IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 6 Ver. II (Nov. - Dec. 2015), PP 87-90
www.iosrjournals.org

Research on High Frequency PI Section Control of Electrochemical DC Power Supply

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Abstract: *The relatively stable voltage output DC power supply is often required in electrolytic plating electrochemical reactions. Based on the analysis of several circuit structures, full-bridge configuration electromagnetic isolation has advantages in efficiency and pressure range. The entire system using voltage feedback loop PI control method of segmentation and the pressure range is divided into multiple parts separately controlled. Finally, MATLAB simulation comparison, it was verified that this control method can not only improve the voltage regulator circuit output voltage range and can reduce the amount of ripple output voltage waveform.*

Keywords: *Full-bridge converter circuit, DC power supply, High-frequency PWM; Section PI control*

I. Introduction

In electrochemical industry and experiments, the concentration of the solution are changing frequently which leads to constant changes of the solution conductivity [1]. The traditional DC-DC converter has the ability to achieve the DC voltage regulator, while simply by adjusting the duty ratios to change the output voltage of power supply, not only the pressure regulating range is very limited.According to the characteristics of electroplating chemical reaction, the full bridge isolated electromagnetic DC-DC converter circuit and high frequency Bi - Directional PWM control strategy is used to further reduce the pulse of output waveform.

1. Multilevel buck-boost converter circuit

In order to reduce the pulsation of the output voltage and lower voltage device bearing, multilevel circuit has been applied in some situations that the ripple of output voltage are relatively high demanded[3]. The multilevel buck chopper circuit structure diagram is given in Figure 1.In real work, the switches VT1 and VT2 will be on alternately. When the control signal duty ratio is larger than 0.5, the turn-on sequence of each device is shown in table 1.

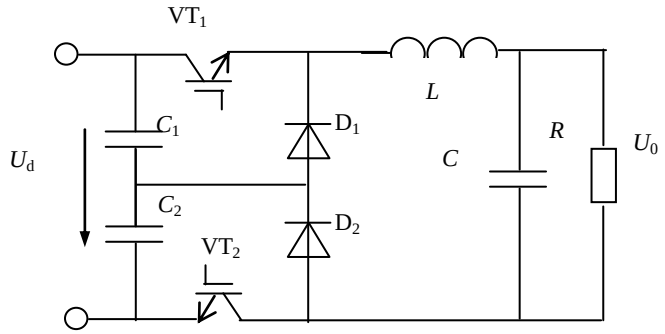

Fig.1. Three-level buck chopper circuit structure

Table 1.switching states for duty cycle more than 0.5

	VT1	VT2	D1	D2	inductance current value
Stage 1	on	on			increase
Stage 2	on			on	decrease
Stage 3	on	on			increase
Stage 4		on	on		decrease

When the inductance current is continuous, the output voltage value of circuit, which changes alternately two times each cycle, is U_d or $U_d/2$, and the circuit works as a two-level converter. While if the inductance current is interrupted, the output voltage will change among U_d, $U_d/2$ or 0 and the circuit works as a

three-level converter. Table 2 shows the turn-on sequence of each device on the situation that duty ratio is less than 0.5.

Table 2.switching states for duty cycle less than 0.5

	VT1	VT2	D1	D2	inductance current value
Stage 1	on			on	increase
Stage 2			on	on	decrease
Stage 3		on	on		increase
Stage 4			on	on	decrease

Now the circuit works in two-level mode. Comparing to the traditional Buck chopper circuit, the output is relatively stable. And the voltage switch withstanding is half of the supply voltage when the switch is in the state of off. But the voltage range of the circuit is still not ideal and the switching frequency is not big enough.

II. High Frequency PWM Control Strategy

Normally, PWM control technology is applied in inverter circuit. Modulating the width of pulse can change the value of output voltage. For the electromagnetic isolated full bridge DC converter circuit with an isolated transformer, it is feasible to change the transformer ratio to have a large range of pressure in the circumstance of having a large voltage range changing. By adjusting the ratio can achieve the circuit's functions of boosting and bucking .The circuit output voltage regulation principle block diagram is illustrated in figure 2.

In the PWM control, the high frequency bipolar triangle wave is used as carrier signal. In order to reduce the output ripple and improve the frequency of the carrier signal, the switching frequency can be improved, and then the efficiency of electromagnetic isolation transformer energy can be improved greatly. At the same time, using MOSFET with high switch frequency can further achieve high frequency. But it shouldn't always go for the higher frequency.

