Control simulation of a single phase Boost PFC circuit

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Abstract

Power Factor Correction (PFC) was a circuit to improve the power factor and reduce the harmonic content, the control effect of high power factor is obtained by power electronic conversion technology.The single-cycle control Boost Power Factor Correction circuit was introduced,its advantages and the principe of work were expounded. The PWM control signal is provided by the combination of the voltage and current double closed loop strategy and PI controller with stable control effect. A simulation model was set up on the Matlab/Simulink platform for experiment to obtain high power factor, low current distortion rate and fast dynamic response speed, which verified the feasibility of the method.

Keywords

Power Factor Correction;Double closed loop control ;PI control; Matlab simulation.

1. Introduction

With the rapid development of economy, the wide application of switching power supplies leads to the distortion of the input side waveform and the reduction of power factor. How to improve the power factor, harmonic suppression and power quality has become the focus of current research[1].

With the development of IGBT, MOSFET and other high-power electronic devices, the power electronic technology has been widely used. In order to reduce the non-linearity of PFC circuit, APFC, which is the best active power factor correction circuit (APFC), is adopted to solve the harmonic pollution problem of the rectifier circuit at present. In the traditional non-control rectifier circuit, high-power switch tube is added to make the ac input side current follow voltage in phase and the current waveform is sinusoidal to some extent. On the basis of previous experience in power factor correction, the author adopted Boost PFC circuit, which has the advantages of [2] :

(1) the input inductance in the circuit can reduce the design requirements of the circuit filter and effectively prevent the power network from impacting the circuit in the high frequency transient;

(2) simple circuit structure, low cost and small EMI;

(3) the voltage of the switch tube is higher than the output voltage value.

At the same time, the hybrid control strategy of combining double closed loop control and PI control is adopted in the circuit, and the power factor correction circuit is modeled and simulated in Matlab to verify the feasibility of the scheme [3].

2. Power factor control principle

2.1 Working principle of the circuit

The circuit is mainly composed of rectifier bridge, energy storage inductance L, power switching tube VT, continuous-current diode VD, energy storage capacitance C and output resistance R. AC power supply through the rectifier bridge to achieve AC-DC transformation, the output of high - order harmonic dual - pulse voltage UI. When the PWM signal of the control switch tube VT is at high power at ordinary times and the VT is in the conduction state, the electric energy is stored in the inductance L, the diode VD is anti-biased off, and the RL is provided with energy by the energy storage capacitor C. When PWM signal is at low power, VT is at the cut-off state. According to the characteristics of inductance L, voltage at both ends of L is left, negative, and right, and VD is conductive. Energy stored in inductance L is partly charged by C and partly supplied to load RL[4],see Fig.1 .

