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Design and Implementation of Modified Split Source Inverter with Quasi Sinusoidal PWM Technique for Stand-Alone System

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Abstract;- **Single-stage DC-AC power converters are recently gaining attention due to their features like size, cost, weight, and complexity of the whole system. Split-Source Inverter (SSI) is a single-stage DC-AC power converter works on the same modulation scheme of the conventional Voltage Source Inverter (VSI) with reduced switch voltage stress and continuous input current. Single-Phase version of SSI having improvements in inverter topology as well as the pulse width modulation (PWM) technique is presented here. Moreover, the features like employing hybrid quasi-sinusoidal and constant PWM technique with the single-phase SSI are designed and implemented. The introduced analysis is enhanced with simulation results using MATLAB model, where a single-phase SSI is designed and simulated. Finally, the designed Single-phase SSI is implemented experimentally**

Keywords: Split Source Inverter, single stage topology, H bridge, pulse width modulation, voltage boosting.

1. INTRODUCTION

With increase in renewable energy sources and energy storage, high-voltage-gain DC–DC power electronic converters find its applications in green energy systems. They are used to interface low voltage sources like fuel cells, Photo Voltaic (PV) panels, batteries, etc. For renewable energy integration inverter is the most widely used power electronics system [1]. In conventional systems, attention has been drawn to increase the boosting capability of inverters [2]–[6].In conventional practice, DC-DC voltage boosting stage cascaded with a two-level inverter was widely used. Since, each stage is controlled independently the controlling becomes complex. Because of high switching frequency the inverter losses increased and efficiency get reduced [7]. In recent times, two stage topology is being frequently used, which is the cascaded H-bridge multilevel inverter and its foremost advantage is that the output harmonics are attenuated efficiently due to the better replication of sinewave in accordance with the multi-level AC voltages. [8]. But its major disadvantage was it required large number of power switches which made the system bulker. Besides, separate renewable sources were required to power the H bridge multilevel inverter.

VSI are the most common DC–AC power converters used in any power electronic system. The VSI possess only the buck capability with the inversion stage, i.e., the output AC voltage cannot be exceeding the available DC input voltage [8]. This point has no issue for many applications with high DC rail. Meanwhile, several applications require the output AC voltage to be exceeded the input DC voltage. Hence, the use of an additional boosting stage is necessary for the applications such as fuel cells-based systems, which has a low and unregulated input voltage. Recently, DC–AC power converters buck boost capability in a single stage are gaining attention due to their merits compared to the two-stage equivalent topology in terms of their size, cost, weight, and complexity of the whole system [9].

The most common topology in power converter category is the conventional Z-Source Inverter (ZSI), exploits an impedance network that comprises of four passive elements in addition to a diode that carries the full power to work as a buck-boost stage [10]. Several topologies exist for the ZSI in addition to the conventional one; among them the quasiZSI (qZSI) and the current fed qZSI are introduced. Other topologies like switched-inductor ZSI and the switched-inductor qZSI are discussed [12]. Moreover, the semi ZSI is another ZSI topology introduced as a low cost solution for single-phase PV systems. The main drawback is its complexity and the output AC voltage cannot exceed the DC input voltage [13].

ZSI requires additional switching state out of the conventional eight states, besides having a discontinuous input current by utilizing four passive elements. Hence, proposes a different topology called the Split-Source Inverter (SSI) [14]. This topology utilizes reduced passive element count compared with the ZSI, in addition a diode for each inverter leg. The advantages of this topology, compared with the ZSI, are: a continuous input current, a standard modulation strategy that employs the same eight states of the VSI, and a constant inverter voltage with a low frequency component. This topology is derived by integrating a boost converter into a VSI, by connecting the boost inductor to the switching nodes of the inverter legs via diodes. The employment of the boost converter in DC–AC power conversion was first studied; it studies the possibility of getting sinusoidal output voltage from two boost converters. However, the inductor is charged with varying duty cycle which is highly depended on the sinusoidal modulation of two level inverter. The converter become more complicated because of this reason. Also, the diodes suffer from high frequency current commutation.

