8. Vector-controlled induction motor drives

- The previous control strategies

  good steady-state but poor dynamic response

  oscillation resulted from the air gap flux
- Vector control (field-oriented control) is related to the phasor control of the rotor flux

8.2 Principle of vector control

- Assume that the position of the rotor flux linkages phasor λ_r is known.
- Let θ_f be referred to as field angle, and λ_r be at θ_f from a stationary reference.
- The transformation in the synchronous frame

$$\begin{bmatrix} i_{qs}^e \\ i_{ds}^e \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \sin\theta_f & \sin(\theta_f - \frac{2\pi}{3}) & \sin(\theta_f + \frac{2\pi}{3}) \\ \cos\theta_f & \cos(\theta_f - \frac{2\pi}{3}) & \cos(\theta_f + \frac{2\pi}{3}) \end{bmatrix} \begin{bmatrix} i_{as} \\ i_{bs} \\ ics \end{bmatrix}$$

- T

i_S

- P

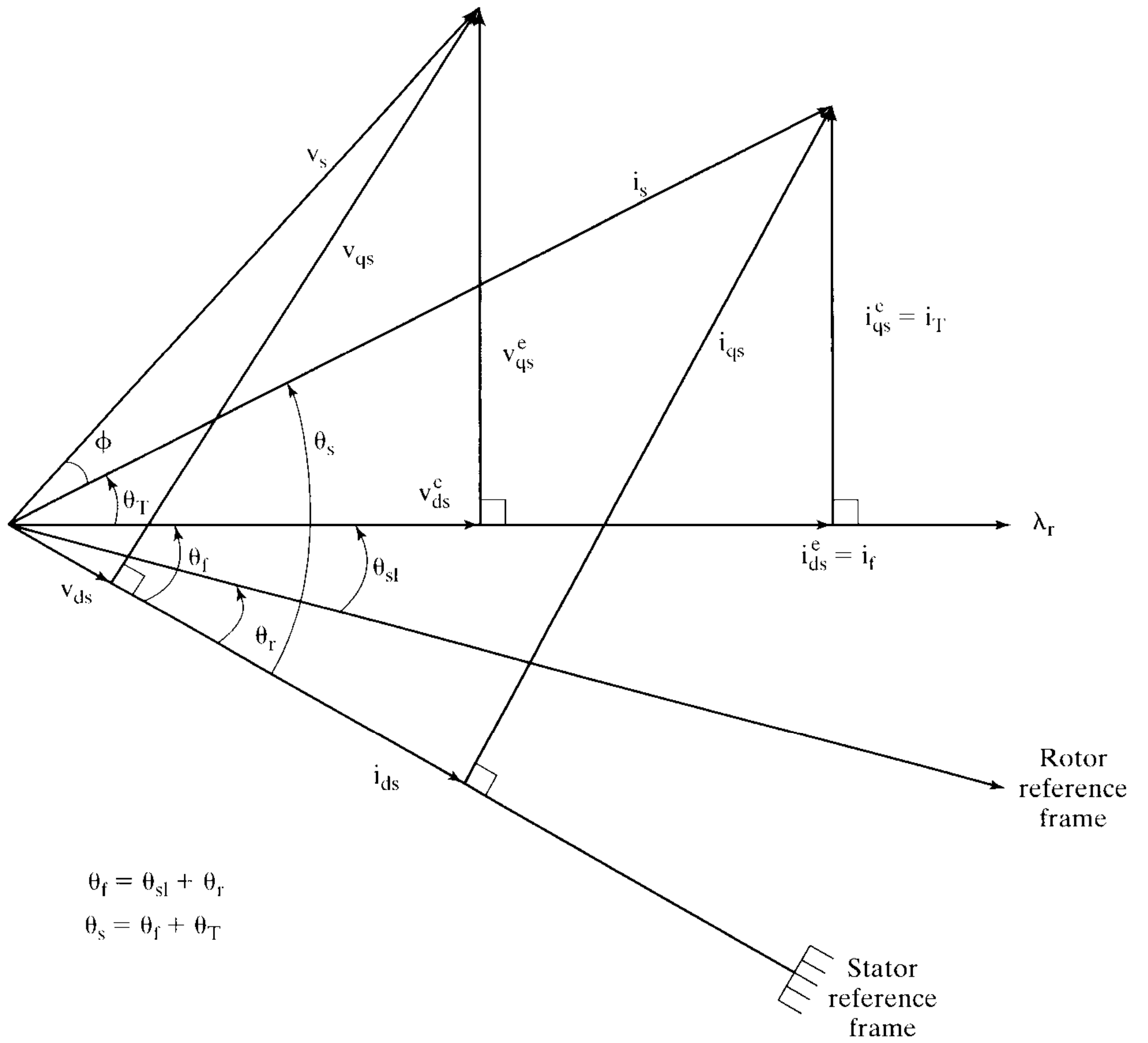


Figure 8.1 Phasor diagram of the vector controller

Summary of vector control

(i) Obtain the field angle

(ii) Calculate i_f*, for the required λ_r*

(iii) From λ_r* and the requied T_e*, calculate the stator current i_T*.

