The Design of the Vector Control System of Asynchronous Motor

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Abstract

Among various modes of the asynchronous motor speed control, vector control has the advantages of fast response, stability, transmission of high-performance and wide speed range. For the need of the asynchronous motor speed control, the design uses 89C196 as the controller, and introduces the designs of hardware and software in details. The Design is completed effectively, with good performance simple structure and good prospects of development.

Keywords: Asynchronous motor, 89C196, Vector control

1. Introduction

AC asynchronous motor is a higher order, multi-variable, non-linear, and strong coupling object, using the concept of parameters reconstruction and state reconstruction of modern control theory to achieve decoupling between the excitation component of the AC motor stator current and the torque component, and the control process of AC motor is equivalent to the control process of DC motor, the dynamic performance of AC speed regulation system obtaining notable improvement, thus makes DC speed replacing AC speed possible finally. The current governor of the higher production process has been more use of Frequency Control devices with vector-control.

2. Vector Control

With the criterion of producing consistent rotating magnetomotive force,the stator AC current i_A, i_B, i_C by 3S/2S conversion in the three-phase coordinate system, can be equivalent to AC current i_d^s, i_q^s in two-phase static coordinate system, through vector rotation transformation of the re-orientation of the rotor magnetic field, Equivalent to a synchronous rotation coordinates of the DC current i_d^e, i_q^e. When observers at core coordinates with the rotation together, AC machine becomes DC machine. Of these, the AC induction motor rotor total flux Ψ_r, it has become the equivalent of the DC motor flux, windings d^e equivalent to the excitation windings of DC motor , i_d^e equivalent to the excitation current, windings q^e equivalent to false static windings, i_q^e equivalent to the armature current proportional to torque. After the transformation above, AC asynchronous motor has been equivalent to DC motor. As a result, imitating the control method of DC motor, obtaining the control variable of DC motor, through the corresponding coordinates anti-transformation, can control the asynchronous motor. As a result of coordinate transformation of the current (on behalf of magnetic momentum) space vector, thus, this control system achieved through coordinate transformation called the vector control system, referred to VC system. According to this idea, could constitute the vector control system that can control Ψ_r and i_q^e directly, as shown in Figure 1. In the figure a given and feedback signal through the controller similar to the controller that DC speed control system has used, producing given signal $i_{qs}^{e\,*}$ of the excitation current and given signal $i_{ds}^e *$ of the armature current, after the anti-rotation transform VR^{-1} obtaining $i_{ds}^s *$ and $i_{qs}^s *$, obtains i_A^*, i_B^*, i_C^* by 3S/2S conversion. Adding the three signals controlled by current and frequency signal ω_1 obtained by controller to the inverter controlled by current, can output three-phase frequency conversion current that asynchronous motor needs for speed.

3. The Content and Thought of the Design

This system uses 80C196 as controller, consists of detection unit of stator three-phase current unit of keyboard input, LCD display modules, given unit of simulation speed detection unit of stator three-phase voltage, feedback unit of speed and output unit of control signals. System block diagram shown in Figure 2, the system applies 16 bits MCU 80C196 as control core, with some hardware analog circuits composing the vector control system of asynchronous motor. On the one hand, 80C196 through the A/D module of 80C196, speed gun and the given speed feedback signals has been obtained, obtaining given torque of saturated limiting through speed regulator, to obtain the given torque current; Use a given function generator to obtain given rotor flux, through observation obtaining real flux, through flux regulation obtaining given excitation current of given stator current, then the excitation current and the torque current synthesis through the K/P transformation, obtaining amplitude and phase stator current, after amplitude of stator current compared to the testing current , control the size of stator current through current regulator.; on the other hand, the stator current frequency is calculated by the simultaneous conversion rate for the time constant of the control inverter, regularly with timer, through P1, submitting trigger word to complete the trigger of the inverter.

4. The Design of Hardware and Software

The hardware circuits of the system mainly consists of AC-DC-AC current inverter circuit, SCR trigger inverter circuit, rectifier SCR trigger circuit, the speed given with the gun feedback circuit, current central regulation circuit, protection circuit and other typical circuits. The design of software includes: speed regulator control and flux detection and regulation.

4.1 AC-DC-AC Current Converter Circuit

The main circuit uses AC-DC-AC Current Converter in the system as shown in Figure 3, and main features can be known as follows:

1) Main circuit with simple structure and fewer components. For the four-quadrant operation, when the brake of power happens, the current direction of the main circuit keeps the same, just changing the polarity of the voltage, rectifier working in the state of inverter, inverter working in the state of rectifier. The inverter can be easily entered, regenerative braking, fast dynamic response. The voltage inverter has to connect to a group of inverters in order to regenerative braking, bringing the electric energy back to power grids.

