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Experimental Study Of Medium Frequency Power Supply Based On Multi-loop Feedback Control And Repetitive Control

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Abstract: The integral structure and mathematical model of the medium frequency power supply are introduced. The strategy of multi-loop feedback control and repetitive control strategy are analyzed, and the two control strategies are applied to the control strategy of the medium frequency power supply. Based on these two kinds of control, a power supply prototype of DSP is built, the control performance of the system is tested and the experimental waveforms are analyzed. The experimental results show that the system has good performance and stable operation.

Key words: medium frequency power supply; Multi-loop feedback control; Repetitive control

Introduction

Nowadays, intermediate frequency power source has been widely used in ship, radar and field of aviation. The early-age intermediate frequency power source was commonly produced by sets of electromotor and made of asynchronous and synchronous motor. However, these kind of power sources was not only in huge shape. The stability in output of voltage and frequency was also that kind. What’s more, the electromagnetism noise of the machine was obvious according to the revolving dynamo. With the development of electronic science, the power source nowadays is in high efficiency, low noise compared to the past ones. And the power-supply property is also reach and surpass the unit power source[1] .

With the development of intermediate frequency power source, the strategy aimed at intermediate frequency power source has also advanced a lot. For example, the repetitive control, multi-loop feedback control and so on. Among these control methods. repetitive control can reduce the rate of distortion in voltage while weak in dynamic ability. The multi-loop feedback control make up for this shortage and can furthermore reduce the effect of the disturbance. This passage take the strategy combining multi-loop feedback control and repetitive control.

1 The design of power source

1.1 The construction of main circuit.

As showed in Fig.1, the whole medium frequency power source is made up of two parts, one is rectification part, another is contravariant part. The function of rectification part is to change the input power frequency current into the direct current in need with the method of non-control rectification, the output part take the method of putting the contactor switch and the resistance in parallel. When join up the power voltage at the beginning, the contactor is disconnect, the resistance is in use of current-controlling. When the voltage is turn to be stable, the contactor will be closed and cut the resistance away. This is used to reduce the loss of the power rate of work. Contravariant circuit mainly turns the direct current into the medium alternating current in 400Hz. The main work is to control the one-phase reverse circuit.

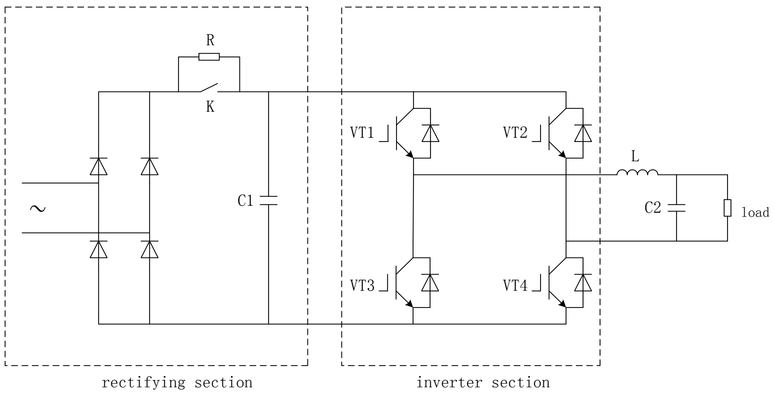

Fig.1 the construction photo of main circuit

1.2 The math module of reverse machine

In the whole construction of the medium power system, the reverse circuit is the core one, the quality of the whole circuit is depend on the reverse circuit[2]. Therefore, we build the math module of the SPWM reverse machine for the design of the reverse circuit controlling machine in convenience.

Fig.2 is the state module of the SPWM reverse machine, among which u_i is the voltage of the reverse circuit, i_L is the inductance current, L is the output smoothing inductance, r is the equivalent resistance made up of the factor of line resistance, switch voltage and dead-zone effection. u_c is the output voltage of the reverse machine. i_o is the output current of the reverse machine. i_c is the loss current in smoothing capacitance.

