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Two Stage Micro Inverters for Small Scale PV Systems: Review & Simulation

Chitra Laksmanasamy[1], Kaviya Ragunathan[2]

[1]Assistant Professor (SS), Department of Electrical and Electronics Engineering, Dr. Mahalingam College of Engineering and Technology, Pollachi, India

[2]PG Scholar, Department of Electrical and Electronics Engineering, Dr. Mahalingam College of Engineering and Technology, Pollachi, India

ABSTRACT

Micro inverters used in Solar photovoltaic applications are gaining more importance due to their highharvesting of energy and simple control scheme. The Micro inverter with half bridge and full bridge topologies along with operating modes are explained. The proposed topologies are simulated using MATLAB/SIMULINK and the results are provided. These topologies have reduced harmonics with increased output voltage. The theoretical values are validated through the simulation results. The obtained output voltage 28V with the input of 10V and harmonics is reduced below 7.5%.

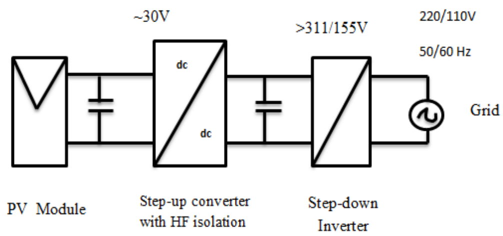
Keywords : MATLAB, SIMULINK, MPPT, IGBT

I. INTRODUCTION

A micro inverter or solar micro inverter,is a device used in photovoltaics that converts direct current (DC) generated by single solar module to alternating current (AC). The output from the several micro inverters are combined and often fed to the electrical grid. Micro inverters with conventional string and central solar inverters, which are connected to multipolesolar modules or panels of the PV system [1]. Micro inverters haveseveral advantages. The main advantage is that small amounts of shading, debris or snow lines on any one solar module, or even a complete model failure do not disproportionately reduce the outputof the entire array. Each micro inverter harvests optimum power by performing maximum power point tracking (MPPT) for its connected module [2]. Simplicity in design, lower amperage wires, simplified stock management, and added safety are other factors introduced with micro inverter solution.For grid connection of a single PV module, it is necessary to boost its voltage around 20% over the peak grid voltage to work properly [3].

The conventional micro inverter composed of two stages: a step-up dc-dc stage is used to boost the dc-link voltage above the grid peak voltage, and a second stage is step-up inverter connected to the grid as shown in general block diagram Fig. 1.a. The high frequency transformer is used in dc-dc stage to achieve the required voltage step-up ratio [4]-[8]. Here two converters are used, one of them with a high frequency isolation transformer, results in lower efficiencies compared to string based inverters [9].

Recently, some single-stage step-up dc-ac configuration have been proposed shown in Fig. 1.b. The single stage step-up have to full fill two functions with a single converter to elevate PV module voltage and realize dc-dc conversion [10]-[14]. Then two stage micro inverter composed of two stages: a step-up converter for dc-dc conversion shown in Fig. 1.c. This is similar to conventional model but the high frequency transformer is eliminated here. And dc-ac conversion is to elevate the output voltage and here two boost converters are connected in differential mode. It greatly reduces the switching losses [16].



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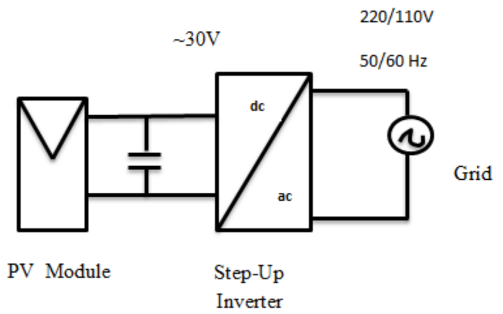

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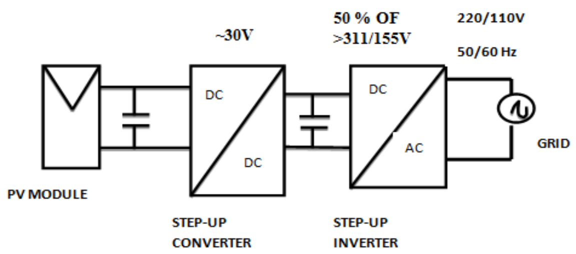

