concept of switched-inductor and switched capacitor, this paper proposes a novel switched-capacitor-based active-network converter (SC-ANC) for high step-up conversion, which has the following advantages: high voltage conversion ratio, low voltage stress across switches and diodes, and self-voltage balancing across the output capacitors. The operating principle and steady-state analysis are discussed in detail, and the experimental results are given to verify the analysis.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

PRINCIPLE OPERATION OF CONVERTER:

Fig. 1 shows the basic structure of active-network derived from the concept of switched inductor, to perform both the series and parallel connection of two inductors. The switches S1 and S2 share the same switching signal, when the switches are turned ON simultaneously, the inductors L1 and L2 are parallel connected; when S1 and S2 are turned OFF, L1 and L2 are connected in series seen from the input port (1–1') of the two-port network.Multiple capacitors and diodes on the output-stacking form a switched-capacitor unit, with the series or parallel connections between the capacitors, high voltage gain can be achieved. The two active switches (S1 and S2) share the same switching signal. Diodes D1, D2, D3 and capacitors C1, C2, C3 are adopted in the switched-capacitor unit.

CCM Operation:

The operating modes in CCM condition are the Mode 1 and Mode 2.
1) Mode 1 [t0, t1]: during this time interval, switches S1 and S2 are turned ON. Inductors L1 and L2 are charged in parallel from the dc source, the capacitor C2 is charged, and the energy stored in the capacitors C1, C3 is released to the load. Thus, the voltages across L1 and L2 are given as follows:
VL1 = VL2 = Vi

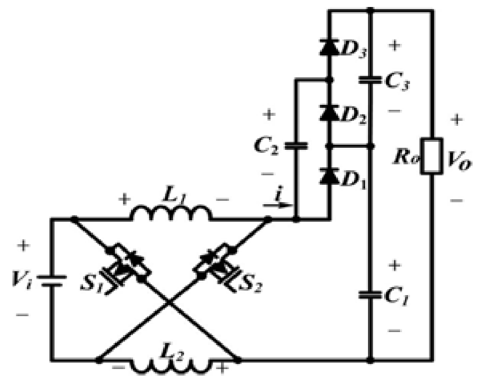

Fig 1: Proposed switched-capacitor-based active-network converter.

During this time, the dc source, the switches S1, S2, the diode D2, and the capacitor C1, C2 forms a circuit loop, according to the KVL rule, the relationship between the VC1 and VC2 is given as follows:
Vi + VC1 = VC2

Mode 2 [t1, t2]: during this time interval, S1 and S2 are turned OFF. C2 is discharged and C1 is charged. According to the KVL rule, the relationship between the capacitor voltage VC1, VC2, and VC3 can be written as follows:
VC2 = VC3
VC1 + VC3 = Vo
DCM Operation
Three modes exist in DCM condition.
Mode 1 [t0, t1]: during this time interval, the operational principle is the same as the mode 1 of CCM. The peak currents of L1, L2 are derived as follows:
IL1p = IL2p = (Vi/L) DTS
Where L is the inductance of L1 and L2.
Mode 2 [t1, t2]: S1 and S2 are turned OFF. The equivalent circuit is shown in Fig. 4(b). C2 is discharged and C1 is charged. At the time of t2, the current through inductors decreases to zero.
IL1p = IL2p = (VC1−Vi)/2L* D2TS = (Vo −Vi)/4L*D2TS
Mode 3 [t2, t3]: S1 and S2 are still turned OFF, the inductor current is 0, and the energy stored in the capacitor C1 and C3 is released to the load.
D2 =4Vi/(Vo − 3Vi)D

STUDY CONVERTER OPERATION

Voltage Gain:
The expressions of the voltage gain in ideal situation (i.e., the ESR of the device and the voltage drop of the diodes are ignored) is
GSC−ANC =3+D/1 – D
GSC−Boost =2/1 – D
GSL−Boost =1+D/1 − D
GBoost =1/1 – D
Voltage Stress of Power Switch:
The normalized voltage stress on the power switch (Vs/Vi) of the four converters is
(Vs/Vi)SC−ANC =1 + GCCM/4
(Vs/Vi)SC−Boost = GCCM/2
(Vs/Vi)SL−ANC = GCCM
(Vs/Vi)Boost = GCCM

