Introduction to Single Stage Boosting Inverter for Photovoltaic Applications

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Abstract - *This paper gives introduction to single stage boosting inverter (SSBI) for photovoltaic applications. The multistage microinverter consists a step-up dc to dc converter front stage, under maximum power point tracking (MPPT) control, an intermediate high frequency dc to dc converter stage used to attain a rectified sine waveform and low frequency unfolding stage to interconnect to the grid. The two-stage microinverter consists a MPPT-controlled step up dc to dc converter and a grid tied high frequency inverter, whereas the single stage microinverter has to perform dc to dc the voltage step-up, the MPP tracking, dc to ac inversion functions all in one stage. As compared to the traditional multistage and two stage microinverter, the SSBI has simpler topology and lower component count. AC voltage output is generated using one cycle control. This proposed SSBI can achieve high dc input voltage boosting, good dc-ac power decoupling, good quality of ac output waveform and good conversion efficiency. The proposed SSBI employs tapped inductor to attain high dc input voltage step-up, thus allows operation from low dc input.*

Key Words: Microinverter, one cycle control (OCC), tapped inductor (TI), steering diodes, decoupling capacitor.

1.INTRODUCTION

The increasing tension of the globe energy supply has given a high boost to the use of renewable energy resources. This presents a significant opportunity for distributed power generation (DG) systems using renewable energy resources, including wind turbines, photovoltaic (PV) generators, small hydro systems and fuel Cells. Among renewable sources, the photovoltaic (PV) has witnessed the unprecedented growth. Within PV systems, power inverters are required to inject the PV power into the ac grid. Microinverter is a device used in photovoltaics that converts direct current (DC) generated by a single solar to alternating current (AC). The output from several microinverters is combined and often fed to the electrical grid. Microinverters contrast with conventional string and central solar inverters, which are connected to multiple solar modules or panels of the PV system.

Micro inverter topologies for photovoltaic (PV) power generation are classified into three major groups the single-stage, the two-stage, and the multi-stage types. The multistage micro inverters are usually comprised of a step-up dc–dc converter front stage, under MPPT control, an intermediate high frequency dc to dc converter stage, used to attain a rectified-sine waveform, and a low frequency unfolding stage to interconnect to the grid. However, the multistage converter requires more number of components and is very costly to implement. The two-stage micro inverter first performs dc to dc voltage step up and then converts dc to ac, whereas the single-stage topology has to perform the dc to dc voltage step up, MPP tracking and the dc to a c inversion functions all in one stage. In order to convert and connect the solar energy to the grid, the low voltage of the PV panel first has to be stepped up significantly to match the utility level. This poses a challenge to the designer of PV inverters as the traditional boost converter cannot provide the required gain at high efficiency. To overcome this problem single stage boosting inverter is used which can attain higher dc gain and the power decoupling is performed at high voltage; hence, low value of dc-link decoupling capacitor is required. There are several topologies of SSBI out of which some are explained in this paper. This topology has several advantages over other traditional topologies. SSBI is regarded as improvement of [3] and [4]. The Proposed SSBI topology is discussed in detail which uses one cycle control (OCC), which helps attaining high -quality ac output regardless of low frequency ripple across the dc link.

In the past, many single-stage topologies were proposed that can realize voltage step up and dc to ac inversion functions in a single stage. The topology presented in [2] uses a dual boost inverter. Here, the load is connected differentially between the outputs of two bidirectional boost converters as shown in Fig 1. As a result, the topology resembles a common *H*-bridge with the boosting inductors connected to the leg midpoint. The disadvantages of this approach are the limited DC Step-up gain; circulating currents, which reduce the efficiency; and complicated control. Since the function of capacitor $C1$ and $C2$ is output filtering, the decoupling capacitor should be placed at the low voltage input, which is another disadvantage.

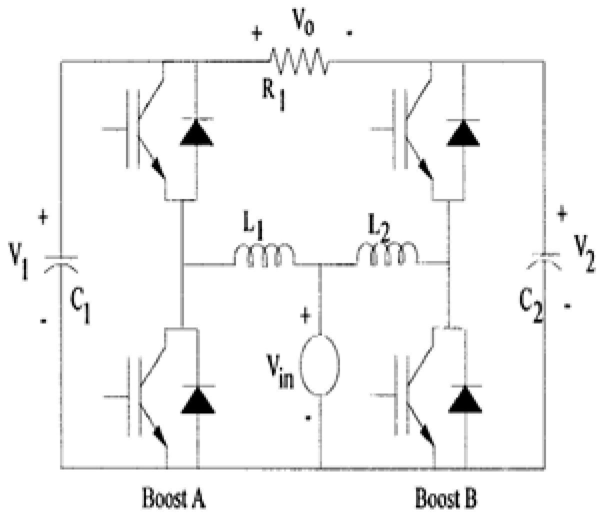

Fig-1: Topology presented in [2]

