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Implementation of Novel DC-AC Converter Suitable for PV Grid Applications

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ABSTRACT: This paper presents a new family of high efficiency DC/AC grid-tied converter suitable for wide variation of input dc voltage. This converter works in Boost in Boost, Buck in Buck mode, also works at only one power stage with high frequency in order to attain minimum switching loss. The outputs of the photovoltaic systems are varying in wide range due to environmental condition. There are different types of inverter topologies are used to convert solar energy in to electrical energy but they are having some shortcomings. In this project a typical Novel DC/AC converter is used to convert solar energy in to electrical energy with high efficiency. The proposed converter uses minimum number of switches so, switching losses of this inverter is minimum and overall cost is lower than compared to other method. This dc/ac inverter is used for wide range of application like distributed energy generation systems, solar power systems, fuel cell power systems. The effectiveness of the proposed converter is verified using MATLAB/SIMULINK and hardware.

I.INTRODUCTION

The improvement of renewable energy generation, grid connected inverters are being more and more broadly used. In order to achieve high efficiency of system use different types of inverter topologies [1]. The transformer less grid connected inverter can support a wide variation in PV panel voltages. It is operates on buck–boost principle. It eliminates concerns pertaining to leakage current because of its neutral point clamped-based structure. It is free from shoot through fault and does not require any sensor for sensing the grid current. But drawback of this inverter additional dc-dc converter is need for conversion process. This will leads to high cost. It is not suitable for separate PV panel or single PV panel [2].The neutral point clamped based inverter is used to convert the solar energy into electrical energy. It is also minimize leakage current. The output of the PV panel voltage is varied due to the environmental conditions. This type cannot support large variation of PV panel voltage [3-4].In H-bridge based transformer less inverter is used to achieve high efficiency and also leads to smaller magnitude of leakage current. The main drawback of this type is reduced consumption of the PV panel voltage because of inverter operate buck mode [5].

In case of negative ground based inverter topology is used to converts the solar energy into electrical energy with help of parasitic capacitance. A parasitic capacitance used to eliminating the leakage current but its required additional dc-dc converter. Presence of parasitic capacitance creates a more power loss and it is also produce the electromagnetic radiation so it leads to the additional concentration for safety [6-7].

In case of Z-source inverter is used for conversion process. It is operate step-up and step-down state. Conduction power loss is more due to presence of two additional inductors in the power loop. Hence increasing losses, efficiency become low. In Z-source inverter not fully utilize the PV panel voltage [8-10]. For a VSI, the reverse recovery power loss and the power losses caused by the tail current of IGBT limit the switching frequency of the VSI [11].However, the conduction power loss of the VSI is low, compared to the CSI. Current source inverter need additional inductance for conversion process but voltage source inverter does not require any additional inductance. Hence its low cost than compare to the current source inverter. For the CSI high power losses caused by the DC link inductor are the main drawbacks related to the efficiency.

The CSI has no reverse recovery power losses. Using the merit of VSI and CSI and avoid the demerit of them, a high efficiency inverter was proposed [12]. The Natural Soft-Switching Inverter (NSSI) consists of five switches but Z-

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source inverter and current source inverter have four switches. While the additional switch of S_5 turn on, the inverter circuit operates at pure VSI by means two types of inverter used LC type for input side LCL type for output side. While S_5 is off, it works like a CSI with a clamped voltage and an *LCL* filter. Thus, this Inverter can well for a wide variation of PV panel voltage. Specially is used for the permanent magnet synchronous wind generator with help of a face-end diode rectifier.

An improved NSSI was proposed to increase the efficiency when it is used for the three-phase photovoltaic inverter application [13], whereas an additional Boost DC/DC circuit had been inserting. Note that the NSSI may have a higher efficiency than the traditional two-stage VSI, since more switches can work in the soft-switching or quasi-soft-switching state. More efficiency analysis about this inverter is introduced in [14]. However, the inductance in the power loop at rest seems large. The traditional two-stage VSI adopt an input DC/DC Boost converter to transfer a variable input DC voltage into a stable DC voltage, then inject the DC energy into the grid. So both two stages of the voltage source inverter work at high frequency. This will leads to considerable switching losses. Overcome this drawback with help of two stage dual-mode time-sharing high efficiency inverter used as a PV inverter.

