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Adaptive Speed Estimation of induction motor Based on Neural network Inverse Control

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Abstract

The performance of the neural network based estimator is investigated with simulations for variations in the rotor resistance from their nominal values, with both speed and load torque disturbances.In this paper, adaptive speed control of induction motor using neural network inverse control scheme are proposed. The controller-structure design is based on a vector control scheme that transforms the three phase motor currents into flux and torque generating current components. The experiment results show that the proposed scheme has excellent dynamic and static control performance.

Keywords- Speed Control, Digital Signal Processing, neural network, Induction Motor

1. Introduction

The induction motor is a multi-variable, nonlinear, strong coupled system. Its rotor parameters change very prominently with the time-varying conditions. All unfolded dynamic effects, such as the change of load torque, the existence of disturbance and magnetic saturation make the differential geometry and inverse system method difficult to be applied in practice [1].

Control method to tackle nonlinear system with uncertain factor. In order to enhance the dynamic response performance of the induction motor, the differential geometry and the inverse system decoupling control methods are investigated. However, the decoupling and linearization of a multivariate nonlinear system demand exact mathematics model of controlled objects [2].

Many researchers work in this field but less used DSP for media controlling. The proposed algorithm is applied to the described induction motor models and estimates the model rotor parameters using the slip-torque motor characteristic. First, describes the overview of induction motor parameter estimationalgorithm that is based on numerical solution techniques [4]. The algorithm is implemented based on the state of the art nonlinear least squares numerical solutiontechniques. For the estimation of all the motor equivalent circuit parameters the slip-torque characteristic alone is not enough and the slip-

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current characteristic or the slip-power factor characteristic can be additionally used, to provide extra information. Such characteristics can be most of the times obtained by the manufacturers. Here the characteristics are assumed to be known as a number of discrete points [3].

2. Motor Parameter Estimation

The estimation methodology makes use of data that, in general, can become available from the motor manufacturer;alternatively, we are easily measured, like the slip-torque characteristic, or the slip-current or slip-power factor characteristics [5]. A parameter estimation procedure becomes even more important, when a slip-dependent parameter model is used [8]

In this case, the model coefficients of eq.(1) are difficult about impossible to be evaluated without the use of an estimation procedure [2]. When the rotor circuit parameters are to be estimated, assuming that the stator and core parameters are known, the slip-torque characteristic of the motor provides adequate information. However, when all the equivalent circuit parameters are to be estimated [6] in total if constant rotor parameters are assumed and [9] if slip-dependent rotor parameters are used, the slip-torque characteristic itself is not enough and some additional information is necessary[8].Such information can be provided using, for example [14], the slip current characteristic of the motor along with the slip-torque curve. In this paper, the estimation problem will be formulated in its general form, assuming that all the equivalent circuit parameters are to be estimated [6],[15]. The parameters' estimation problem can be formulated as a least square optimization problem, the objective being the minimization of the deviation between the measured torque and current curves and the model generated curves. These curves are known as a set of discrete measurement points [13],[15].

$$dI_{sd}/d_r = I\left\{L^2 aR_R + L^2 a\frac{R_R}{\sigma L_2 L_r^2}\right\} i_{sd} + \left\{n_p\omega_r + \frac{L_m R_r}{L_r\varphi_r i_{st}}\right\} i_{st} + \frac{L_m R_r}{\sigma L_2 L_r^2}\varphi_r + V_{sl} \qquad (1)$$

(1)

(2)

These equations are used in the estimation procedure because the motor curves and thus the measurement data are obtained under nominal operating conditions. Therefore the estimation is performed under nominal conditions.

