Implementation of Single Phase Transformerless Inverter for Grid Connected PV System

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Abstract: In a DC-AC system, some problems may threaten the reliability of the whole system, such as the shoot through issue and the failure of reverse recovery. Some methods are proposed to improve the reliability of the converters. In proposed inverter due to the splitting structure of inductor avoids reverse-recovery issues for the main power switches. High-frequency pulse width modulation switching commutation and the grid zero crossing instants, improving the quality of the output ac-current and increasing the converter efficiency. Also due to two additional AC-sides switches conducting the currents during the freewheeling phases so that the photovoltaic array is decoupled from the grid. This reduces the high-frequency common-mode voltage leading to minimized ground loop leakage current. This Paper describes H5 & H6 transformerless inverter topology.

Keywords: Conventional H5 and H6 Transformerless Inverters, Proposed Transformerless Inverter, Ground leakage current analysis

I. INTRODUCTION

The fast development of the clean energy power generation requires the inversion system, especially the inverters, to be more and more reliable. Yet shoot through problem of the power devices is a major threaten to the reliability. As is known, a traditional method to solve the shoot through issue is by setting dead time. However, the dead time will cause a distortion of the output current. Also, during the dead time, the current may flow through the body diode of the switch which can cause the failure of the reverse recovery [1]. For the purpose of solving the above problems, the dual buck topologies are proposed in a lot of research. By combining two unidirectional buck circuits, the dual buck inverters will not suffer the threaten of shoot through problem and the freewheeling current will flow through the independent diodes which can solve the reverse recovery problem of the MOSFET's body diodes. However, the major drawback of the dual buck topologies is the magnetic utilization. Only half of the inductance is used in every working mode. And it will obviously increase the weight and volume of the system [2]-[4].

In order to improve the magnetic utilization of the dual buck inverter, a kind of single inductor dual buck topology was proposed in [5]. Compared with the traditional full bridge inverter, two extra switches are applied in the proposed topology. The single inductor topology can make full use of the inductance, but the conducting loss is largely increased because four switches are flown through during the power delivering modes. This paper proposed a kind of novel phase leg topology with series connected diodes and single inductor to highly improve the reliability of the inverter, especially for the MOSFET inverter [6].

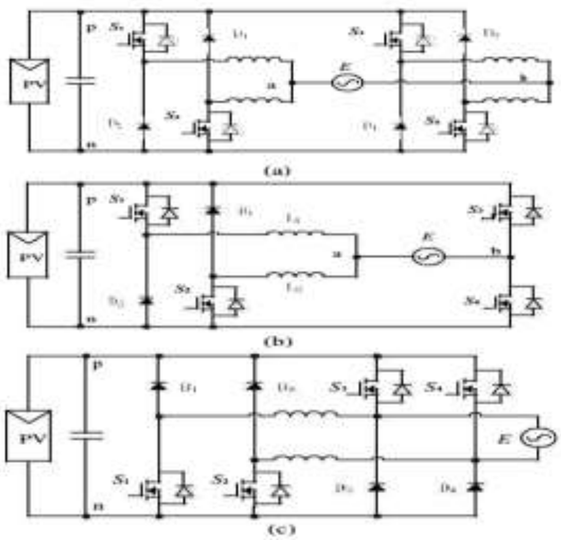

Fig. 1. Traditional Dual buck and dual boost full bridge inverters.

Applying the phase leg to the single phase inverter, an improved single inductor dual buck inverters are proposed in this paper. The novel topology has the following advantages: firstly, retains the advantages of the traditional dual buck inverters, secondly, makes full use of the inductance, thirdly, the proposed inverter saves two switches compared to the traditional single inductor topology, which makes a lower conducting loss and a simpler controlling strategy. The simulation and experimental results have verified.

