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Three-Level Boost Converter Design for High Efficiency Photovoltaic Power Conditioning System

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Abstract. This paper proposes the three-level boost converter for high-efficiency photovoltaic power conditioning system. Different from the existing two-level high boost converter, it has the advantage of high voltage gain and thus it is easy to make a high voltage from a low voltage. The proposed three-level boost converter reduces the reverse recovery losses of the diodes and increases the overall power efficiency. Experimental results show the high performance for a 4kW resistive load and grid-connected power condition system.

Keywords: Three-Level Boost Converter, Photovoltaic Power Conditioning System, PV PCS

1 Introduction

Nowadays the alternative energy researches are constantly performed due to the environmental pollution and the depletion of fossil fuels, and particularly the photovoltaic research is constantly underway. Photovoltaic power system is mainly to be used in grid-connected system. Photovoltaic power system consists of the grid-connected inverter and the boost converter to earn a high output voltage from the low output voltage of solar power system [1].

The conventional two-level solar inverter is to implement as it has a simple structure and the already proven control and PWM technique. However, it also has the disadvantage to contain higher harmonics in the inverter output voltage and it has the high reverse recovery losses of diodes and increases the overall power efficiency. However, the three-level solar inverter requires somewhat more complex PWM technique than the two-level solar inverter, but it has the benefit to reduce harmonic content. In addition, it has the disadvantages to require a mid-point of the DC link and the controller to control the mid-point voltage separately [2-4].

The boost converter is ideally to infinite voltage gain but has the limit to raise the voltage by more than 5-6 times in practice due to the equivalent series resistance of the inductor. This paper is to implement the PWM method and the controller of three-level boost converter which has the higher voltage advantage than the conventional 2-level boost converter. In order to verify the proposed three level boost converter, this paper is devoted through the resistance load variation experiment and the grid-connected experiment.

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2 Proposed Three Level Boost Converter

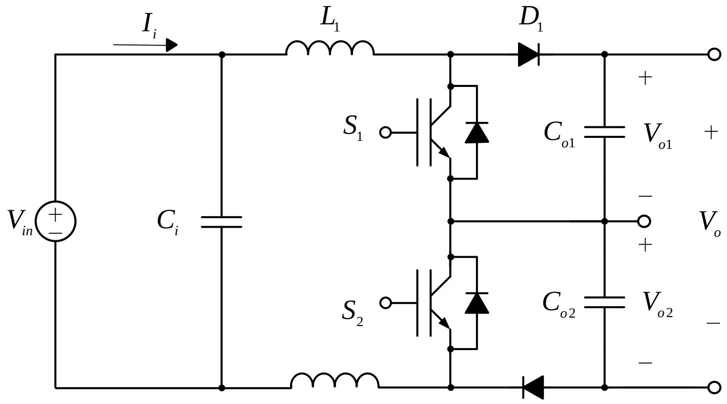


Fig. 1. Schematic of three level boost converter

Fig. 1 shows the circuit diagram of a three level boost converter proposed in this paper. The development trend of photovoltaic PCS is valuing the increase of the capacity and high performance and efficacy. Comparing the proposed three-level boost converter with the conventional two-level converter, three-level converter has the advantages that the voltage gain is increased doubled, and the voltage across the switching element and a diode is to be halved. Also, it has the advantage to equivalently maintain the output voltages of V_{o1} and V_{o2} by controlling the mid-point and to realize the multi-level inverter.

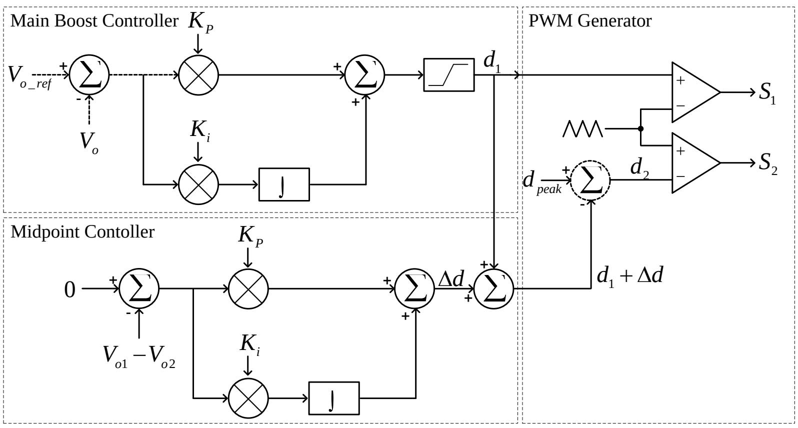
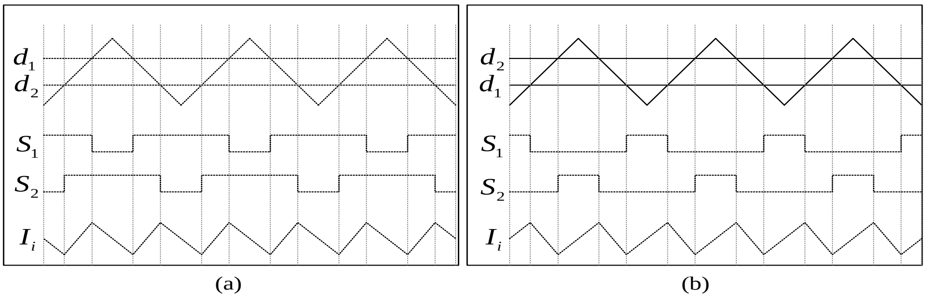


