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New inverter topology for ground current suppression in transformerless photovoltaic system application

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Abstract An interesting inverter topology is proposed in this paper. It is similar to the typical three-phase full bridge inverter from the topology point of view, but smartly designed for the ground current reduction in single-phase photovoltaic (PV) inverter applications. Theoretical analysis is conducted to clarify the operation mechanism of the proposed topology. Performance evaluation is carried out to verify the effectiveness of the proposed topology for the ground current suppression.

Keywords Ground current, Grid-connected inverter, Photovoltaic (PV) system

1 Introduction

Photovoltaic (PV) power is a clean and renewable alternative form of energy, which becomes increasingly attractive in recent years. According to the latest national survey report of PV power applications [1], in 2011, 2.5 GW PV systems has been installed in China, reached a total installed capacity of 3.3 GW, which represents 5% of the global total installed capacity. Fig. 1 shows annual and cumulated PV installation in China.

In order to improve the efficiency and reduce the cost of the PV power system, the transformerless inverter topology is a good choice, because it does not need heavy and costly transformer. However, the ground current may arise because there is no galvanic isolation between the inverter and grid. The ground current results in electromagnetic interference and safety issues [2]. Therefore, the suppression of ground current is a necessity for the transformerless PV inverter [3]. Many transformerless inverter topologies have been reported in literature. Most of them are derived from the single-phase full bridge inverter, such as H5 [4] and H6 [5], which has the potential risk of the bridge shoot through. It may lead to the inverter switch damage and reduce the system reliability. In order to solve the problem, a new inverter topology is proposed in this paper. It is similar to the typical three-phase full bridge inverter from the topology point of view, but smartly designed for the ground current suppression in single-phase PV inverter applications. The theoretical analysis and performance evaluation are carried out to demonstrate the feasibility of the proposed topology.

2 Proposed topology

Fig. 2 depicts the schematic of the proposed topology. It is interesting to note that the proposed topology is analogy to the typical three-phase full bridge inverter topology [6], but smartly modified for the ground current reduction. Furthermore, it has the advantages that the bridge shoot through is enabled without any switch damage, which increase the system reliability. Following we will present the operation mechanism of the propose topology.

In general, the ground current results from the high-frequency voltage components across the parasite capacitor between the PV system and the ground. Therefore, in this paper, the basic idea for the ground current suppression is to keep the parasite capacitor voltage free of high-frequency components.

Fig. 3 shows the system operation in the positive half cycle. When S_1 and S_6 are on, the parasite capacitor voltage in Fig. 3a is equal to the voltage across the inductor L_2, which is a half the input voltage and grid voltage. On the

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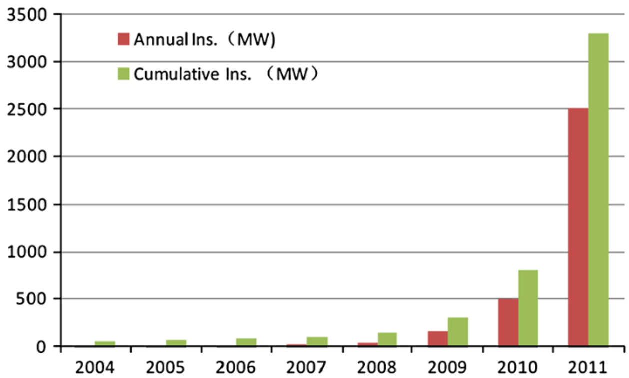

Fig. 1 Annual and cumulated PV installation in China [1]

