

A Novel Photovoltaic Off-grid Inverter Based on Boost Converter

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Abstract. Isolated DC/DC converters have the disadvantage of inefficiency, instability, magnetic bias and shoot-through problems, etc. They also influence the other electrical devices severely in the same power network. Therefore, a novel photovoltaic off-grid inverter based on the boost converter is designed in this paper. The following works have been done in the study: to design the circuit of the photovoltaic off-grid inverter, to design the parameters of the photovoltaic off-grid inverter, to simulate. The research of this paper has laid a theoretical foundation for the photovoltaic off-grid inverter in industrial applications.

Introduction

Solar energy is characterized by clean, non-polluting and renewable energy. It is one of the energy with scale popularization value [1]. Photovoltaic power system is one of the forms of solar energy utilization. With the development of the photovoltaic power system, the photovoltaic inverter has become a hot research issue [2] [3].

At present, isolated DC/DC converters are widely used in the design of the photovoltaic inverter, such as full-bridge circuit, half-bridge circuit, push-pull circuit and so on. The full-bridge circuit and half-bridge circuit have the disadvantage of shoot-through problems and a complicated driving circuit. The push-pull circuit has the disadvantage of magnetic bias. It may lead to the instability of the system.

The boost circuit is characterized by efficiency, reliability and a simple structure. The design of the inductor of the boost circuit is relatively easy [4] [5]. The input current is continuous. The electromagnetic interference of the power system is reduced. The driving circuit is not complicated.

Therefore, aiming at the above-mentioned questions, a photovoltaic off-grid inverter based on the boost converter is designed in this paper. The following works have been done in the study: to design the circuit of the photovoltaic off-grid inverter, to design the parameters of the photovoltaic off-grid inverter, to simulate.

Circuit of Photovoltaic Off-grid Inverter

The voltage is converted from 37V DC to AC 50Hz/220V by the off-grid inverter. According to the requirement of the converting voltage, a circuit of the photovoltaic off-grid inverter is designed. The circuit of the photovoltaic off-grid inverter is shown in Fig.1.

The photovoltaic off-grid inverter consists of PV module, boost circuit, full-bridge inverter, filter and controller. The controller is realized by PI algorithm and the PWM module. The working process is as follows:

- 1) 37V DC generated by the PV module is boosted to 400V DC by the boost circuit.
- 2) 400V DC is inverted into AC 50Hz/220V by the full-bridge inverter.
- 3) The harmonic is filtered out by the filter.

PI algorithm is used in the closed-loop control. Trigger signals of the full-bridge inverter are provided by the PWM module.

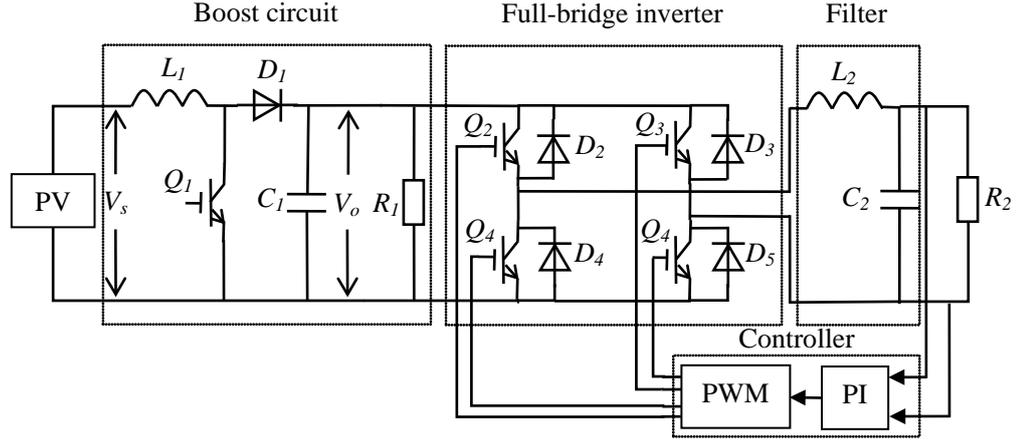


Fig.1. Circuit of the photovoltaic off-grid inverter

In the boost circuit, the inductance L_1 can store energy and limit the ripple current. The capacitance C_1 can decrease the output voltage ripple. In the filter, the inductance L_2 and the capacitance C_2 can filter harmonics. It is a kind of the band-pass filter. Therefore, the design of L_1 , C_1 , L_2 and C_2 is very important for the photovoltaic off-grid inverter.

