Simulation of PMSM Vector Control System with Fuzzy Self-Adjusting PID Controller Using MATLAB

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Abstract- The mathematical model of PMSM, using the powerful simulation modeling capabilities of Matlab/Simulink is implemented. The entire PMSM control system is divided into several independent functional modules such as PMSM body module, inverter module and coordinate transformation module and SVPWM production module and so on. The simulation model of the PMSM control system can be obtained by combining these modules. The main advantage of SIMULINK over other programming softwares is that, instead of compilation of program code, the simulation model is built up systematically by means of basic function blocks. With the simulation of the motor, we can analyse a variety of simulation waveforms and it provide an effective means for the analysis and design of the PMSM control system.

Index Terms- PMSM, SVPWM, Vector control, Fuzzy Logic Controller

I. Introduction

With the development of permanent magnetic materials and control technology, permanent magnet synchronous motor (PMSM) is mostly used due to high torque/inertia ratio, high power density, high efficiency, reliability and ease for maintenance, and is used in CNC machine tools, industrial robots and so on. The establishment of the simulation model of PMSM and its control system is of great significance to the verification of a variety of control algorithms and the optimization of entire control system. To achieve high performance, the vector control of the PMSM drive is employed.

The analysis of mathematical model of PMSM, with the powerful simulation modeling capabilities of Matlab/Simulink, the PMSM control system will be divided into several independent functional modules such as PMSM motor module, inverter module and coordinate transformation module and SVPWM production module and so on. By combining these modules, the simulation model of PMSM control system can be built.

The main advantage of SIMULINK over other programming softwares is that, instead of compilation of program code, the simulation model is built up systematically by means of basic function blocks. Through the simulation of the motor, we can analyse a variety of simulation waveforms and it provide an effective means for the analysis and design of the PMSM control system.

II. PERMANENT MAGNET SYNCHRONOUS MOTOR

A permanent magnet synchronous motor (PMSM) is a motor that uses permanent magnets to produce the air gap magnetic field rather than using electromagnets. These motors have significant advantages, attracting the interest of researchers and industry for use in many applications.

A.THE MATHEMATICAL MODEL OF PMSM

Detailed modeling of PM motor drive system is required for proper simulation of the system. The d-q model has been developed on rotor reference frame as shown in figure 1. At any time t, the rotating rotor d-axis makes an angle θr with the fixed stator phase axis and rotating stator mmf makes an angle α with the rotor d-axis. Stator mmf rotates at the same speed as that of the rotor.

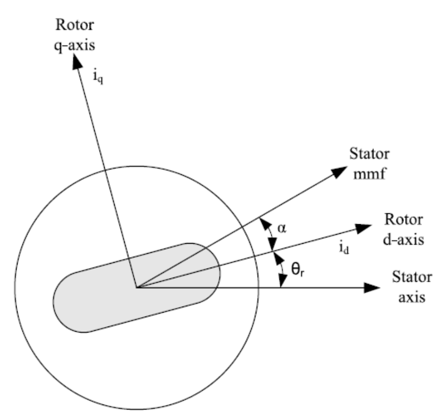

Figure 1: Motor Axis

The model of PMSM without damper winding has been developed on rotor reference frame using the following assumptions:

1) Saturation is neglected.
2) The induced EMF is sinusoidal.
3) Eddy currents and hysteresis losses are negligible.
4) There are no field current dynamic

B.STEPS TO PERFORM VECTOR CONTROL

1. Measure the motor quantities (phase voltages and currents).

2. Transform them to the 2-phase system (α ,β) using a Clarke transformation.
3. Calculate the rotor flux space vector magnitude and position angle.
4. Transform stator currents to the d-q coordinate system using a Park transformation.
5. The stator current torque- (i_{sq}) and flux- (i_{sd}) producing components are separately controlled.
6. The output stator voltage space vector is calculated using the decoupling block.
7. An inverse Park transformation transforms the stator voltage space vector back from the d-q coordinate system to the 2-phase system fixed with the stator.
8. Using the space vector modulation, the output 3-phase voltage is generated.