Now, an *LCL*-filter is used as an alternative of an *L*-filter to reduce the total inductance. The important characteristics of this inverter chopping will occur only one power stage at high frequency time. So the switching power losses can be decreased compared to other conventional two stage power converter with the constant DC-link voltage. The characteristics of this inverter operate at buck in buck, boost in boost at high frequency. It means an inverter works step down or step up mode with high frequency. These modes are minimizing the switching losses. To reduce the conduction power loss of the dc inductance with help of bypass diode. When the inverter is operate at step up or boost mode the equivalent circuit of this inverter is look like a CL-CL filter so, the conduction loss inductance cannot be avoided.

Voltage source inverter does not require large inductor since the energy storage element; while current source inverter should be require large inductance. Its increase more conduction losses and switching loss [16, 17].Furthermore in the renewable power generation system the input dc voltage of the converter may vary greatly. For example the output dc voltage of a solar panel will be change a lot under the different temperature conditions. To transfer this kind of dc energy into grid a two (or) three stage inverter may be required as the power line especially for the VSI based system [18].

In this paper propose a typical novel dc/ac converter is used for PV grid applications. Hence power losses will be less than compared to previous method. Does not require any additional inductor and dc-dc converter so cost is lower than compare to Z-source inverter .If the output voltage of the PV panel greater than grid voltage buck operation will conduct else if boost operation will conduct. Hence the output of the Novel dc/ac converter is maintaining the constant grid voltage does not need any additional dc /dc converter. Only one converter circuit works at both buck and boost mode. Finally simulations are given to verify the theoretical analysis and the principle of operation.

II.SINGLE-STAGE INVERTERS

The voltage source inverter operates at buck mode which means the output of the solar panel (DC) voltage is higher than the grid voltage (as shown in Fig.1).The current source inverter operates at boost mode which means the output of the solar panel (DC) voltage is lower than the grid voltage(as shown in Fig.2). Generally, the output DC voltage of the renewable power source (for example, a PV panel) may vary in a large range, then the VSIs or the CSIs have their own limitations as a renewable power conditioner connected to the grid directly, and after an additional DC/DC converter is used

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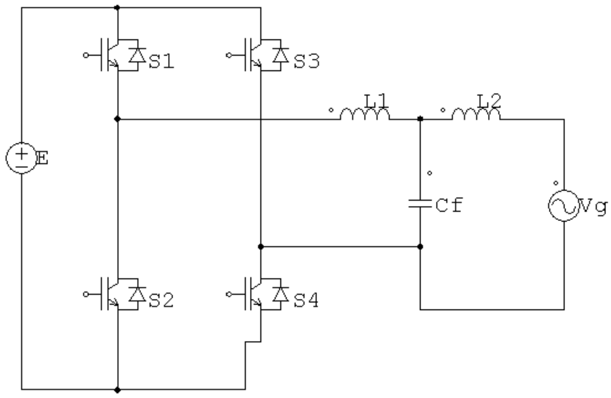

