

Design and Simulation of PMSM Feedback Linearization Control System

Song Xiao-Jing

Department of Automation Engineering, Zhonghuan Information College Tianjin University of Technology
No.99 LiuKou Road, Yangliuqing Town, Xiqing District, Tianjin, Zip code: 300380, Tel: 022-60541845
e-mail: sxj819@126.com

Abstract

With the theory of AC adjustable speed as well as a new control theory research is unceasingly thorough, the permanent magnet synchronous motor control system requires high precision of control and high reliability of the occasion, access to a wide range of applications, in the modern AC motor has play a decisive role position. Based on the deep research on the feedback linearization technique based on, by choosing appropriate state transformation and control transform, PMSM model input output linearization, and the design of the feedback linearization controller, realized PMSM decoupling control based on Matlab, and PMSM feedback linearization control system simulation. The simulation results show that, the system in a certain range of speed than the traditional PI controller has better control performance, but to the parameter variation has strong sensitivity. It also determines the direction for future research.

Key words: PMSM, Nonlinear, Feedback linearization control

Copyright © 2013 Universitas Ahmad Dahlan. All rights reserved.

1. Introduction

In AC drive system, due to the simple structure, high power, high torque, high power factor and strong advantages of robustness, received extensive attention and permanent magnet synchronous Motors applied to such as CNC machine tools, industrial robots and other precision position control of servo systems. Precise speed control of PMSM, however, because of their speed and nonlinear coupling between current and torque equations nonlinear and has become a very complex issue [1]. Feedback linearization for nonlinear control of a, in the settlement of multivariable nonlinear decoupled control of coupled systems [2] have shown their superiority, In recent years has been successfully applied in high speed AC motor drive system nonlinear.

As we all know, performance and complexity of the model is to a great extent depends on the choice of coordinate system. Feedback linearization for nonlinear system's main objective[4] is to, through appropriate selection of coordinates, determines the appropriate State, the mathematical model of the system relative to the new State or output is linear, or in relation to which both are linear. Specifically using algebraic transformation transforms into a linear dynamic characteristics of a nonlinear system of Dynamics characteristics, so as to simplify the design of controllers to ensure global stability, so it is a global linearized methods. Vector control on the basis of this method is the development of a new type control. The main idea is to first find a transform $u = u(x, v)$ and enter feedback linearization transforms $\xi = \xi(x)$, the dynamics of nonlinear systems equivalent to the equation into a linear time-invariant system of equations, nonlinear model linearized, and then using standard linear control techniques designed to control input. After the linearization of nonlinear systems, the system transforms into a linear system, and without losing system controllability and accuracy. The advantages of this method is that it allows design of linear controller to get a high-performance speed regulating control system, and can implement input decoupling control. And traditional linear method, by feedback linearization technology of linear model is the result of accurate transformation and status feedback in a very wide range of work is effective, traditional linear technology is only valid on the linearization points. However the method is based on the complete elimination of nonlinear system model, parameter uncertainty and interference to systems has a strong sensitivity.

2. Design of PMSM Feedback Linearization Controller

Under $d-q$ coordinate system, mathematical model as shown in the type of PMSM:

$$\dot{x} = f(x) + g_1(x)u_d + g_2(x)u_q$$

In the above formula:

$$x = \begin{bmatrix} i_d \\ i_q \\ \omega_m \end{bmatrix}, f(x) = \begin{bmatrix} -\frac{R_s}{L}i_d + p_n\omega_m i_q \\ -p_n\omega_m i_d - \frac{R_s}{L}i_q - \frac{p_n\psi_f}{L}\omega_m \\ \frac{3}{2J}p_n\psi_f i_q - \frac{T_l}{J} \end{bmatrix}, g_1(x) = \begin{bmatrix} \frac{1}{L} \\ 0 \\ 0 \end{bmatrix}, g_2(x) = \begin{bmatrix} 0 \\ \frac{1}{L} \\ 0 \end{bmatrix},$$