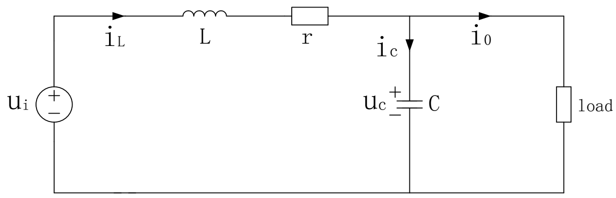

Fig.2 state module of SPWM reverse machine

Select u_c and i_L as the state variable, and we can get the space equation of the continuous state in reverse machine.

$$\begin{bmatrix} \dot{u}_c \\ \dot{i}_L \end{bmatrix} = \begin{bmatrix} 0 & 1/C \\ -1/L & -r/L \end{bmatrix} \begin{bmatrix} u_c \\ i_L \end{bmatrix} + \begin{bmatrix} 0 & -1/C \\ 1/L & 0 \end{bmatrix} \begin{bmatrix} u_i \\ i_o \end{bmatrix} \tag{1}$$

Transform the foemula(1) by Laplace method, and we can get:

$$u_c(s) = \frac{1}{LCs^2 + rCs + 1} u_i(s) + \frac{Ls + r}{LCs^2 + rCs + 1} i_o(s) \tag{2}$$

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We can see from the formula(2), the resistance is the smallest when the reverse is in no-load state, however the shock is the most violent, the degree of control is the most difficult. So the design of the controlling machine must in the no-load state.

2 The controlling strategy

2.1 Multi-loop feedback control

Multi-loop feedback control is a double close-loop controlling strategy based on output voltage and then increase the current as the inter loop. It uses the characteristic of timely, rapid anti-interference characteristic of the inner ring to reduce the affection of load disturbance.

Fig.3 is the construction block diagram of multi-loop feedback control in reverse machine, this system take the method of double-loop feedback control in momentary current and voltage. The outer-loop voltage is measured by comparing the given and feedback voltage to get the error and then through the regulator to get the preset of inner-loop current. It will appear SPWM signal when the error of given and feedback current is amplified and then coincide with triangular wave.

Through this method, we can control the power machine, and ensure the stability od output voltage then turn into the typical multi-loop control. This system conclude the voltage loop, current loop , pulse width control part, and the output wave smoothing part.

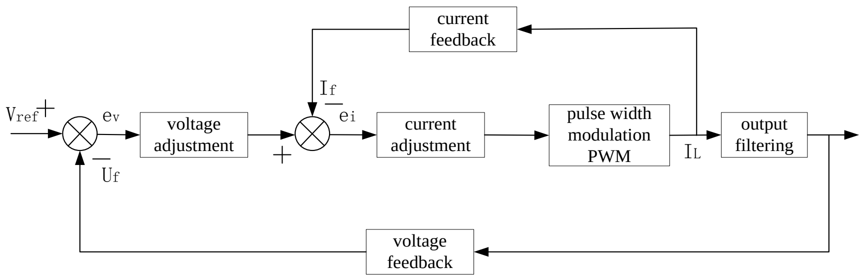

Fig.3 the construction block diagram of multi-loop feedback control reverse machine

2.2 Repetitive control

Repetitive control is a control strategy based on the principle of inner-module. Which means when we need a reference signal need to be traced, we need to add a math module which can produce this reference signal inside the feedback control circuit. We call this as inner-module[3]. we can see that Fig.4 is the inner-module of a repetitive control machine, N is the number of sampling to output voltage per fundamental wave cycle. Input signal E（z）is an error signal, but actually t is a positive feedback system. Output signal F（z）has a periodic accumulation to the input signal, If the input signal is not zero, then the output signal will have a periodic change until the stable error of the whole system is zero[4]. This time the output signal will not change and the system output voltage will have a no-static-error tail towards the input reference signal.

