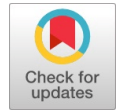# Removal of Initial Phase Transient Current in DC-DC Boost Converter using Modified Switched Inductor

Preeti Gupta, Shimi S.L.

Abstract: This paper presents the removal of initial phase transient currents in an existing dc-dc boost converter topology with the help of a modified switched inductor cell. In an earlier proposed topology, a novel single switch boost converter was proposed with high voltage gain, which however gave a high initial transient current of the order of 26kA on simulating in MATLAB Simulink environment. This initial phase current was removed by placing a small valued inductor and a freewheeling diode in series with boost capacitor. The inductor is placed in parallel with the diode and creates an open circuit initially, this arrangement limits the current to a bearable value, i.e. approximately 180A, without compromising with the high gain of the cell. The results of the proposed modifications are validated using MATLAB Simulink.

Keywords: dc-dc converter, switched inductor cell (SIC), switched inductor switched capacitor (SISC), switched capacitor cell (SCC).

I. INTRODUCTION

Nowadays, distributed power generation has gained excessive attention, especially in the field of non-conventional energy sources owing to fast depletion of fossil fuels and greenhouse gas emission [1]. The solar energy, over the years has become a necessary non-conventional clean energy resource [2]. Output power from the solar panel is low, however several panels needs to be linked in a series-parallel fashion to improve the output [3]. Voltage accessible from the series-parallel arrangement of solar PV cells is in of the order of 20–60 V. Interfacing of the PV panels with the load requires an optimal energy converter. In many applications such as renewable energy-based power generation scheme, a dc-dc boost converter achieves importance in order to increase the voltage at the output [4]. To achieve a high voltage gain, in applications such as solar-based power generation, an isolated dc-dc converters is not the preferred alternative owing to issues such as transformer core saturation at high frequency, low effectiveness, bulk in size etc. [5]. For obtaining large voltage gain at a high duty ratio, the standard dc-dc boost converters with non-isolated topologies suffers from the issues such as reverse-recovery problems of diode and high voltage stress on switching devices. The shortcomings of isolated converter topologies can be readily eliminated with the help of non-isolated converters [6]. Combinations of different voltage lifting methods are discussed in [7], for various non-isolated high-gain dc-dc converter topologies for PV systems. Cascaded technique is one of the simplest methods to increase the voltage gain however, its second stage suffers from the problem of instability, reverse recovery of the diode and high voltage stress on the switch. High voltage gain is achieved from the voltage multiplier technology [8] unfortunately, when the voltage gain exceeds 10 the power handling capability decreases [9]. Topologies in which coupled inductors are used provide high voltage gain. But leakage inductance creates severe issues such as Electromagnetic Interference (EMI) and resonance in power circuit. To lift the voltage, various voltage lifting methods incorporated with coupled inductor-based topologies are used such as switched capacitor cells, voltage multiplier cell etc. [10]. Boost converters with switched capacitor-based can deliver a high voltage gain, and minimum voltage stress on power switch by charging the capacitors parallel and discharging them in series. But the voltage regulation of these types of converters is weak [11, 12]. Zeta based converters consists of switched capacitor cells, can deliver large voltage gains [13]. However, when the input current is discontinuous, it becomes unsuitable for renewable photovoltaic applications. Boost converters consists of switched inductor cells, are convenient to increase the voltage gain with large passive elements by energizing the inductors in parallel and discharging them in series [11]. Converters based on passive switched inductors, the entire switched inductor cell is connected in series with a single active switch [11]. However, for active switched inductor network, an active switch is connected with every inductor for reducing the voltage stress of active switches, requiring higher number of components [14]. A high gain is achieved in combined active and passive SI cells, though it requires a larger number of active switches and has a large overall component count. This leads to high conduction and switching losses [15]. In this paper, the authors proposed a novel methodology to reduce the initial current burst in a switched inductor-switched capacitor (SISC) based non-isolated single switch dc-dc boost converter. The simulation of both original and modified topologies is carried out in MATLAB-Simulink® environment and results are compared.