The comparison of switch voltage stress in the four converters is shown in Fig. 8. To realize the same voltage ratio, the boost converter and SL-Boost converter present the high voltage stress across the switches; while the switch voltage stress is greatly decreased in SL-ANC and SC-Boost. That means the switches with low Rds on can be utilized, which is beneficial to the efficiency and cost.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Inductor Current
The normalized average inductor current (IL /Io) of the four converters is
IL/Io |SC−ANC = ([GCCM + 1]/2) IL/Io |SC−Boost = GCCMIL/Io |SL−ANC = GCCM + 1/2IL/Io |Boost = GCCM.
Multiple Stage Structure:
If higher voltage-conversion ratio is required, we can set more capacitors and diodes on the output-stacking, which is shown in Fig. 2. The operation principle of the improved topology is similar to the proposed converter. The voltage gain is given by
GCCM = Vo/Vi= (n + D)/(1 – D)
n must be an odd number

SIMULATION RESULTS:

In order to verify the effectiveness of the proposed converter, a 200-W SC-ANC simulation circuit was designed in MATLAB/Simulink.

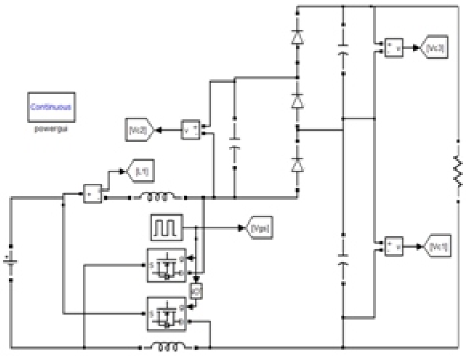

Fig 2: simulation design of proposed converter topology

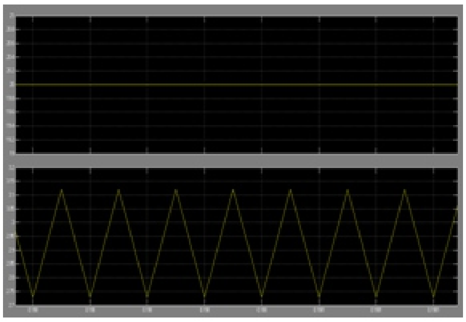

Fig 3: input voltage and input current when Vi=20v

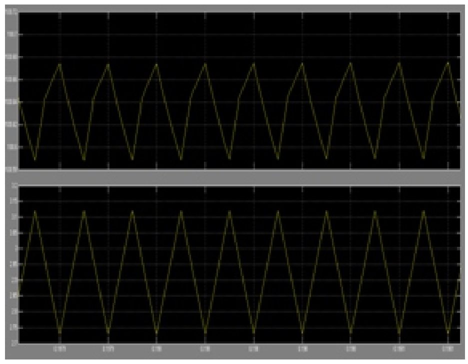

Fig 4: output voltage and input current when Vi=20v

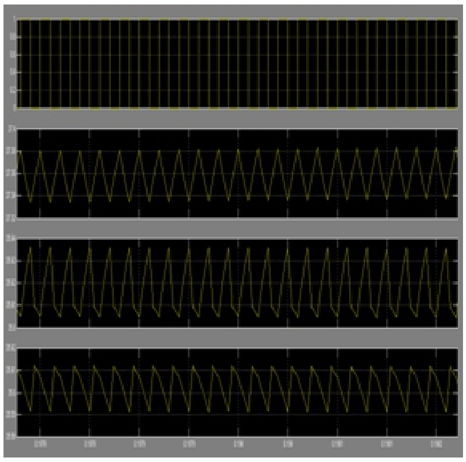

Fig 5: switching signal, input capacitor voltage and output capacitors voltages when Vi=20v

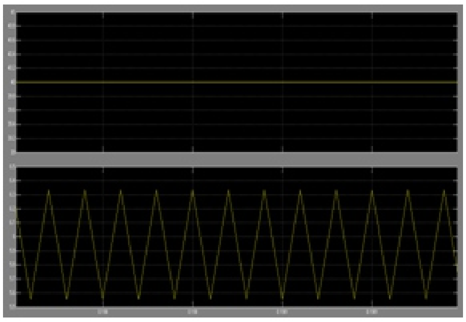

Fig 3: input voltage and input current when Vi=40v

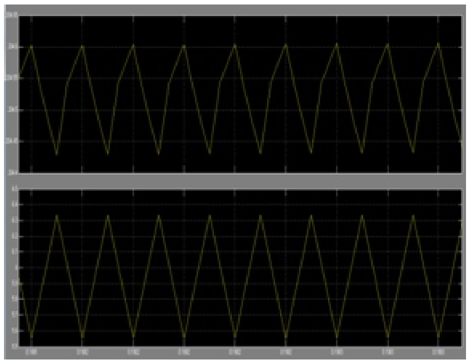

Fig 4: output voltage and input current when Vi=40v

ISSN No: 2348-4845
International Journal & Magazine of Engineering,
Technology, Management and Research
A Peer Reviewed Open Access International Journal