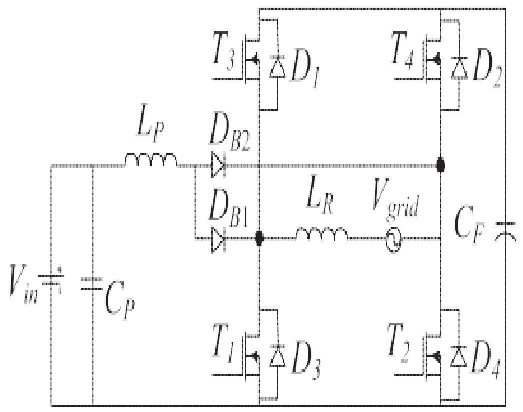

Fig-2: Topology presented in [4]

Another single-stage topology is shown in Fig 2. This topology uses a single boost inductor; have no circulating currents; have a high voltage dc link and a smaller decoupling capacitor.

2. DESCRIPTION OF THE PROPOSED SSBI TOPOLOGY

The schematic diagram of the proposed SSBI is given in Fig 3. SSBI is comprised of four semiconductor switches M1, M2, M3 and M4 arranged in a full-bridge configuration; steering diodes D1, D2 ; dc-link diode D3 , the tapped inductor (TI) W1:W2; the decoupling capacitor Cdc; and the output filter Lo – Co. The load is represented by the resistor RL. The proposed SSBI is supplied by a dc voltage source, Vg obtained from single PV panel, and generates ac output voltage Vo .Here, the input current is considered as Ig, the output current is io and its average component is Io. Compared to traditional methods the proposed SSBI topology has the advantages of a larger voltage step up which can be achieved adjusting the Tapped Inductor turns ratio, and smaller decoupling capacitor, which is placed on high voltage dc bus. Principle of operation of the proposed SSBI is dependent on implementation of a specialized switching pattern of the h bridge. For generating output of positive polarity, three topological states are created during the switching cycle as shown in Fig 4.

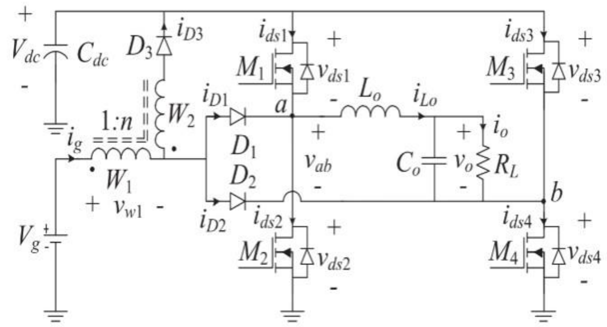

Fig-3: Topology of the proposed SSBI [1]

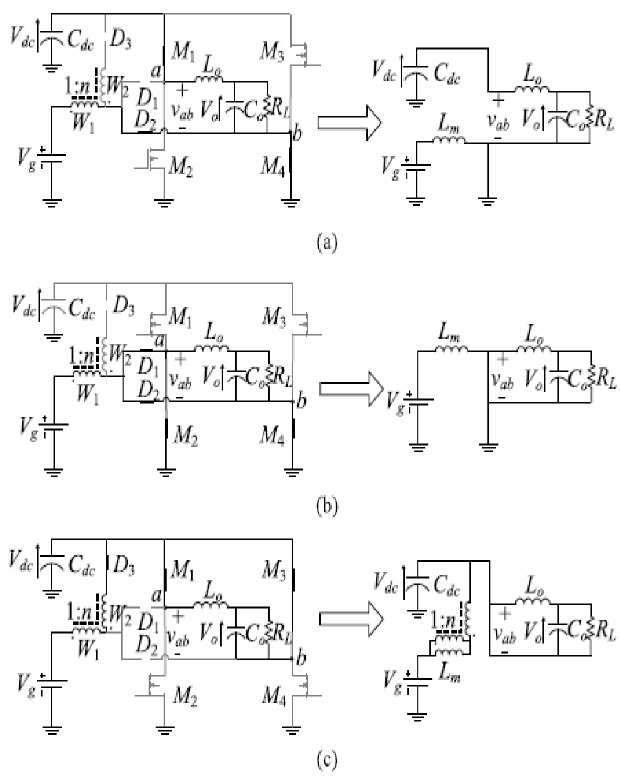

Fig-4: Topological states of the proposed SSBI [1]

The switching cycle starts with State A, as shown in Fig 4(a). The state A lasts for duration of ta. Here, the switches M1 and M4 are ON, switches M2 and M3 are OFF, D2 conducts and D1, D3 are cut-off. During this state, the TI primary magnetizing inductance Lm is charged from the input voltage source Vg, while the dc voltage Vdc is applied to the input terminals of the output filter so the filter inductance L_O is charged feeding also the filter capacitor C_O and the load R_L.