2) Since the middle using a reactor, current limit, is constant current source. Coupled with current Loop conditioning, current limit, so it can tolerate instantaneous load short-circuit, automatic protection, thereby enhancing the protection of over current and operational reliability

3) The current inverter can converter with force, and the output current instantaneous value is controlled by current inverter, meeting the vector control requirements of AC motors. Converter capacitor charging and discharging currents from the DC circuit filter by the suppression reactor, unlike a greater inrush current in voltage inverter, the capacitor’s utilization is of high level.

4) Current inverter and the load motor form a whole, and the energy storage of the motor windings is also involved in the converter, and less dependent on the voltage inverter, so it has a certain load capacity.

4.2 Inverter SCR trigger drive circuit

The Inverter SCR trigger drive circuit as shown in Figure 4. Inverter trigger signal is controlled by P1 of 80C196, slip signal outputting through P1 via PWM regulation in the SCM through the photoelectric isolation to enlarge, to control the trigger of the inverter. The system uses P1.6 as control and uses P1.0~P1.5 to control six SCR inverters separately, so the trigger circuits is composed by six circuits above.

The principles of drive circuit of SCR trigger inverter are as follows: when the PWM from P1 is high signal after and gate, photoelectric isolation is not on, composite pipe in a state of on-saturated, the left side of the transformer forming circuit, and that the power of the signal amplifies (current enlarges); when the PWM from P1 is low signal after and gate, photoelectric isolation is on, composite pipe in a state of cut-off, and the left side of the transformer can not form circuit; thus, composite pipe equivalent to a switch, and its frequency relied on the frequency of the PWM, so the left side of the transformer form AC signals, to trigger SCR inverter after transformer decompression, half-wave rectifier and filter.

4.3 Current Loop conditioning circuits

After the vector calculation, outputting given current through D/A module, testing feedback current by the current testing circuit, sending them to the simulator of the P1 regulator to regulate, can eliminate static difference and improve the speed of regulation. The output of the analog devices can be regarded as the phase-shifting control signals of the rectifier trigger. Current Loop conditioning circuits as shown in figure 5.

4.4 The control of speed regulator

Speed regulator uses dual-mode control. Setting a value N_T of speed error, when the system is more than the deviation (more than 10 percent of the rated frequency), as rough location of the start, using on-off control, at this time, speed regulator is in the state of amplitude limit,equivalent to speed loop being open-loop, so the current loop is in the state of the most constant current regulation. Thus, it can play the overload ability of motor fully and make the process of regulation fastest possibly. When the system enters into a state of small deviation, the system uses PI linear control instead of on-off control. As result, absorbing the benefits of non-linear and linear, the system meets stability and accuracy. The speed regulator flowchart is as shown in figure 6.

4.5 Flux Regulation

Slip frequency vector control system can be affected by the motor parameters, so that the actual flux and the given flux appear a deviation. This system is of observation and feedback in the amplitude of the magnetic flux, regulating flux of the rotor, actual flux with the changes of given flux.

Flux regulator is also the same as the speed regulator, using PI regulator. The discrete formula is:

$$i_m(n) = i_m(n-1) + k_m\{\Delta e_i(n) + T_s e_i(n) / t_n \quad (1)$$

Plus a reminder to forecast for correction:

$$I_m = 2i_m(n) - i_m(n-1) \quad (2)$$

In the formula, k_m is proportional coefficient, t_n is integral coefficient, T_s is sampling period, I_m is the actual output value.

$$\Delta e_n = e(n) - e(n-1) \quad (3)$$

$$e_n = \Phi_2^*(n) - \Phi_2(n) \quad (4)$$

When it is in the state of low frequency (f<5HZ), r_1 can not be ignored, the phase difference between V_1 and E_1 enlarges, and the formula $V_1 \approx V_1^{'}$ no longer sets up. Through the Approximate rotor flux observer and the formula $\Phi_2 = I_{m1}L_m = (V_1 - I_T r_1) / \omega_0 - I_{m1}L_1$ to observe the flux amplitude, only open-loop control of flux, that is, to calculate from a given flux, and that is $I_m = \Phi_2^* / L_m$.

In addition, in order to avoid disorders, or too weak and too strong magnetic, limiting the output i_m in preparation for the software, making it in the ranges from 75% to 115% rated value.

5. Design Summary

This text researches the vector control variable speed control system of the asynchronous motor design. The SCM 80 C196 and the external hardware complete the asynchronous motor speed vector control system design efficiently, and meet the timing control requirements. The vector control system design thinks clearly, has a good speed performance and simple structure. It has a wide range of use and a good prospect of development from the analysis and design of the speed asynchronous motor vector control systems.

The innovations:

(1) Complete the data acquisition of the speed and voltage, output the control signal and save the devices effectively with the help of the 80C196 microcontroller owned A/D, D/A.

