Research on the different kinds of speed sensorless induction machine flux observer control technology

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Abstract. A compensated voltage model is proposed in this paper, which consists of a second order band pass filter and its compensator. Based on this compensated voltage model, a new flux estimator is constructed. To solve this multiple equilibrium states problem, a method to improve the flux estimator is proposed and the different kinds of induction motor flux observer control technology are studied. The traditional model reference adaptive speed estimation method is modified and using the band pass filter compensated voltage model proposed in this paper as the reference model. The precision of speed estimation is improved. On the basis of this modified model reference adaptive speed estimation method, a speed sensorless induction machine vector control strategy is proposed and then validated through simulation.

Introduction

In recent years, induction motor speed sensorless vector control algorithm has achieved rapid development. Many scholars have studied deeply and provided a lot of practical ways. Especially, the speed adaptive full order observer method had been attracted widespread attention, which included induction motor model, observer feedback gain and the rotor speed adaptive law[1~5]. Traditional speed adaptive law is based on the Lyapunov stability theory or Popov super stability theory [6~7]. In order to speed up the convergence rate estimation error, the method of pole assignment is used usually in order to design for observer feedback gain matrix. However, many research and practical work have shown that, even in the absence of parameter error and measurement noise conditions, adaptive full order observer of induction motor drive system will produce an unstable phenomenon. This paper will discuss the stable operation of induction motor speed sensorless vector control based on the improved voltage model flux estimate method. Through theoretical analysis, a new speed adaptive observer method is proposed.

Induction motor speed estimate model

Stationary reference frame

The stator and rotor flux vector equations as follows:

$$y_s = L_s i_s + L_m i_r \tag{1}$$

$$y_r = L_m i_s + L_r i_r \tag{2}$$

The stator and rotor voltage vector equations as follows:

$$u_s = R_s i_s + \frac{dy_s}{dt} \tag{3}$$

$$0 = R_r i_r + \frac{dy_r}{dt} - jw_r y_r \tag{4}$$

The rotor angular frequency ω_r is contained in the equation(4), the rotor angular frequency ω_r equations as follows:

$$w_r = \frac{-\frac{dy_{ra}}{dt} - \frac{1}{T_r} y_{ra} + \frac{L_m}{T_r} i_{sa}}{y_{rb}} \tag{5}$$

Which, $y_{ra} = \frac{L_r}{L_m}(y_{sa} - L_s^{'} i_{sa})$ $y_{rb} = \frac{L_r}{L_m}(y_{sb} - L_s^{'} i_{sb})$ $y_{sa} = \int (u_{sa} - R_s i_{sa})dt$ $y_{sb} = \int (u_{sb} - R_s i_{sb})dt$

According to the equation(5) , the expression of rotor speed ω_r includes the rotor flux differential term which wills produce a large glitch in the numerical calculation process.

Stator flux rotating *MT* reference frame

The voltage and current equation of stationary reference frame as follows:

$$u_s - (R_s + \frac{L_s R_r}{L_r})i_s - L_s^{'} \frac{di_s}{dt} = -\frac{R_r}{L_r} y_s + jw_r(y_s - L_s^{'} i_s) \tag{6}$$

With the coordinate transformation into Stator flux rotating *dq* reference frame, the equation as follows:

$$[u_s - (R_s + \frac{L_s R_r}{L_r})i_s - L_s^{'} \frac{di_s}{dt}]e^{-jr_s} = -\frac{R_r}{L_r}|y_s| + jw_r(|y_s| - L_s^{'} i_s^M) \tag{7}$$

$$-\frac{R_r}{L_r} y_s + jw_r(y_s - L_s^{'} i_s) = -\frac{R_r}{L_r}(y_{sM} + jy_{sT}) + jw_r(y_{sM} + jy_{sT} - L_s^{'}(i_{sM} + ji_{sT})) \tag{8}$$