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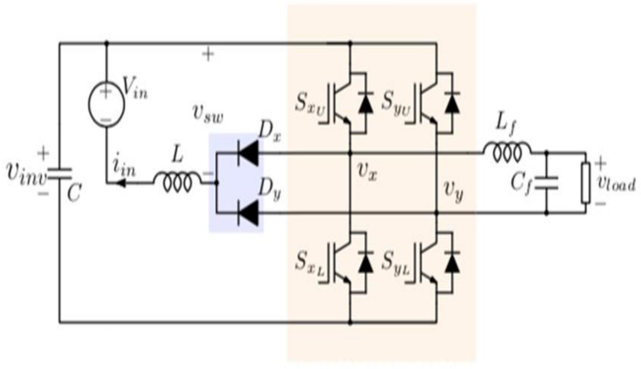

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Fig 1. Conventional Split Source Inverter

Here, in order for resolving the aforementioned problems an improved single-phase version of SSI with hybrid quasi-sinusoidal and Pulse Width Modulation is proposed. The modulation given for each leg is different. One leg is responsible for charging the inductor at constant duty cycle while the other leg is responsible to produce ac output according to sinusoidal PWM. The hybrid quasi-sinusoidal and constant PWM enable the adoption of two MOSFETs operating at fundamental frequency to eliminate high frequency current commutation. This eliminate requirement of external DC-DC stage or AC-AC Stage for voltage boosting.

2. OPERATION OF MODIFIED SPLIT SOURCE INVERTER

The proposed single-phase SSI in this work retains the inherent merit of the earlier SSI. It provides extended capability to resolve the high frequency current commutation problem existing in the earlier SSI while enabling bidirectional power flow so that the proposed SSI can operate in rectification mode or inversion mode. This refinement is made feasible by the proposed hybrid quasi-sinusoidal and constant PWM.

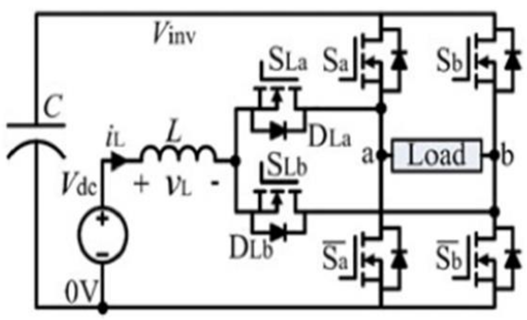

Fig 2. Modified Single Phase Split Source Inverter

It is worth pointing out that between the two legs of the full bridge inverter, it is essential for one leg to operate at constant duty cycle (for DC–DC boost conversion) while the other leg operates at sinusoidally varying duty cycle (for DC–AC sinusoidal output). The complementary switches S_{La} and S_{Lb}, which operate at fundamental frequency, play their role in clamping the leg which operates at constant duty cycle to the inductor and dc source, so as to boost the dc voltage across the dc link.

2.1 Operation and Modulation

The proposed single-phase SSI retains the inherent merit of the earlier SSI. It provides the capability to resolve the high frequency current commutation problem existing in the earlier SSI while enabling bidirectional power flow so that the proposed SSI can operate in rectification mode or inversion mode. This refinement is made possible by the proposed hybrid quasi-sinusoidal and constant PWM. It is worth pointing out that the two legs of the full bridge inverter, it is essential for one leg to operate at constant duty cycle (for DC–DC boost conversion) while the other leg operates at sinusoidally varying duty cycle (for DC–AC sinusoidal output). The complementary switches S_{La} and S_{Lb}, that operate at fundamental frequency, play their role in clamping the leg which operates at constant duty cycle to the inductor and dc source, so as to boost the DC voltage across the dc link.

