Implementation of PV based high step up boost converter and z source inverter system

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ABSTRACT— *This paper proposed transformer less modular interleaved boost converter is used to achieve high step-up ratio and high efficiency for AC-Micro Grid applications. The output of Photo Voltaic panel (PV) is given to the Interleaved Boost Converter (IBC). Using the Z-source inverter convert high step up AC voltage from high step up dc voltage to the load/ micro grid applications. By using the soft switching (ZVS) to reduce the voltage stress, switching loss and conduction loss. The ZSI has reliable and highly efficient for boost conversions and reduce the harmonics.It is seen that, for higher power applications, more converter modules can be paralleled to increase the power rating and the dynamic performance. Then, steady-state analysis is made to show the merits of the proposed converter module. The performance of the proposed system is validated with simulations carried out using MATLAB software.*

Keywords-Interleaved Boost Converter (IBC), ZVS, AC-Micro Grid, ZSI, voltage stress

1, INTRODUCTION

The public concern about global warming and climate change, much effort has been focused; limited fossil energy and increased air pollution have spurred researchers to develop clean energy sources in recent years. The photovoltaic (PV) power generation system is a clean, quiet and an efficient method for generating electricity. Photovoltaic cells convert sunlight directly to electricity. They are basically made up of a PN junction. The photocurrent generation principle of PV cells [1]. In fact, when sunlight hits the cell, the photons are absorbed by the semiconductor atoms, freeing electrons from the negative layer. This free electron finds its path through an external circuit toward the positive layer resulting in an electric current from the positive layer to the negative one. Individual solar cells can be connected in series and/or in parallel. In order to maximize the power generation from each cell, corresponding to its particular irradiance level, the best choice is the parallel connection [2]. This solution has the advantage over The PV panel could be used in battery charging, water pumping, PV vehicles, satellite power systems, grid-connected power systems, standalone power systems, and numerous practical applications. The low conversion efficiency of PV panel, on way to reduce the cost of the overall system is by using high efficiency power processors. A DC to DC converter is used as energy processing system in panel processor.

When a DC/DC converter is used in a PV panel power system, it is operated at the maximum power point (MPP) of the PV panel. The maximum possible power is extracted for increasing the utilization rate of the PV panel. Appropriate driving algorithm including Maximum Power Point Tracking (MPPT) should be implemented in converter control unit in order to assure maximization of PV energy productivity and high conversion efficiency [2].

An interleaved boost converter (IBC) could be extended magnetically coupling a boost type auxiliary step-up circuit that charges a voltage-doubler in the output in order to achieve the required voltage gain. A modular integrated boost converter which provides an additional step-up gain with the help of a coupled inductor auxiliary step-up circuit was also proposed. An another technique is by using the z-source inverter converts high step up AC voltage from high step up DC voltage to the load/ micro grid applications. Advantages of Z-source inverter (ZSI) has reliable and highly efficient for boost conversions and reduce the harmonics.The advantage of a AC micro grid are that loads/sources/ and energy storage can be connected through a simpler and more efficient power electronic interfaces. AC micro grids have been used in sensitive load, industrial, and residential house.

A. Objective

The objective of the paper to develop a modular high-efficiency high step-up boost converter with a forward energy-delivering circuit integrated voltage-doubler as an interface for ac-micro grid system applications. In the proposed topology, the inherent energy self-resetting capability of coupled inductor can be achieved without any resetting winding. Moreover, advantages of the proposed converter module such as low switcher voltage stress, lower duty ratio, and higher voltage transfer ratio features are obtained. Steady-state analyses are also made to show the merits of the proposed converter topology. For further understanding the dynamic characteristic, small-signal models of the proposed converter are derived by using state-space averaging technique. For higher power applications, modules of the high step-up converters are paralleled to further reduce the input and output ripples. Analysis and control of the overall system are also made. Then the DC – AC conversion made by Z Source invert er and fed to the grid applications.

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B. Block Diagram description

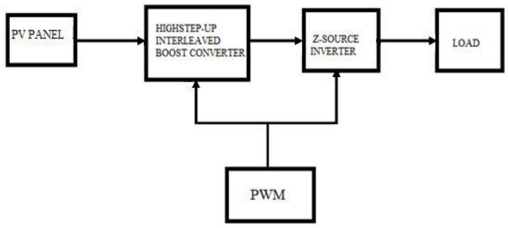

Fig. 1 Block diagram of PV based high step up boost converter and Z source inverter

1) The PV module model

Cells are normally grouped into “modules”, which a re encapsulated with various materials to protect the cells and the electrical connectors from the environment. The manufacturers supply PV cells in modules, consisting of N_{PM} parallel branches, each with N_{SM} solar cells in series, as shown in Fig 2. The PV module consists of N_{PM} parallel branches, each of N_{SM} solar cells in series [1].