Because it is carried in the stator flux orientation, so

$$\begin{cases} y_{sM} = |y_s| \\ y_{sT} = 0 \end{cases} \tag{9}$$

Put the he formula (9) into formula(8), so

$$\begin{cases} u_M = -\frac{R_r}{L_r}|y_s| + w_r L_s^{'} i_{sT} \\ u_T = w_r(|y_s| - L_s^{'} i_{sM}) \end{cases} \tag{10}$$

Induction motor flux observer

Current models flux observer

The equations of current models flux observer as follows:

$$\begin{cases} \frac{T_r}{L_m}\frac{dy_{ra}}{dt} = i_{sa} - \frac{1}{L_m} y_{ra} - w_r \frac{T_r}{L_m} y_{rb} \\ \frac{T_r}{L_m}\frac{dy_{rb}}{dt} = i_{sb} - \frac{1}{L_m} y_{rb} + w_r \frac{T_r}{L_m} y_{ra} \end{cases} \tag{11}$$

Convert into a block diagram:

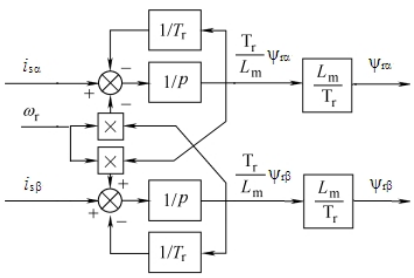


Fig. 1 the block diagram of current model flux observer

Voltage models flux observer

The equations of voltage models flux observer as follows:

$$u_s = R_s i_s + \frac{dy_s}{dt} \tag{12}$$

The flux observer formula as follows:

$$y_s = \int (u_s - R_s i_s)dt \tag{13}$$

The pure integral part will cause zero drift and the flux observer is not inaccurate. The method of eliminating zero drift is adopted by the first-order low-pass filter usually.

Improved voltage model flux observer

The improved voltage modle flux observer is given in this paper. The stator winding voltage, stator winding current through the filter $S/(S+\lambda_H\omega_s T_s)$ and the filter $1/(S+\lambda_L\omega_s T_s)$ successively. Finally, the amplitude and phase compensation are executed. The block diagram of improved voltage model flux observer is shown in Fig.2. The simulation results of improved voltage model flux observer are shown in Fig.3. The observation value and actual values of rotor flux are shown in Fig.4 (a), Fig.4 (b) is the enlarged view of Fig.4 (a). It can be seen that the rotor flux observer effect is good and the deviation is relatively small.

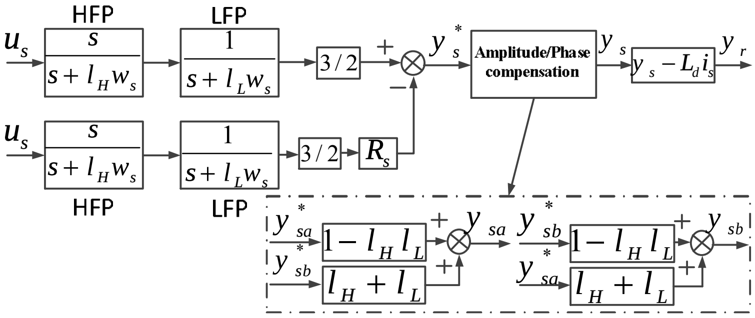
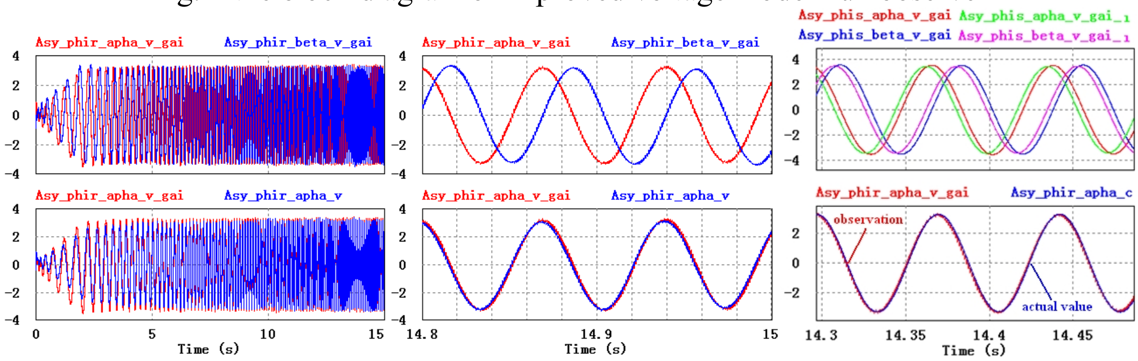


