8 Implementation Of Field Oriented Control in DSP

Since a lot of nonlinear elements such as multipliers, function generators, etc. are essential to perform the signal processing necessary for indirect field orientation, analog electronic system becomes expensive and difficult to adjust. Therefore a digital implementation is the only feasible solution and is a practical proposition with current trends in Digital Signal Processors and Vector Processors. This carries with it all the advantages of digital control by software. The implementation of the scheme using Digital Signal Processor and Vector Processor is discussed here.

As a first step towards digital signal processor - DSP control, it is necessary to digitize the various analog signals. This requires that the necessary resolution in amplitude and the sampling rate be fixed. In the case of amplitude resolution, the use of 12 bit A/D converters is adequate for analog signals from the motor such as speed and current. Only in exceptional cases is a higher resolution required. The DSP from Analog Devices ADSP 2101 provides sufficient digital word length for this resolution. The digital to analog converters are again of 12 bit resolution. The sampling rates, however, cannot be the same for all the control processes and have to be selected depending on the nature of the signals being processed.

Basically there are three main control functions in an induction motor speed control system :

- Torque Control

- Speed Control

- Flux Control.

In a position control application, there will be an additional position loop. Of the three control functions, torque control requires the sensing of stator currents which may vary at frequencies of upto 200 Hz for a 50 Hz motor with field weakening operation. Therefore the sampling rate is the highest for torque control. The speed control loop should have a next lower sampling rate with flux control function at a possibly slower rate.

eg.
Sampling rates for torque control at 5 kHz includes following functions

- AD Conversion
- update of flux model
- transformation to field coordinates
- torque control
- transformation of reference currents from field to stator coordinates.
- output of stator current reference

Sampling rates for Speed Control at 500 Hz include following functions

- flux control including field weakening
- speed control

Where a position encoder is used for sensing speed/position, the sampling rate has to be varied with speed. The use of an absolute encoder is preferable for sensing speed and position as it removes any ambiguity regarding initial position.

With such a high sampling rate, control loops can be treated as continuous time systems. As the induction motor has become decoupled and linearised to a considerable extent due to field orientation, familiar methods used in conjunction with **DC** drives can be used in the design of controllers.

A block diagram of an induction motor drive with a DSP and Vector Processors is shown in *figure* 7.9. Using normalised variables and Vector Processors through out reduces the need for complex floating point DSPs and a fixed point DSP like a 2101 can suffice.

The software needs to be organised in such a way that torque control gets the highest priority.

Usually the controllers are all of PI type :

$$u(t) = k_p\, e(t) + k_i \int e(t)dt$$

$$x(t) = \int_{t_0}^{t} e(t)dt + x(t_0)$$

The digital realisation for a DSP PI controller is as follows :

$$x(kT) = T/2\ \{e(kT) + e[(k-1)T]\} + x(k-1)T$$

$$u(kT) = k_p\ e(kT) + k_i x(kT)$$

using trapezoidal rule for integration.

Consider the drive block diagram give in *figure* 7.9. Assuming that the torque, speed and flux controllers are of the PI type and also that the sampling rates for torque, speed and flux are T_0, T_1, and T_2 respectively, the computations required to be performed in each loop are listed below.

8.1. Computations For Machine Model

$$i_{sa}(kT_0) = (3/2)i_{s1}(kT_0)$$

$$i_{sb}(kT_0) = (\sqrt{3}/2)(i_{s2}(kT_0) - i_{s3}(kT_0))$$

$$\rho(kT_0) = \rho((k-1)T_0) + T_0 * \omega_{mr}(k-1)$$

$$i_{ds}(kT_0) = i_{sa}(kT_0) \cos \rho(kT_0) + i_{sb}(kT_0) \sin \rho(kT_0)$$

$$i_{qs}(kT_0) = i_{sb}(kT_0) \cos \rho(kT_0) - i_{sa}(kT_0) \sin \rho(kT_0)$$

$$x(kT_0) = (1/T_r)(i_{ds}(kT_0) - i_{mr}((k-1)T_0)$$

$$i_{mr}(kT_0) = (T_0/2) * \{x(kT_0) + x((k-1)T_0)\} + i_{mr}((k-1)T_0)$$

$$M_d(kT_0) = (\text{const}) * i_{qs}(kT_0) * i_{mr}(kT_0)$$

$$\omega_2(kT_0) = i_{qs}(kT_0)/(T_r * i_{mr}(kT_0)$$

$$\omega_{mr}(kT_0) = \omega(kT_0) + \omega_2(kT_0)$$

8.2. Torque Loop Computations

Torque Error $M_{de}(kT_0) = M_{dref}\,(kT_0) - M_d(kT_0)$

$x_m(kT_0) = x_m((k-1)T_0) + T_0/2)*(M_{de}(kT_0)+M_{de}(k-1)T_0)$

$i_{qsref}(kT_0) = k_{pm}*m_{de}(kT_0) + k_{im}*x_m(kT_0)$

$i_{saref}(kT_0) = i_{dsref}(kT_0)\cos\rho(kT_0) - i_{qsref}(kT_0)\sin\rho(kT_0)$

$i_{sbref}(kT_0) = i_{dsref}(kT_0)\sin\rho(kT_0) + i_{qsref}(kT_0)\cos\rho(kT_0)$

$i_{s1ref}(kT_0) = (2/3) * i_{saref}(kT_0)$

$i_{s2ref}(kT_0) = -(1/3)i_{sbref}(kT_0) + (1/\sqrt{3})i_{sbref}(kT_0)$

$i_{s3ref}(kT_0) = -(1/3)i_{saref}(kT_0) + (1/\sqrt{3})i_{sbref}(kT_0)$

8.3. Speed Loop Computations

Speed Error $\omega_e(kT_1) = \omega ref(kT_1) - \omega(kT_1)$

$x_s(kT_1) = x_s((k-1)T_1) + T_1/2 * (\omega_e(kT_1) + \omega_e((k-1)T_1)$

Speed Controller Output

$M_{dref}(kT_1) = k_{ps} * \omega_e(kT_1) + k_{is} * x_s(kT_1)$

8.4. Flux Loop Computations

if $\omega(kT_2) > \omega_{base}$
then $i_{mrref}(kT_2) = i_{mrmax} * \omega_{base}/\omega(kT_2)$
else
$i_{mrref}(kT_2) = i_{mrmax}$

Magnetizing current error

$i_{mre}(kT_2) = i_{mrref}(kT_2) - i_{mr}(kT_2)$

$x_f(kT_2) = T_2/2 * (i_{mre}(kT_2) + i_{mre}((k-1)T_2)) + x_f((k-1)T_2)$

$i_{dsref}(kT_2) = k_{pf} * i_{mr}(kT_2) + k_{if} * x_f(kT_2)$

8.5. Summary

The basic principle of field oriented control of a squirrel cage induction motor was developed assuming controlled current PWM inverter. Considerations for implementations using DSP and Vector Processors have been outlined.

The assumptions of constant current supply are usually not valid at high speeds where the inverter ceiling is reached and the **DC** bus voltage cannot force current against the back *emf* of the motor. Further, in the case of high power thyristor inverters operating at switching frequencies of a few hundred hertz, it can no longer be assumed that a current of any value can be instantaneouly forced into the stator windings. In such cases, the inverter becomes a voltage source rather than a current source. In this case also the technique of field orientation can be applied.

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