The topology developed in [16], is used to test the voltage gain in transient and steady state conditions. In the proposed topology, the passive SI cell is modified to remove the initial enormous transient current burst. For the purpose, a small inductor and a freewheeling diode are used as additional components for removing the transients caused by the boost capacitor. The proposed modification does not reduce the gain of the converter cell, however improves the transient switching characteristics as evident in the simulation results. Also, in both topologies the ripples are found to be negligible in the output.

II. DC-DC CONVERTER WITH SWITCH INDUCTOR CELL

In this the performance of the passive switched inductor cell (SIC) has been improved with some modifications.

A. Passive Switched Inductor cell

Passive Switched Inductor cell is shown in Fig. 1. Those boost converter which consist of passive switched inductor cell in Place of inductor give much higher gain as in this two energy storing elements are present L_1 & L_2. When the switch is ON L_1 & L_2 energize in parallel as the diode D_1 & D_2 become forward biased and D_F is reversed biased. When the switch is OFF the L_1 & L_2 supply the store energy in series as in this mode D_F is forward biased and D_1 & D_2 reversed biased.
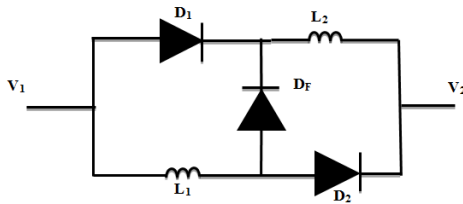

Fig. 1. Passive Switched Inductor cell

B. Modified Switched Inductor cell

The modified switched inductor cell is shown in Fig. 2. It gives much higher gain in comparison to passive SIC as it consist of three energy storing elements. The operation of modified switched Inductance cell can be explained as given below.
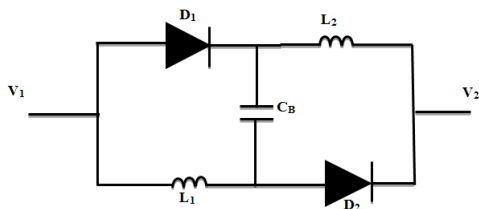

Fig. 2.Modified Switched Inductor cell

Mode 1: When the switch is ON

L_1 & L_2 and boost capacitor C_B energize in parallel as the diode D_1 & D_2 become forward biased.

Mode 2: When the switch is OFF

The L_1, L_2 & C_B supplies their stored energies in series as in this mode D_1 & D_2 are reversed biased.

The switched inductor cell [16] gives higher gain as there are three energy storing elements are present. But, the initial

value of the charging current is enormous which can damage the system because the initial voltage across C_B is zero & currents through L_1 & L_2 are also zero. When switch is turned on, both inductance L_1 & L_2 are energized through D_1 & D_2 respectively. C_B is also charged through D_1 & D_2. Since initial voltage across C_B is zero and there is insignificant resistance of the circuit elements V_{IN}, D_1, C_B, D_2 and switch S. Therefore, initial value of the charging current is enormous. This high initial current can be minimized by connecting a resistance in series with C_B but, this will increase loses.

C. Proposed modified switched inductor cell

So, author modified the SIC as shown in Fig. 3 in which initial current is limited without compromising with gain. For this the diode of SIC was replaced by a boost capacitors C_B with small inductor L_{01} in series and freewheeling diode D_F is placed in parallel to inductor L_{01}.
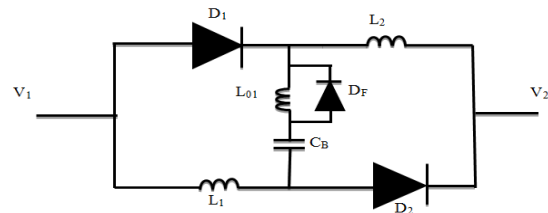

Fig. 3.Modified Switched Inductor cell

The operation of modified switched Inductance cell can be explained as given below.

With zero initial values, the charging current of C is as follows:

$$ic = \frac{V_{in}}{Z_c} \sin w_0 t \tag{1}$$

$$Vc = V_{in}(1 - \cos w_0 t) \tag{2}$$

Where $Z_c = \sqrt{L/C}$ is the characteristic impedance of series LC circuit and w_0 is the natural frequency of oscillation and is given by $w_0 = \frac{1}{\sqrt{LC}}$.