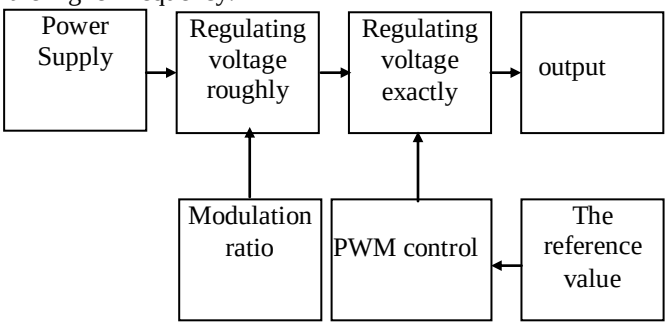

Fig.2 Voltage regulating principle diagram

III. Control Strategy

3.1 PI Section Control

PI control can be applied in linear systems. And if the non-linear control system is treated as linear system, then PI control can also acquire ideal control effect. Section PI control method is used to divide the range of voltage regulation into several sections.Schematic diagram as shown in figure 3 below.

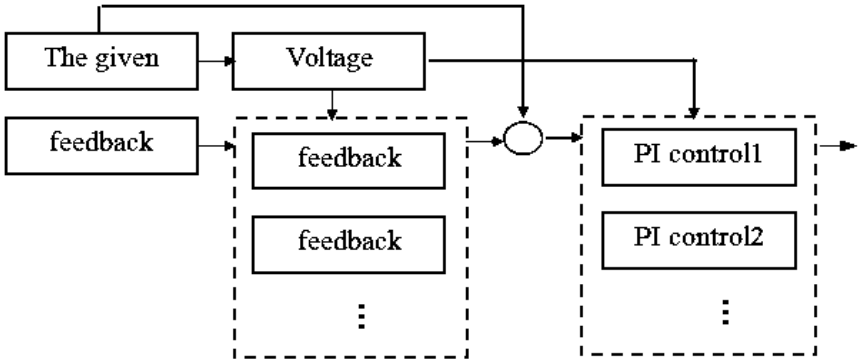

Fig.3 The section control principle diagram.

Firstly, divide the range of regulating voltage into several interval regions. Then compare the feedback voltage and the given voltage to get the difference. Finally, get the final control signal and set diffent proportional values and integral values in different sections.

3.2 DC voltage regulating system

The DC voltage regulating system consists of a DC power supply, electromagnetic isolated full bridge converter circuit, filter circuit, PWM signal generator, multilevel control device and other parts. The concrete structure diagram as shown in figure 4.

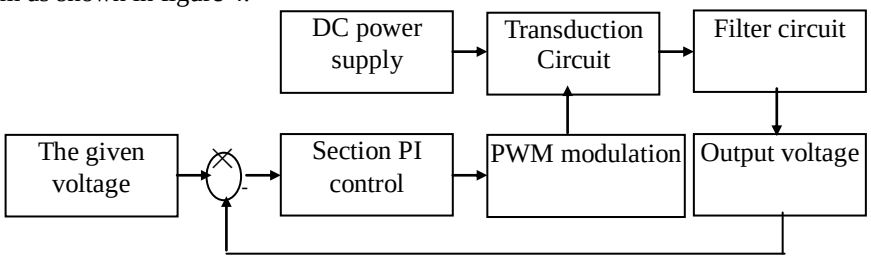

Fig.4. DC voltage regulating system principle diagram.

The given voltage value is determined according to the need of load settings. Comparing the output voltage to the given voltage, we can obtain the error sent back to the voltage regulator to have section PI control. And then making a comparison between regulating signal and PWM carrier signal to, so that the duty cycle signal, which controls the states of devices, can be determined. There is a filter circuit using an inductor and capacitor to filter the output voltage at the terminal of the main circuit. Thus a stable output waveform is achieved. Although it is voltage feedback single-loop control, in the theory the good results of the regulator can be achieved and the output voltage is stable.

IV. Analysis Of Simulation Results Analysis

In the section PI control, the given voltage changes from 86V to 76V, the output voltage waveform of the circuit as shown in Figure 5. And Figure 6 shows the result of the given voltage changed from 15V to 10V.