(iv) Calculate the stator-current phasor magnitude, is i_s*, from the vector sum of i_T* and i_f*.

(v) Calculate torque angle

$$\theta_T = \tan^{-1}\frac{i_T^*}{i_f^*}$$

(vi) Add θ_T and θ_f to obtain θ_s.

(vii) Through the dqo transformation to abc variables:

$$i_{as}^{*} = i_s^{*} \sin \theta_s$$

$$i_{bs}^{*} = i_s^{*} \sin(\theta_s - \frac{2\pi}{3})$$

$$i_{cs}^{*} = i_s^{*} \sin(\theta_s + \frac{2\pi}{3})$$

(viii) Synthesize these currents by using an inverter.

- Direct vector control

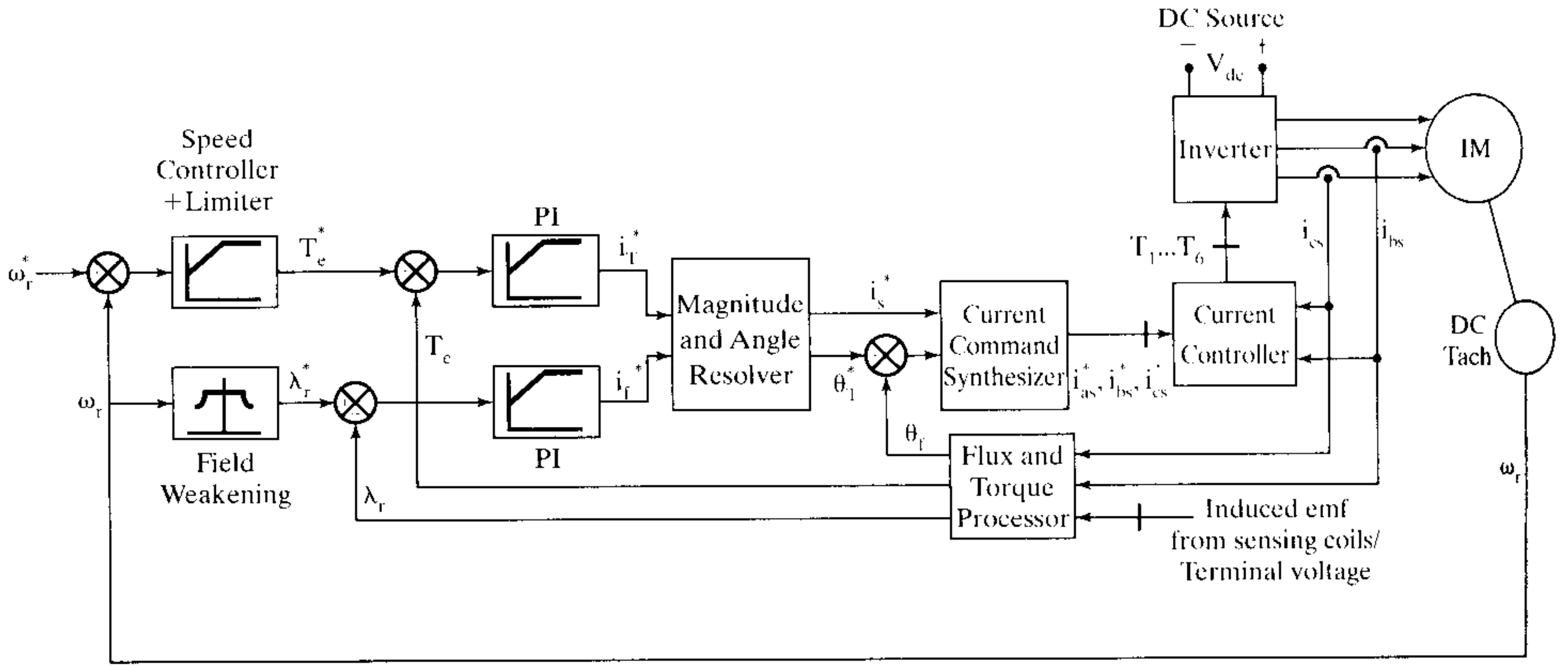
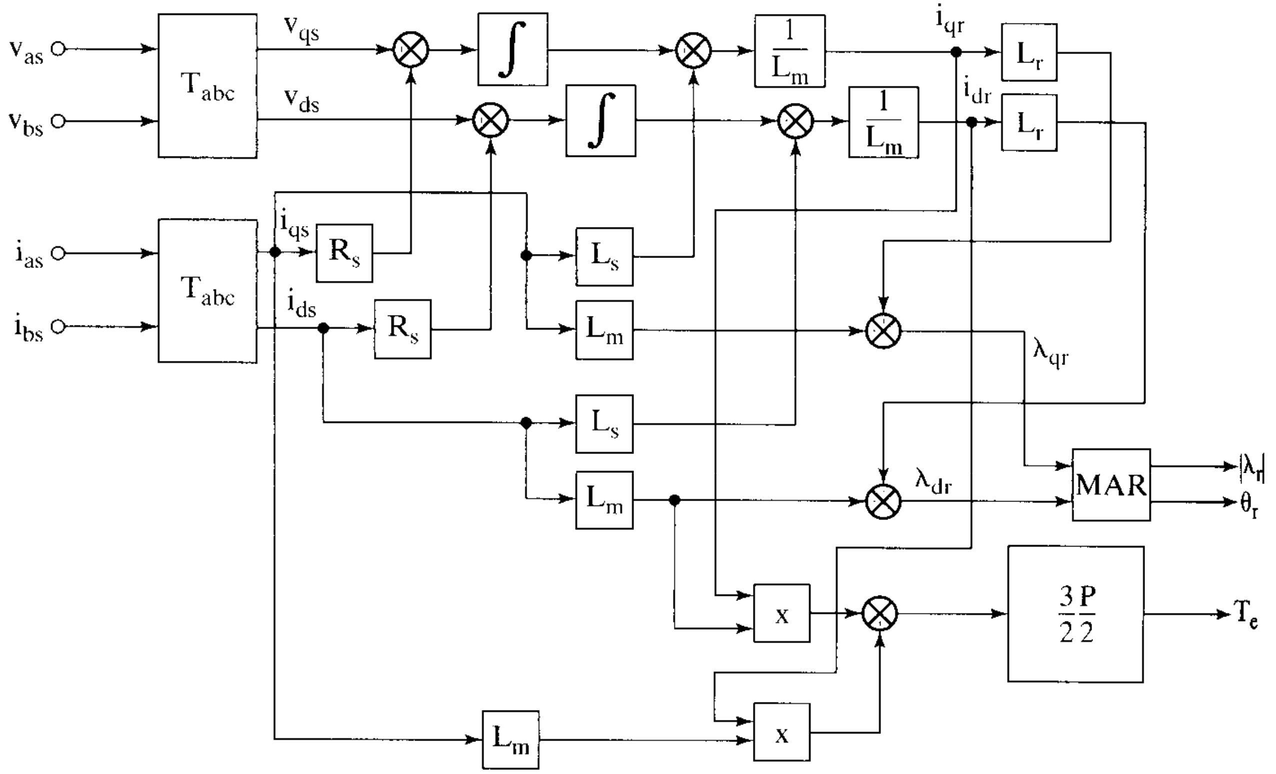