According to the equation (1) the current rises sinusoidally and at the end of half cycle, it becomes zero and V_O rises to $2V_{in}$. When switch is turned OFF, the components L_1, L_2, & C_B are in series and they release their energies to the circuit on their right side. Now, the capacitor is not required to discharge through L. These discharge current flows throw the freewheeling diode D_F. In comparison to single inductor circuit, there are three energy storing components in SIC, so that the gain increases significantly without enormous initial current initially. It can be validated by MATLAB/Simulink. Switched capacitor cell (SCC) provide high voltage gain with low voltage stress on the switches. This is accomplished by charging the capacitors in parallel and discharging them in series.
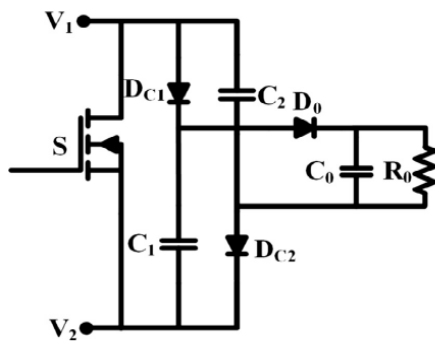
Fig. 4.Switched Capacitor Cell

III. SIMULATION RESULTS

The small inductor is connecting in series of boost capacitor C_B and a freewheeling diode in parallel to the inductor. The working of this modified SIC is explained above. Its parameters are given below. This topology is simulated in MATLAB as shown in Fig. 5. The specifications of components used in original and proposed topologies are given in Table I and Table II respectively.

Table- I: Specifications of dc-dc converter

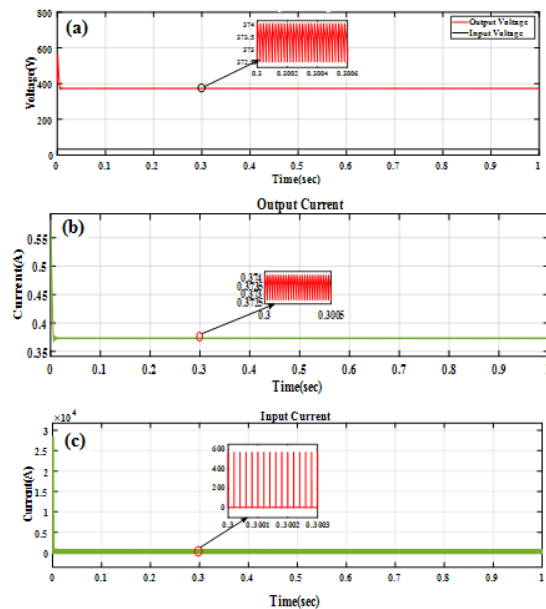| S. No.	Specification	Value
1	DC voltage source	34 V
2	Inductors	180 µH
3	Capacitor C_B	15 µF
4	Capacitor C_1, C_2,	10 µF
5	Output capacitor	4.7 µF
6	Duty Ratio	0.65

Fig. 6. Simulation Results Obtained For Existing Topology

Table- II: Specifications Of Proposed Dc-Dc Converter

S. No.	Specification	Value
1	DC voltage source	34 V
2	Inductors	180 µH
3	Inductor L_B	10 µH
4	Capacitor C_B	15 µF
5	Capacitor C_1, C_2,	10 µF
6	Output capacitor	4.7 µF
7	Duty Ratio	0.65

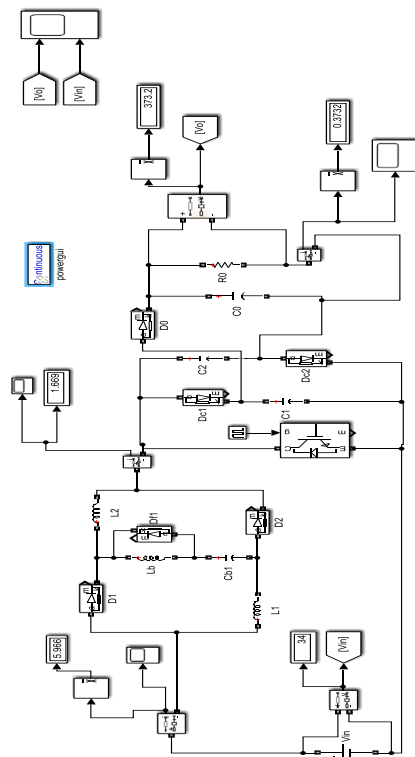**Fig. 5. Simulation Model Of Existing Topology**