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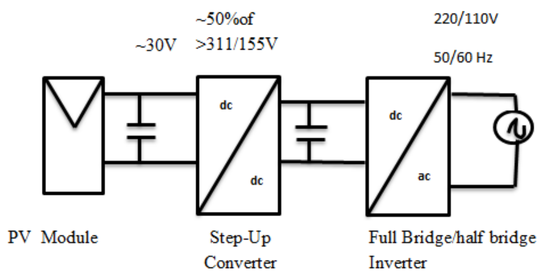

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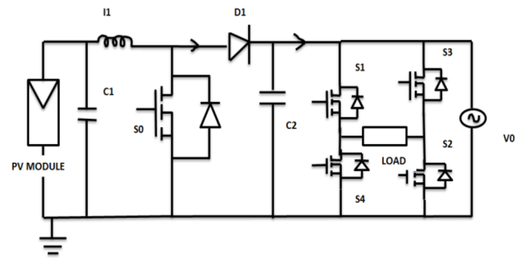
Figure 1. General diagram of micro inverter configurations: a) Conventional configuration compose of a step-up dc-dc stage and a step-down dc-ac stage, b) single-stage step-up dc-ac configuration, c) existing configuration composed of a step-up dc-ac stage and step-up dc-ac stage, d) proposed configuration composed of step-up converter and full-bridge inverter

In this paper two stage micro inverter composed of step-up converter and full bridge inverter. The step-up converter is used for dc-dc conversion and full bridge inverter is used for dc-ac conversion. These topologies present less conversion stages and accuracy is good. The efficiency achieved in this paper is around 93% at rated output. With this configuration, it is possible to distribute the voltage step-up ratio effort between two stages, increasing overall efficiency, as shown in preliminary results.

The paper is described as follows. The main features and model of topologies are present in section II. The simulation results are present in section III. Finally the conclusion are detailed in section IV.

II. TOPOLOGIES DESCRIPTION

The two-stage step-up PV micro inverters shown in figure 2. In dc-dc stage boost inverter is used due to its structure and no need of HF isolation, while full bridge inverter and half bridge inverter are employed for dc-ac conversion. Although none of the converters is new on its own, the combination of both in subsequent stages are used.



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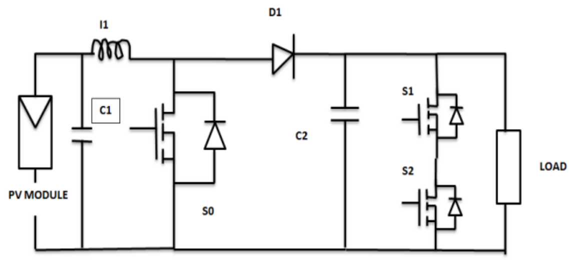

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Figure 2. (a) Two stage step-up dc-ac converter: the boost dc-dc converter and full bridge inverter (b) The boost dc-dc converter and half bridge inverter

A. Step-Up Converter

The average output voltage is greater than the input voltage then it is clled as boost converter. It is equivalent to the step-up chopper operation. Figure. 3 shows the boost converter circuit. The operation of circuit is divided into two modes.

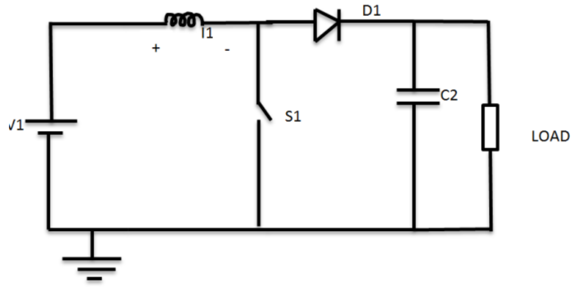


Figure 3. (a)Circuit diagram of step-up converter

B. Mode 1 Operation

The switch S1 is turned on by applying base signal. At t=0, T1 comes to ON state. At that time, diode D is reverse biased. Due to this, load is isolated from the input. The input supplies energy to the inductor L. Now, the inductor current increases from I_1 to I_2.

C. Mode 2 Operation

At $t=t_1$, the base signal of he transistor is zero, then the transistor T_1, comes to off state. During the off period (T_{off}), the diode D comes to conduction and the current flow through the inductor, diode, C and the load. The energy stored in the inductor L is transferred to the load. The inductor current decreases from I_2 to I_1. The voltage across the inductor is (V_S-V_0). Here the output voltage is greater than the input voltage. Figure 3.b. shows the equivalent waveforms of step-up converetr.