III. SPACE VECTOR PULSE WIDTH MODULATION

A. PRINCIPLE

SVPWM tries to output a sine-wave, supplying power, whose three parts are balanced and whose frequency and voltage can be adjusted. Its controlling principle is to try to decrease output harmonic components. Three- phase windings of the motor can define a three phase static coordinate system. It has three axes. The phase voltage of three-phase stator Ua, Ub and Uc are on three-phase windings, and form three phase votage vector Ua, Ub and Uc. Their directions are on their own axis and their volumes change with time in accordance with the sine regulation. Therefore, all three phase voltage space vector form a total voltage space vector u, which is a space vector circulating at the speed of power angle frequency ω.

Motor can be controlled by making use of the opening and closing condition and the orders of the inverter power and by modulating the time of opening and closing. Different combinations of switch tube constitute eight space voltage vectors, six of which are non-zero voltage vectors and the other two are zero vectors. After Clark transforming, phase voltage in the three-phase ABC plane coordinate system can be changed into αβ right-angled coordinate system.

IV. FUZZY SELF-ADAPTING PID CONTROLLER

The fuzzy self-adapting PID controller is adopted in speed loop instead of the traditional PI controller. The PI controller is used in current loop in the PMSM two closed loops control system. The fuzzy inference of fuzzy self-adapting PID controller is based on the fuzzy rule table set previously. So the algorithm of fuzzy inference is not complex. The parameters of PID can system be adjusted on-line, which can be changed through the inquiry to fuzzy control rules table saved aforehand in the computer. The calculation speed of controller is very quick, which can satisfy the rapid need of controlled object.

V. SIMULATION MODEL OF PMSM VECTOR CONTROL SYSTEM

The PMSM control system mainly includes: PMSM body module, inverter module, coordinate transformation module and SVPWM production module.

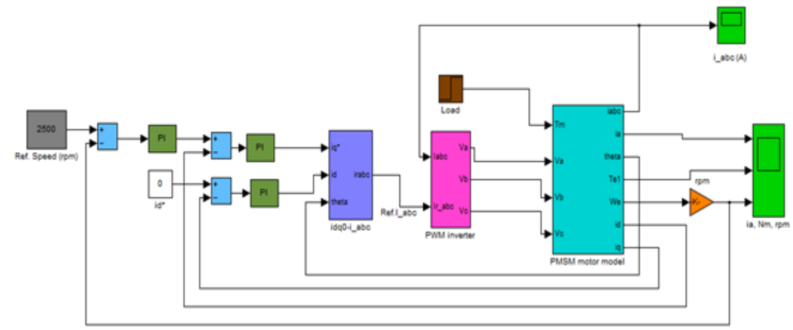

Figure 2: Simulation Block of PMSM Vector Control Block using PI controller

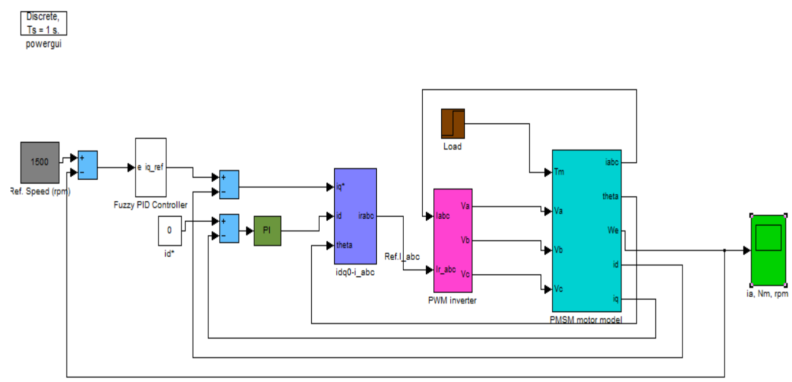

Figure 3: Simulation Block of PMSM Vector Control Block using Fuzzy Logic Controller

In this paper, different controllers for PMSM is used and the following results are obtained;

The MATLAB software is used in entire system simulation. Simulink is the simulation tool in the MATLAB, which can provide us with the function block. So the simulation analysis time can be saved and the design work can be reduced. The fuzzy self-adapting PID controller can be designed conveniently using the Fuzzy Logic Toolbox of MATLAB. The FIS editor can be opened by the input command FUZZY in the MATLAB. The membership function of every input and output variable are established in the FIS editor. The rules are formed. At last the whole system simulation block diagram is constructed.

