Simulation analysis of power electronic converter based on PWM

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ABSTRACT

With the development of power electronics technology, converters are increasingly widely used in industry and daily life. Pulse Width Modulation (PWM) technology, due to its high efficiency and flexibility, occupies an important position in the control of converters. This paper explores the application of PWM in converters through simulation research, analyzes the impact of PWM control strategies on the performance of converters, and provides beneficial references and insights for further research and experiments.

Keywords: Converters, pulse width modulation, simulation

1. INTRODUCTION

Power electronics technology, as an important branch of modern electrical engineering, directly affects the performance and efficiency of power systems. As a core component of power electronics technology, converters mainly achieve efficient conversion and precise control of electrical energy and are widely used in fields such as industrial automation, new energy power generation, electric vehicles, and home appliances[1-3]. With the continuous improvement of energy efficiency and system performance requirements, the research and optimization of converter performance have become particularly critical. Pulse Width Modulation (PWM) technology, as an efficient and flexible control method, has been widely used in the control of converters. PWM technology can precisely control the output voltage or current by adjusting the duty cycle of the pulse signal, thereby regulating the power of the load. Compared with traditional analog control methods, PWM technology has the advantages of high control precision, fast response speed, and easy digital implementation. However, the choice and design of PWM control strategies directly affect the performance of converters. Different PWM control strategies may lead to different output waveform quality, system efficiency, and thermal loss. Therefore, in-depth research on PWM control strategies and their analysis and optimization in conjunction with simulation technology are of great significance for improving the performance of converters[4]. This paper will explore the application of PWM technology in converters through simulation research and analyze the impact of different PWM control strategies on the performance of converters. Firstly, this paper will introduce the basic principles and control methods of PWM technology; secondly, a simulation model of the converter will be established, and the corresponding parameters will be set; then, different PWM control strategies will be simulated and their impact on the performance of the converter will be analyzed; finally, optimization methods will be proposed, and future research directions will be discussed[5-8]. Through the study of converter PWM simulation, it can not only provide theoretical basis and technical support for the design and control of converters but also contribute to the further development of power electronics technology. With the rapid development of new energy technology and the intelligent upgrading of power systems, in-depth research and optimization of PWM technology in the application of converters will help promote the progress of the entire power electronics industry[9,10].

1.1 Overview of PWM technology

Pulse width modulation is a method of controlling the average output signal by changing the pulse width. In PWM control, the output signal is a periodic square wave, and its duty cycle can be adjusted according to the control requirements. PWM control methods mainly include uni-polar PWM and bipolar PWM. The output signal of uni-polar PWM has the same polarity in the positive and negative half cycles, while bipolar PWM has opposite polarity in the positive and negative half cycles. The application of PWM technology in converters mainly includes DC-DC converters, DC-AC inverters, and AC-DC rectifiers. Through PWM control, precise control of the output voltage and current of the inverter can be achieved. PWM (Pulse Width Modulation) technology is an electronic control method widely used in fields such as motor control, power management, and LED brightness adjustment. The basic principle is to equivalently

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International Conference on Optics, Electronics, and Communication Engineering (OECE 2024),
edited by Yang Yue, Proc. of SPIE Vol. 13395, 1339526 · 0277-786X · doi: 10.1117/12.3049811

adjust the output of the analog signal by changing the duty cycle of the pulse signal (i.e. the proportion of high-level time to the entire cycle time). In PWM control, the frequency of the signal is usually kept constant, while the width of the pulse (i.e. high-level time) is adjusted according to the control requirements. In terms of control methods, PWM technology is usually achieved through digital circuits or microprocessors. Digital circuits can generate PWM signals through components such as counters, cooperators, and logic gate circuits, while microprocessors can use their internal timers or PWM controller modules to directly output PWM wave-forms. During the control process, the duty cycle of the PWM signal can be changed through software or hardware programming to achieve precise control of the analog signal output level. For example, in motor control, PWM technology can control the speed and torque of the motor by adjusting its average voltage. When the duty cycle of the PWM signal increases, the average voltage received by the motor also increases, leading to an increase in motor speed or torque. On the contrary, when the duty cycle decreases, the average voltage received by the motor decreases, and the motor speed or torque correspondingly decreases. This control method has the advantages of fast response speed, high control accuracy, and low energy consumption, so it has been widely used in many modern electronic systems.