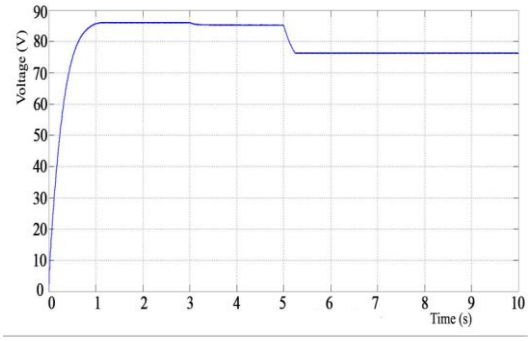

Fig.5 the output voltage waveform: given voltage is from 86V to 76V

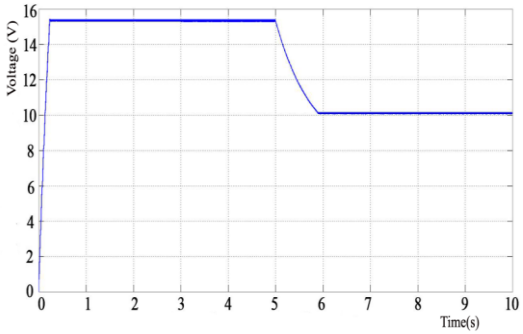

Fig.6 the output voltage waveform: given voltage is from 15V to 10V

From the waveform can be seen, the electromagnetic isolation bridge DC converter circuit which use multilevel PI control can be within the error range of 86V to 10V, voltage output waveform is very stable, almost no pulse, the ability to resist disturbance is very strong, response speed is very fast. Figure 7 shows the output waveform with the traditional PI control, when the given voltage is 30V ,25V. Figure 8 shows the output voltage waveform with the carrier frequency down to 50Hz when the given voltage is from 86V to 76V.

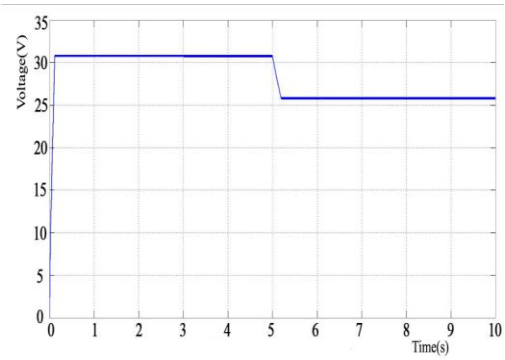

Fig.7 the output voltage of the traditional PI control

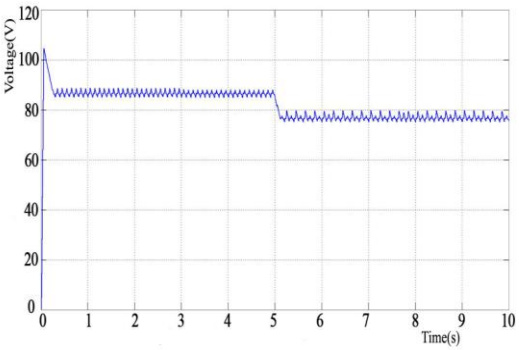

Fig.8 the output voltage when the Carrier frequency down to 50Hz

From Figure 10 it can be seen that the output voltage is also relatively small in the case of no PI control. However, when the given voltage is 30V, the output voltage has reached the threshold value. When the given voltage is less than 30V, the error will be more than 2%.So without the multilevel PI control, the range of voltage will decrease from 86V to 30V. As can be seen from Figure 11, when the carrier frequency is reduced, the fluctuation of the output voltage will significantly increase. So the high frequency PWM control is important for the stability of the output voltage.

V. Conclusion

In this paper, the electrochemical DC power supply circuit and DC converter circuits are studied in detail. It is appropriate to use the electromagnetic isolation type of full bridge converter as the electrochemical DC voltage regulation circuit. In the control of the circuit, a high frequency bipolar PWM signal is proposed and the voltage feedback loop structure is used in control system. Meanwhile,nultilevel PI control method is adopted to improve the output voltage of the circuit and reduce the output fluctuation. Finally, by the establishment of MATLAB simulation model, the characteristics of this method are compared with the traditional PI control and the low frequency PWM control. The advantages of the range of voltage regulation are verified.

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