Fig. 2. Block diagram of the purposed boost converter controller

Fig. 2 shows the controller of boost converter proposed in this paper. Boost converter has two controllers and one PWM generator. The main boost controller controls the output voltage V_o by using PI controller which is widely used in the automation system. Usually the voltage unbalances between V_{o1} and V_{o2} can occur. To reduce this voltage unbalance, the difference between two voltages is to be controlled to 0 through PI controller. Finally, PWM is generated by using d_1 and d_2 generated from the controller. Fig. 3 shows the major waveforms for three-level boost converter proposed in this paper.



(a) $0.5 \le d_1 \le 1$ or $V_i < \frac{V_o}{2}$, (b) $0 \le d_1 < 0.5$ or $V_i \ge \frac{V_o}{2}$

Fig. 3. Key waveform of the proposed three level boost converter

3 Experimental Results and Discussions

3.1 Resistance load variation experiment result

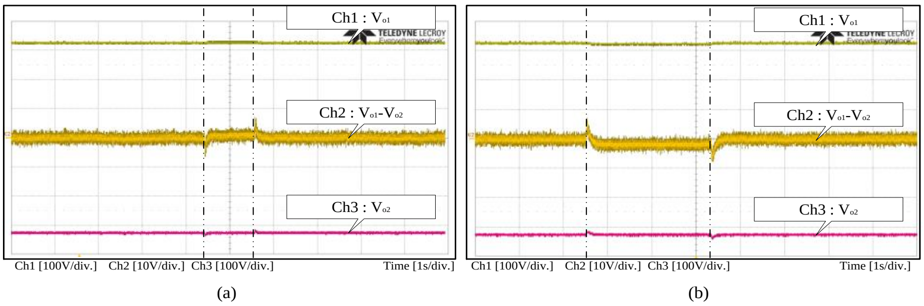


Fig. 4. Waveform of resistance load variation experiment

Fig. 4 shows the boost converting from 320 V to 650 V by using the boost converter proposed in this paper. And the output voltage of V_{o1} and V_{o2} was connected to 250Ω load resistor. (A) Waveform is the one to be observed its output voltage by changing the V_{o1} resistor load to 166Ω load resistor. (B) Waveform is the one to be observed its output voltage by changing the V_{o2} resistor load to 166Ω. All of these two waveforms can be observed swaying mid-point in the initial stage. However, it was verified that the original voltage resumed to the normal voltage within 100ms.

3.2 Grid-connected experiment result

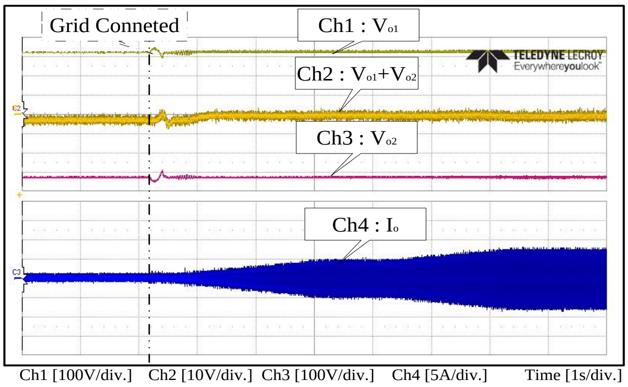


Fig. 5. Waveform of grid-connected experiment

The waveform of Fig. 5 is the observed result of the boost converter output voltage when it is connected with the grid. As experimental result of the output current of the inverter system up to 5A, at the time that the relay is turned on it was observed a little bit shaky. However, it was verified to return to the normal voltage range within 500ms.

4 Conclusion

This paper proposes three-level boost converter for high-efficiency solar inverter. The proposed boost converter was set to control the algorithm by one triangular wave, which was controlled by two conventional triangular waves. The boost converter proposed in this paper could be verified through the resistive load experiment and the grid-connection experiment. Experimental results show the high performance for a 4kW resistive load and grid-connected power condition system.

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