Design of High Efficiency Single-Phase Bridge Passive Inverter Based on SG3525

Zhen Zhu¹, Renda Wang¹*, Yong Yin¹, Shengwei Xing¹
¹Navigation College, Dalian Maritime University, Dalian, Liaoning Province, 116026, China
*Corresponding author’s e-mail: radar@dlmu.edu.cn

Abstract. In this work, a method for simultaneously improving the conversion efficiency and power quality of marine distributed generation was proposed. Aiming at the insufficient correction of output waveform based on inverter technology, a model of improved inverter conversion system was built. For the limitation of external power grid pollution treatment, the self-regulation ability of the output voltage waveform was improved by adding high-performance real-time feedback technology and PI regulation. The test results showed that the proposed method had the advantages of stable output, high precision, good power quality, and superior to the traditional method of indiscriminate feedback regulation in terms of power conversion efficiency.

1. Introduction
The ocean energy contained in seawater is enormous, and its theoretical reservation is hundreds or even thousands of times of the total annual energy consumption in the world. In recent years, the efficient conversion technology of new energy has received more attention, and the proportion of new clean-energy from seawater in the national energy strategy was also gradually increased. At present, how to improve the conversion efficiency while ensuring the output stability is a difficult point in the applications of new energy conversion technology.

In this research direction, reducing the distortion of the waveform is a point that must be considered. The conventional method of the researcher is to ignore the internal and external interference and the interaction between components in the operation of the system by controlling the integrity of the waveform at the input. Its advantages are simple structure, easy maintenance and low cost, but at the same time there is a shortage of power quality and power conversion efficiency that is easy to change with external influences. In order to solve the above problems, the control module of the main circuit will be optimized through adding PI regulation and phase-locked circuit as well as precision rectification real-time feedback technology to enhance the system conversion performance.

2. Establishment of theoretical model of inverter system
2.1. Principle and application of inverter circuit
The SPWM pulse sequence diagram was shown in Figure 1. The width of circuit waveform of voltage source sine wave \( u_\theta = U_{01}\sin\omega t \) inverter varies according to the pulse width of the corresponding position of the sine wave, so the waveform of this width modulation is called SPWM (sinusoidal pulse width modulation) waveform \(^{(1)}\). Its advantage is that the system loss is small, so higher power factor can be obtained. By increasing pulse frequency, high-order harmonics can be easily filtered out, and the
The appearance of low-order harmonics can also be well suppressed, thereby reducing the distortion of the system sine wave.

Figure 1. Sine wave pulse width modulation

The generated SPWM wave is applied to the control circuit and the driving circuit, so that the purpose of controlling the turning on and turning off of the MOS transistor can be realized, and the conditions required for the single-phase inverter can be achieved [10]. The SPWM sampling value can be obtained by the equal area method. The advantage of such method is that the dynamic response of the system is relatively stable and not susceptible to external interference.

2.2. The working principle of the MOSFET

MOSFET is widely used in electric power conversion process. The driving circuit controls the on-time and off-time of the MOSFET, thereby controlling the output voltage waveform [4]. As shown in Figure 3, the main circuit is a single-phase bridge inverter circuit which is suitable for high current, large voltage and high-power output circuits. The circuit consists of a MOSFET switch with IRF640 as the core and a Butterworth filter circuit [8]. By adding drain protection to the MOS transistor, the normal turn-on and turn-off function of the MOS transistor is ensured, it can also be prevented from being broken down [2].
2.3. Principle characteristics of the main chip circuit

2.3.1. SG3525 circuit principle analysis
The selected SG3525 is a full-featured and versatile monolithic integrated PWM control chip with excellent performance. It is simple, reliable and easy to use, and can increase the driving ability of the system through the output-driven push-pull form. The single-phase inverter circuit controlled by SG3525 chip has good flexibility [3].

Figure 4. SG3525 structure block diagram [4]

The SG3525 has many advantages: it can be added to the internal circuit to greatly reduce the interference, which improves the relative stability and accuracy of the system and achieves the mutual balance of the electrical components. With a soft start function [5], the reference voltage UURF is powered by the corresponding constant current source.

2.3.2. IR2110 circuit principle analysis
In designing the model of this circuit, in order to ensure the stability of the relevant system, the IR2110 driver chip is used as the core of the driver circuit. The chip reduces the number of drive components by using two-channel, gate-driven, high-integration level shifting techniques and the use of an external bootstrap capacitor power-up mode in the upper tube [6].