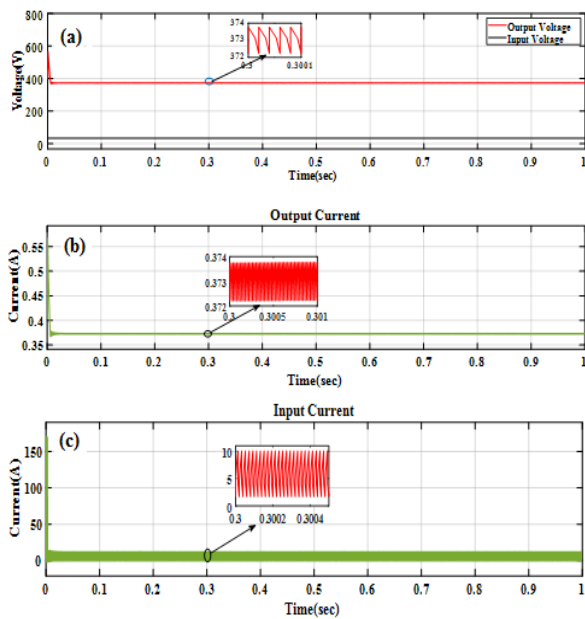**Fig. 7. Simulation Model of Proposed dc-dc converter Topology**

Fig. 8. Simulation Results Obtained For Proposed Topology

IV. DISCUSSION

In this paper, a different and novel methodology is proposed to eliminate the starting current spikes. These current spikes, Fig. 4, originate due to the capacitor C_1 placed between the different potential points, i.e. the upper and lower inductor branches of switched inductor cell. In initial phase, the capacitor become short circuited which causes the current to shoot up to approximately 26kA is given in Fig. 7(c). The proposed alteration in given topology removes this problem by in which initial current is limited without compromising with gain. This can be confirmed from input current waveform in Fig. 8(c), with initial transient current to 180A. Also, the circuit offers high voltage gain with addition of only two passive components in the circuit.

V. CONCLUSION

In this paper, a non-isolated step-up modified switched inductor/switched capacitor-based dc-dc converter topology is proposed where the initial burst of current is eliminated by using only two passive components a diode and an inductor, in this a low value of inductor is used in series to the boost capacitor along with a freewheeling diode in parallel to the inductor. This arrangement allows the circuit to establish on startup while maintaining the high gain offered by originally modified switched inductor cell presented in this paper.

This novel modification yielded a voltage gain of 10.96 which is slightly less than the voltage gain of the existing topology, *i.e.* 11. The simulation results are presented for both originally proposed as well as the modified SIC in this paper. The proposed methodology in this paper does not increase the size of the converter because of low value of inductor. The main advantage of the present study is the use of only single active switch, thus offering better component utilization and further ease of implementing control algorithms. This converter can be used for interfacing the PV panels with dc micro grid and medium voltage dc bus. Future

research can be directed towards further decreasing the starting current and increasing the voltage gain.

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AUTHORS PROFILE

Ms. Preeti Gupta received her Bachelor of Technology in Electrical Engineering from M.J.P. Rohilkhand University Bareilly, Uttar Pradesh. Presently she is pursuing her M.E. in Instrumentation and Control Engineering from Electrical Engineering Department, National Institute of Technical Teachers Training and Research (NITTTR), Sector- 26, Chandigarh. Her research areas include power electronics, real-time simulation of dc-dc converters using Opal-RT and Typhoon HIL for electrical vehicles.

Dr. Shimi S. L. received her Bachelor of Engineering in Electrical Engineering from Bharathidasan University Trichy and M.E. in Power electronics and drives from Anna University, Chennai. She obtained her Ph.D. in in the area of power electrical from PEC University of Technology, Chandigarh. Presently she is working as Assistant Professor in Electrical Engineering Department, National Institute of Technical Teachers Training and Research (NITTTR), Chandigarh. Her areas of interest includes power electronics and drives, digital control, soft-computing and optimization techniques, renewable energy applications, real-time simulation using Opal-RT and Typhoon HIL for electrical vehicle applications etc.