Fig. 1 shows the traditional dual buck and dual boost inverters [7]-[8]. The most attractive advantage of the dual buck topologies is the high reliability. Firstly, without adding the extra dead time, the dual buck topologies can solve the shoot through problem. Secondly, compared to the traditional H-bridge inverter, the current will not flow through the body diodes of the switches in the dual buck topologies which means no reverse recovery problem exists in the MOSFET phase legs. Considering the above two aspects, the dual buck topologies can achieve high reliability without the shoot through and reverse recovery issues.

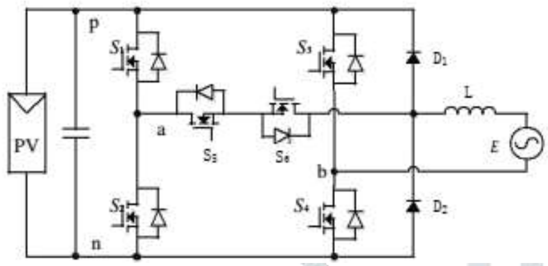

Fig. 2. Traditional Dual buck full bridge inverter with single inductor

However, the main drawback of the dual buck topologies is the low magnetic utilization. In each power delivering and freewheeling modes, the current only flow through half of the inductance, which means the other half of the inductance is wasted in each working condition. The low utilization of the inductance makes the increasing of the weight and volume for the whole system. To solve this problem, a concept of single inductor dual buck full bridge inverter [5] is proposed. Fig. 2 shows the single inductor topology. The novel topology includes six switches and two diodes. Comparing to the traditional dual buck full bridge inverter, the single inductor topology can save half of the inductance. And the novel topology retains the original advantages of high reliability.

Also, there is no need to add the dead time in the high frequency unipolar switching strategy. The inductance can be fully utilized in the single inductor inverter. However, a high level of conduction loss is the main drawback of the novel topology. During the power delivering mode, the current flows through four switches which is a lot more than the traditional full bridge inverters. Besides, compared to the traditional Hbridge inverters, the extra two switches make controlling strategy more complex. And in the dual buck single inductor inverter, the current will flow through the body diodes of the series MOSFET switches which can cause the problem of reverse recovery.

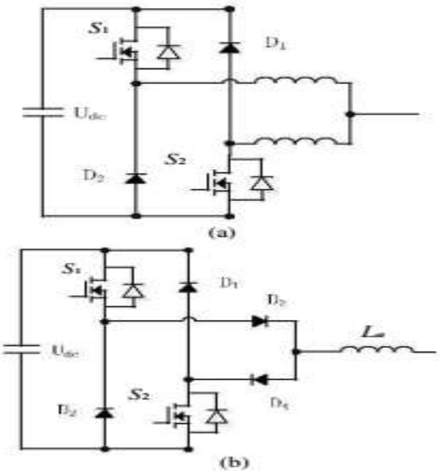

Fig. 3. (a)Traditional dual buck phase leg (b) proposed dual buck phase legs with series connected diodes and single inductor.

To solve the problem of traditional H-bridge inverter, including the shoot through issue and the reverse recovery of the MOSFET, a kind of dual buck inverter with series connected diodes and single inductor is proposed in this paper. The newly proposed topology retains the advantage of traditional dual buck inverter and solve the problem of low magnetic utilization. Also, the proposed topologies will not invite extra switches which means a simpler controlling strategy compared to the traditional dual buck single inductor full bridge inverter in [5].

II. SYSTEM CONFIGURATION

The proposed transformerless PV inverter, which is composed of six MOSFETs switches (S1–S6), six diodes (D1–D6), and two split ac-coupled inductors L1 and L2 as shown in Fig.4. The diodes D1–D4 perform voltage clamping functions for active switches S1–S4. The ac-side switch pairs are composed of S5, D5 and S6, D6, respectively, which
provide unidirectional current flow branches during the freewheeling phases decoupling the grid from the PV array and minimizing the CM leakage current. The proposed inverter topology divides the ac side into two independent units for positive and negative half cycle. In addition to the high efficiency and low leakage current features, the proposed transformerless inverter avoids shoot-through enhancing the reliability of the inverter.

