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Unit Power Factor Servo Drive Control System

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Abstract: *In order to solve the problem that the load of the servo drive system can easily lead to the decrease of the power grid's power factor and generate the harmonic pollution, in this paper, single-phase PWM rectifier is applied to servo drive control system. In the design of single-phase PWM rectifier, the double closed-loop control strategy of current voltage and the virtual phase lock technology are applied to make the power grid side current sinusoidal and track the phase of the power grid side voltage to achieve unity power factor control. In the servo motor control, the maximum current torque ratio control strategy is used. PWM rectifier as the servo drive control system front, for its energy. And build a simulation model in MATLAB, through the simulation analysis, it is verified that this method can realize the control of the grid side unity power factor, and the servo drive system is robust.*

Keywords - *single phase PWM rectifier, PMSM, MATLAB*

I. INTRODUCTION

With the development of industrial production, servo drive systems are more widely used. Because of its fast reaction speed and good stability, permanent magnet synchronous motor has been widely used in servo drive system. However, the permanent magnet synchronous motor is a kind of nonlinear resistive load. In the process of using, the reactive power will be generated and transmitted to the power grid, which will reduce the power factor of the grid side. For such problems, with the single-phase PWM rectifier provides permanent magnet synchronous motor servo drive system's energy, to reduce the reactive power transmission to the power grid from servo drive system, and to achieve unity power factor in power grid side. In this paper, in order to design PWM rectifier, the virtual three-phase technique is applied to the voltage and current double closed-loop control mode, and combining the PWM rectifier and servo motor vector control system together, to establish simulation model in MATLAB, through the simulation model to verify the reliability and validity of the method.

II. SINGLE-PHASE PWM RECTIFIER DESGN

2.1 Mathematical model of single-phase PWM Rectifier

The switch is considered as the idealized switch model, and the simplified model of the main circuit of single-phase PWM rectifier as shown in Fig.1.

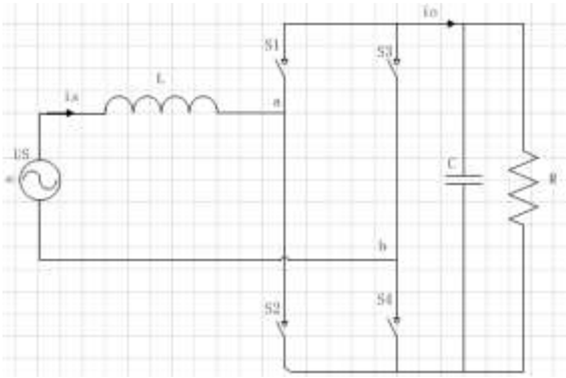


Fig.1 Simplified model of single phase PWM rectifier' main circuit

When s_1 is on,s_2 is off,$s_a = 1$; Whens_1 is off, s_2 is on$s_a = 0$; Whens_3 is on,$s_4$is off,$s_b = 1$; When s_3 is off,$s_4$is on, $s_b = 0$;then:

$$u_{ab} = \begin{cases} u_{dc} \\ 0 \\ -u_{dc} \end{cases} \qquad (1)$$

Where u_{ab} is the grid side voltage;u_{dc} is the DC side voltage;s_a and s_b are the conditions of the two bridges, and when the upper bridge is on, then it is compared to 1,otherwise it is compared to 0. Simplified equation (1) can get:

$$u_{ab} = (s_a - s_b)u_{dc} \qquad (2)$$

From the equation (2), it can be obtained more simplified AC side circuit model, as shown in Figure 2.

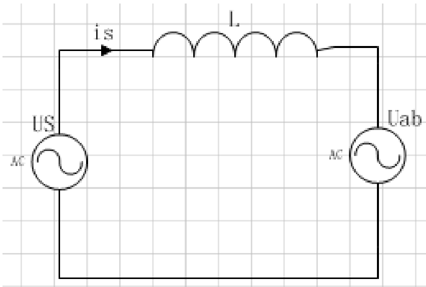


Fig.2 Simplified circuit model of AC side for single phase PWM rectifier

By Kirchhoff's law can get:

$$u_s = L\frac{di_s}{dt} + u_{ab} (3)$$

The power balance principle can be got when the switch loss is neglected：

$$u_s i_s = u_{dc} i_o \quad (4)$$

Wherei_o is output current, and:

$$i_o = (s_a - s_b)i_s (5)$$

In the DC side can get:

$$i_o = C\frac{du_{dc}}{dt} + \frac{u_{dc}}{R} (6)$$

Combined all equation of above can get:

$$\begin{cases} L\frac{di_s}{dt} = u_s - (s_a - s_b)u_{dc} \\ C\frac{du_{dc}}{dt} = (s_a - s_b)i_s - \frac{u_{dc}}{R} \end{cases} \quad (7)$$

2.2 Controller design for single phase PWM rectifier

In the single-phase PWM controller design, aimed at stabilizing the DC voltage in the DC side and realize unity power factor in the grid side.In this paper, the virtual three-phase technology is applied to the voltage current double closed-loop control mode, in order to constitute the control system of PWM rectifier.