To gain more insight into the operation of improved single phase SSI, the equivalent circuits at combinations of the gating signals Sa and Sb are obtained. In state 0, the lower MOSFETs of both legs are ON. The resultant 0 V output voltage leads to the charging of inductor L through D_{La} and D_{Lb}. With the load clamped to $-V_{inv}$ in state 1, diode D_{Lb} is reversed biased and the inductor L is charged through D_{La}. In contrast, with the load clamped to $+V_{inv}$ in state 2, diode D_{La} is reversed biased and the inductor L is charged through D_{Lb}. In state 3, ON states of both the upper MOSFETs give rise to the 0 V output voltage which further provoke the discharging of inductor.

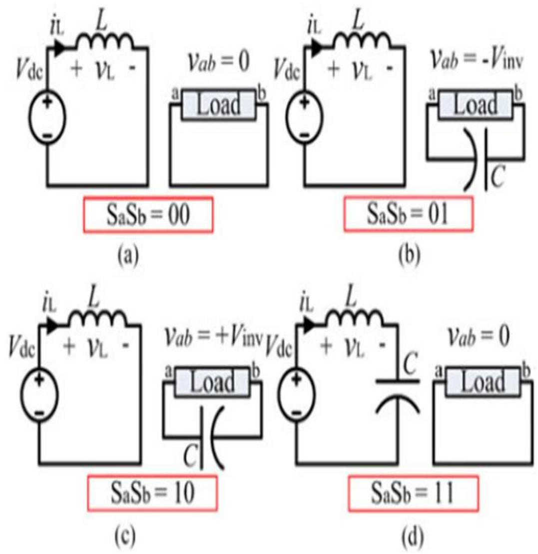

Fig 3. Equivalent circuits at different switching states: (a) state 0, (b) state 1, (c) state 2, and (d) state 3

2.2 Hybrid Quasi-Sinusoidal and Constant PWM

As the name implies, hybrid quasi-sinusoidal and constant PWM in this work refers to the simultaneous employment of constant duty cycle switching and sinusoidally varying duty cycle switching on two legs of the full-bridge inverter,

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respectively. As distinct from where inductor L is charged and discharged with variable duty cycle, hybrid quasi-sinusoidal and constant PWM is a simpler approach by enabling constant duty cycle to control the charging and discharging of inductor L. Therefore, despite the single stage topology, the proposed hybrid quasi-sinusoidal and constant PWM has the merit of detached modulation for dc-dc voltage boosting from the sinusoidal modulation (for controlling ac output). This characteristic greatly simplifies the circuit analysis and the equations for a typical dc-dc boost converter can thus be used to find the relationship between dc link voltage Vinv and dc source Vdc.

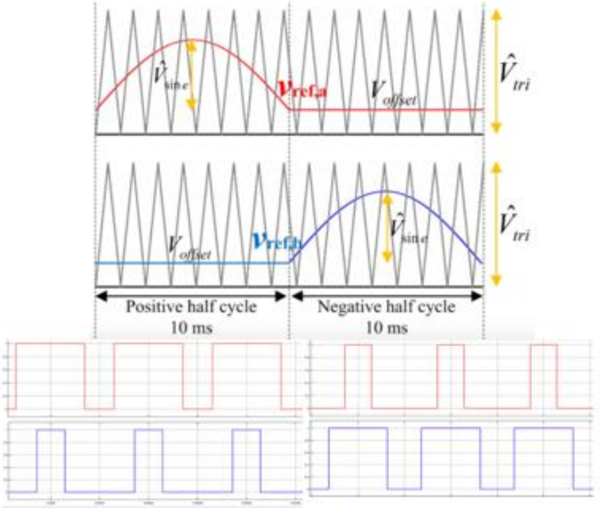

Fig. 4 Key waveforms of hybrid quasi-sinusoidal and constant PWM

3 ANALYSIS OF SIMULATION RESULTS

Simulation is carried out in MATLAB 2016 version. Simulink is a block diagram environment for multi domain simulation and model-based design.