2. PWM CONTROL SIMULATION ANALYSIS

2.1 PWM signal simulation

At the beginning of the simulation, we set the sampling frequency fs to 2MHz and generated a random signal x with a length of 8 to simulate the original data. as shown in Figure 1. However, since the standard PWM signal modulates the signal by changing the pulse width, and here we did not directly implement the duty cycle modulation of PWM. Instead, we adopted the method of simulating pulses, that is, by manually assigning values at specific positions in the wave_into array to simulate the PWM waveform. Although this method is not entirely equivalent to standard PWM modulation, it is sufficient to demonstrate some basic characteristics of PWM signals.

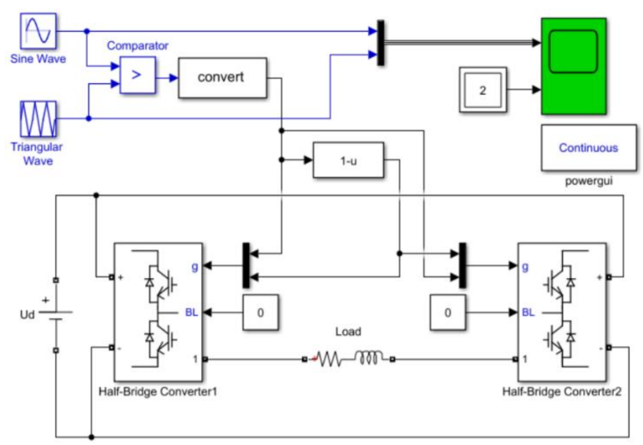

Figure 1. Simulation model.

2.1 Interpolation and shaping

Next, we performed interpolation processing on the simulated PWM signal to increase the sampling rate of the signal. By setting Ample to 2, we achieved twice the interpolation of the original signal. The interpolated signal wave_pint not only maintains the characteristics of the original signal but also provides higher time resolution, which is helpful for subsequent signal processing and analysis.

2.2 Filtering process

In order to remove high-frequency noise and unnecessary components in the signal, we used a raised cosine filter for filtering the interpolated signal. By setting the roll-off factor to 0.9 and the delay to 8, we obtained a filter with good frequency response characteristics. The filtered signal wave_LPF not only retains the effective information in the original signal but also reduces out-of-band radiation and improves signal quality, as shown in Figure 2.

