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AN205403

Inverter Platform Rotor Position For PMSM Motors

This application note explains the process of estimating commutation angle (θ) and motor speed (ω). Motor position and speed are estimated based on measured currents and calculated voltages.

Contents

1 Introduction

This application note describes rotor position have three part:

1. Base technology.
2. Position estimate.
3. Speed estimate.

2 Base technology

Base technology about sensor less field oriented control for PMSM motors

2.1 Overview

This application note part use to explain the process of estimating commutation angle (θ) and motor speed (ω).Motor position and speed are estimated based on measured currents and calculated voltages.

2.2 Motor Formula

Well-known, the PMSM Motor can using a DC-motor represent, the formula:

$$\mathbf{v_s} = \boldsymbol{R}\mathbf{i_s} + \mathbf{L}\frac{\mathbf{d}}{\mathbf{dt}}\mathbf{i_s} + \mathbf{e_s}$$

Solving for is:

$$\mathbf{i_s}(\boldsymbol{n}+\mathbf{1}) = \boldsymbol{F} * \mathbf{i_s}(\mathbf{n}) + \mathbf{G} * (\mathbf{v_s}(\mathbf{n}) - \mathbf{e_s}(\mathbf{n}))$$

F: $\mathbf{1} - \mathbf{T_s}\frac{\mathbf{R}}{\mathbf{L}}$ G: $\frac{\mathbf{T_s}}{\mathbf{L}}$

2.3 Constant

In this formula we can know the parameters about F and G calculate from motor, they can be deemed to as constant. For example, a motor running at 10kHz control frequency, and at the motor nameplate line to line resistance measured is 4.0Ω, and line to line inductance is 8 mH, then the motor model parameters are:

$$\mathrm{F} = 1 - \mathrm{T_s}\frac{\mathrm{R}}{\mathrm{L}} = 1 - \left(\frac{1}{10\mathrm{kHz}}\right) * \frac{4\Omega/2}{8\mathrm{mH}/2} = 0.95$$

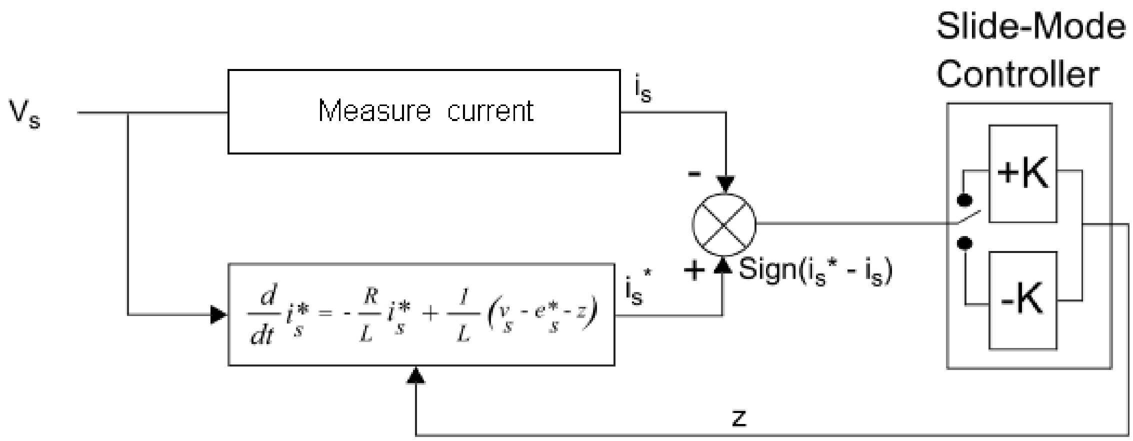
$$\mathrm{G} = \frac{\mathrm{T_s}}{\mathrm{L}} = \frac{(1/10\mathrm{kHz})/2}{8\mathrm{mH}/2} = 0.0125$$

2.4 Current (is)

Here have two parts, one is the measured current(hardware),another is the estimated current(software) , in order to match measured current and estimated current, the digitized motor model needs to be corrected using the closed loop. Show in Figure 1

The same input (vs) fed into both systems, and matching the measured current (is) with estimated current (is*) from the model.