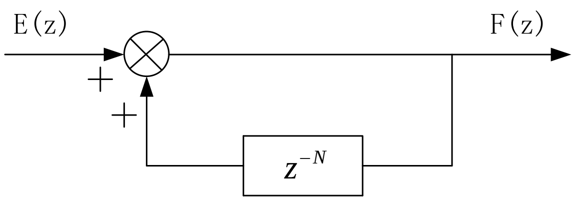

Fig.4 Internal model of repetitive controller

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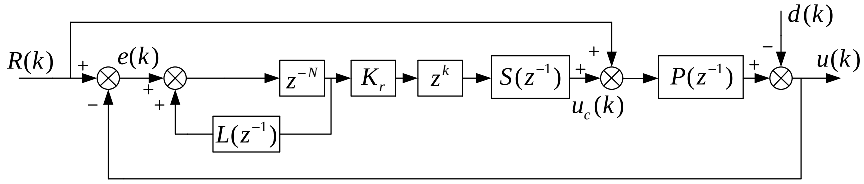

Fig.5 the constructive diagram of repetitive controlling

Fig.5 is the constructive diagram of repetitive controlling, it is mainly contain 5 parts: 1.periodic delay z^{-N}, it's function is to let the controlling part delay a cycle of the passageway. 2.smoothing machine $L(z^{-1})$, it acts as the function of stability. 3.compensation machine $S(z^{-1})$, $S(z^{-1})$ is designed for the $P(z^{-1})$ afterwards, it acts to improve the ability of anti-interference and stability. It mainly contains two function, as formula(3) and (4). 4.increase K_r, it is used to adjust the value of $u_c(k)$. When increase K_r, it will reduce the error and increase the reflect speed of the system, reduce K_r, the stability of the system will increase. 5. phase position compensation z^k is the phase position compensation delay produced by the compensation object $P(z^{-1})$ in the system.

$$S_1(z^{-1}) = \frac{a_1 z^{-1} + a_2 z^{-2}}{1 + b_1 z^{-1} + b_2 z^{-2}} \quad (3)$$

$$S_2(z^{-1}) = \frac{a_m(z^{-m} + z^m) + a_{m-1}[z^{-(m-1)} + z^{m-1}] \cdots + a_0}{2a_m + 2a_{m-1} \cdots + a_0} \quad (4)$$

We analyze the stability of Fig.5, according the information of Fig.5, we can get:

$$E(z^{-1}) = \frac{[1-P(z^{-1})][1-L(z^{-1})z^{-N}]}{1-[L(z^{-1}) - K_r z^k S(z^{-1})P(z^{-1})]z^{-N}} R(z^{-1}) + \frac{1-L(z^{-1})z^{-N}}{1-[L(z^{-1}) - K_r z^k S(z^{-1})P(z^{-1})]z^{-N}} D(z^{-1}) \quad (5)$$

To put the system in a stable state, the on characteristic roots of the disperse system must all locate on a unit circle with a center on the original point.

$$1-[L(z^{-1}) - K_r z^k S(z^{-1})P(z^{-1})]z^{-N} = 0 \quad (6)$$

$$\text{Let}: H(z^{-1}) = L(z^{-1}) - K_r z^k S(z^{-1})P(z^{-1}) \quad (7)$$

The equation correspond to fomula(7) is:

$$H(e^{j\omega T}) = L(e^{j\omega T}) - K_r e^{j\omega kT} S(e^{j\omega T})P(e^{j\omega T}) \quad (8)$$

To make $|z| < 1$, then we must ensure $|H(e^{j\omega T})| < 1$, $\omega \in [0, \pi/T]$, T is the period of sampling.

Combining multi-loop feedback controlling and repetitive controlling as Fig.6, it actually is a double level construction, multi-loop feedback controlling as inner level. When the system is in a stable state, repetitive controlling acts as dominant function. When the system has a big disturbance, multi-loop feedback controlling acts as a dominant function[5].