Fig. 1 Single-phase grid-tied voltage source inverter

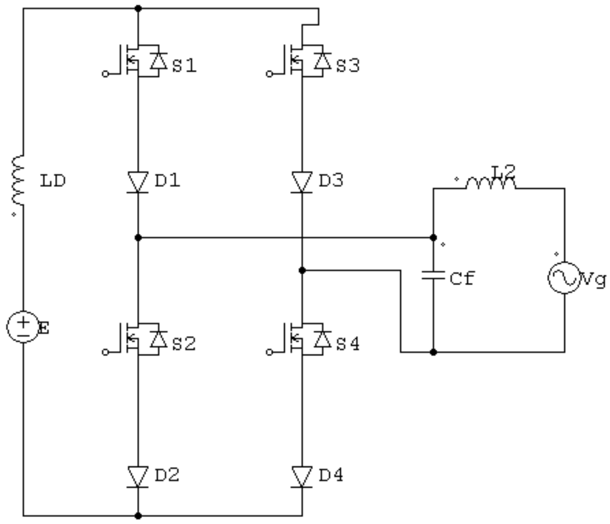

Fig.2 Single-phase grid-tied current source inverter

III.Z-SOURCE INVERTER

The combination of voltage source inverter and current source inverter characteristics, Z-source inverter was proposed. In, Z-source inverter (as shown in Fig.3) can work in both step-down and the step-up state depends upon requirement and its reliability can be improved a lot, owing to its immunity to the electromagnetic interference. However, uses of the two additional inductors in the inverter circuit, the conduction power loss is high and filter circuit is need. Difficult in Z-source inverter is overall parameter optimization, when the input DC voltage varies in a large range. The efficiency of the Z-Source inverter is not higher than that of the other conventional two stage inverters.

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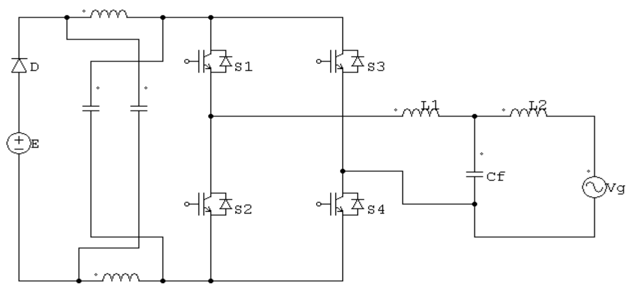

Fig.3 Single-phase grid-tied z-source inverter

IV.PROPOSED CONVERTER

A typical novel DC/AC converter is used for PV grid applications. Novel DC/AC converter operates both buck and boost mode with minimum number of switches. Hence power losses will be less than compared to previous method. Does not require any additional inductor and DC-DC converter so cost is lower than compare to Z-source inverter. If the output voltage of the PV panel greater than grid voltage buck operation will conduct else if boost operation will conduct. Hence the output of the Novel DC/AC converter is maintaining the constant grid voltage does not need any additional DC /DC converter. Only one converter circuit works at both buck and boost mode

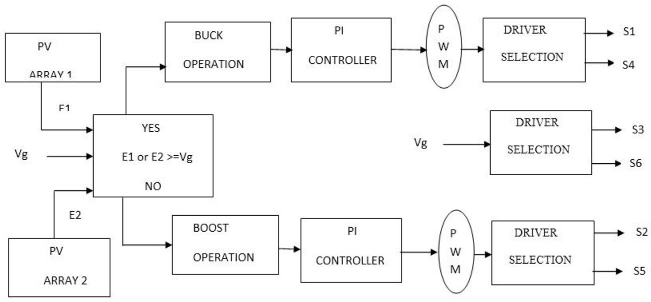

Fig.4 Block diagram of proposed system

The proposed system works only one power stage at high frequency and the output power stage works at the line frequency. Compared with the inverter in, the main difference is that the physical position of “Boost” stage and “Buck” stage has been exchanged and one inductor can be saved. So in theory, the related conduction power loss is also reduced and a higher efficiency can be achieved.