Make $K_C = \frac{3}{2}p_n\psi_f$, $\omega_r = p_n\omega_m$, then

$$\begin{bmatrix} \dot{i}_d \\ \dot{i}_q \\ \dot{\omega}_m \end{bmatrix} = \begin{bmatrix} -\frac{R_s}{L} & p_n\omega_m & 0 \\ -p_n\omega_m & -\frac{R_s}{L} & -\frac{p_n\psi_f}{L} \\ 0 & \frac{3}{2J}p_n\psi_f & 0 \end{bmatrix} \begin{bmatrix} i_d \\ i_q \\ \omega_m \end{bmatrix} + \begin{bmatrix} \frac{u_d}{L} \\ \frac{u_q}{L} \\ -\frac{T_l}{J} \end{bmatrix} \quad (1)$$

In order to achieve the decoupling of the system, selection i_d, ω_r output for the system, define the new output variable[4]: $y_1 = h_1(x) = i_d, y_2 = h_2(x) = \omega_r$, So

$$\dot{y}_1 = \frac{\partial h_1}{\partial x} \dot{x} = L_f h_1 = \dot{i}_d = -\frac{R_s}{L}i_d + \omega_r i_q + \frac{1}{L}u_d,$$

$$\ddot{y}_2 = \ddot{\omega}_r = p_n \ddot{\omega}_m = -\frac{K_C p_n}{JL} (L\omega_r i_d + R_s i_q + \psi_f \omega_r - u_q),$$

$$\ddot{y}_2 = \ddot{\omega}_r = p_n \ddot{\omega}_m = -\frac{K_C p_n}{JL} (L\omega_r i_d + R_s i_q + \psi_f \omega_r - u_q),$$

Based on virtual control: $v_1, v_2, v_1 = \dot{y}_1 = \dot{i}_d, v_2 = \ddot{y}_2 = \ddot{\omega}_r$,

$$\text{So } v_1 = -\frac{R_s}{L}i_d + \omega_r i_q + \frac{1}{L}u_d, v_2 = -\frac{K_C p_n}{JL} (L\omega_r i_d + R_s i_q + \psi_f \omega_r - u_q)$$

and then

$$u_d = Lv_1 + R_s i_d - \omega_r i_q L, u_q = \frac{JL}{K_C p_n} v_2 + L\omega_r i_d + R_s i_q + \psi_f \omega_r \quad (2)$$

The pole assignment for linear systems theory [5] [6] design!! EMBED Equation.3 ¶ ±,!! EMBED Equation.3 ¶ ±:

$$\text{a. !! EMBED Equation.3 ¶ ±} \quad (3)$$

Get the corresponding closed loop control system block diagram is as follows:

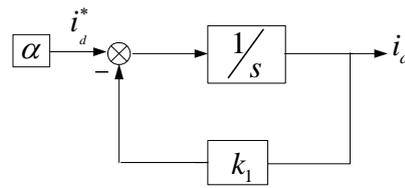


Figure 1. i_d Closed-loop system block diagram

The Closed loop transfer function is:
$$G(s) = \frac{\alpha \cdot \frac{1}{s}}{1 + \frac{k_1}{s}} = \frac{\frac{\alpha}{k_1}}{\frac{1}{s} + 1}$$

Because a typical first-order system closed-loop transfer function is: $\Phi(s) = 1/(T_0s + 1)$, so

$\alpha = k_1$, $k_1 = \frac{1}{T_0}$, substitution of the above equation (3) by: $v_1 = -k_1 i_d + k_1 i_d^* = k_1 (i_d^* - i_d)$.