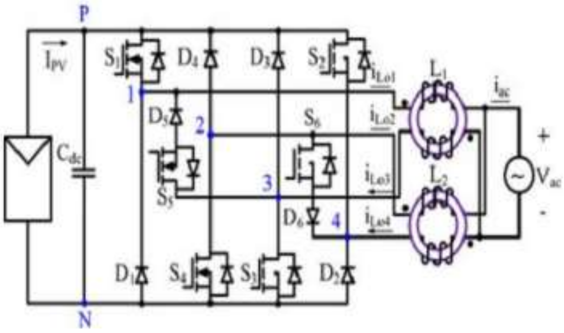

Fig.3. Proposed transformerless inverter

For proposed inverter, in the PWM scheme, when the reference signal Vcontrol is higher than zero, MOSFETs S1 and S3 are switched simultaneously in the PWM mode and S5 is kept on as a polarity selection switch in the half grid cycle; the gating signals G2, G4, and G6 are low and S2, S4, and S6 are inactive. Similarly, if the reference signal Vcontrol is higher than zero, MOSFETs S2 and S4 are switched simultaneously in the PWM mode and S6 is on as a polarity selection switch in the grid cycle; the gating signals G1, G3, and G5 are low and S1, S3, and S5 are inactive.

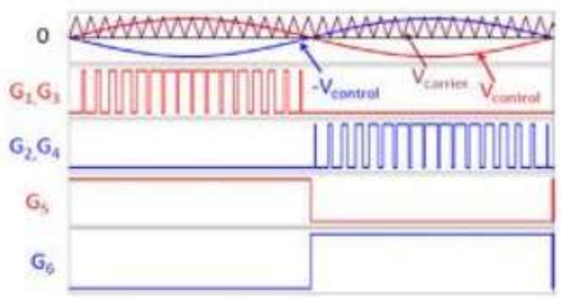

Fig.4 Gate signal of proposed transformerless inverter

The four operation stages of the proposed inverter are within one grid cycle. In the positive half-line grid cycle, the high-frequency switches S1 and S3 are modulated by the sinusoidal reference signal Vcontrol while S5 remains turned ON. When S1 and S3 are ON, diode D5 is reverse-biased, the inductor currents of iLo1 and iLo3 are equally charged, and energy is transferred from the dc source to the grid; when S1 and S3 are deactivated, the switch S5 and diode D5 provide the inductor current iL1 and iL3 a freewheeling path decoupling the PV panel from the grid to avoid the CM leakage current. Coupled-inductor L2 is inactive in the positive half-line grid cycle.

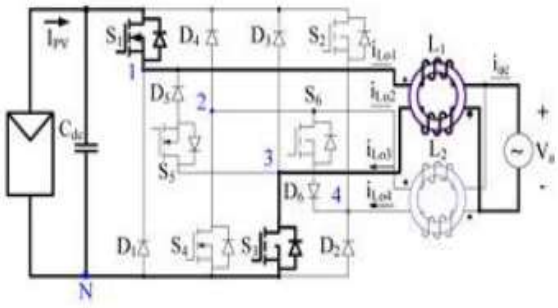

Fig.5 (a) Active stage of positive half cycle

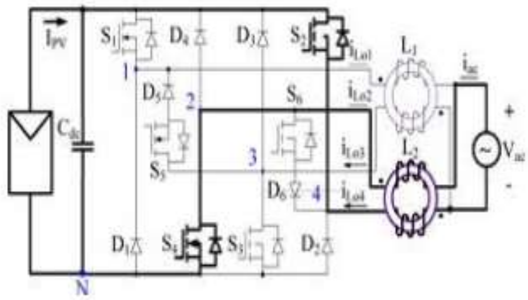

Fig.5 (b) Active stage of negative half cycle

III. SIMULATION RESULTS

The MATLAB Simulation model of Proposed Transformerless Inverter having 5 kW output power with 380V DC input voltage and 230V AC Grid voltage is as shown in Fig.6.