D. Analysis

$I_2\_I_1 = V_S\, T_{ON} L$----------(1)

$I_2\_I_1 = (V_0 - V_S)T_{OFF}/L$------(2)

Equating (1) and (2)

$$I_2 - I_1 = (V_O - V_{S)}T_{OFF}/L$$

$$V_S T_{ON} = (V_0 - V_S)(T - T_{ON})$$

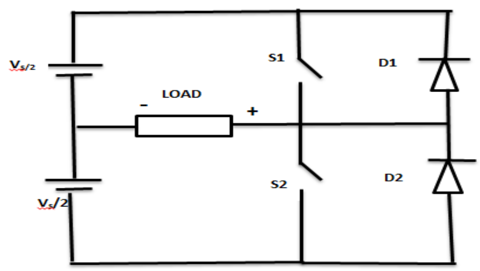
$$V_S T_{ON} = V_0 T - V_0 T_{ON} - V_S T_S + V_S T_{ON}$$

$$V_0 = (V_S\, T)/T - T_{ON}$$

$$V_0 = V_S/(1 - a)$$

E. Half Bridge Inverter

The basic principle of the single phase half bridge inverter is shown in Figure 4. a. The circuitry for turning on or turning off of the thyristors is not shown for simplicity. During the first half of the time S1 is turned on by applying the gate signal. The voltage across the resistive load is VS 2. During the second half cycle the S2 is turned on. The output frequency can be changed by changing T.



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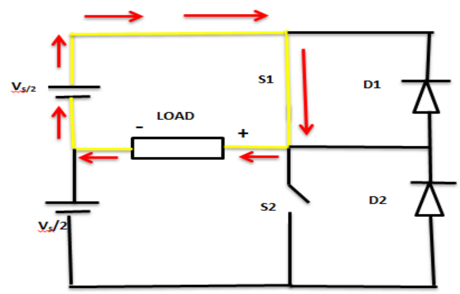

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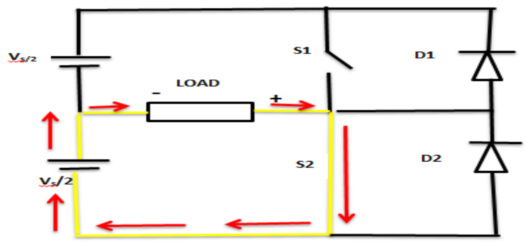

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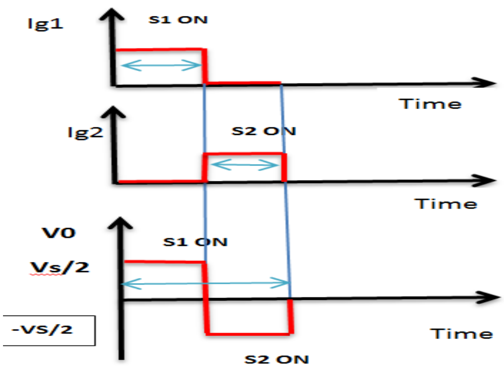

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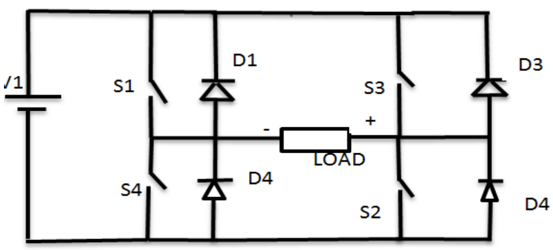
Figure 4. (a) Circuit diagram of half bridge inverter (b) Operation state-1 of half bridge inverter (c) Operation mode-2 of half bridge inverter (d) Operational graph of half bridge inverter.

F. Analysis

$$V_{0rms} = \left\{{}^{V_S}/_2\right\}$$
$$V_1 = 2V_S/2$$
$$\pi = 0.45V_S$$

G. Full Bridge Inverter

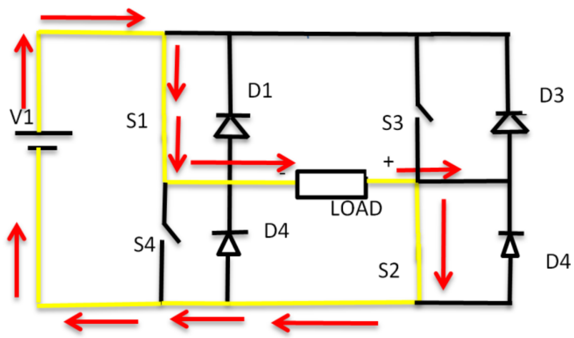
The power circuit of Single Phase Unipolar inverter has bidirectional **IGBT** arranged in bridge form. The circuit diagram of the power circuit is shown in figure 5.a.The circuit diagram consists of four distinct **IGBT** such that they are connected as the bridge circuit. The input to the circuit is the 220v DC supply from the rectifier unit. The **IGBT** are triggered accordingly such that the AC output voltage is obtained at the output. The operation of the circuit is as follows.