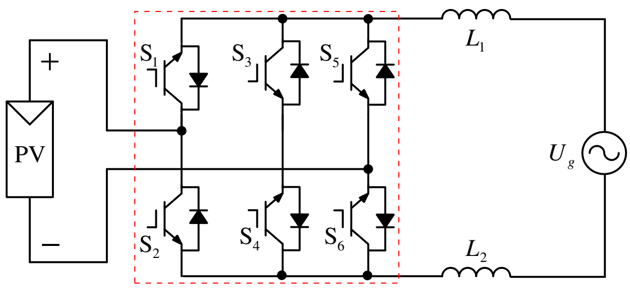

Fig. 2 Proposed topology

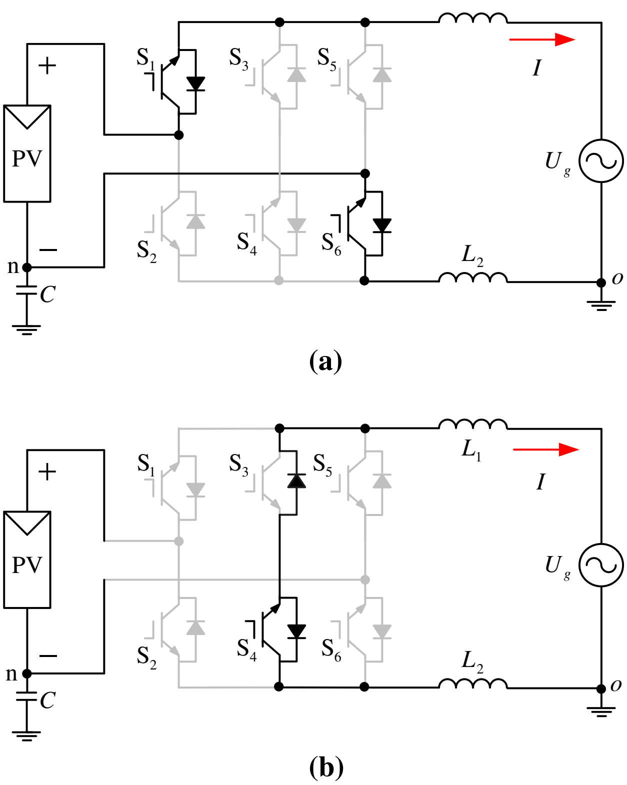

Fig. 3 Operation in the positive half cycle

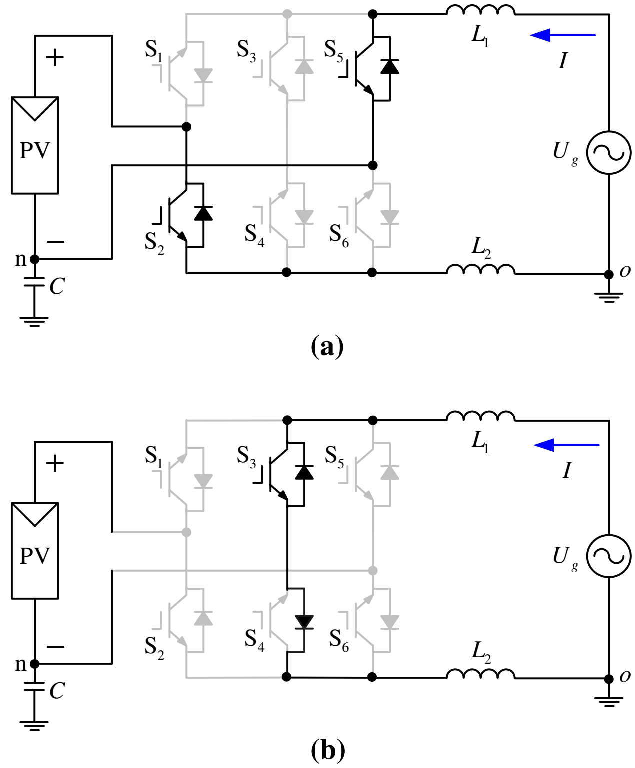

Fig. 4 Operation in the negative half cycle

other hand, When S_4 and S_3 diode are on, the parasite capacitor voltage in Fig. 3b is equal to the voltage across the S_6 and inductor L_2, where the voltage drop of S_6 is a half the input voltage and the voltage drop of inductor L_2 is a half the grid voltage.

Fig. 4 shows the system operation in the negative half cycle. When either S_2/S_5 (See Fig. 4a) or S_3/S_4 Diode (See Fig. 4b) are on, the parasite capacitor voltages are equal to a half the input voltage and grid voltage, which is exactly the same as one in the positive half cycle.

In summary, the parasite capacitor voltage in the entire cycle is free of high frequency components. Therefore, the ground current can be reduced.

Another consideration that should be noted is the effect of the switch parasitic capacitance on the ground current. An interesting analysis and solution has been reported in [7]. In practice, however, these parasitic capacitances can not be accurately predicted [8], and may be time-varying as the operating temperature and operating state change [9]. Therefore, further investigation is needed to deal with it, which is the subject of our future research.