$$V_{sd}(t) = R_s.i_{sd}(t) - n_p\omega_m(t).\lambda_{sq} + \frac{d}{dt}\lambda_{sd} \qquad (3)$$

$$V_{sq}(t) = R_s.i_{sq}(t) + n_p\omega_m(t).\lambda_{sd} + \frac{d}{dt}\lambda_{sq}$$

$$(4)\ V_{rd}(t) = 0 = R_r.i_{rd}(t) - n_p\omega_m(t).\lambda_{rq} + \frac{d}{dt}\lambda_{rsd}$$

$$(5)\ V_{rq}(t) = 0 = R_r.i_{rq}(t) + n_p\omega_m(t).\lambda_{rd} + \frac{d}{dt}\lambda_{rq}$$

(6)

$$V_{rd}(t)\ ,\ V_{rq}(t) = 0 \qquad (7)$$

These equations are used in the estimation procedure because the motor curves and thus the measurement data obtained under nominal operating condition. Therefore the estimation is performed under nominal conditions a pseudo-linear composite system can be gotten by cascading the inverse system before the original system [7].And it was equivalent to two second-order integral linear subsystems, so that system control of induction motor which is complex multi-variable and strong coupling was transformed into two second-order integral linear subsystems control, a fully dynamic decoupling was achieved between flux and speed of induction motor [10].

$$\lambda_{sd} = L_s.i_{sd}(t) + L_m.i_{rd}(t) \qquad (8)$$

$$\lambda_{sq} = L_s.i_{sq}(t) + L_m.i_{rq}(t) \qquad (9)$$

$$\lambda_{rd} = L_s . i_{rd}(t) + L_m . i_{sd}(t) \tag{10}$$

$$\lambda_{rq} = L_s . i_{rq}(t) + L_m . i_{sq}(t) \tag{11}$$

$$: T_{em} = n_p \frac{L_m}{L_r} (\lambda_{rd} . i_{sq}(t) - \lambda_{rq} . i_{sd}(t)) \tag{12}$$

$$J_{eq} \frac{d}{dt} \omega_m(t) = T_{em}(t) - T_b(t) - T_L(t) \tag{13}$$

$$T_b(t) = B_m . \alpha_m(t) \tag{14}$$

$$\frac{d}{dt} \theta_m(t) = \omega_m(t) \tag{15}$$

3. Proposed Adaptive Speed Control

The overall system block diagram is shown in Fig.1. TMF28335 DSP is used as the central processor of the control system and implements the corresponding control algorithms - vector control and direct torque control. DC link voltage Ed, the stator currents i_{as}, i_{bs}, i_{as}, and the speed *w*, are sampled and transmitted to the DSP through 161/08 DSPLINK interface. With the combination of these information and control methods, the required PWM gating signals are generated to drive the three-phase induction motor.

All mathematical operations of both processors are preceded at an integer form to ensure the high-speed processing. The programs are written in the form of macro instructions. This method permits fast and well-arranged programming of new structures on the base of recently debugged and tested macroinstructions. The programs are written in the form of macro instructions. This method permits fast and well-arranged programming of new structures on the base of recently debugged and tested Macroinstructions.

The adaptive speed controller is derived from the mechanical model of system. The conversion of eq.(2-5) into its discrete form gives

$$V_{sd}(t) = ((n_p . \omega_m(t) . \lambda_{rq} + \frac{R_r}{L_r} \lambda_{rd}) . \frac{L_m}{\sigma . L_s . L_r} + (\frac{L_m}{\sigma . L_s . L_r{}^2} + \frac{R_s}{\sigma . L_s}) . i_{sd}(t) + \frac{d}{dt} i_{sd}(t) . \sigma . L_s \tag{16}$$

$$V_{sd}(s) = n_p . \frac{L_m}{L_r} \omega_m(s) . \lambda_{rq} + \frac{R_r L_m}{L_r{}^2} \lambda_{rd} + (\frac{L_m}{L_r} + R_s + \sigma . L_s . s) . i_{sd}(s) \tag{17}$$