(a)

H. Mode 1 Operation

First the IGBT S1 and S2 are turned on by triggering the gate of the IGBT . During this time the input supply is 220v DC and at the output the 220v is applied across the load. The current starts from the supply positive, S1, S2, load and to the negative of the supply. The conduction path for the first cycle of operation is shown in figure 3. At time 2 t =T2, the switches 1 S and 2 S are turned on and the pair of switches 3 S and 4 S are turned off. Just as in case 1, the current takes time to become zero and diodes D1 and D2 conduct as long as its non-zero



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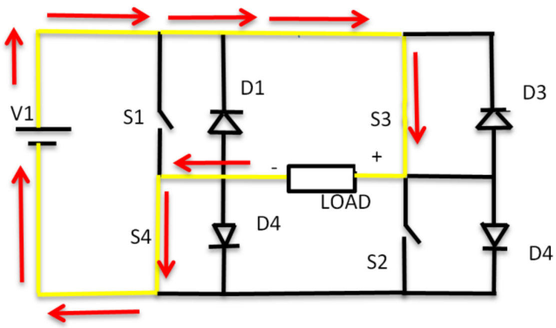
I. Mode 2 Operation

During the next phase or the cycle the **IGBT** S3 and S4 are turned on by giving trigger pulse to the gate of the **IGBT** . During this period the input voltage is applied at the output but in the negative direction. The current conduction starts from the supply, S3, S4, load and to the negative of the supply.



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As the two cycles continue the positive and the negative voltage is applied at the load and the current direction changes in the two cycles. As the current direction changes the alternative voltage is obtained at the load thus converting Dc voltage to AC voltage.

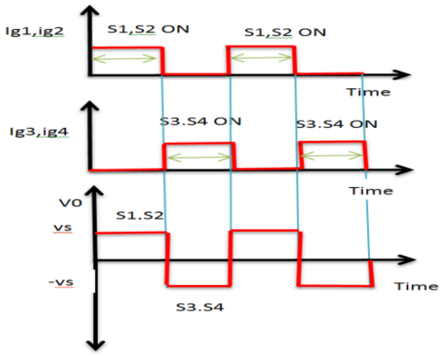

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Figure 5. (a) Circuit diagram of full bridge inverter (b) Mode 1 Operation of full bridge inverter (c) Mode 2 Operation of full bridge inverter (d) Operational graph of full bridge inverter

J. Analysis

$V_{0rms} = (1/T\ (V_s^2.T))^{1/2}$

$V_{0rms} = (\ V_s^2)^{1/2}$

$V_{0rms} = V_s$

The instantaneous output voltage expressed in fourier series as,

$V_0 = 4V_s/n\ pi(\sin nwt)$

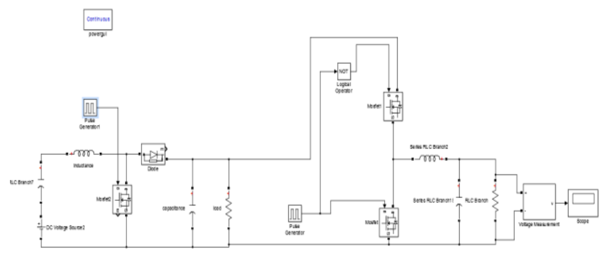
III. SIMULATION RESULTS

In order to validate the proposed configuration, the system composed of the boost converter and single phase full bridge inverter and half bridge inverter has been simulated. the simulation parameters are listed in table 1.The results of each stage is shown below.The results of dc-dc side is shown in figure 8 .a. The signals of those figure composed of ac and dc components

Table 1. Simulation Results

Variable	Parameters	Value
V_s	Grid Voltage	110[VRMS]
F_s	Grid frequency	60[Hz]
R_s	Grid resistor	0.1[Ohm]
L_s	Grid Inductor	5[mH]
P_{PV}	Grid power	215[W]
	DC-DC STAGE	
C_{PV}	Input Capacitor	6.8[mF]
L	Boost Inductor	1.6[uH]
C_{DC}	DC-link capacitor	90[mF]
	DC-AC SIDE	
R	Half Bridge inverter load	0.1[Ohm]
R	Full bridge inverter load	1[Ohm]

The maximum efficiency of full bridge and half bridge inverters are increased by introducing dc-dc stage before the dc-ac converter. The global efficiency of the system increased and the efficiency with this proposed model is 93%. The results of step-up converter with half bridge inverter is shown in Figure 8. b. And the result of step-up converter with full bridge inverter is shown in Figure 8. c.