In order to have a clear specification of which element (cell or module) the pa-ammeters in the mathematical model are regarding, the following notation is used from now on: the parameters with superscript ” M ” are referring to the PV module.

The parameters with superscript “ C” are referring to the solar cell. Thus, the applied voltage at the module’s terminals is denoted by V^M, while the total generated current by the module is denoted by I^M.

A model for the PV module is obtained by replacing each cell in Fig 2. by the equivalent diagram from Fig 2. In the following, the mathematical model of a PV module, suggested by (Lorenzo, 1994), is briefly reviewed [2]. The advantage of this model is that it can be established applying only standard manufacturer supplied data for the modules and cells.

The PV module’s current I^M under arbitrary operating conditions can thus be described as:

$$= \quad 1 - \exp \quad \frac{- \quad + \quad .}{\quad}$$

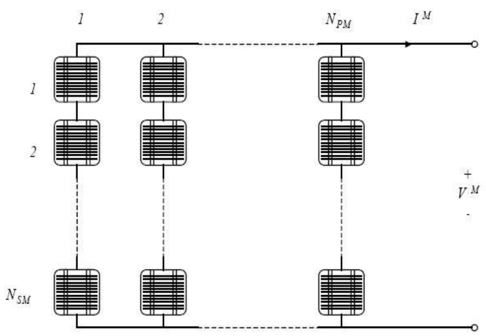

Fig. 2 The PV module consists of N_{PM} parallel branches, each of N_{SM} solar cells in series

2, OPERATION PRINCIPLE

The proposed interleaved converter topology with high voltage transfer ratio is proposed as shown in Fig 3. The proposed converter consists of two-phase circuits with interleaved operation [3]. The first phase is a boost integrating the forward-type circuit structure, which includes inductor L1 and switch S1 for the boost and an isolated forward energy-delivering circuit with turn ratio N. The second phase of the proposed converter is a boost circuit which contains inductor L2, switch S2, blocking capacitor C2, and diode D2 followed by the common output capacitor Co.

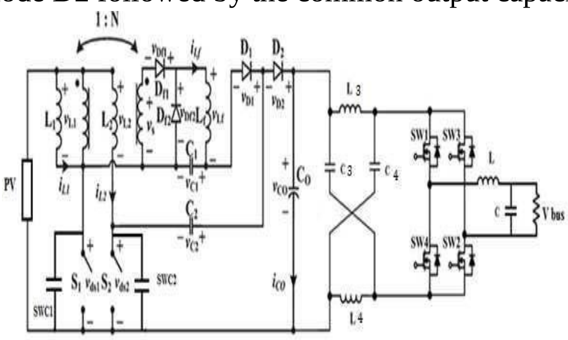

Fig.3 PV based high step up boost converter and z source inverter topology

Fig.3, one can see that the proposed converter is basically based on the conventional voltage-doubler for the second phase circuit [6]. However, for the first phase, in order to reduce the voltage stress of switch S1 and diode D1, an additional blocking capacitor C1, is added to function as that of C2 for the second phase. The operation principle can be described by considering the key waveforms of the proposed converter as shown in Fig.3 For simplicity, assume that all the components in Fig.3 including the high-frequency transformer of the forward energy delivering circuit are assumed ideal and under steady-state condition. As the main objective is to obtain high voltage gain and such characteristic is achieved when the duty cycle is greater than 0.5, hence, the steady-state analysis is made only for this case[3-6]. It is important to point out that the proposed high step-up converter can also function for duty cycle lower than 0.5. However, with duty cycle lower than 0.5, the secondary induction voltage of the transformer is lower, and consequently, it is not possible to get the high voltage gain as that for duty ratio greater than 0.5.

As the fig. 3 to applying the ZVS to reduce the voltage stress of the switches S1, S2.From Fig. 4, one can see that when the duty ratio is greater than 50%, there are four operation modes according to the ON/OFF status of the active switches.

A. Modes of Operation

*1)Mode 1 [t0 < t ≤ t1];*From Fig. 4, one can see that for mode 1, switches S1, S2 are turned on. Diode Df1 is forward biased, while diodes D1, D2, Df2 are reverse biased. During this operation mode, both iL1 and iL2 are increasing to store energy in L1 and L2, respectively. Meanwhile, the input power is delivered to the secondary side through the coupled inductor and inductor Lf to charge capacitor C1. Also, the output power is supplied from capacitor Co. The voltage across inductances L1 and L2 can be represented as follows:

$$= \quad = \qquad (1)$$

2) Mode 2 [t1 < t ≤ t2]; For this operation mode, switch S1 remains conducting, and S2 is turned off. Also, diodes D1 and Df2 remain reverse biased; D2 and Df1 are forward biased. The energy stored in inductor L2 is now released through C2 and D2 to the output. However, the first phase circuit including the forward-type converter remains the same. The voltage across inductances $L1$ and $L2$ can be represented as the following:

$$\overline{\quad} = \qquad (2)$$

$$\overline{\quad} = + - \qquad (3)$$

3)Mode 3 [t2 < t ≤ t3]; For this operation mode, both $S1$ and $S2$ are turned on. The corresponding operating principle turns out to be the same as Mode 1.