2.2.1 Voltage-Current double closed-loop control

In the design of PWM rectifier controller, the voltage loop is used as the outer loop and compared with the reference value of voltage. Then get the voltage error signal and as the input signal of proportional integral regulator. The output of the regulator is the magnitude of the current command, and use the regulator's output signal multiply the sinusoidal signal can get the current command.The current instruction value is adjusted in the inner loop of the current regulation, and then compared with the sine wave, so that the corresponding modulated wave is obtained.Through the SPWM algorithm, it can achieve the expected control target.Current voltage double closed-loop control block is shown in Fig.3:

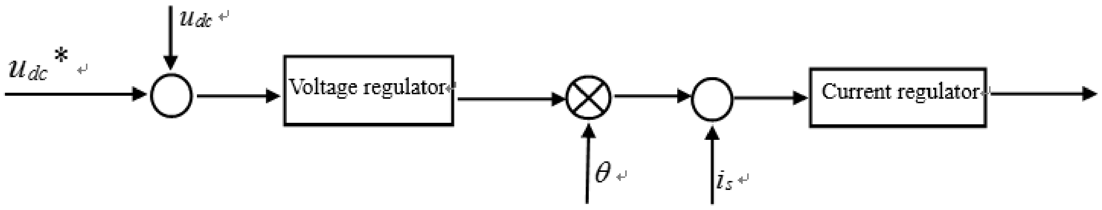


Fig.3 Voltage-Current double closed-loop control block diagram

In Fig.3,u_{dc}^{*} is the voltage command value; θis the voltage phase of power grid; i_s is the current of grid side.

2.2.2 Virtual three-phase technology

Phase locked loop (PLL) is a kind of phase feedback control system can not only realization of constant frequency signal tracking control, and changes in the frequency of signal has higher tracking accuracy and sensitivity.In this paper, the virtual three-phase technology is used to construct the single phase current into the virtual three-phase current.The method of single synchronous rotating coordinate system phase locked loop is used to realize synchronous tracking of the current to the voltage.Control system block as shown in Fig.4:

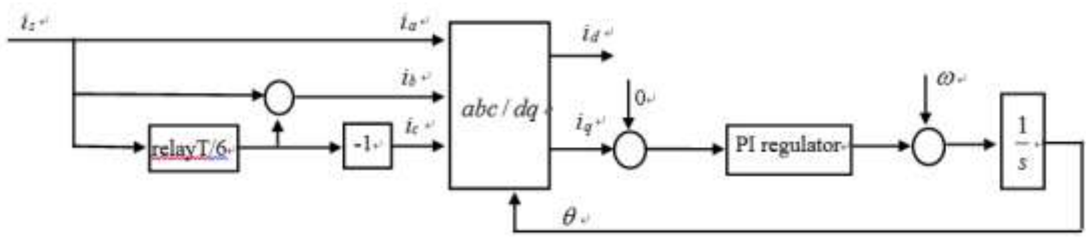


Fig.4 The block diagram of the virtual three-phase technology PLL

In Fig.4,i_s is the current of grid side;ω is the grid angular frequency;θ is the voltage phase of power grid. First, the grid side current lags 1/6 period, then reverse, then get the current that phase-lead 120 degrees of grid side currenti_s.And use the lags 1/6 period's current subtract grid side current i_s can get the current that phase-lags 120 degree of grid side current i_s. Thus, the single-phase current is constructed into the virtual three-phase current. And applied it to the single synchronous coordinate system PLL. Then get i_d and i_q which are d- and q-axis current by synchronous rotating coordinate transformation. When$i_q = 0$, realize the phase lock, and the synchronization of the current and the voltage phase of the power grid is realized. The virtual three-phase technology is applied to the voltage current double closed-loop control system can get the system control block diagram as shown in Fig.5:

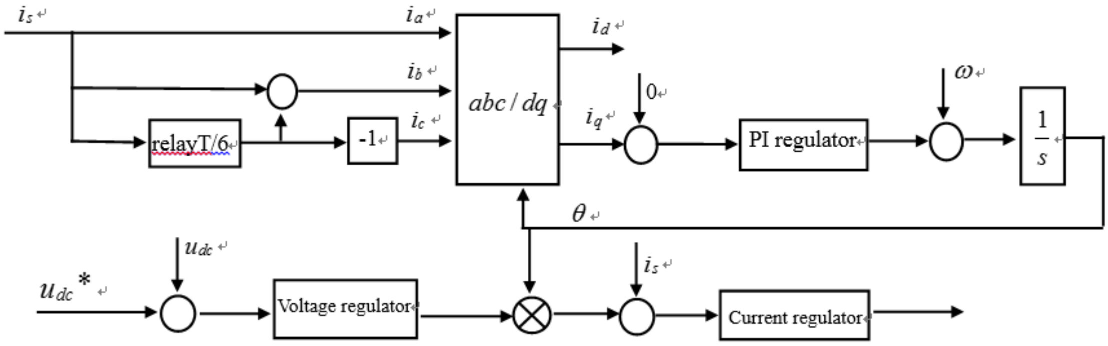


Fig.5 Virtual three-phase technology applied to the voltage-Current double closed-loop control

The virtual three-phase technology is applied to the voltage current double closed-loop control strategy of single-phase PWM rectifier control system block shown in Fig.6:

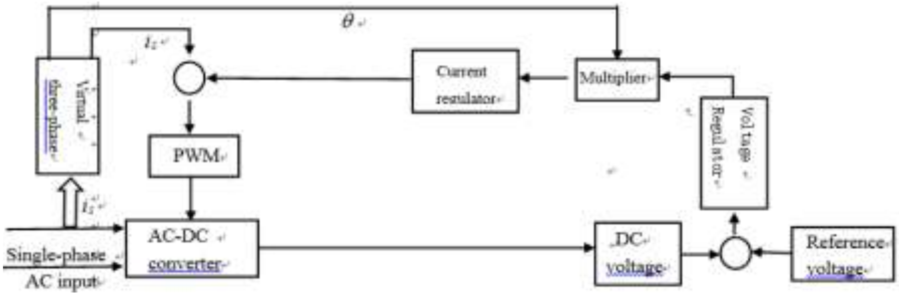


Fig.6 Control system block diagram of single phase PWM rectifier

III. PMSM VECTOR CONTROL SYSTEM DESIGN

3.1 PMSM mathematical model

In this paper, the permanent magnet synchronous motor is SPMSM, that is: $L_d = L_q$, and use with maximum torque current ratio control strategy, that is: $i_d = 0$, so the mathematical model of permanent magnet synchronous motor can be turned into:

$$\begin{cases} u_d = -\omega_r L_q i_q \\ u_q = L_q \frac{di_q}{dt} + R_s i_q + e \\ T_e = \frac{3}{2} p \varphi_f i_q \\ T_e = J \frac{d\omega_r}{dt} + B\omega_r + T_L \end{cases} \qquad (8)$$

Where u_d and u_q are the d- and q-axis voltage, respectively; i_d and i_q are the d- and q-axis stator current, respectively; ω_r is the rotor mechanical speed; L_d and L_q are the d- and q-axis inductance; R_s is the winding stator resistance; φ_f is the permanent-magnet flux linkage; e is the counter electromotive force; T_e is the electromagnetic torque; B is the viscous friction coefficient; T_L is the load torque; and p is the number of pole pairs.

3.2 PMSM vector control system design

By the maximum torque current ratio of the control strategy, the block diagram of the PMSM vector control system is shown in Fig.7:

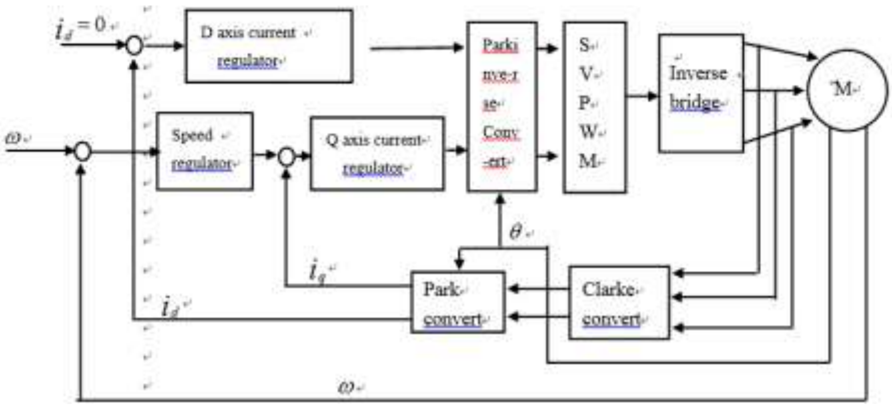


Fig.7 PMSM vector control system block diagram

IV. SINGLE PHASE PWM RECTIFIER SERVO DRIVE CONTROL SYSTEM DESIGN

From the first two sections of this paper, a mathematical model of single-phase PWM rectifier and PMSM is obtained.In the single-phase PWM rectifier, the control strategy of the combination of the virtual three-phase technology and the voltage current double closed-loop is adopted, and the maximum current torque ratio control for PMSM is adopted. Therefore, the single phase PWM rectifier servo drive control system block diagram is shown in Fig.8:

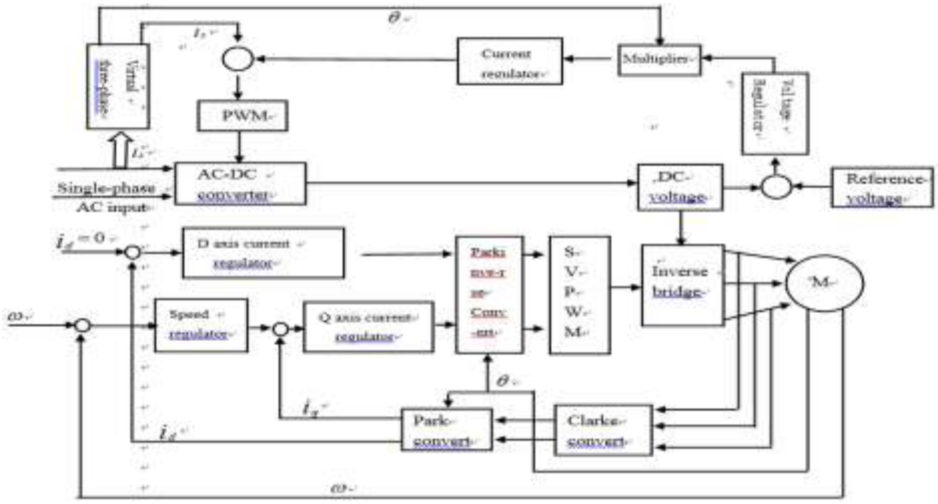


Fig.8 Servo drive control system for single phase PWM rectifier

V. SIMULIATION ANALYSIS

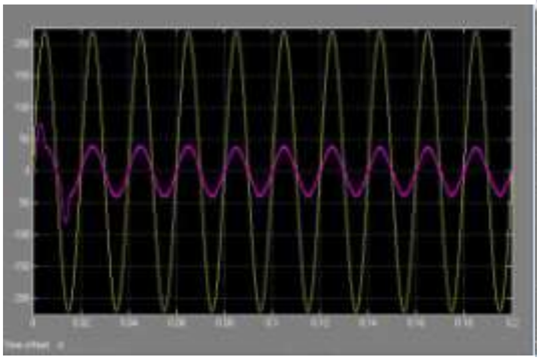
The simulation model of the servo drive control system of single phase PWM rectifier in MATLAB is establis5hed by figure 8.

The parameters of single-phase PWM rectifier are as follows:

$u_s = 220V$;f = 50Hz;L = 5mH;C = 600μf;$R_d = 51\Omega$;$u_{dc} = 450V$. PMSM parameters are as follows:

$R_s = 2.875\Omega$;$\varphi_f = 0.175wb$; $L_d = L_q = 8.5mh$; p = 2 ; J = 0.01kg $\bullet$ m^2 ;n = 500n/min.