3.1 Simulation Parameters

Fig 5 Shows the simulation diagram of single phase SSI feeding RL load at 50 Hz. Quasi-Sinusoidal PWM is utilized to drive the H-Bridge of SSI.

Table 1. Simulation Parameters

PV Array: Open Circuit Voltage	18V
PV Array: Maximum Power	120W
PV Array: Voltage at Maximum Power Point	12V
PV Array: Current at Maximum Power Point Imp	10A
Capacitance	1000 µF, 2000 µF
Inductance	11µH, 3 mH
Load Resistance	15 Ω
PV Array: Cell per Module	60

3.2 Simulation Result

The complete model of the developed SSI is shown in Fig.4

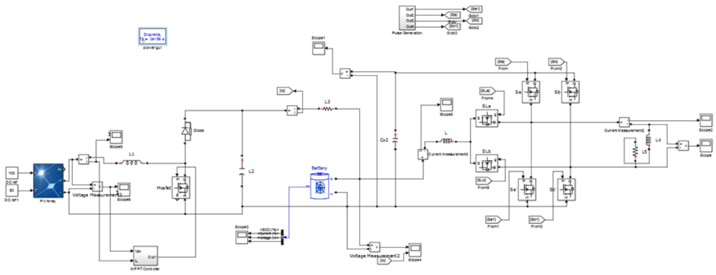

Fig 5. Simulation diagram of single phase SSI

Simulation has been performed and the results are presented for each converter stage.