Figure 8.2 Direct vector-control scheme

- The phase-current control loops use

1. PWM
2. Hysteresis
3. Space-vector modulation

- Flux and torque processor implementation



Note : MAR — Magnitude and Angle
Resolver Block

Figure 8.3 Flux and torque processor implementation

• Voltage-source direct vector control

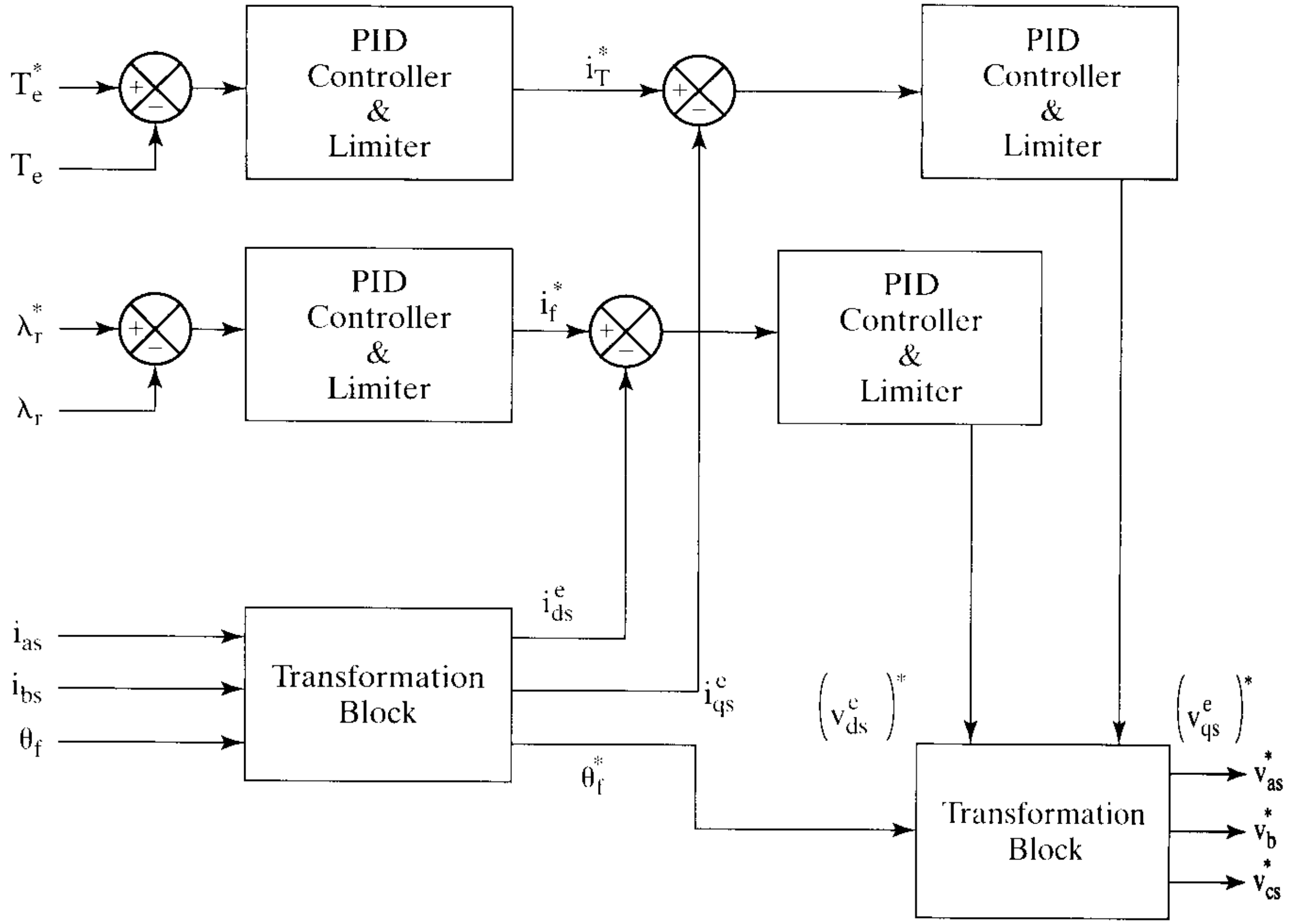


Figure 8.6 Functional block diagram of a voltage-source direct vector controller

8.4 Derivation of indirect vector-control

- From the dynamic equations of the induction machine in the synchronous rotating reference frames.
- The electrical field angle

