5 Implementation In DSP

5.1. Introduction

Vector control needs a lot of nonlinear elements such as multipliers, function generators etc. Implementing them in analog hardware is expensive and makes tuning difficult. Therefore a digital implementation is a practical proposition. The implementation of the scheme using Digital Signal Processor and AC Vector Processor is discussed here.

PROCESSOR

The computations required by the controller are done by ADSP-2101. A processor of that calibre is a perforce requirement because of the computations involved. ADSP-2101, with its high throughput, proves to be an ideal choice for this application as will be seen later in this chapter.

The controller is implemented in software which runs on ADSP-2101. The controller comprises the following modules

- Speed Loop
- Flux Loop
- Current Loops

The speed and the current loops are intrinsically PI controllers. Flux loop is a function generator.

5.2. Speed Loop

Speed loop takes the speed error(difference between the reference speed and the actual speed) as input. This error signal is passed through a PI controller. The output of this PI element is the reference torque to be developed by the motor.

This is divided by the torque sensitivity to get the q-axis current reference. In addition the limiting of torque as well as current references is done.

Mathematically, the speed loop does the following

Speed Error (input to the speed loop) is determined as

$$\omega_e(kT) = \omega_r^*(kT) - \omega_r(kT)$$

Torque Reference is computed as

$$M_{dref}(kT) = Ks\ \omega_e(kT) + (Ks/Ts)T\ \Sigma\omega_e(nT)$$

The reference torque is limited to TUL if it exceeds the same. TUL is given by

if $\omega(kT) \le \omega_{rb}$,
TUL = Rated Torque

else
TUL = Rated Torque ($\omega r(kT)/\omega_{rated}$)

The q-axis current reference (output of speed loop) is calculated as

$iqs^*(kT) = M_{dref}(kT) / K_T$

5.3. Flux Loop

The flux loop is basically a function generator. The flux loop takes the actual speed as reference and gives the d-axis current reference as output. The mathematical relation between the input speed and the output d-axis current is as follows.

if $\omega_r(kT) \leq \omega_{rb}$,
$i_{ds}{}^*(kT) = 0$
else
$i_{ds}{}^*(kT) = [K_E/((P/2)L_s)](1-\omega_r(kT)/\omega_{rb})$

5.4. Current Loops

If the inverter used is a Voltage Controlled Inverter, as is mostly the case, the current references generated by the speed and the flux loops need to be converted into voltage references. The current loops do this conversion. There are two current loops, *viz.* IDS LOOP and IQS LOOP, each controlling one of the two components of the current.

IDS LOOP

This loop takes the error in direct component of current as input and gives out the d-axis voltage reference. To the output of the IDS Loop PI controller, compensation voltage is added. This is necessary to compensate for the effect of q-axis component in the d-axis voltage - cross coupling.

The computations involved are as follows.

The error in i_{ds} is found as

$i_{ds\,e}(kT) = i_{ds}{}^*(kT) - i_{ds}(kT)$

The direct component voltage reference is computed as

$u_{ds}{}^*(kT) = kid\ i_{ds\,e}(kT) + (kid/Tid)T\ \Sigma\ i_{ds\,e}(nT)$

The compensation voltage to be added, as given by equation, is

$= -\omega_s L_s i_{qs}(t)$

IQS LOOP

This loop takes the error in direct component of current as input and gives out the q-axis voltage reference. To the output of the IQS Loop PI controller, compensation voltage is added. This is necessary to compensate for the effect of d-axis component in the q-axis voltage - cross coupling.

The computations involved are as follows.

The error in i_{qs} is found as

$i_{qs\,e}(kT) = i_{qs}^{*}(kT) - i_{qs}(kT)$

The quadrature component voltage reference is computed as

$u_{qs}^{*}(kT) = kid\ i_{qs\,e}(kT) + (kiq/Tiq)T\ \Sigma\ i_{qs\,e}(nT)$

The compensation voltage to be added, as given by equation, is

$= \omega_s\ L_s\ i_{ds}(t) + K_E\ \omega_r(t)$

5.5. Feedback Signals

The feedback signals required by the vector controller are

- Position
- Velocity
- Currents

Position

The rotor position feedback is given by the resolver. A resolver to digital converter - AD 2S82A is used to convert the resolver signals to the digital position.

Velocity

The velocity of the motor also needs to be monitored. AD 2S82A, in addition to the position, gives the velocity signal. Another option to determine velocity is differentiating the position.

Currents

The voltages proportional to the three phase line currents of the motor are given as input to the AD 2S100, which transforms these to two phase rotor frame quantities.

5.6. Hardware

DIGITAL ANALOG INTERFACING

While the controller is digital, the plant to be controlled is analog. This necessitates the interfacing of the two with the help of Digital to Analog Converter(DAC) through which the controller passes the references to the control plant(motor) and Analog to Digital Converter(ADC) to get feedback signals from the motor.

AC VECTOR PROCESSOR

The controller generates the voltage reference signals in two phase rotor co-ordinates. They have to be rotated to stator co-ordinates (Park's Transformation) and converted to three phase signals before feeding to the inverter. Since this transformation is computation intensive, the DSP doing this will bring down the update rate drastically. Hence the vector co-processor AD 2S100 is used to do the required transformations.

ACCESSORIES

Besides the above mentioned software and hardware a pulse width modulator and a voltage controlled inverter are required.

5.7. Summary

The software running in the DSP generates two phase rotor frame voltage references based on the reference set by the user and the feedback signals. These are transformed into three phase stator frame quantities by the vector co-processor. The low power output of the vector co-processor are transformed into high power signals, capable of driving the motor, by the pulse width modulator - voltage controlled inverter combination.

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