Parameters Design of Photovoltaic Off-grid Inverter

Selecting the inductance L_1 . In the continuous conduction mode, the duty cycle D , the input voltage V_s and the output voltage V_o must be satisfied the following formula:

$$D = 1 - \frac{V_s}{V_o} \quad (1)$$

V_o , D , the critical load current I_{OB} , the theoretical inductance L_1' and the switching frequency f_s must be satisfied the following formula:

$$I_{OB} = \frac{V_o}{2L_1' f_s} D(1-D)^2 \quad (2)$$

V_o , D , the minimum load current I_{Omin} , L_1' and f_s must be satisfied the following formula:

$$I_{Omin} > \frac{V_o}{2L_1' f_s} D(1-D)^2 \quad (3)$$

The theoretical inductance L_1' can be calculated by Eq.1 and Eq.3.

Selecting the capacitance C_1 . D , f_s , the resistance R_1 , the theoretical capacitance C_1' and the output voltage ripple $\Delta V_o/V_o$ must be satisfied the following formula:

$$\frac{\Delta V_o}{V_o} = D \cdot \frac{f_c}{f_s} = D \cdot \frac{1}{f_s} \cdot \frac{1}{R_1 C_1'} \quad (4)$$

The theoretical capacitance C_1' can be calculated by Eq.4. In a practical application, a larger capacitance is needed to decrease the output voltage ripple.

Selecting the inductance L_2 and the capacitance C_2 . The output voltage frequency f , the inductance L_2 and the capacitance C_2 must be satisfied the following formula:

$$f = \frac{1}{2\pi\sqrt{L_2 C_2}} \quad (5)$$

The inductance L_2 and the capacitance C_2 can be calculated by Eq.5.

Simulation of Photovoltaic Off-grid Inverter

According to the circuit of the photovoltaic off-grid inverter, the model of the system is set up. The simulation model of a photovoltaic off-grid inverter is shown in Fig.2.