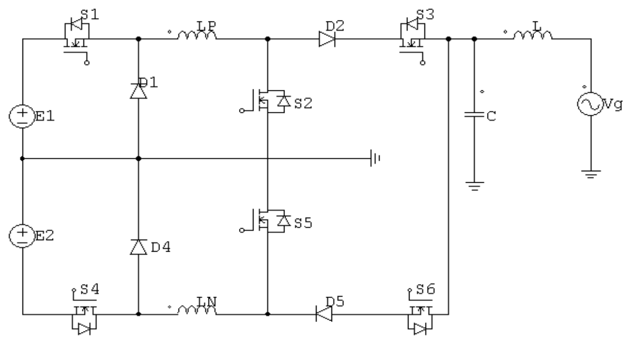

Fig.5 Novel dc/ac converter

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MODE 1: During T_1 andT_3 period when the input voltage of inverter is greater than the grid voltage or reference voltage V_g, buck operation will be conduct. At this mode during positive half cycle S_3 is turn on, S_2 is turn off, S_1 is work at high frequency. When the supply is through E_1 is shown in figure.6.During the negative half cycle S_6 is turn on, S_5 is turn off and $S_4$is work at high frequency with help of E_2source.Because it provide the supply for negative half cycle operation is shown in figure.7.

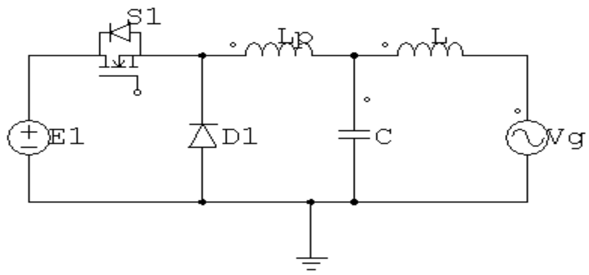

Fig.6 Equivalent circuit during T_1andT_3

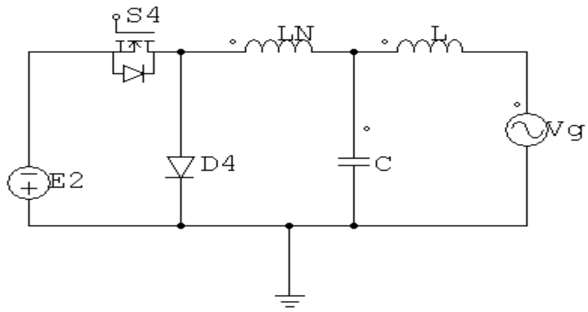

Fig.7 Equivalent circuit during T_4andT_6

MODE2: During T_3 period the input voltage of inverter is lower than grid voltage boost operation will be conduct. At this mode during the positive half cycleS_1 and S_3 are conducts or turn on andS_2 works at high frequency. Similarly, during T_4 and T_6, S_6 is on, S_4 works at high frequency, and the rest of the switches are off. Remaining switches are turn off like S_4, S_5, S_6 is shown in figure.8.During T_5 period the negative half cycle S_4 and S_6 are turn on andS_5 works at high frequency remaining switches are turn off. In this circuit similar to the CSI with a CL- filter circuit connected to the grid. Hence the current will be fully controlled with the help of inductor is shown in figure.9

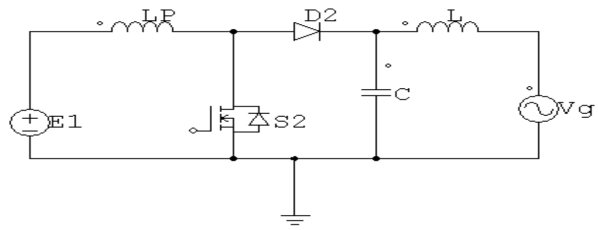

Fig.8 Equivalent circuit during T_2

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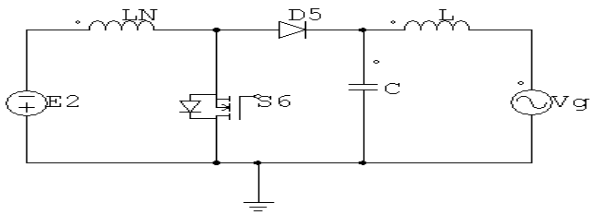