Take the time to adjust $t_s = 5ms$, cause $t_s = 3T_0$, then $T_0 = \frac{5}{3}ms$ and $k_1 = \frac{1}{T_0} = 600$,

So: $v_1 = 600(i_d^* - i_d)$

b. $v_2 = \ddot{y}_2 = \ddot{\omega}_r = -k_2 \omega_r - k_3 \dot{\omega}_r + \beta \omega_r^*$ (4)

Get the corresponding closed loop control system block diagram is as follows:

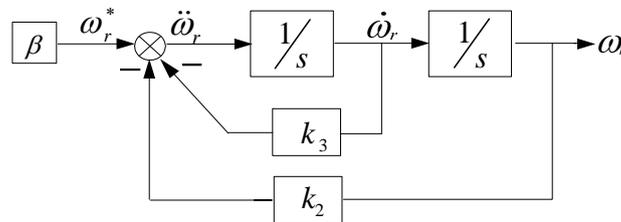


Figure 2. ω_r closed-loop system block diagram

The Closed loop transfer function is:
$$G(s) = \frac{\beta \cdot \frac{1}{s} \cdot \frac{1}{s}}{1 + \frac{k_3}{s} + \frac{k_2}{s^2}} = \frac{\beta}{s^2 + k_3 \cdot s + k_2}$$

Because a typical second order system closed-loop transfer function is: $\Phi(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$,

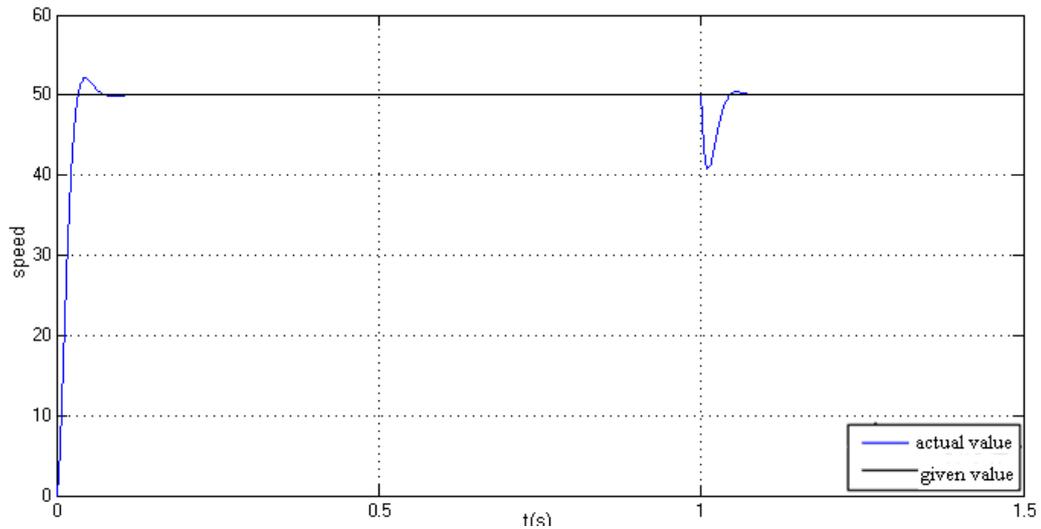


Figure 4. PMSM feedback linearization control of stable operation after mutation load speed simulation waveform

b. No load starting, stable operation after the mutation load, at the same time the motor parameters from time to time: PMSM feedback linearization control $\omega_r = 50 \text{ rad/s}$, $t = 0 \sim 1 \text{ s}$, $T_L = 0 \text{ N}\cdot\text{m}$; $t \geq 1 \text{ s}$, $T_L = 40 \text{ N}\cdot\text{m}$; At the same time the motor stator resistance from normal changes in 0.01, 0.02, the change of parameters before and after the simulation waveforms are shown in figure 5.