(2) Because the Current Source Inverter uses forced converter, the maximum operating frequency is free from the power grid frequency. And it is with wide speed range.

(3) This system uses constant flux to keep the constant flux stably. Use stator physical voltage amplitude to approximate the observed flux amplitude value. The magnetic flux overcomes the impact of the parameters changes. This way is simple and effective.

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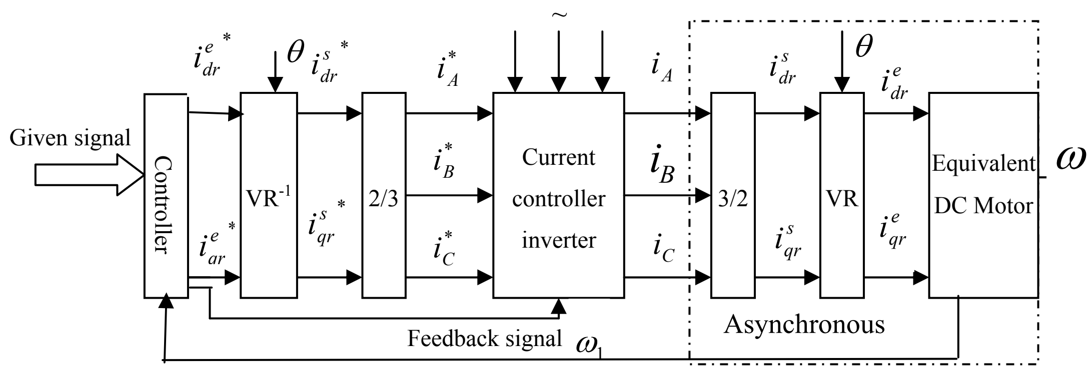