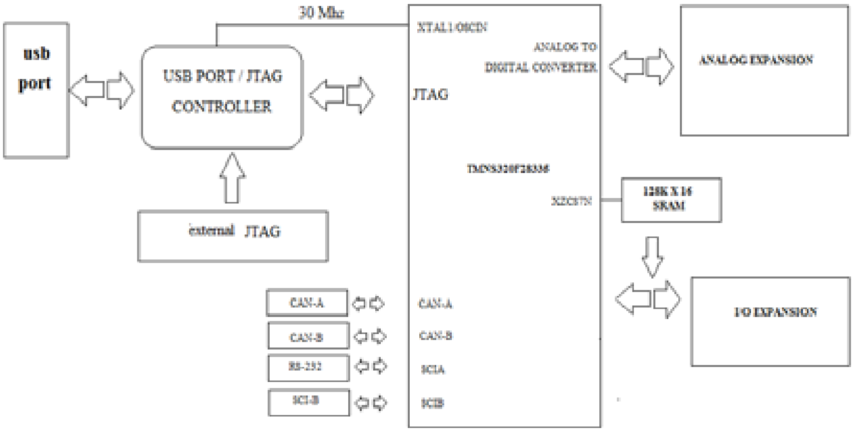

Fig. 1. Overall hardware architecture of control system

$$\frac{\omega_m(s)}{V_{sd}(s)} = \frac{\dfrac{n_p.L_m(\lambda_{rd}.i_{sq}(s) - \lambda_{rq}.i_{sd}(s))}{L_r.(J_{eq}s + B_m)}}{n_p.\dfrac{L_m}{L_r}\omega_m(s).\lambda_{rq} + \dfrac{R_r L_m}{L_r^{\ 2}}\lambda_{rd} + (\dfrac{L_m}{L_r^{\ 2}} + R_s + \sigma.L_s.s).i_{sd}(s)} =$$

$$\frac{\omega_m(s)}{V_{sd}(s)} = \frac{1.78}{0.72 x 10^{-3} s^2 + 0.0157 s + 3.168} \tag{18}$$

$$\frac{\omega_m(s)}{V_{sd}(s)} = \frac{2470}{s^2 + 21.79 s + 4400} \tag{19}$$

$$G(s) = \frac{2470 K (K_P + K_D s)}{s^2 + (21.79 + 2470 KK_D)s + 6870 + 2470 KK_P} \tag{20}$$

$$G(s) = \frac{435.8(K_P + K_D s)}{s^2 + (21.79 + 435.8K_D)s + 6870 + 435.8K_P} \tag{21}$$

$$K_V = \lim_{s \to 0} sG(s) = \frac{435.8 K_P}{21.79} \tag{22}$$

$$= 20 K_P$$

Finally, the algorithm of a controller computation task can be outlined as follows:

1. Initialization: select a reference model.
2. Select the initial values of gain matrix *K* and covariance matrix *P*
3. Read the *k*"value of rotor speed obtained from an *encoder.*
4. Compute the required control signal from the updated plant parameters along together with the information from the reference model.
5. Record the control signal u(k)given to the power module. Calculate andupdate the information vector.
6. Calculate and update the gain and covariance matrices.

4. Result And Discussion

In the experiment as shown in Fig. 2, the speed control of the induction motor will be tested under conditions: step input set point, set-point changes as well as disturbance changes. The induction motor used in this experiment is 4poles, 60 Hz, 280V and 1.8A rating.