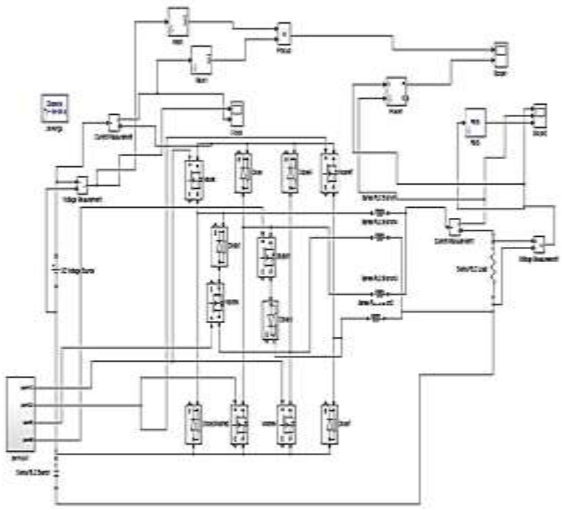

Fig. 6 Simulation Model of Proposed transformerless Inverter

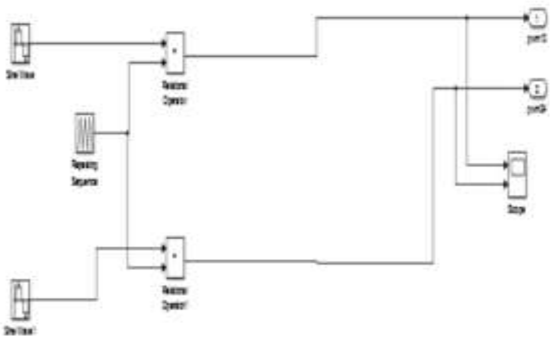

Fig.7 Simulation for PWM signal generation for S1, S3 and S2, S4

PWM at zero instant for freewheeling MOSFET S5 and S6 are generated as shown in Fig.7.

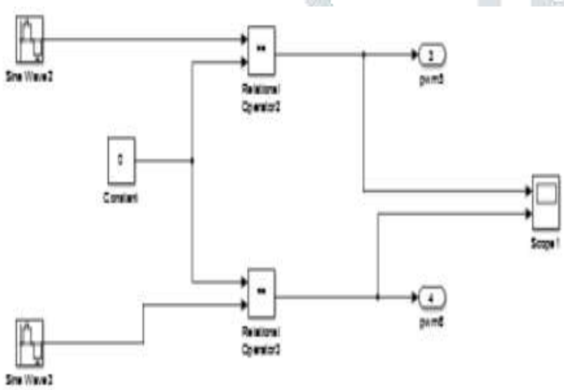

Fig.8 Simulation for PWM Signal Generation for S5 and S6

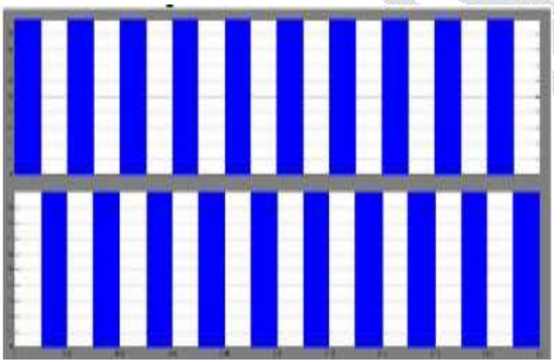

Fig.9 Gate signal of S1,S2 and S3,S4

Fig.10 Gate signal of S5 and S6

IV. CONCLUSION

In this paper study of conventional H5, H6 and Proposed transformerless inverter has been done. A high efficiency Proposed Transformerless Inverter for PV grid-connected power generation systems is simulated and corresponding simulation results are presented. The main characteristics of the proposed transformerless inverter are summarized as follows:

1. High efficiency can be achieved by employing super junction MOSFETs for all switches since their body diodes are never activated.

2. CM leakage current is reduced due to two additional unidirectional current switches (S5 and S6) which decouple the PV array from the grid during the zero stages

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