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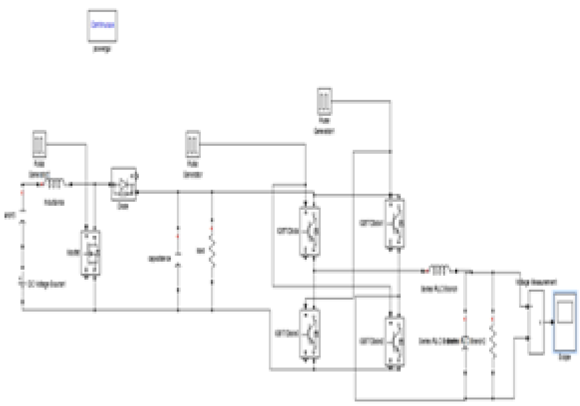

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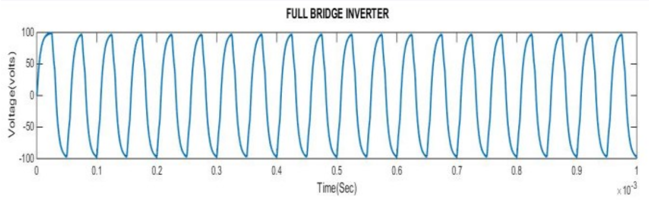
Figure 7. (a) Simulation of step-up converter plus half bridge inverter (b) Simulation result of step-up converter plus full bridge inverter



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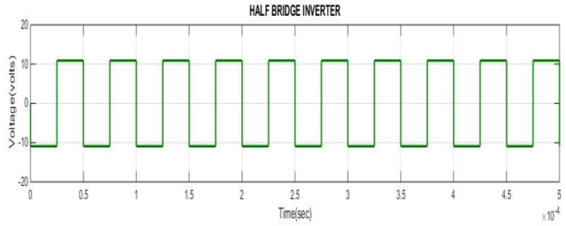

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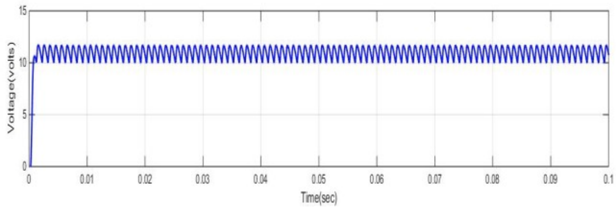
Figure 6. (a) Voltage graph of single phase full bridge inverter (b) Voltage graph of single phase half bridge inverter



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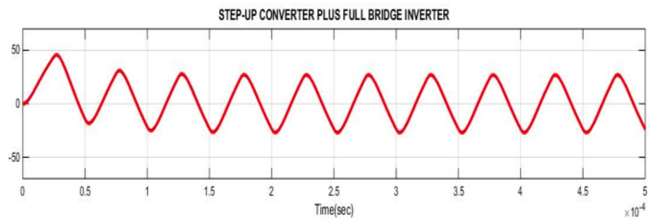

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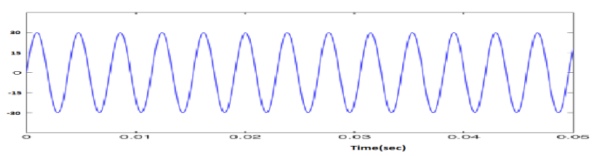

(c)

Figure 7. (a) Voltage graph of step-up converter (b)Voltage graph of step-up converter plus full bridge inverter (c) Voltage graph of step-up converter plus half bridge inverter

Table 2. comparision f results

Parameters	**Step-Up Converter Plus Half Bridge Inverter**	**Step-Up Converter Plus Full Bridge Inverter**	**Step-Up Converter Plus Pwm Inverter**
INPUT VOLTAGE	10V	10V	10V
OUTPUT VOLTAGE	29V	30V	28.5V
HARMON ICS	5.17%	4.37%	7.10%

IV. CONCLUSION

The main challege of Solar based PV inverters are cost and less efficiency.In order to reduce the cost and increase the efficiency of the microinverter,the topologies are analysed and simulated.The proposed topologies has higher efficiency with incresed output voltage compared to the previous approaches.The harmonics of the topologies also below 7.5%.Because of the above advantages ,these topologies can be used in industrial, commercial, and residential photovoltaic systems.

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