Figure 1. Vector Control System Principle

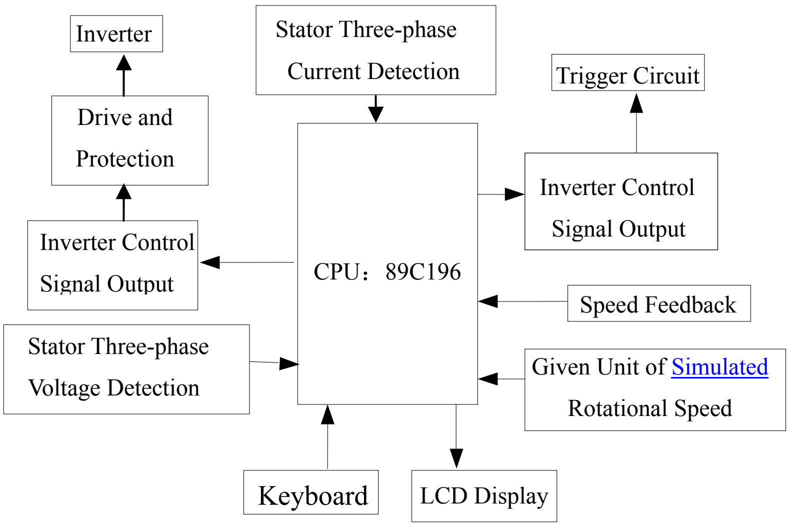

Figure 2. Scheme of system

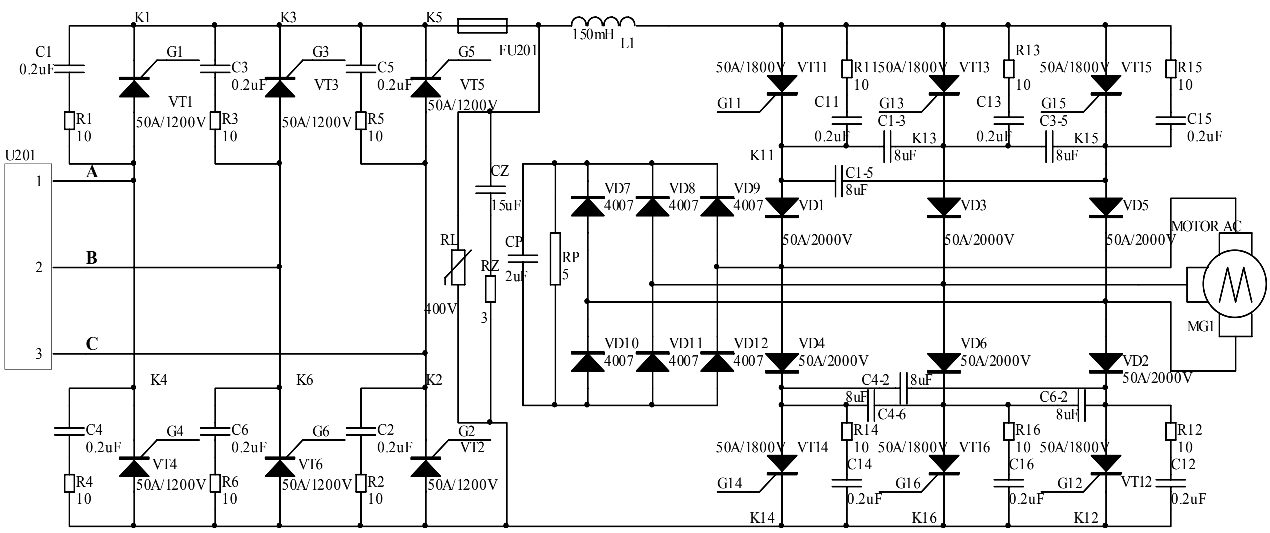

Figure 3. AC-DC-AC Current inverter circuit

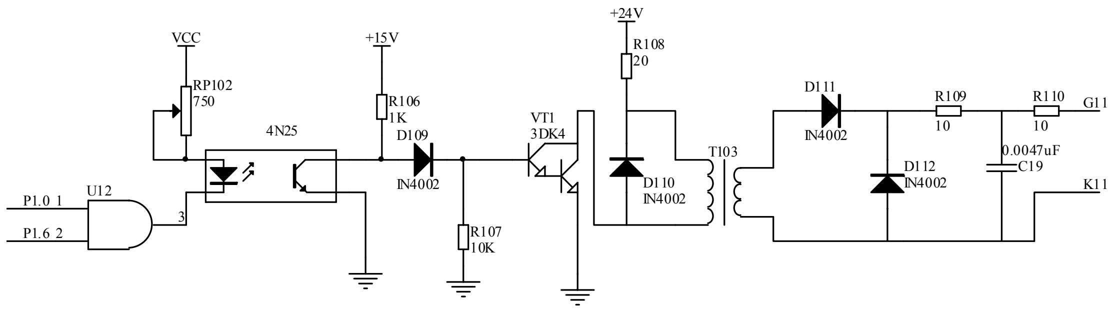

Figure 4. Inverter SCR trigger drive circuit

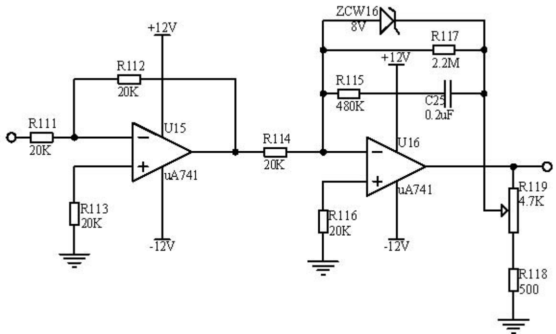

Figure 5. Current Loop conditioning circuits

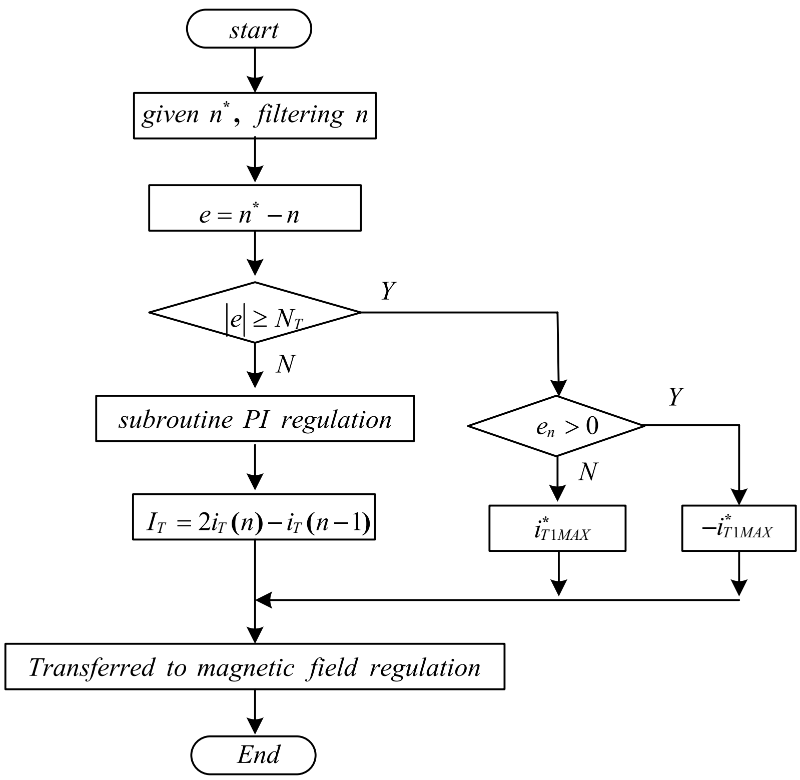

Figure 6. Flux regulation flowchart