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APPLICATION OF VECTOR CONTROL TECHNIQUE TO AC MOTORS

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ABSTRACT

The position-sensor less vector control simulation by observer using optimal feedback gain as an example of process from algorithm design to logic verification, using MATLAB/Simulink is presented in the paper. The same technique can be also applied to other motor type (e.g, PMSM).

However, some of the control methods representing flux-weakening control, one of the highly efficient control methods of IPMSM, should consider hysteresis characteristics by magnetic saturation.

Keywords: *vector **control**, AC motors, optimal feedback*

INTRODUCTION

This paper demonstrates that MATLAB/Simulink is a tool suitable for vector control (2) of AC Motors. In vector control, accuracy of internal parameter such as resister of motor armature and inductance affects control performance. Internal parameters are used, for example, feed-forward compensator of current controller and parameters of observer model in position sensorless (1).

VECTOR CONTROL MODEL

Vector Control Basic principles

Basic principles of vector control are discussed here for modeling description. The armature current " I " of three phase AC motors(3)can be observed as rotating vector by power supply angular velocity.

System Modeling

It is important to determine accurate flux vector in induction motors. Some of the methods to detect flux vector include direct detection, where magnetic sensor by hall element is used, and indirect detection, where slip angular frequency is added to the detected rotating angular velocity. Here, we consider a model that estimates flux vector and rotating angle using flux observer. This is one of the sensorless methods that do not require magnetic and positionsensors.

Transformation	Equation
From fixed coordinate to rotating coordinate	$\underline{i}^e = C\underline{i}$
From rotating coordinate to fixed coodinate	$\underline{v} = C^T\underline{v}^e$
From three phase to two phase	$\underline{i}_2 = D\underline{i}_3$
From two phase to three phase	$\underline{v}_3 = D^T\underline{v}_2$

Where:

Rotary matrix: $C = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix}$,

three-phase to two-phase transformation matrix: $D = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos 0 & \cos(2\pi/3) & \cos(4\pi/3) \\ \sin 0 & \sin(2\pi/3) & \sin(4\pi/3) \end{bmatrix}$

Where, *v* denotes vector, *e* denotes direct-current value, *T* denotes transpose, subscript 2 denotes two-phase, 3 denotes three-phase.
This can be modeled by mathematical formula definition of Fcn block in Simulink.

Usage of SimPowerSystems

Motor, PWM Generator and Inverter of carrier wave comparison can be modeled by using Simulink. If time saving of modeling is desirable, SimPowerSystems, Simulink's extended option can be used. Synchronous Motor, Induction Motor Drive, DC Motor and others modeling can be prepared in the blocklibrary.

VELOCITY SENSORLESS BYADAPTIVE SECONDARY FLUX OBSERVER

Model Analysis and Principle

Rotor flux should be estimated if the same input voltage as the actual input is applied to the mathematical model simulator that is implemented on the processor. However, when constructing velocity sensorless system, changes of nonstationary velocity term can not be made by actual velocity sensor output, and the estimated value of flux will deviate from the actual value. So, adaptive observer that modifies incorrect constant term of mathematical model with function of the output deviation is applied. In this case, the terms of electric angular velocity are regarded as the incorrect terms. State-space expression of induction motor in orthogonal two axis fixed coordinate system can be expressed in the equation below:
dx dt Ax Bv i Cx
Then, consider feedback system comprising linear time-invariant block G(s) and nonlinear time variation block. Applying Popov's hyper stability, the following needs to be satisfied to ensure stability, limit> 0
1) linear time-invariant block G(s) is SPR (Strictly PositiveReal).
2) input, v1, and output, w1, of nonlinear time variation block satisfy Popov's equation for all timet1>t0.

Modeling of Observer

Parameters of motor and each matrix of state-space expression are defined in program (M-file) of MATLAB language, and formula is solved using the Control System Toolbox, and optimal feedback is obtained. A program example is shown as follows:
Feedback gain is obtained in the last line.
[H, P, E] = lqe(A, Bw, C, Q, R)
The lqe is a function provided for designing Kalman filter estimator in Control System Toolbox. It returns feedback gain, H, solution of Riccati equation, P, and pole of estimator, E=eig(A-H*C). Once executed, M-file is loaded onto memory (workspace) in MATLAB, and defined as each block parameter of Simulink model. Model example is inside the subsystem of adoptive observer. The key to the modeling is to separate and add the nonstationary term

SIMULATION RESULTS

This model includes PI gain that requires tuning for velocity controller, current controller and velocity estimator. Each control parameter is tuned by trial-and-error from response results of simulation.(Refer to reference 1) for design method of parameter proportional gain, Kp, integrator gain, K1 of velocity estimator. Fig.1 illustrates simulation results from 0 to 1.5 seconds. 0 to 0.5 seconds show velocity step response when velocity reference value is changed from 0[rpm] to 1000[rpm], 0.5 to 1.0 show velocity step response of 1000[rpm] to 500[rpm],and 1.0 to 1.5 show torque step response when external load torque is changed from 1[N] to 50[N]. Voltage between inverter UVs, armature current, rotating velocity, and transient response of torque are simulated.