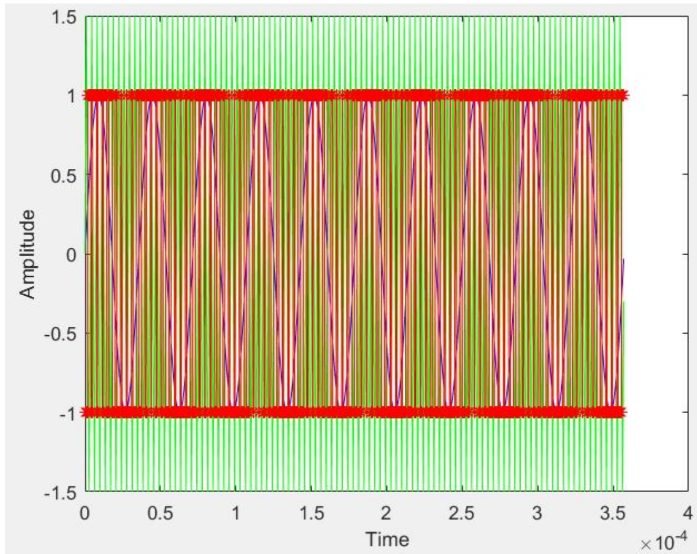

Figure 2. Time-domain Graph

2.3 Spectral analysis

To analyze the frequency characteristics of the filtered signal, we performed FFT transformation on wave_LPF and calculated its power spectrum. By plotting the power spectrum graph, as shown in Figure 3. We can clearly see the energy distribution of the signal at different frequencies. In addition, we also plotted the waveform diagrams of the original signal, the interpolated signal, and the filtered signal, as shown in Figure 4, and the normalized frequency domain diagram is plotted, as shown in Figure 5 for comparison.

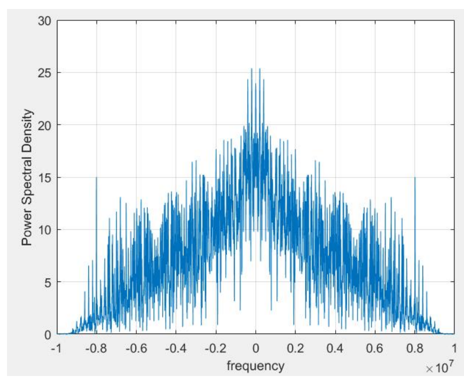

Figure 3. Power spectrum graph

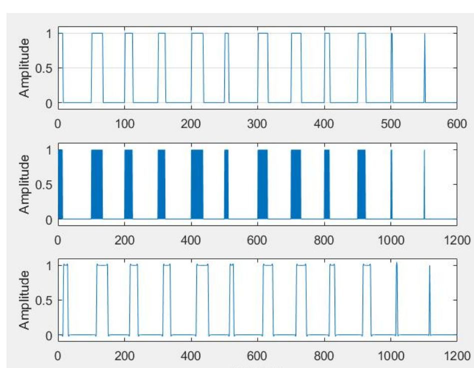

Figure 4. Waveform diagram

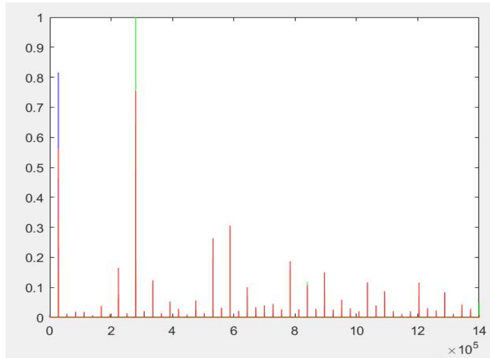

Figure 5. Normalized frequency domain

2.4 Simulation results analysis

From the simulation results, it can be seen that after the simulated PWM signal is interpolated and filtered, its waveform becomes smoother, and high-frequency noise is effectively suppressed. In the spectral analysis graph, we can see that the filtered signal has a higher energy distribution in the low-frequency band and decays rapidly in the high-frequency band. This indicates that the raised cosine filter effectively removes high-frequency noise and out-of-band radiation from the signal.Furthermore, by comparing the waveform diagrams of the original signal, the interpolated signal, and the filtered signal, we can find that the interpolation process improves the sampling rate of the signal, making it more continuous in the time domain; while the filtering process further improves the quality of the signal, making it more concentrated and pure in the frequency domain.

3. CONCLUSION

This simulation used MATLAB to simulate the generation, interpolation, filtering, and spectral analysis of PWM signals. By comparing and analyzing the waveform and spectral characteristics of the signals at different stages, we have gained an in-depth understanding of the basic characteristics of PWM signals and their application in communication systems. At the same time, this simulation also provides beneficial references and insights for subsequent research and experiments.

FUNDING

The paper is supported by the Special Project for Technological Innovation and Entrepreneurship of Tiandi Technology Co., Ltd., with the project number 2023-ID-ZD003-008, and the project name being "Development of Intelligent Power Supply System for Ultra-long Working Faces.

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