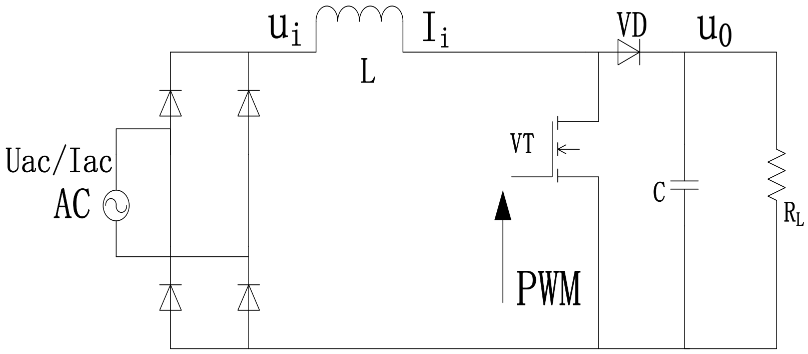

Fig.1 Boost PFC Circuit diagram

2.2 Double closed loop controller

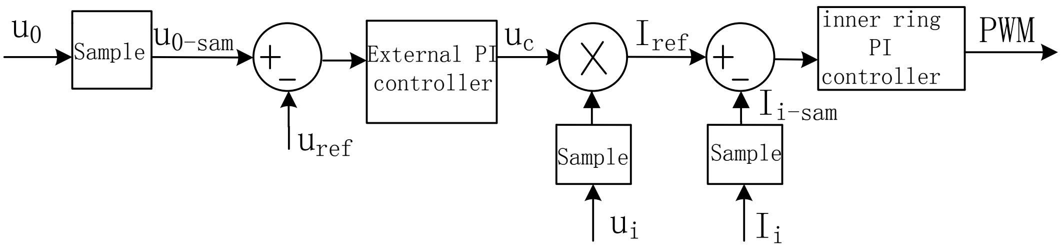

Fig.2 Schematic of double closed loop control

The PFC circuit adopted in this paper is a control mode combining voltage and current double closed loop control and PI control. The control principle is shown in Fig.2. The voltage loop is used as the outer ring, and the control mode of the reference voltage uref is adopted. The difference between uref and the output voltage u0 is processed by PI controller and multiplied by the input voltage UI, and the result Iref is used as the reference value of the internal ring control, so as to achieve the design purpose of tracking error. The current loop is the inner loop, and the error generated after sampling Iref and input current Ii are compared with the sawtooth wave. The generated signal can be used to control the working state of the power switch tube in the circuit, so as to ensure the stability of output voltage and the input voltage and current are in the same phase [6].

The transfer function of PI controller of voltage loop is obtained as follows:

$$G_v(s)=\frac{u_c}{u_{ref}-u_{0-sam}}=K_{pv}+\frac{K_{iv}}{s} \tag{1}$$

K_{pv} and K_{iv} are the control parameters of the voltage loop PI controller.In formula (1), suppose:

$$e_1=u_{ref}-u_{0-sam} \tag{2}$$

The bilinear transformation is adopted to eliminate the influence of the high frequency part $(f_s/2)$. Suppose:

$$s=\frac{2}{T_s}\bullet\frac{1-z^{-1}}{1+z^{-1}} \tag{3}$$

Substitute equations (2) and (3) into equations (1), and carry out z transformation, and we can get:

$$u_c(k)=u_c(\mathrm{k}-1)+(\mathrm{K}_{pv}+\frac{K_{iv}T_s}{2})\bullet e_1(k)-(K_{pv}-\frac{K_{iv}T_s}{2})\bullet e_1(k-1) \tag{4}$$

Suppose $X = K_{pv} + \frac{K_{iv}T_s}{2}$, $Y = K_{pv} - \frac{K_{iv}T_s}{2}$ .Then the transfer function of the voltage PI controller is obtained by simplifying equation (5) :

$$u_c(k) = u_c(k-1) + X \bullet e_1(k) - Y \bullet e_1(k-1) \quad (5)$$

Similarly, according to the above figure 2, the transfer function of current loop PI controller is:

$$G_i(s) = \frac{I_e}{I_{ref} - I_{i-sam}} = K_{pi} + \frac{K_{ii}}{S} \quad (6)$$

Where K_{pi} and K_{ii} are the control parameters of current loop PI controller.

In formula (6), suppose:

$$e_2 = I_{ref} - I_{i-sam} \quad (7)$$

After the transformation of equation (7) bilinear z, we get:

$$I_e(k) = I_e(k-1) + (K_{pi} + \frac{K_{ii}T_s}{2}) \bullet e_2(k) - (K_{pi} - \frac{K_{ii}T_s}{2}) \bullet e_2(k-1) \quad (8)$$

Suppose $M = K_{pi} + \frac{K_{ii}T_s}{2}$, $N = K_{pi} - \frac{K_{ii}T_s}{2}$ .Then the transfer function of the voltage PI controller is obtained by simplifying equation (8) :

$$I_e(k) = I_e(k-1) + M \bullet e_2(k) - N \bullet e_2(k-1)$$

(9)

3. Experimental waveform and analysis

Simulink simulation model built by Matlab software. The system input ac power supply AC220V is set, the frequency is 50Hz, the inductance L=10mH, the output capacitance C=1500uF, the output resistance R=80, and the simulation time is set to 0.5s. Voltage loop PI controller PI parameter K_{pv} =0.12,K_{pi} =10, current loop PI controller PI parameter K_{pi}=10, K_{ii}=0.2,see Fig.3.