3. System parameter selection and calculation

3.1. General block diagram of single-phase inverter power system

Figure 5. General block diagram of single-phase inverter power system

This experiment simulates the 50V DC voltage generated by the new energy source to be converted into a sine wave AC output with a standard frequency of 50Hz and an amplitude of 24v. The main contents of this design are as follows:

3.2. MOS tube selection calculation
The input is DC/50V and the output is AC/24V/2A.
\[ P_0 = \eta \times P_i \Rightarrow P_i = \frac{48}{0.9} = 53.33W \]
\[ P_i = U_i \times I_i \Rightarrow I_i = \frac{53.33}{50} = 1.067A \]

Among:
- \( P_0 \): MOS tube output power;
- \( \eta \): Conversion efficiency (90%-95%);
- \( P_i \): MOS tube input power.

In summary: IRF 640 is selected as the MOS transistor in the main circuit to realize the turn-on and turn-off function.

### 3.3. Output Filter Circuit Design

Its transfer function is the Butterworth function, which approaches the relatively ideal filtered rectangular model in the form of the highest order Taylor series \([9]\). The Butterworth filter uses the normalized design data of the Butterworth filter. Filter cutoff frequency \( \omega = 2\pi f = 1 \). That is \( f = \frac{1}{(2\pi)} \), when the cutoff frequency is used, the normalized low-pass filter design data is used as a reference filter, and its cutoff frequency and characteristic impedance load are changed to corresponding parameters to be designed\([4]\).

Since there are other circuits affecting the filter circuit, the loss of the LC component in real life will reduce the filtering performance, and the cutoff frequency is selected as follows:

\[ f_0 = 0.1 \times f_c = 2kHz < (2N - 3) \times f_c = 39850Hz \]  
(1)

Then the rated load can be found as:

\[ R_L = \frac{U^2}{P_f} = \frac{24^2}{(24 \times 2)} = 12\ \Omega \]  
(2)

\[ P_f = \frac{2000}{1/2\pi} = 12566, \ K = \frac{12}{1} = 12 \]  
(3)

\[ L = \frac{1.41421}{12566} \times 12 = 0.00135 = 1.35mH \]  
(4)

\[ C = \frac{1.41421}{12566 \times 12} = 9.38\mu F \]  
(5)

### 4. Simulation Verification

#### 4.1. Main Circuit Simulation

The open circuit simulation of the design circuit is carried out using the Simulink module in MATLAB. The simulation diagram is as follows:
4.2. Correlated waveform output

![Figure 7. The output voltage of the oscilloscope shows](image1)

Obtained by the oscilloscope, the system inputs 50V DC voltage, and the output is about 24.1V/50Hz AC voltage, and the conversion efficiency is about 83.4%.

![Figure 8. Feedback loop related voltage oscilloscope display](image2)

![Figure 9. Drive circuit voltage oscilloscope display](image3)

### Table 1. Comparison of data between two experimental results

| Input voltage (V) | Output current (A) | f (Hz) | Output voltage (V) | Conversion efficiency (η) | Waveform category |
|-------------------|--------------------|--------|-------------------|--------------------------|------------------|
| M1                | 50                 | 2±0.5  | 50±6              | 34.91                    | 69.81% Concussion |
| M2                | 50                 | 2±0.1  | 50±1              | 41.57                    | 83.14% stable     |

The conversion efficiency was improved by 13% compared with the conventional inverter method (M1)\(^7\). In addition, the output waveform is more stable and the distortion is lower. Therefore, the method (M2) provided in this paper well solved the fusion problem of the improvement of conversion efficiency and the reduction of distortion, and has advantages in constant voltage and constant frequency.

5. Conclusion

In this paper, by constructing an experiment inverter model and selecting the appropriate control, drive, input, and main circuit modules as well as introducing a series of real-time feedback techniques to select and calculate the corresponding experimental parameters, a simulation module was finally proposed to build a more stable experimental waveform with constant voltage and frequency. The power conversion efficiency calculated based on our built model was improved by 10% compared with the conventional method. Therefore, by studying the energy efficiency of inverter technology and the distortion of output waveform, this paper provides a good reference for more in-depth study of the stability of distributed power grid and the reduction of power pollution.

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