The state B is shown in Fig 4(b). Here, the switch M_1 is turned OFF and M_2 is turned ON, M_4 keeps conducting. Here, both D_1 and D_2 conduct while D_3 is cut-off. The state B lasts for duration of tb. As a result, the TI magnetizing inductance L_m continues charging from the input voltage source V_g, whereas the input terminals of the output filter are shorted so the filter inductance L_O is discharged to the output capacitor C_O and the load R_L.

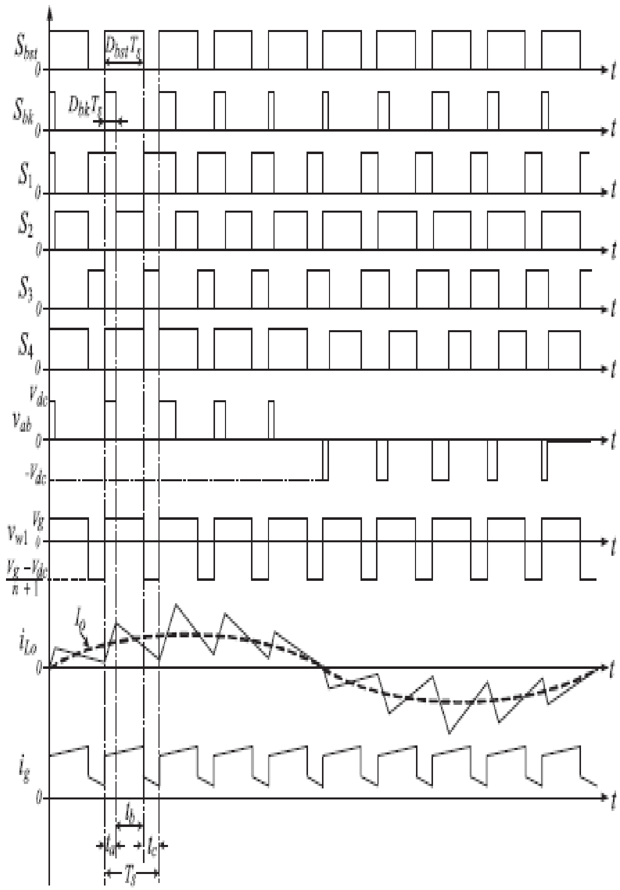

Fig-5: Key waveforms of the proposed SSBI topology [1]

The state C is shown in Fig 4(c). Here, the switches M_1, M_3 are turned ON and M_2, M_4 are turned OFF. State C lasts for duration of tc and completes the switching cycle. Here, both D_1, D_2 are cut-off and D_3 conducts; the TI magnetizing inductance L_m is discharged via both windings and D_3 into the dc-link capacitor C_{dc}, while the input terminals of the output filter are shorted and the filter inductance L_O feeds the output capacitor C_O and the load R_L. In order to generate output voltage of negative polarity, complementary switching states A_, B_, and C_ are created by the controller.

Key waveforms of the proposed SSBI throughout a line frequency cycle are illustrated in Fig 5. Note that since the switching cycle of SSBI is comprised of three states, there are 3 possible permutations or state sequences. In other words, the order of appearance of the states is not unique and other possibilities exist, that is A–C–B, C–B–A, etc. An ideal SSBI can generate same dc–dc conversion ratio under any of these switching regimes. The advantage of the implemented A–B–C state sequence is that each switch is turned on and off only once in a switching cycle, which helps reducing the switching losses.

3. CONCLUSIONS

Some traditional high gain single stage boosting inverters are presented in this paper. It can be seen that proposed single stage boosting inverter has several advantages over other traditional single stage boosting inverter topologies. By comparing the proposed SSBI with a number of selected single-stage and two-stage topologies. Among the single-stage topologies, SSBI has the best efficiency. Two-stage inverters also attain better efficiency but due to the maximum number of components it is expensive compared to single-stage topologies. The proposed single stage boosting inverter has a simpler topology and a lower component count. The proposed SSBI can achieve high dc input voltage boosting, good dc-ac power decoupling, good quality of ac output waveform, and good conversion efficiency. The proposed SSBI topology has the advantage of high voltage step-up which can be further increased adjusting the Tapped Inductor turns ratio. The ac to dc power decoupling is attained on the high-voltage dc link and therefore requires a relatively low capacitance value.

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