Output waveform of Uac power supply and current Iac. In the system simulation process, after 0.03s, the input current has been well tracking the input voltage on the phase, see Fig.4.

The waveform of the output voltage u0 of the PFC circuit. It can be seen that u0 is stable around 311V after a short time, see Fig.5.

The FFT analysis of the input current Iac, and the harmonic content figure of the input current is obtained. It can be seen that the fundamental wave component of the output current is the largest, THD=4.06%, and the experimental results are good, see Fig.6.

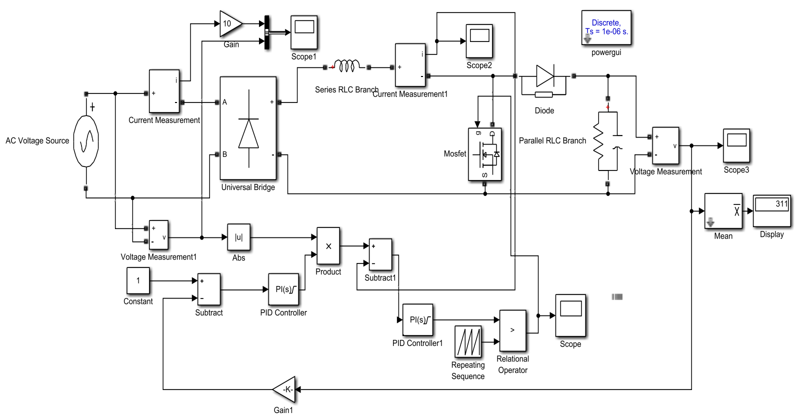

Fig.3 Circuit simulation model

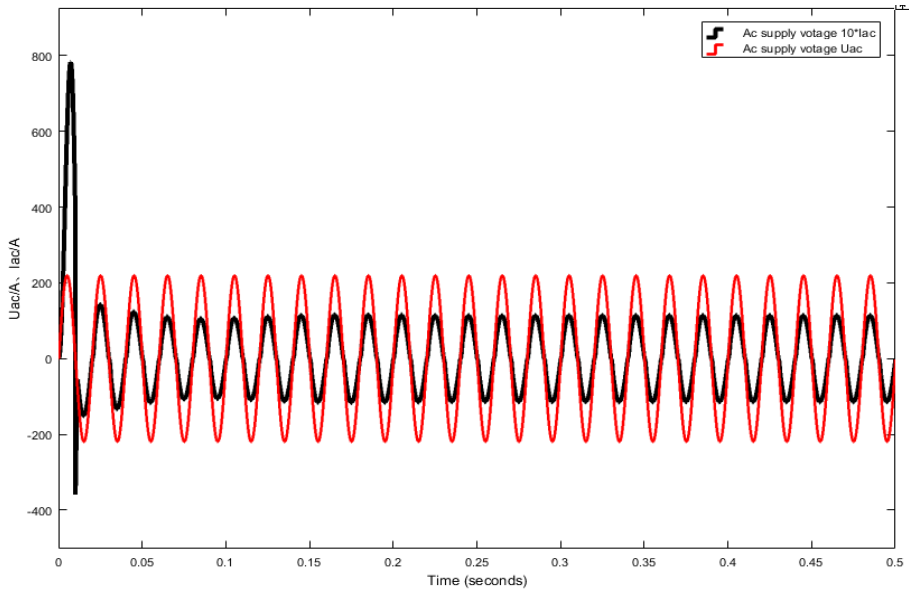

Fig.4 Ac power supply voltage Uac, current Iac waveform

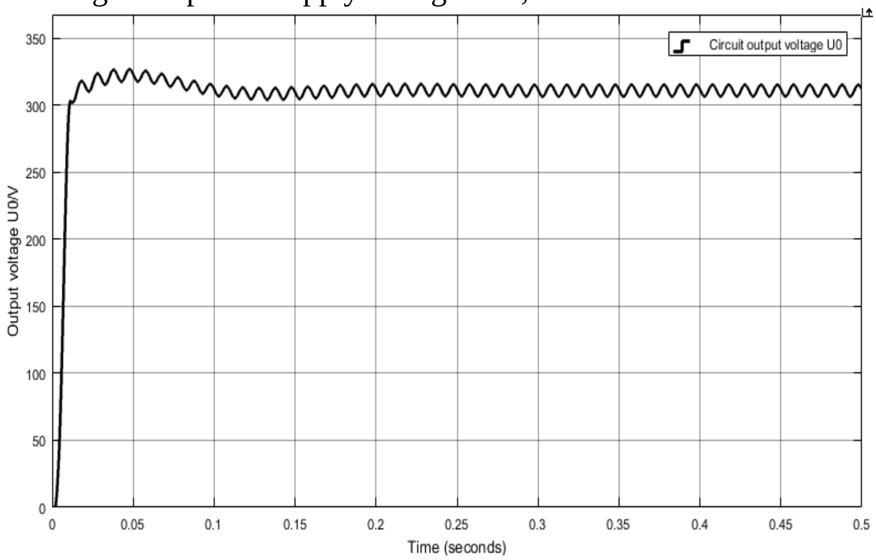

Fig.5 Output voltage u0 waveform

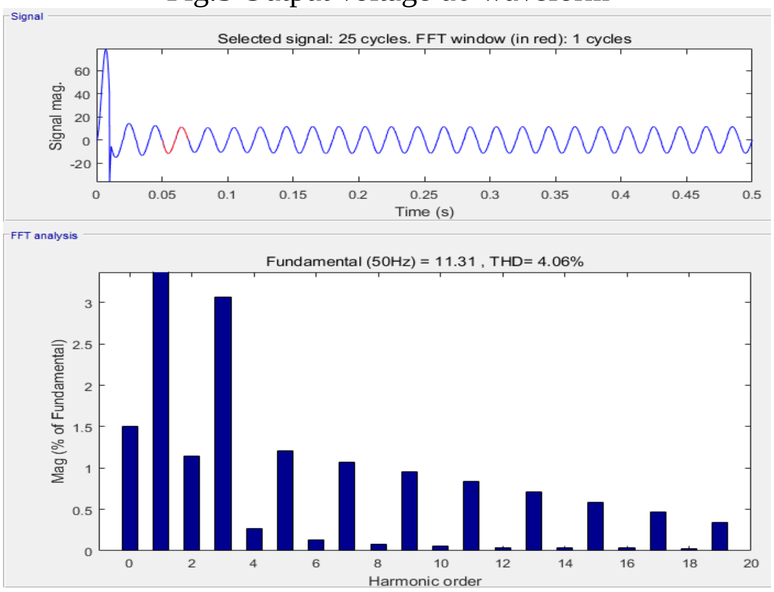

Fig.6 FFT analysis of ac input current

4. Conclusion

In this paper, the PFC circuit is taken as the research object, and the working principle of the circuit is expounded. Combined with its own working characteristics, the control mode of the voltage and current dual control system combined with PI control is adopted, which has a good control effect.

The results show that the output current of the ac power supply has high quality characteristics, the current waveform is basically a standard sine wave, and the output voltage of the ac power supply is similar to that of the ac power supply in phase. The distortion rate of the current is only 4.06%, less than the national standard 5%, realizing the purpose of high power factor control. Compared with other control methods, the combination of the voltage and current control system and PI control improves the reliability of the system and increases the power factor to above 0.98. Such control effect reduces the power loss of the system. The simulation results verify the feasibility of this scheme.

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