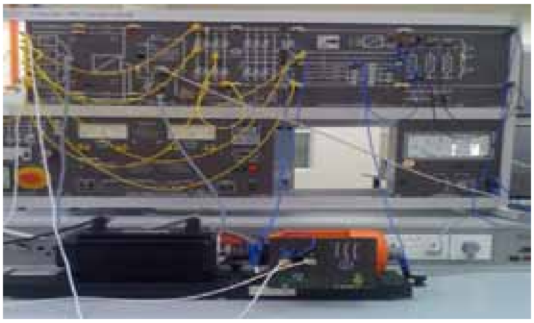

Fig.2. experimental set up

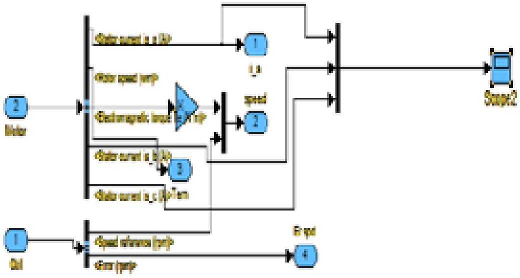

Fig.3.Stator Controlling Circuit

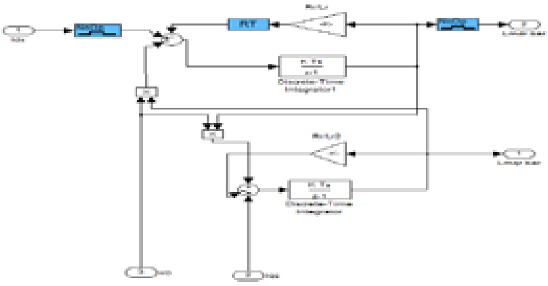

Fig.4. Estimators Adaptive in controlling

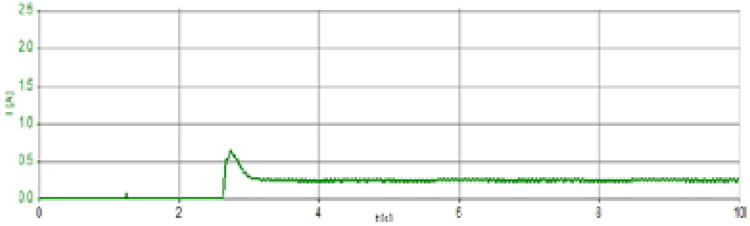

Fig.5. Stator Current

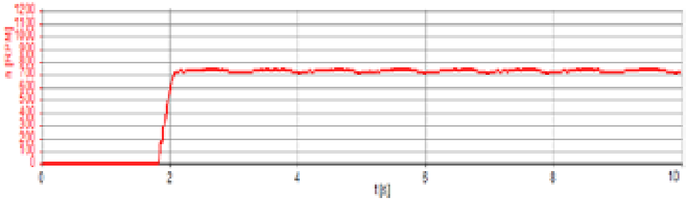

Fig.7. Speed

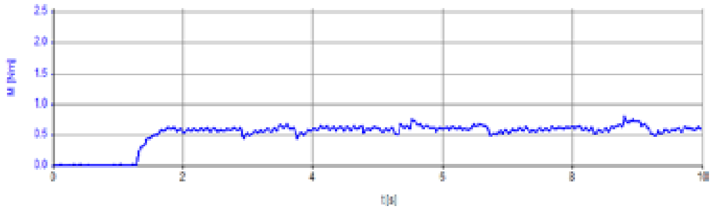

Fig.8. Torque

Comparing the simulated responses (Fig.4-Fig.5) and measured responses (Fig.6-Fig.8), it can be stated that the simulation gives relatively exact results. Some differences at the current response or Control voltage response may be caused, for example, by the actual properties of the real sensors whichconcentricity of the increment sensor and motor may appear. Generally, it can be stated that the correspondence between measured arid simulated responses is acceptable to. Carry out sufficiently exact analysis of the drive processes.

5. Conclusion

The paper has demonstrated the implementation of this high performance direct torque control technique utilizing the floating point TI DSP, TMS320F28335. The experimental results show that an excellent torque response is achieved and agree with the theoretical and simulation results. In the end, the system is implemented on Mat lab-Simulink and DSP TMS320F28335. Simulation and experiment results show that the system has the good dynamic and static properties and excellent characteristic of speed tracking, and the decoupling effect between controlling Induction. For all experimental (speed responses for step set point input, increasing and decreasing set point changes as well as disturbance changes), the adaptive speed control of induction motor can give good tracking and disturbance rejection performance, where it yields zero steady state error and quick response time (most of the responses have response times less than 200 ms).

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