The simulation waveform without using any controller is shown in figure 10.1. The simulation waveform when using traditional PI controller in speed and current loop is shown in figure 10.2. The response curve for speed when using fuzzy self-adjusting PID controller is shown in figure 10.3. Comparing the other two waveforms with the simulation waveform when using the fuzzy self-adjusting PID controller shows that, the fuzzy self-adjusting PID control has better dynamic and static performance, and has less rise time, less transition and smaller overshoot.

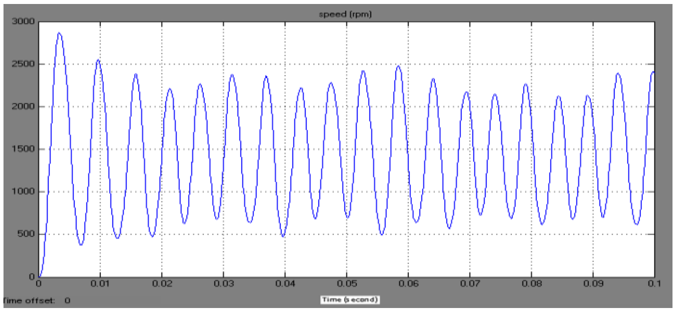

Figure. 4: Simulation waveform without using controller

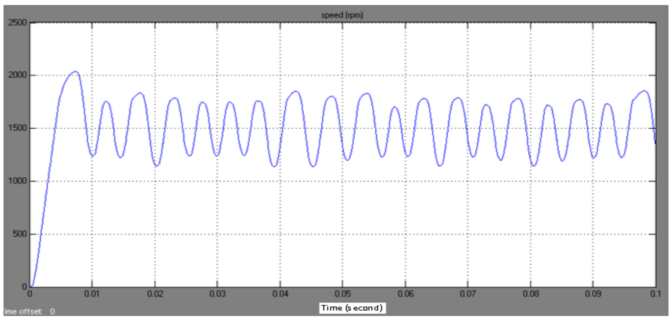

Figure 5: Simulation waveform when using traditional PI controller

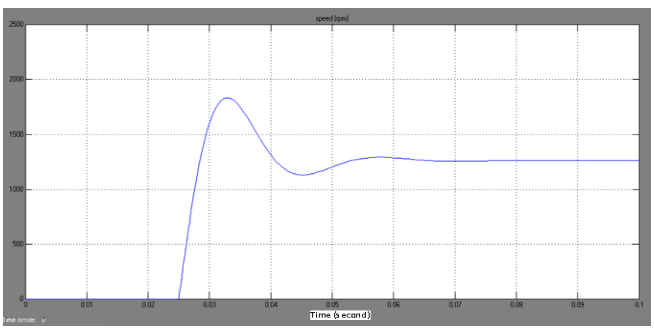

Figure 6: Simulation waveform when using fuzzy self-adjusting PID controller

VI. CONCLUSION

The PMSM servo system is a nonlinear time-varying complex system. The results of traditional PI control is not satisfactory to the higher degree of accuracy condition. The fuzzy control syatem has the prominent advantage in complex, time lag, time varying and non-linear system control and the mathematical model of the controlled object is not required.

The fuzzy-PID controller has the advantages of both PID control and fuzzy control, so it can get better control performance. The controller is used as the speed controller in PMSM control system, which can adjust the controller parameters on-line according to the speed error and the derivative of speed error change.

Based on the rotor field oriented control of permanent magnet synchronous motor, the simulation model of PMSM control system is established using Simulink toolbox of Matlab. The simulation results show that, the system can run smoothly and still it has perfect dynamic and static characteristics for a speed of 1500 rpm and the fuzzy self-adapting PID controller have less regulating time and it is stronger, robust compared to the traditional PI controller.

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