Fig. 2 the block diagram of improved voltage model flux observer



(a) (b) (c)

Fig. 3 the simulation results of improved voltage model flux observer

Speed sensorless induction motor flux observer control technology

The block diagram of model reference adaptive system is shown in the Fig.4 which is a close loop system. The reference model usually monitored by the voltage model which observes the rotor flux, and the adjustable model usually monitored by the current model which observes rotor flux. The adaptive mechanism adopts flux cross-multiplication.

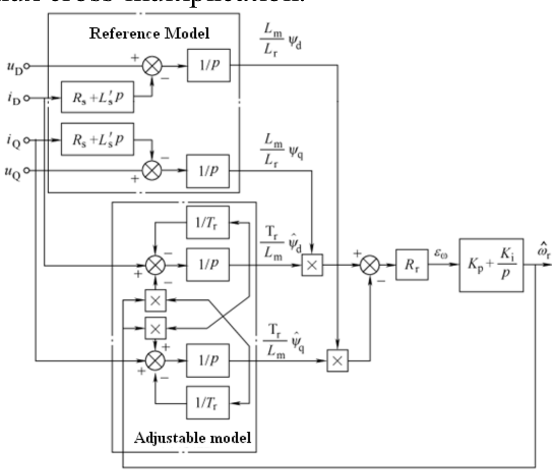
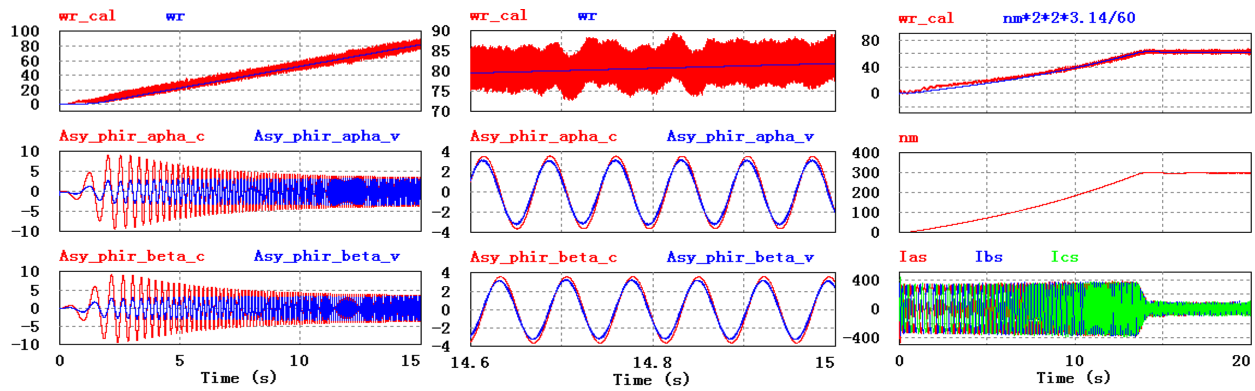


Fig. 4 the block diagram of model reference adaptive system



(a) (b) (c)

Fig. 5 the simulation results of improved voltage model flux observer

The observation value and actual values of rotor angular frequency ω_r, the current model and voltage flux observer of rotor winding flux are shown in Fig.5 (a), Fig.5 (b) is the enlarged view of Fig.5 (a). The observation value and actual values of rotor angular frequency ω_r in the indirect field oriented closed loop control system are shown in Fig.5 (c). It can be seen that the speed observer effect is good and the deviation is relatively small.

Summary

This paper presents a novel model reference adaptive observer in the speed sensorless induction machine vector close loop control system, and the speed and flux observer effect is good.

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