4)Mode 4 [t3 < t ≤ t4]; During this operation mode, S1 is turned off, and S2 is turned on. Diode D2 and Df1 are reverse biased, and diode D1 is forward biased. Since diode Df1 is reverse biased, diode Df2 must turn on to conduct the inductor current iLf. The energy stored in L1 is now released through C1 and D1 to charge capacitor C2 for compensating the lost charges in previous modes. The energy stored in coupled inductor is now treated to perform the self-resetting operation without additional resetting winding. Also, the output power is supplied from capacitor Co. The voltage across inductances L1 and L2 can be represented as follows:

$$\overline{\quad} = + - \qquad (4)$$

$$\overline{\quad} = \qquad (5)$$

B. Voltage stress of the power devices

The voltage of the switched capacitor can be derived as

$$= (\overline{\quad}) \qquad (6)$$

It shows that the switched capacitor works like a dc source. Inserted between the coupled inductor and the load. Voltage across the switched capacitor related to the turns ratio and duty cycle [6]. The voltage stress of the main switch is given by converter at the same input voltage as well as the step-up voltage Because of the extended voltage gain and reduced duty cycle , it is obvious that the switch voltage stress is greatly reduced compared with the conventional ratio. The voltage stress of the auxiliary switch is the same as that of the main switch

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$$= \overline{\quad} \qquad (7)$$

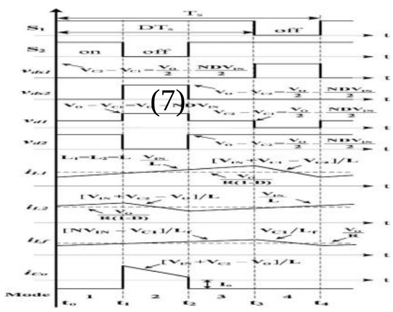

Fig.4. Key waveforms of the proposed converter

3, Z- SOURCE INVERTER

The main objective of static power converters is to produce an AC output waveform from a dc power supply. Z-source inverter (ZSI) has been presented as a new topology of power electronic converters. It operates as a buck-boost converter with wide range of obtainable output voltage compare to traditional voltage and current source inverters. General representation of a Z-source converter is shown in Fig.5 where an impedance network placed between a converter and a power source. A two-port impedance network which consists of inductors (L3 and L4) and capacitors (C3 and C4) connected in a special configuration to provide an impedance source (Z source) which couples the converter to the power source. The main circuit of the Z-source inverter and its operating principle have been described in [7-10] .The control methods, to obtain a maximum voltage gain and to minimize the voltage stress across the inverter for any desired voltage gain [9].

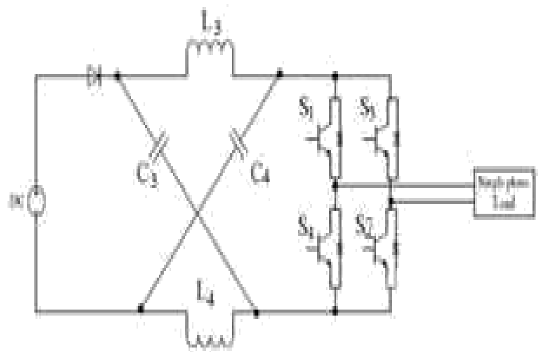

Fig.5 Single phase full bridge Z source inverter

Fig.6 shows the operating states of a single phase Z-source inverter. Fig 6 shows switching state of the Z source inverter where two switches of one leg or two legs or all three legs are turned on simultaneously [9-11]. In this state, the diode D at input side is reverse biased and the capacitors, C3 and C4 charge the inductors, L3 and L4 and the voltage across the inductors are:

$$= \; - \qquad (8)$$

The dc-link voltage across inverter bridge during non shoot through interval (T) is:

$$= \; - \; = 2 \; - \qquad (9)$$

After that the conversion is completed (DC-AC) then, inverter is fed to the single phase AC micro grid/motor load.

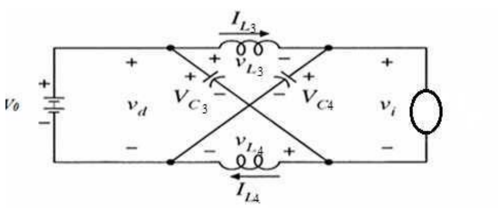

Fig. 6 Equivalent Circuit of the ZSI in the operating States.