Fig.9 Equivalent circuit during T_5

V.SIMULATION WORK

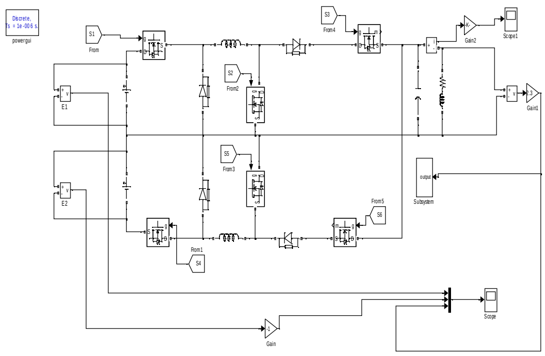

Fig.10 Simulation circuit for novel dc/ac converter

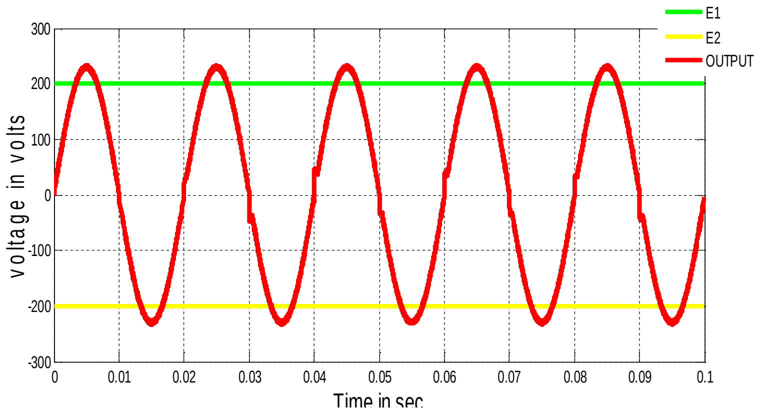

Fig.11 Output voltage forE_1=200V, E_2=200V

Fig. 11 shows the simulation results of the input DC voltages (E_1, E_2), and output voltage, while E_1= E_2 = 200V. It can be seen that the inverter works as a pure VSI and the current of the DC inductor is a rectified sinusoidal waveform.

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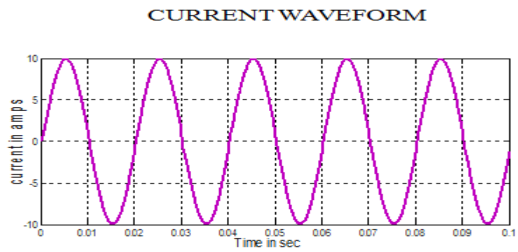

Fig .12 Output current forE_1=200V, E_2=200V

Fig.12 shows the simulation result of output current while E_1= E_2 = 200V. It can be seen that the inverter works as a pure VSI and the current of the DC inductor is a rectified sinusoidal waveform.

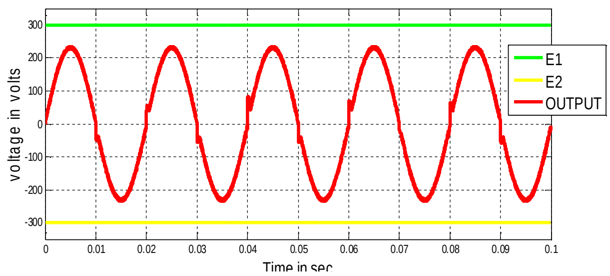

Fig.13 Output voltage forE_1=300V, E_2=300V

Fig.13 shows the simulation results of the input DC voltages (E_1, E_2), and output voltage, while E_1= E_2 = 300V. It can be seen that the inverter works as a pure VSI and the current of the DC inductor is a rectified sinusoidal waveform

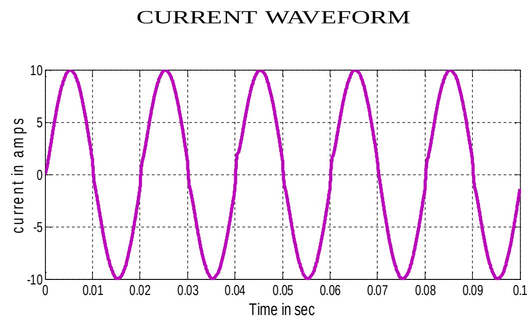

Fig .14 Output current forE_1=300V, E_2=300V

Fig.14 shows the simulation result of output current while E_1= E_2 = 300V. It can be seen that the inverter works as a pure VSI and the current of the DC inductor is a rectified sinusoidal waveform.