Figure 1

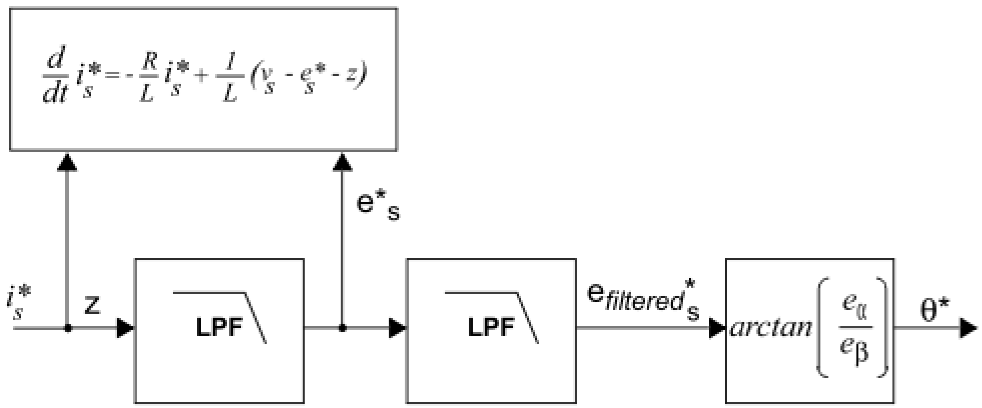


2.5 Back-EMF (es)

In a PMSM, the rotor flux is locked to the rotor position, it can also be measured indirectly from the motor back-EMF sine this is a function of the rotor position and speed.

The back-EMF estimation (es*) is fed back to the model to update the variable es* after every control cycle. Values eα and eβ (vector components of es) are used for the estimated theta calculation.

Figure 2.



Through the back-EMF filter, we can output smoother signal.

The output of the first filter is used in two blocks. The first block is the model itself, used to calculate the next estimated current (i_s*), and also to calculate the estimated theta (θ_*). A second, first-order filter is used to calculate a smoother signal coming out of the motor model.

3 Position estimate

Relationship between Back-EMF and Rotor Position

In the Figure 2 ,the theta is calculated use the formula:

$$\boldsymbol{\theta} = \boldsymbol{arctan}\,(\boldsymbol{e_\alpha}\,, \boldsymbol{e_\beta})$$

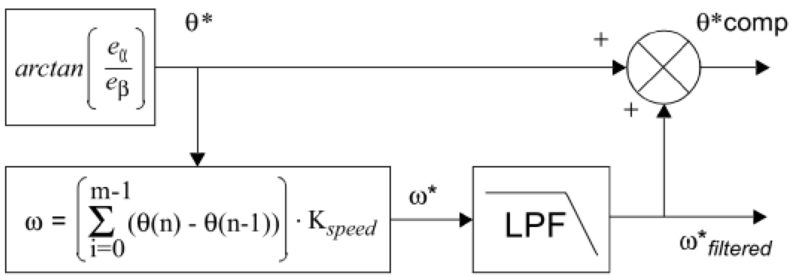
The relationship between e_s and θ can be explained based on the formula. The vector of the back-EMF e_s can be analyse into e_α , e_β, and rotor angle (θ). Arctangent is computed on the back EMF vector components to calculate theta.

4 Speed estimate

After calculated the θ, some phase compensation is needed before the calculated angle is used to energize the motor windings. The amount of theta compensation depends on the rate of change of theta, or speed of the motor. So calculated need:

1. the speed of the motor is calculated based on the uncompensated theta calculation.
2. the calculated speed is filtered and used to calculate the amount of compensation, as shown in Figure 3

Figure 3



Speed is calculated by accumulating theta values over samples and then multiplying the accumulated theta by a constant.

$$\boldsymbol{\omega} = \sum_{i=0}^{m} (\boldsymbol{\theta}_n - \boldsymbol{\theta}_{n-1}) * \boldsymbol{K}$$

Omega (ω) = Angular velocity of the motor

Theta (θn) = Current Theta value

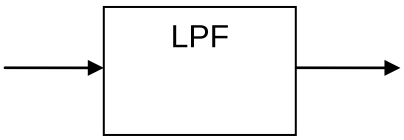
Prev Theta (θn-1) = Previous Theta value

K = Amplification factor for desired speed range

m = Number of accumulated Theta deltas

5 LPF Theory

In slide mode controller algorithm, we use LPF (low pass filter) technology to get angle of rotor. Below is the principle of LPF.



Where,

X is the input of low pass filter

Y is the output of low pass filter

$Y(n) = Y(n-1) + T*2\pi f_c*(X(n) - Y(n-1))$ (6)

In our actual system, we will get:

$e(n) = e(n-1) + T*2\pi f_c*(z(n) - e(n-1))$ (7)

Where,

e (n) is next time BEMF,

e (n-1) is last time BEMF

f_c is the cutoff frequency

Z (n) is the unfiltered BEMF

6 Document History

Document Title: AN205403 - Inverter Platform Rotor Position for PMSM Motors

Document Number: 002-05403

Revision	ECN	Orig. of Change	Submission Date	Description of Change
**	—	CBZH	03/16/2010	Initial release
			04/10/2010	Added LPF function
*A	5043107	CBZH	12/17/2015	Converted Spansion Application Note “MCU-AN-510119-E-20” to Cypress format
*B	5717937	AESATP12	04/28/2017	Updated logo and copyright.

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