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IV. SIMULATION RESULT

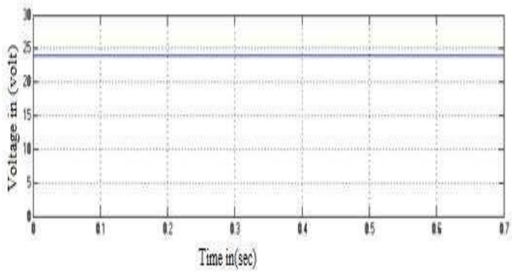

Fig .7 Input voltage of proposed system

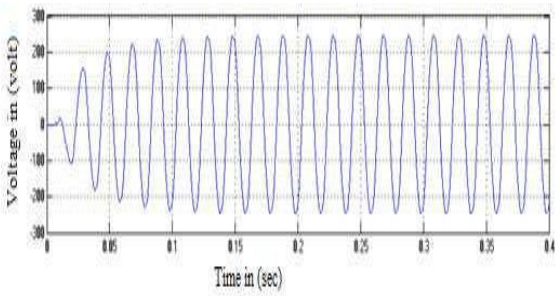

Fig.8 Output voltage of proposed system

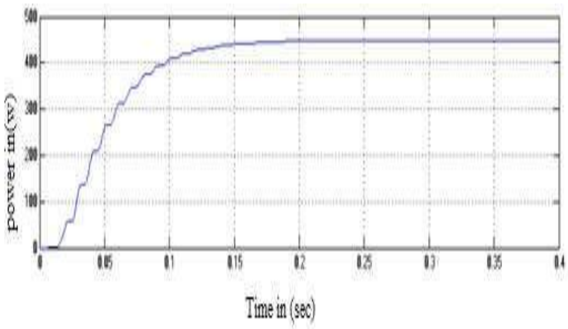

Fig.9 Output power of proposed system

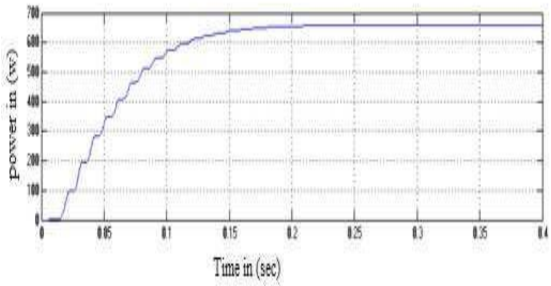

Fig .10 Output power of Parallel connection IBC with Z source inverter

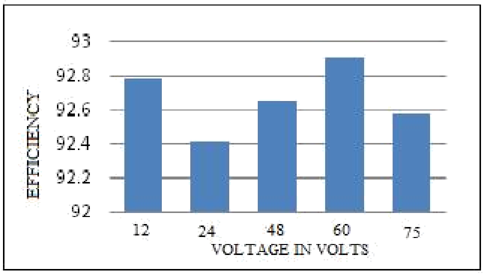

Fig .11 Efficiency of various input voltage

TABLE I
Efficiency of various input voltage

INPUT VOLTAGE	INPUT POWER	OUTPUT POWER	EFFICIENCY
12	180	167	92.77777778
24	725	670	92.4137931
48	2925	2710	92.64957265
60	4575	4250	92.89617486
75	7000	6480	92.57142857

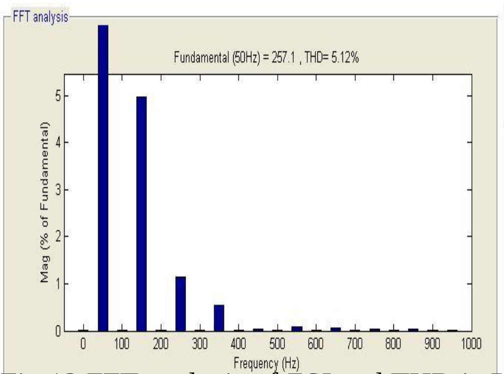

Fig.12 FFT analysis of ZSI and THD is 5.12%

5, CONCLUSIONS

This paper has presented the procedures for a new modular interleaved boost converter (IBC) by integrating a forward energy-delivering circuit with a voltage-doubler and Z-source inverter is proposed for achieving high step-up and high-efficiency objective. The input source of the interleaved boost converter (IBC) from the photo voltaic. Steady-state analysis is performed to show the merits of the proposed converter topology. Soft switching technique is used to reduce the voltage stress, switching loss and conduction loss. For further understanding the dynamic characteristic for the proposed converter module, steady state and small-signal models of this converter are derived. For higher power applications and satisfying the demands of low-voltage and high-current distributed power sources, a two-module parallel high step-up converter system is implemented. A Z-source inverter is used to convert high step up AC voltage from high step up DC voltage to the load/ micro grid applications. Experimental results show that the proposed high step-up boost converter and z-source Inverter module achieve an efficiency of 92.89% approximately.

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