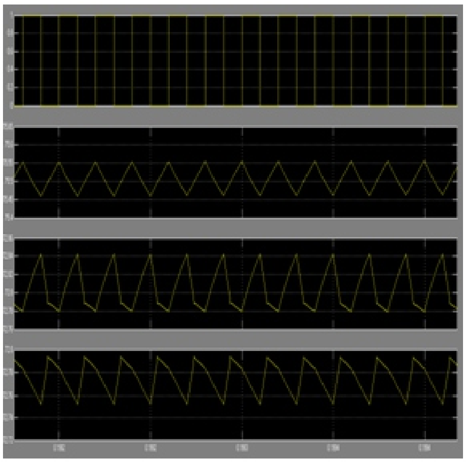

Fig 5: switching signal, input capacitor voltage and output capacitors voltages when Vi=40v

CONCLUSION:

The operatingprinciples of the proposed converter in CCM and DCM havebeen discussed in detail. The voltage stress on active switchesand diodes is low, which is beneficial to the system efficiencyand cost. Comparisons of the proposed topology with the boostconverter, switched inductor boost converter, and switched capacitorboost converter are shown. Compared with these converters, the voltage gain of the proposed converter is higher; thevoltage across the power devices is lower; the inductor currentis smaller.By using ahybrid boost-SC converter topology, a high voltage was generated with maximal efficiencywith a converter of minimum mass.

REFERENCES:

[1] X.Wu, J. Zhang, X.Ye, and Z. Qian, “Analysis and derivations for a familyZVS converter based on a new active clamp ZVS cell,” IEEE Trans. Ind.Electron., vol. 55, no. 2, pp. 773–781, Feb. 2008.

[2] W. Li, L. Fan, Y. Zhao, X. He, D. Xu, and B.Wu, “High-step-up and highefficiencyfuel-cell power-generation system with active-clamp flyback–forward converter,” IEEE Trans. Ind. Electron., vol. 59, no. 1, pp. 599–610,Jan. 2012.

[3] L.-Sheng Yang and T.-J. Liang, “Analysis and implementation of a novelbidirectionalDC–DCconverter,” IEEE Trans. Ind. Electron., vol. 59, no. 1,pp. 422–434, Jan. 2012.

[4] L.-S.Yang, T.-J. Liang, and J.-F. Chen, “Transformer-lessDC–DC converterswith high step-up voltage gain,” IEEE Trans. Ind. Electron., vol. 56,no. 8, pp. 3144–3152, Aug. 2009.

[5] W. Li and X. He, “Review of non-isolated high step-up DC/DC convertersin photovoltaic grid-connected applications,” IEEE Trans. Ind. Electron.,vol. 58, no. 4, pp. 1239–1250, Apr. 2011.

[6] F. Forest, A. Thierry Meynard, E. Laboure, B. Gelis, J.-J. Huselstein, andJ. C. Brandelero, “An isolated multi-cellintercell transformer converterfor applications with a high step-up ratio,” IEEE Trans. Power Electron.,vol. 28, no. 3, pp. 1107–1119, Mar. 2013.

[7] C. M. Wang, “A novel ZCS-PWM flyback converter with a simple ZCSPWM commutation cell,” IEEE Trans. Ind. Electron., vol. 55, no. 2,pp. 749–757, Feb. 2008.

[8] R. J. Wai, C. Y. Lin, C. Y. Lin, R. Y. Duan, and Y. R. Chang, “High efficiencypower conversion system for kilowatt-level stand-alone generationunit with low input voltage,” IEEE Trans. Ind. Electron., vol. 55, no. 10,pp. 3702–3714, Oct. 2008.

Author’s:

U.Anusha
M.Tech Student, Power Electronics,
Dept of Electrical and Electronics Engineering,
Sahaja Institute of Technology and Sciences for Women, Karimnagar, Telangana, India.

S.Srividya
Assistant Professor,
Dept of Electrical and Electronics Engineering,
Sahaja Institute of Technology and Sciences for Women, Karimnagar, Telangana, India.