The simulation waveforms shown in MATLAB are as follows:



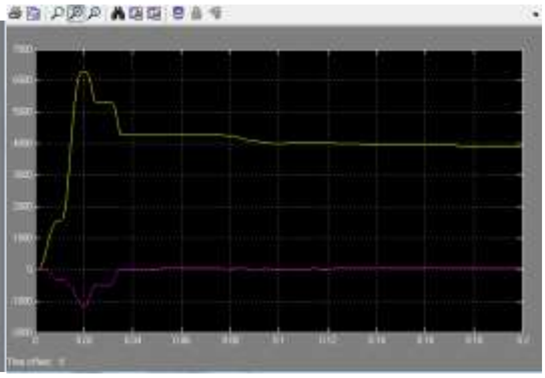
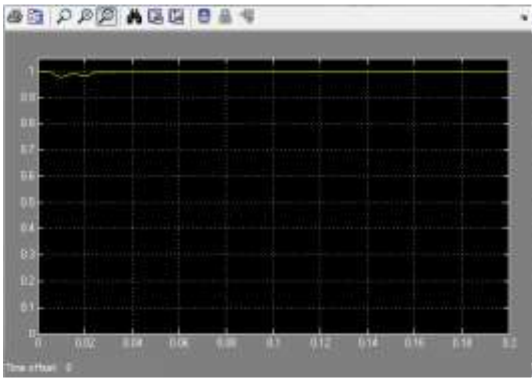


Fig.9 grid side voltage and current waveformFig.10 Grid side input active and reactive power



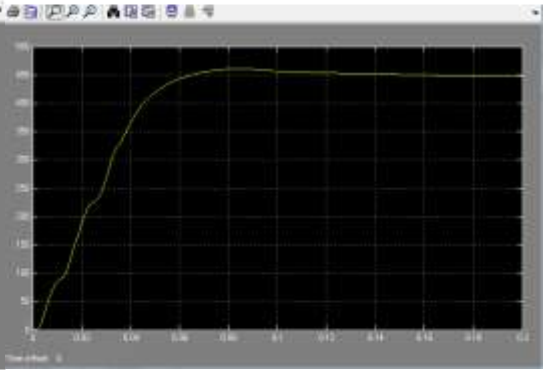


Fig.11 Grid side power factorFig.12 Rectifier output DC voltage

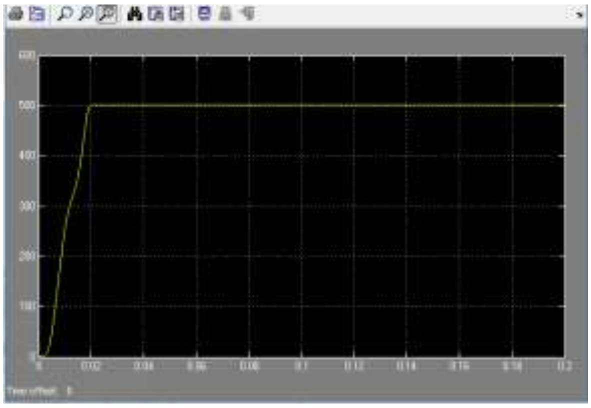


Fig.13 Permanent magnet synchronous motor speed

In Fig.9,it is the waveforms of grid voltage and current. From thisfigure, after 0.02s, the grid side current and voltage phase almost simultaneously;In Fig.10, the red line indicates reactive power, yellow line is active power.Obtained from the figure, after the 0.035s and grid side of the rectifier's reactive power and active power are stability, and the grid side without reactive power. In Fig.11,it is the waveform of power fact.After 0.035s, the grid side power factor of the rectifier is equal to one.By Fig.9, fig.10 and fig.11, the rectifier can achieve the grid side unity power factor.

Fig. 12 shows the rectifier output DC voltage, when the rectifier is stable, the output DC voltage is stable at the DC voltage setting 450V.Fig.13 shows the speed of the permanent magnet synchronous motor in the servo drive control system, After 0.02s, the motor speed is stable at the speed setting 500n/s.

Through the above analysis,the servo drive system controlled by single phase PWM rectifier can realize unity power factor of the grid side, stabilize the DC side output voltage and stabilize the servo drive system.

VI. CONCLUSION

In this paper, the energy source of the single phase PWM rectifier is used as the servo drive system,the voltage current double closed-loop control is adopted to single phase PWM rectifier, and the virtual three-phase technology is applied to double closed-loop control,in order to achieve the sinusoidal input current and to achieve the same phase of the input current and input voltage.Maximum torque current ratio control strategy is used to permanent magnet synchronous motor's vector control system, and build simulation model in MATLB. By simulation, this method can make the input current sinusoidal, and make input current and input voltage have the same phase.Through the PWM rectifier with unity power factor control, can greatly reduce the reactive power which produced by Servo drive system transmitted to the power grid, and improve power quality of power grid.At the same time, it can make the servo drive system run stably.

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