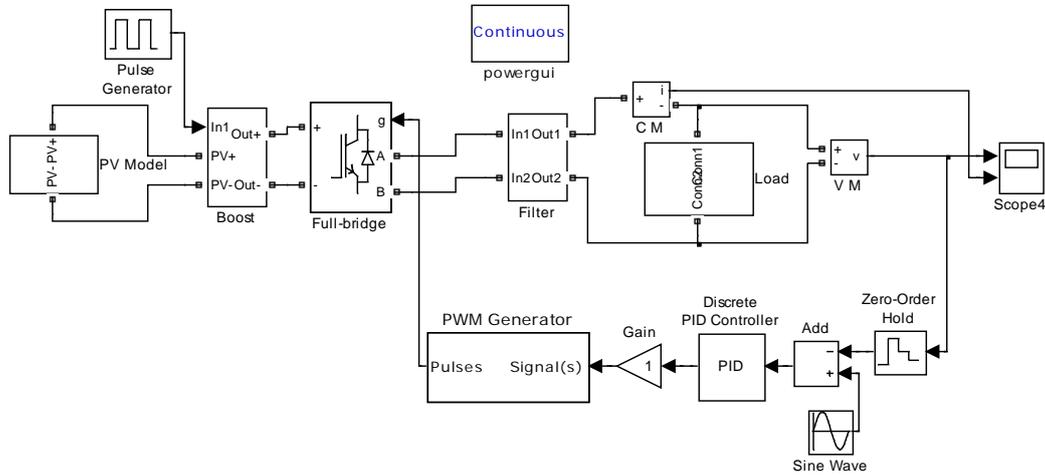
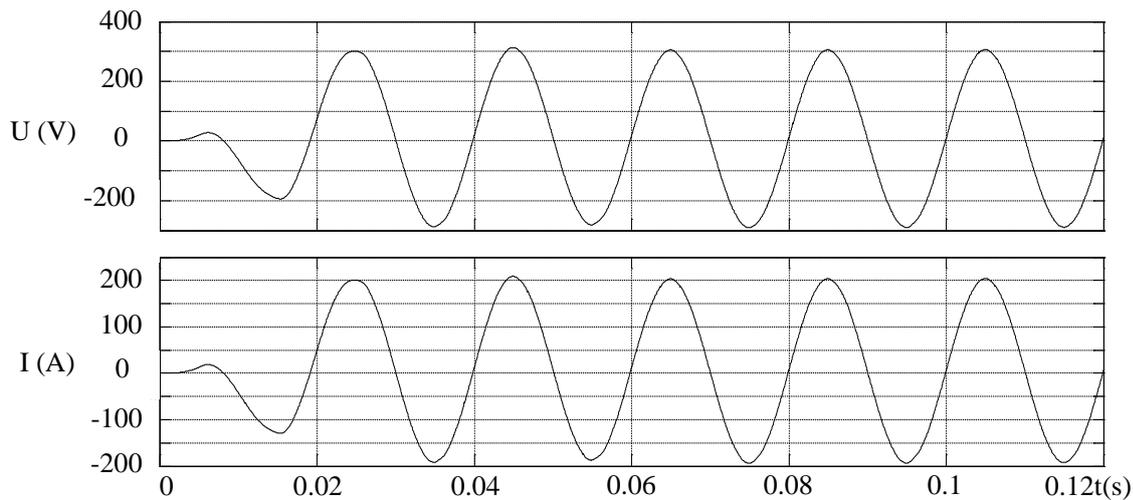


Fig.2. Simulation model of a photovoltaic off-grid inverter

Simulation parameters are shown in Table 1.

Table 1. Simulation parameters

| | | | |
|---|---------|-------------------------------|----------|
| Input voltage V_S (V) | 37 | Duty cycle D | 0.91 |
| Output voltage V_O (V) | 400 | Inductance L_1 (mH) | 0.1 |
| Switching frequency f_s (Hz) | 15k | Capacitance C_1 (mF) | 5 |
| The minimum load current I_{Omin} (A) | 1 | Resistance R_1 (Ω) | 2 |
| Resistance R_1 (Ω) | 2 | Inductance L_2 (mH) | 1.5 |
| Output voltage ripple $\Delta V_O/V_O$ | 1% | Capacitance C_2 (μ F) | 6761.6 |
| Theoretical inductance L_1' (mH) | 0.09828 | Resistance R_2 (Ω) | 1.5 |
| Theoretical capacitance C_1' (mF) | 3.03 | K_p | 0.175643 |
| Systemic simulation time (s) | 0.12 | K_i | 612.5 |



Simulation curves of the output voltage and current are shown in Fig. 3.

Fig.3. Simulation curves of the output voltage and current

In Fig.3, curves of the output voltage and current are sine wave. The frequency is 50Hz. The amplitude of the output voltage reaches expectations in the third cycle, and it keeps invariant. The phases of the voltage and the current are consistent. Therefore, the simulation model and parameters designing meet the design requirement of the photovoltaic inverter.

Conclusions

Nowadays, isolated DC/DC converters are widely used in the design of the photovoltaic inverter. It has the disadvantage of inefficiency, instability, magnetic bias and shoot-through problems, etc. Therefore, a photovoltaic off-grid inverter based on the boost converter is designed in this paper.

The following works have been done in the study: to design the circuit of the photovoltaic off-grid inverter, to design the parameters of the photovoltaic off-grid inverter, to simulate. Simulation results show that the amplitude of the output voltage reaches expectations quickly, and it keeps invariant. The research of this paper has laid a theoretical foundation for the photovoltaic off-grid inverter in industrial applications.

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