$$\theta_f = \theta_r + \theta_{s1}$$

- Getting the slip angle by

$$\theta_{s1} = \int \omega_{s1} dt$$

• 8.5 Indirect vector-control scheme

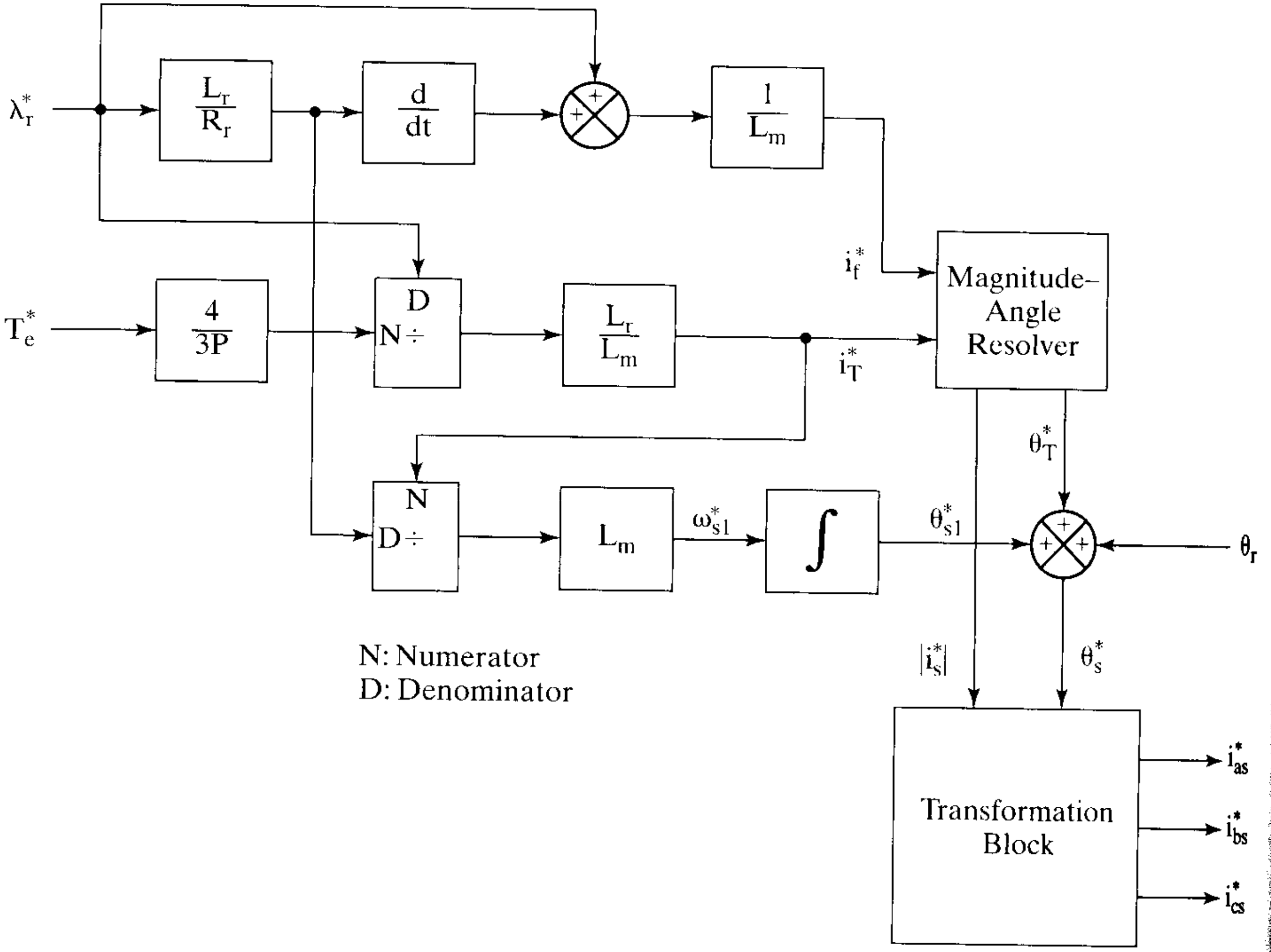
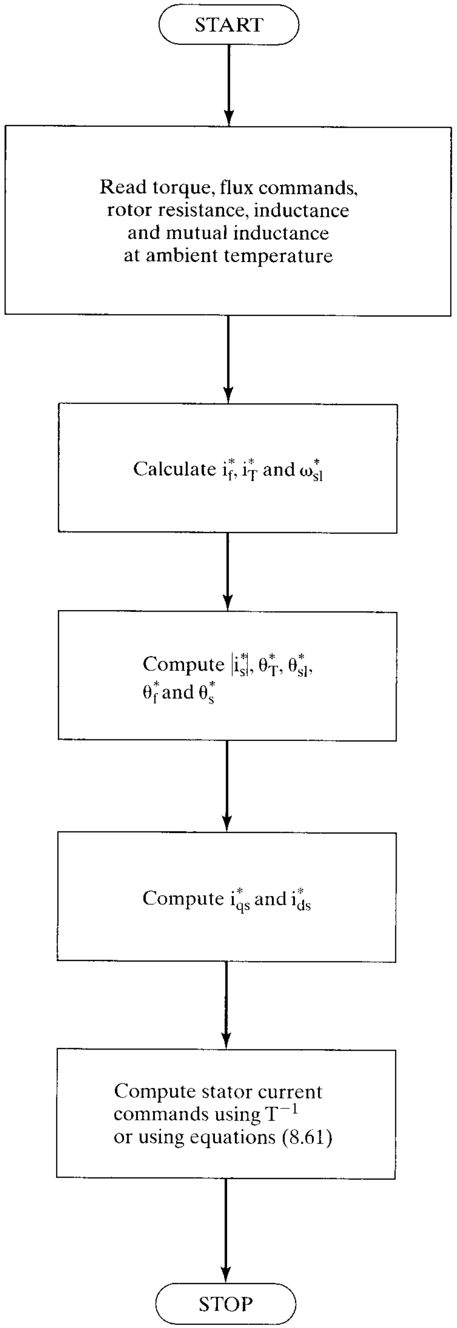