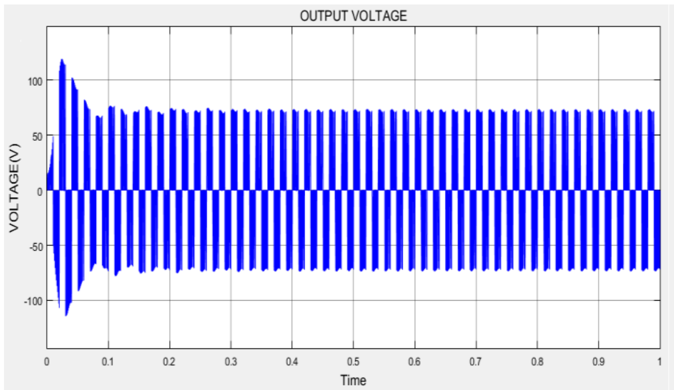

Fig 6. Output Voltage of Single Phase SSI

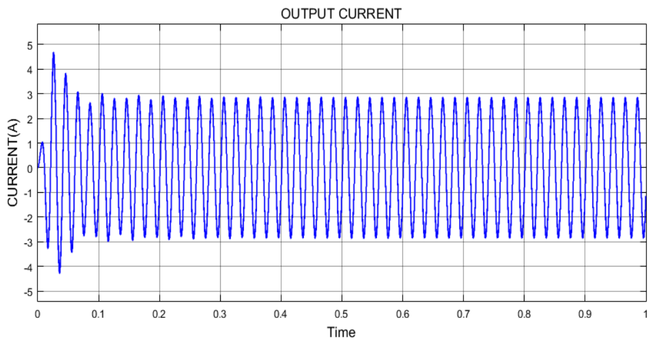

Fig 7. Output Current of Single Phase SSI

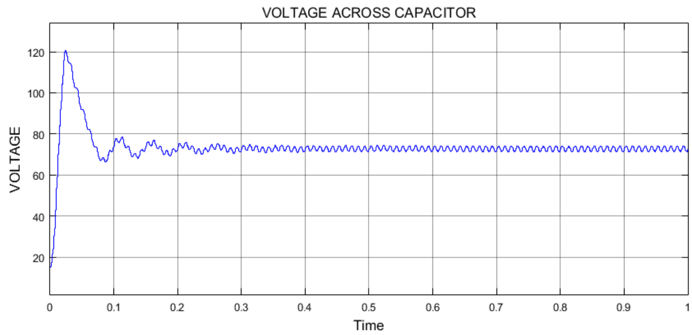

Fig 8. Voltage Across the Capacitor

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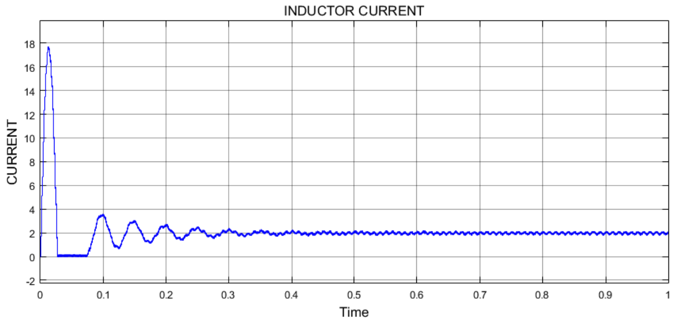

Fig 9. Current Flowing Through the Inductor

4. CIRCUIT IMPLEMENTATION

A 47 W single-phase SSI is implemented experimentally in order to verify the simulation results and evaluate its efficiency. This 47 W single phase SSI prototype is shown in Fig.10 and its parameters are same as that have been taken from the simulated one.

The hardware implementation of SST consists of a 12V DC power supply, a converter section, Boost section, driver section and output section. The switches in each section are controlled by means of hybrid quasi sinusoidal and constant PWM. Technique.

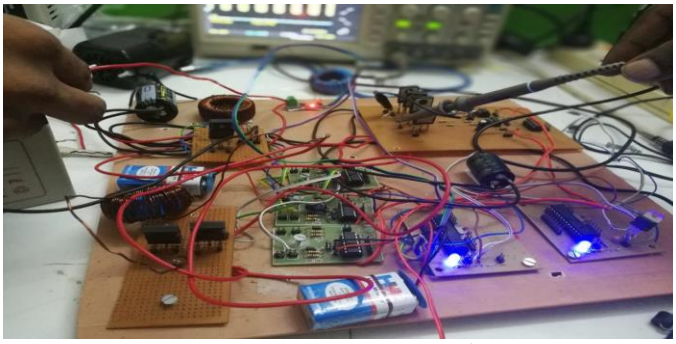

Fig 10. Hardware Implementation of SSI

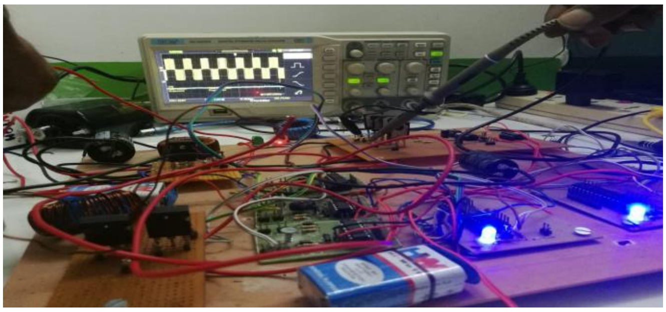

Fig 11. Final Output of Single Stage SSI

3. CONCLUSION

The design and analysis of split source inverter for commercial application from a renewable source is done successfully. Replacing two diodes with two MOSFETs operating at 50Hz frequency is made possible by the hybrid quasi-sinusoidal and constant PWM technique so as to resolve the high frequency current commutations problem. The use of MOSFETs enables bidirectional power flow with inversion and rectification modes. Coupled with the proposed single-stage topology, hybrid quasi-sinusoidal and constant PWM provides dc voltage boosting from input source to DC output voltage. This inverter achieves buck–boost capability with wide range of output voltage. The operation of SSI and modulation technique was theoretically analysed. Simulation and experimental evaluation of a low voltage prototype were conducted. The prototype was designed for 47 W power and an efficiency of 80% was obtained. The modified P&O algorithm used in renewable system provides an efficient and reliable maximum power tracking performance under rapid change in irradiance and temperature conditions. The experimental results show that the proposed system is more efficient than the conventional design.

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