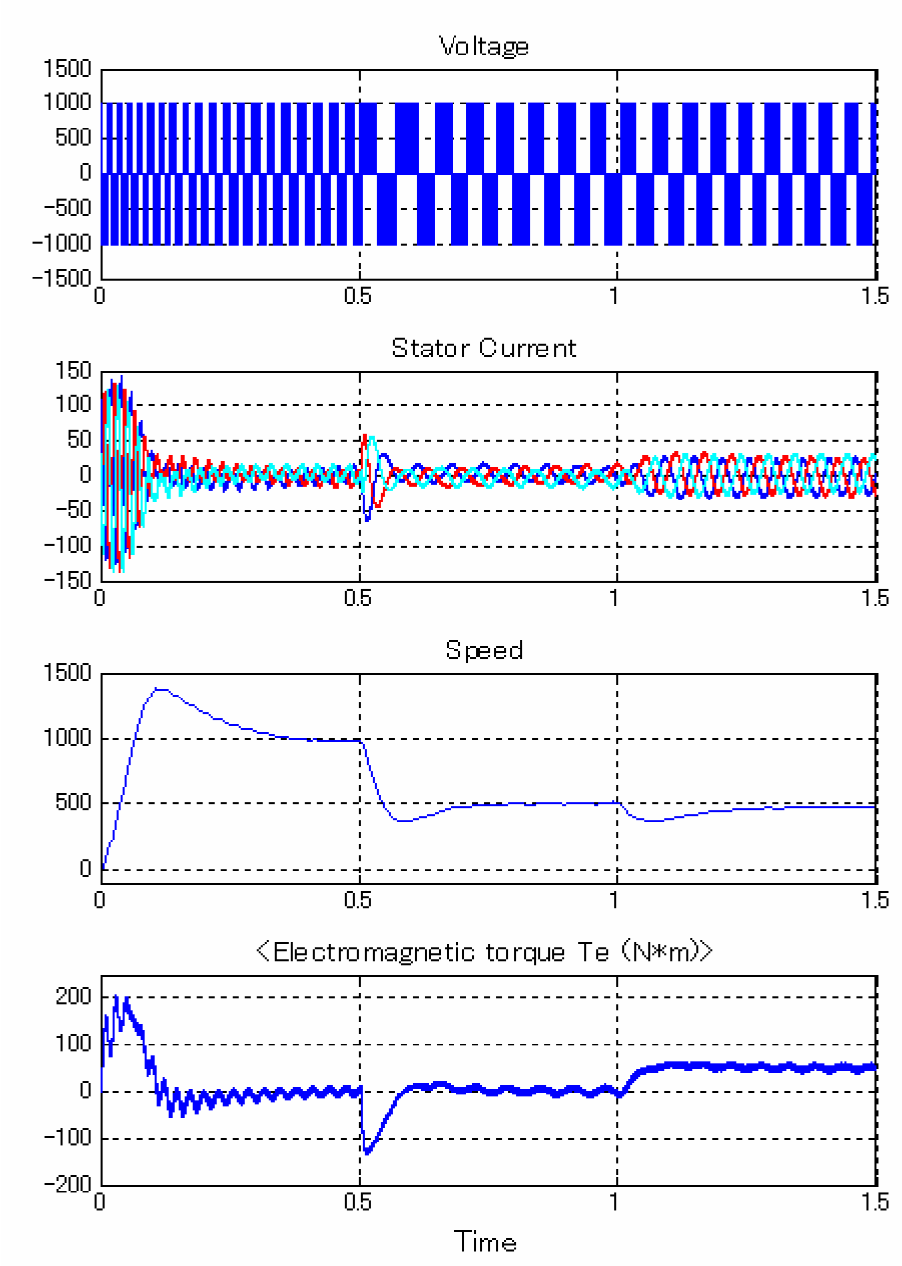

Fig.1 simulation results

CONCLUSION

This paper presents position-sensor less vector control simulation by observer using optimal feedback gain as an example of process from algorithm design to logic verification, by using MATLAB/Simulink. The same can be also applied to other motor type (e.g, PMSM).

However, some of the control methods representing flux-weakening control, one of the highly efficient control methods of IPMSM, should consider hysteresis characteristics by magnetic saturation.

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