Figure 8.22 Functional block diagram of a current-source indirect vector controller

• Flowchart



START

Read torque, flux commands, rotor resistance, inductance and mutual inductance at ambient temperature

Calculate i_f^*, i_T^* and ω_{sl}^*

Compute $|i_s^*|$, θ_T^*, θ_{sl}^*, θ_f^* and θ_s^*

Compute i_{qs}^* and i_{ds}^*

Compute stator current commands using T^{-1} or using equations (8.61)

STOP

Figure 8.23 Flowchart for the indirect vector-controlled induction motor

• 8.6 An implementation

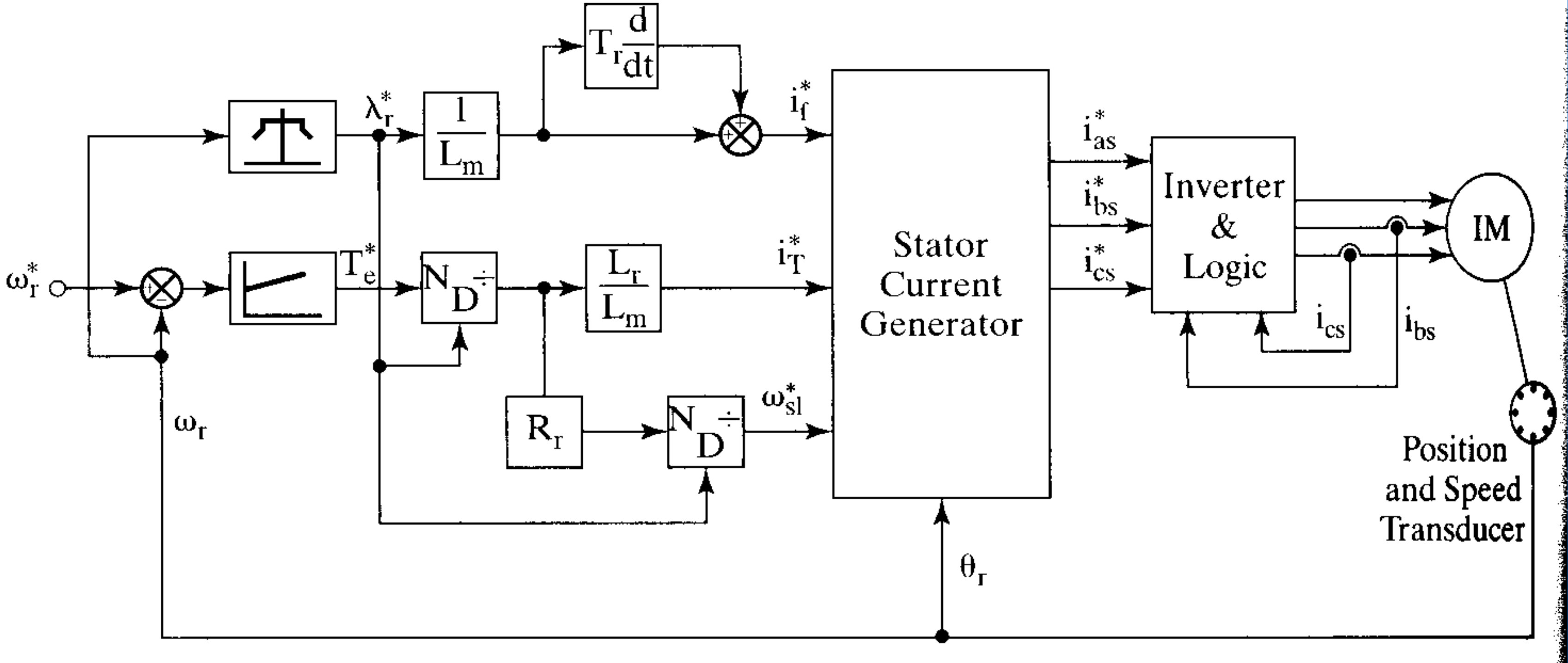


Figure 8.24 The implementation of the indirect vector-controlled induction motor servo

- 8.10 Parameter sensitivity of …
- Parameter changing occurs a mismatch between the vector controller and induction motor.
- This mismatch produces

(i) The rotor flux linkage deviation.