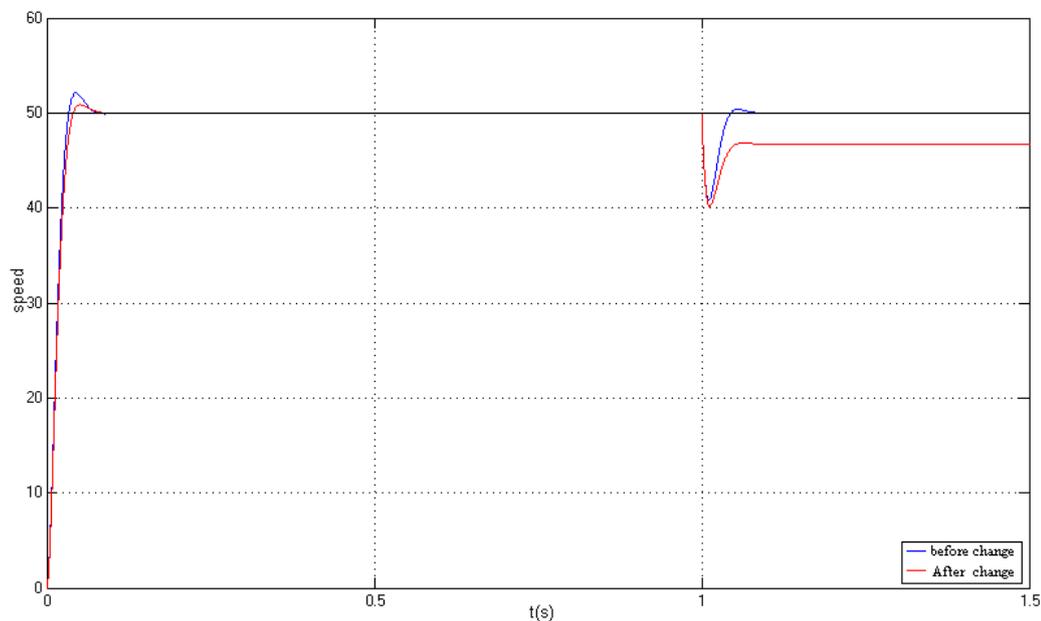


Figure 5. PMSM feedback linearization control of stable operation after stator resistance parameter uncertainty speed simulation waveform

Visible feedback linearization method after the motor unloaded and stable operation, load noise immunity performance is better when all of a sudden. However, when the speed of the motor parameters time output waveform has changed, overshoot significantly increased, the controller immunity capabilities are greatly weakened, after the abrupt load, rotational speed

output does not track properly given. Visible feedback linearization control method on the parameter dependence of the more traditional control methods is stronger, with a strong sensitivity to parameter changes.

4. Conclusion

This article on traditional design control method of PMSM [8] based on application of feedback linearization control method, to coordinate transformation and status feedback, the motor current and angular velocity to achieve decoupling, thereby achieving linear motor control system. Final adoption of the method of simulation and experimental analysis of the advantages and disadvantages, the advantages of this method is that it allows design of linear controller to get a high-performance speed regulating control system, and can implement input decoupling control. Since this method is based on the complete elimination of nonlinear system model, so the system wide speed regulation range, fast response, steady-state error is small. Disadvantages to strong dependence on parameters of the system, has a strong sensitivity to parameter changes. This is the system currently remaining deficiencies.

References

- [1] J Zhou and Y Wang. Adaptive Backstepping Speed Controller Design for a Permanent Magnet Synchronous Motor. In *IEE Proceedings on Power Applications*. 2002.
- [2] Long Yi, Zhu Xiao-dong. Nonlinear control of permanent magnet linear synchronous motor servo systems. *Micro-motors*. 2007; 40(2): 23~25.
- [3] Zhang Run and, Liu Yong-he, Cui Li-li. Permanent magnet synchronous motor servo system based on direct feedback linearization control. *Micro motor*. 2006; 12: 26~30.
- [4] Xia Yi, Qu Bai-da, Xu Bao-guo. Nonlinear control of permanent magnet synchronous motor based on feedback linearization. *Journal of Southern Yangtze University*. 2007; 6(1): 1~3.
- [5] Du Juan, Xu Qiang, Jia Zheng-chun. Feedback linearization control of permanent magnet synchronous motor. *Motor technology*. 2002; 2: 2~4.
- [6] Xuesong Yan, Qinghua Wu, Hammin Liu. An Improved Robot Path Planning Algorithm Based on Genetic Algorithm. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2012; 10(8).
- [7] Hu Shou-song. *Principle of automatic control. The fourth edition*. Beijing: Science press, 2001.
- [8] Doaa M Atia, Faten H Fahmy, Ninet M Ahmed, Hassen T Dorrah. A New Control and Design of PEM Fuel Cell System Powered Diffused Air Aeration System. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2012; 10(2).