3 Performance evaluation

As we know, the typical H-bridge inverter with bipolar modulation or unipolar modulation is not suitable for the

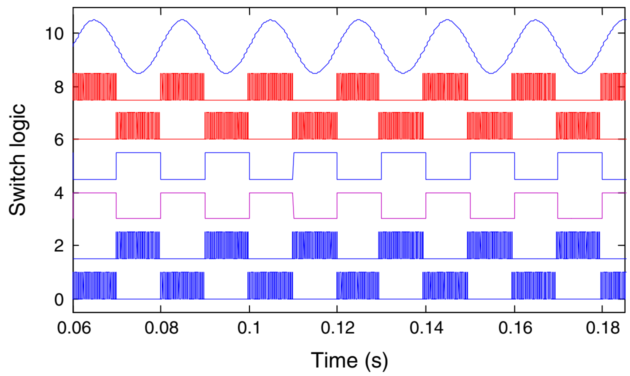

Fig. 5 Switch logic, from bottom to top: S_6, S_5, S_4, S_3, S_2 and S_1

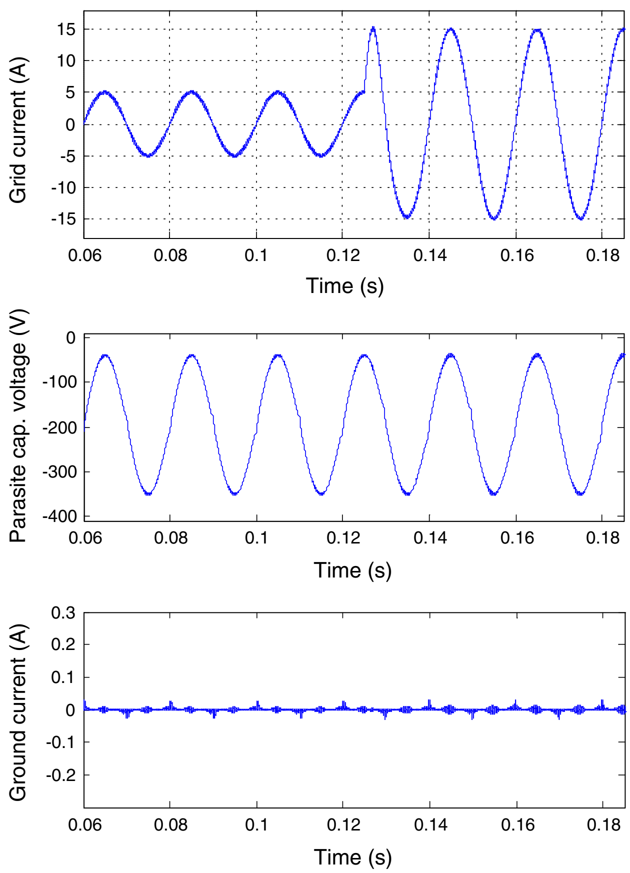

Fig. 6 Performance evaluation results

transformerless PV system application due to its low efficiency or high ground current [10], and the extensive evaluation results have been reported in [2, 3]. Therefore, it is not duplicated here. In order to verify the effectiveness of the proposed solution, following will present the performance evaluation of the proposed topology. System parameters are listed as follows: input voltage is 390 V; grid voltage is 220 V/50 Hz; inverter switching frequency is 16 kHz; filter $L_1 = L_2 = 5$ mH; ground parasitic capacitor is 25 nF. The evaluation results are presented as follows. From Fig. 5, it can be observed that only two switches operate in high frequency mode at any instance, leaving four switches in the fundamental frequency mode, which greatly reduces the switching losses and increase the system efficiency.

From Fig. 6, it can be observed that the current waveform is sinusoidal. At 0.12 s, the current steps from 5 A to 15 A. It can be observed that the grid current has good tracking capability and dynamic response. On the other hand, the parasite capacitor voltage is free of high-frequency components. The ground current is much less than 300 mA, and it meets the international standard of VDE 0126-1-1. It should be noted that this paper mainly focused on the ground current reduction in single-phase PV systems. For three-phase PV systems, some possible solution has been reported in [11], which is beyond the scope of this paper.

4 Conclusions

This paper has presented an interesting inverter topology for the single-phase transformerless PV systems. It can achieve the ground current reduction by keeping the parasite capacitor voltage free of high frequency components. It is expected that the proposed topology is attractive and promising for the ground current reduction in transformerless grid-connected PV applications.

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