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VI.HARDWARE DEVELOPMENT

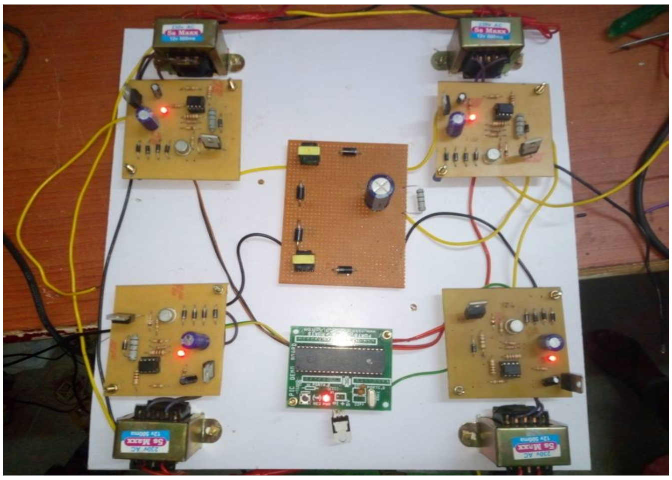

Fig.15 Photocopy of hardware

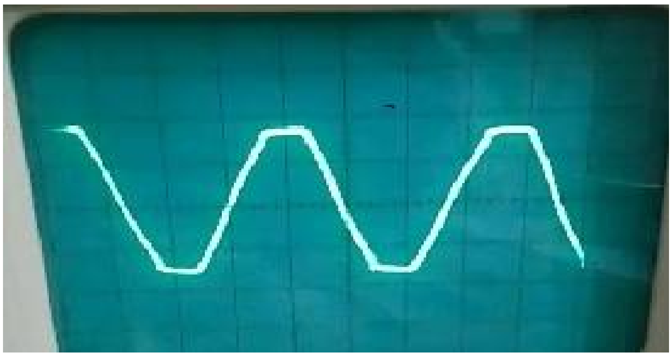

Fig .16 Hardware Output Voltage

Where the X-axis represent the time in sec, Y-axis represent voltage in volt. Input voltage E1=E2=21.6V (DC), output voltage=20V (AC).Total time is 20ms.

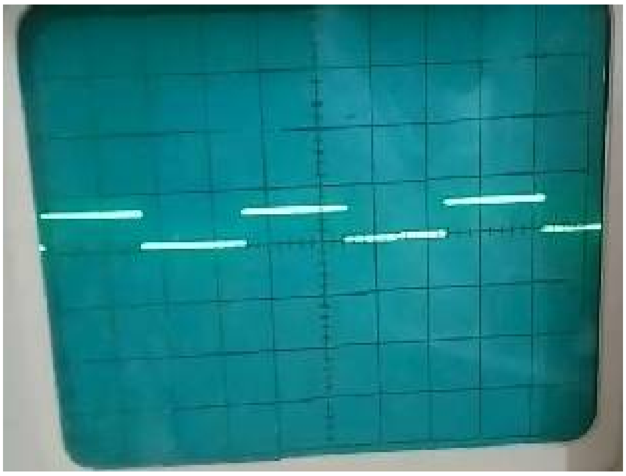

Fig.17 PWM waveform

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VII. CONCLUSION

In this paper a new Novel DC/AC converter is proposed. The working modes of converter are introduced in detail through equivalent circuits. For this type of converter, when the output of the solar panel (DC) voltage is lower than the grid voltage it works at combination of VSI and CSI during the different working stages. If the output of the solar panel (DC) voltage is higher than the grid voltage, it work at pure VSI .This converter operates at only one power stage works in the high frequency stage at any time, which results in minimum switching losses .A 220 V/50 Hz/ 1000 W prototype have been finished. Simulations and experimental result shows that converter has good control performance.

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