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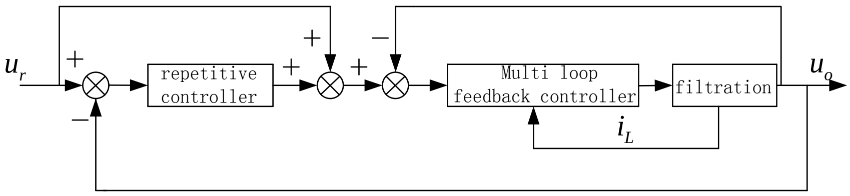

Fig.6 The picture of construction

3 Experiment research

According to the control strategy above, we set up a 10VA experimental machine centered with DSP TMS320F28335 , input power source is three-phase AC380V±3%,frequency is 50Hz ±5%, output is single-phase AC220V±3%,frequency is 400Hz±1%.

Fig.7 The experimental sample machine

Fig.8 and fig.9 is the phase voltage wave shape, actuate signal dead-zone wave shape of the medium power source respectively. We can see from fig.8 that it is soft start when in medium power source starts, the voltage output wave shape starts from zero to the maximum, and then reduce to stability. From fig.9 we can see the PWM dead-line time of the sample machine is about 3.0us，it is mainly depend on the used size of IGBT.

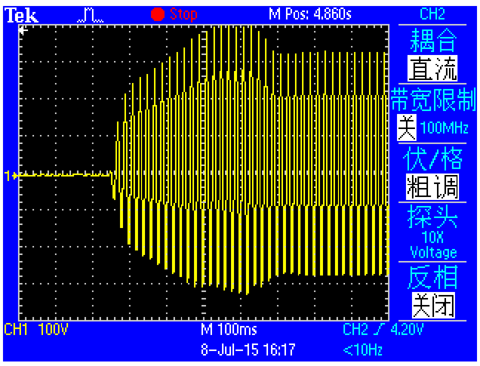

Fig.8 The output wave x of the starting phase voltage

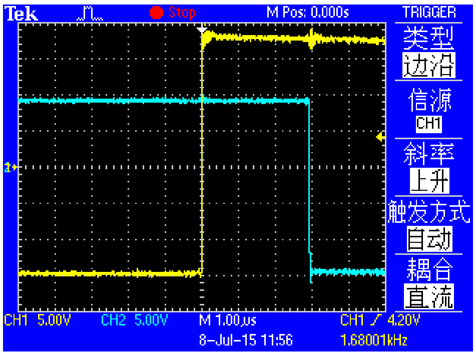

Fig.9 Drive signal dead-zone wave shop

Fig.10 voltage output wave shape when I is full load. Fig.11 is the voltage output wave shape after amplify, we can see from the picture that the output of the voltage is stable, and the shape of the wave is smooth.

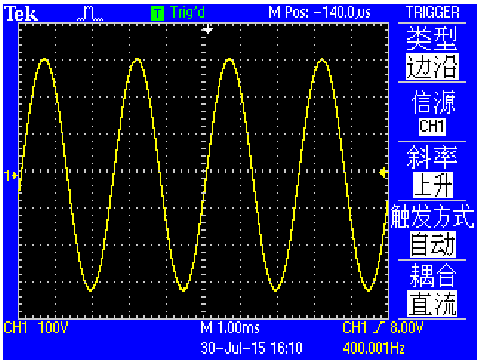

Fig.10 The full-load voltage output wave shape

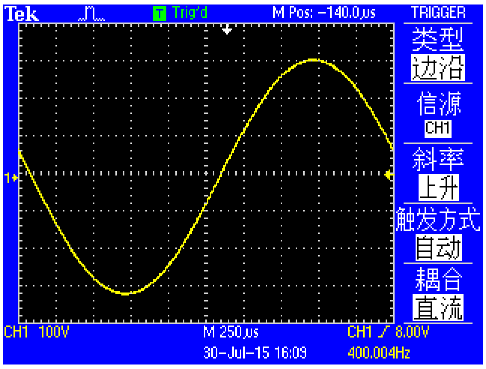

Fig.11 Output voltage partly amplified picture

4 Conclusion

This essay analyze the two strategy of the multi-loop feedback control and the repetitive controlling, and furthermore by combining two strategies to get the strong points which can be applied to the research in the medium power source. The result of the experiment shows that the ability of this kind of controlling system is in good quality and can run well and it is a reliable controlling project which can be applied to the medium power source system.

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