(ii) The electromagnetic torque deviation.

(iii) An oscillation is caused both in the rotor flux linkage and in torque response.

- Expression for electromagnetic torque

$$\frac{T_e}{T_e^*} = \alpha\beta\left[\frac{1+(\omega_{s1}^* T_r^*)^2}{1+(\alpha\omega_{s1}^* T_r^*)^2}\right] \quad \text{Where} \quad \alpha = \frac{T_r}{T_r^*},\ \beta = \frac{L_m}{L_m^*}$$

- Expression for the rotor flux linkage

$$\frac{\lambda_r}{\lambda_r^*} = \beta\sqrt{\frac{1+(\omega_{s1}^* T_r^*)^2}{1+(\alpha\omega_{s1}^* T_r^*)^2}}$$

- Steady-state results

ranges of α and β

$0.5 < \alpha < 1.5$

$0.8 < \beta < 1.2$

- Torque and its command versus α

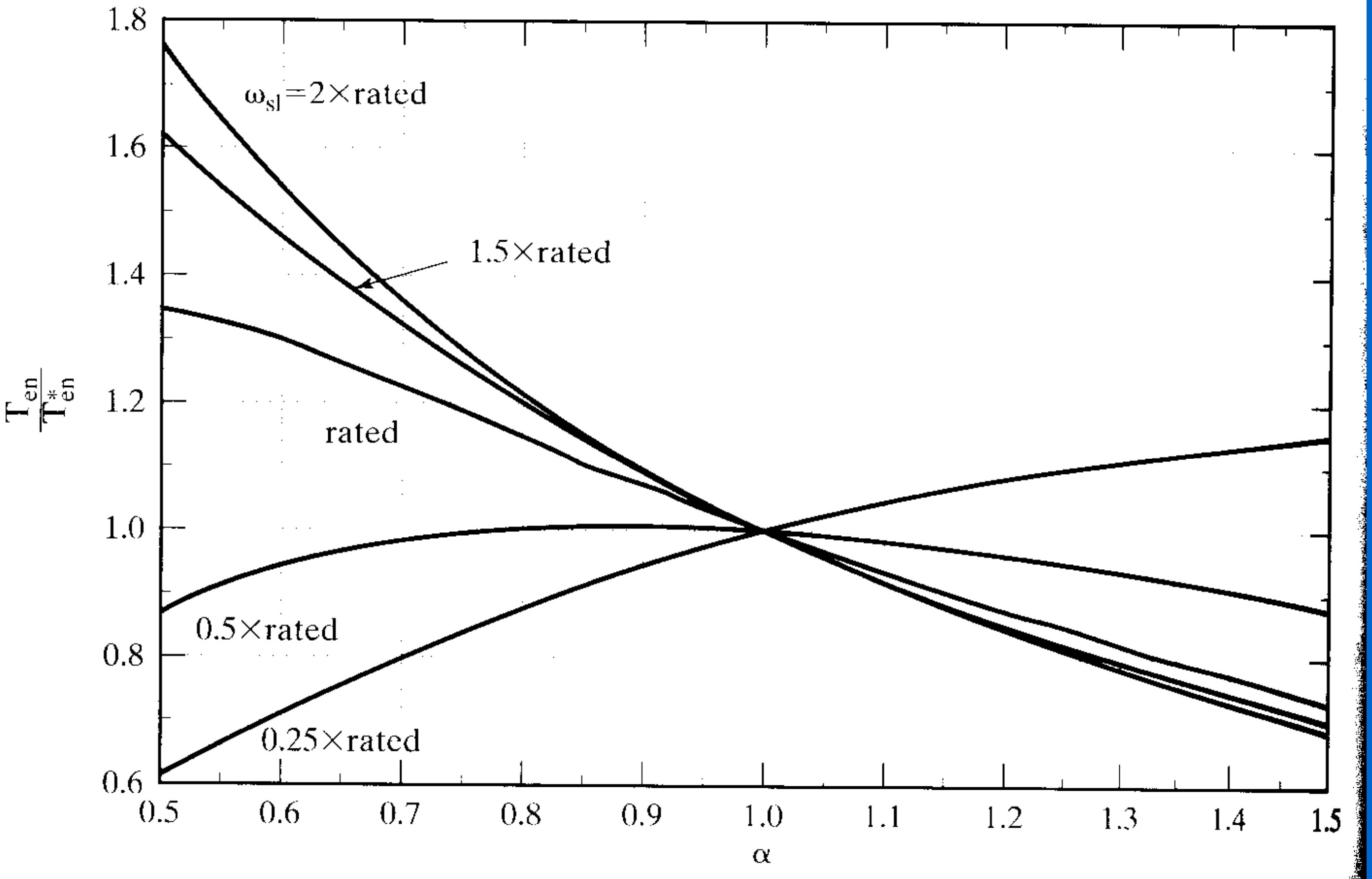


Figure 8.29(i) Torque and its command versus α for various slip speeds

- Rotor flux linkage and its command versus α

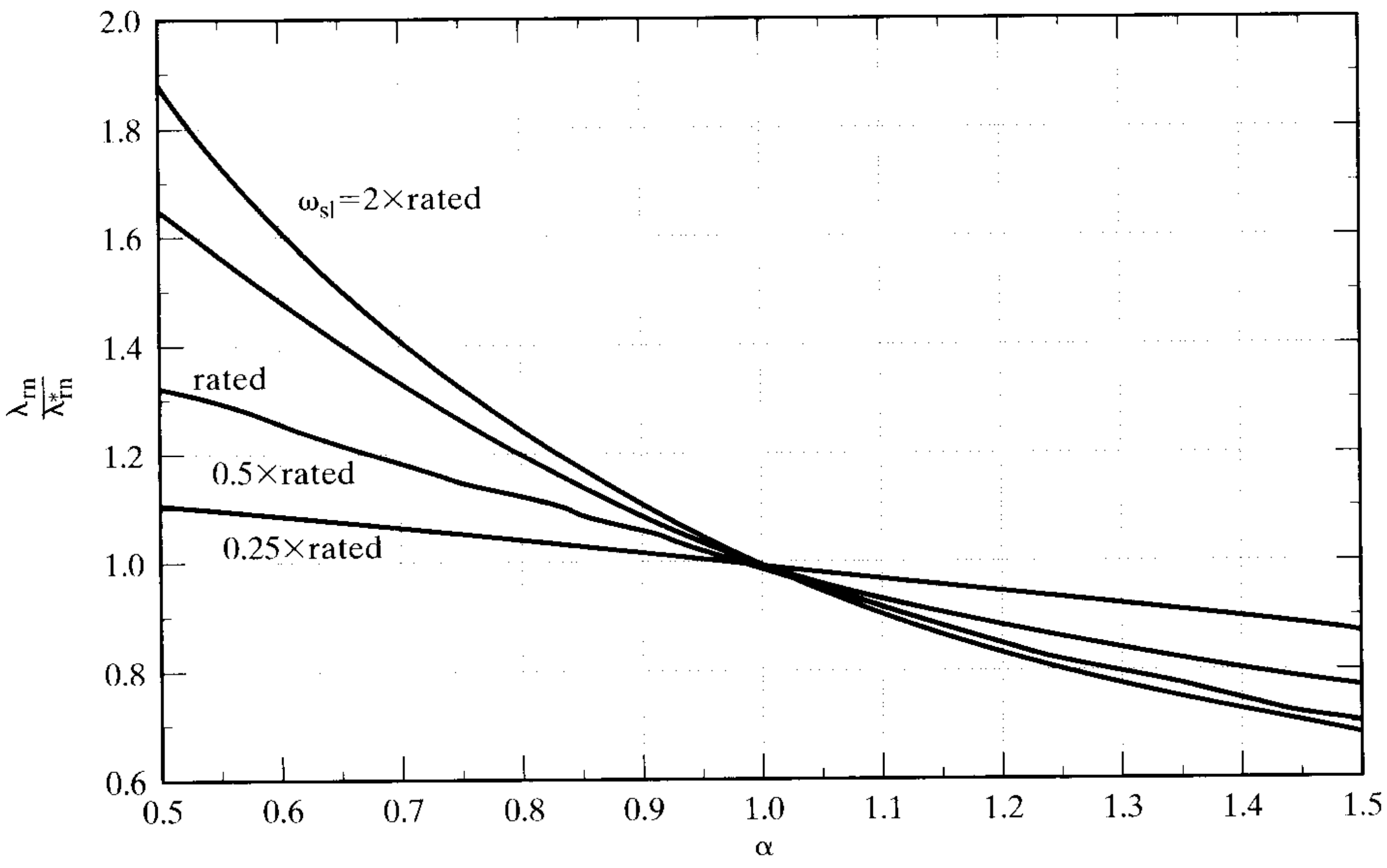


Figure 8.29(ii) Rotor flux linkage and its command versus α for various slip speeds

- Parameter-sensitivity compensation
- Modified reactive-power compensation

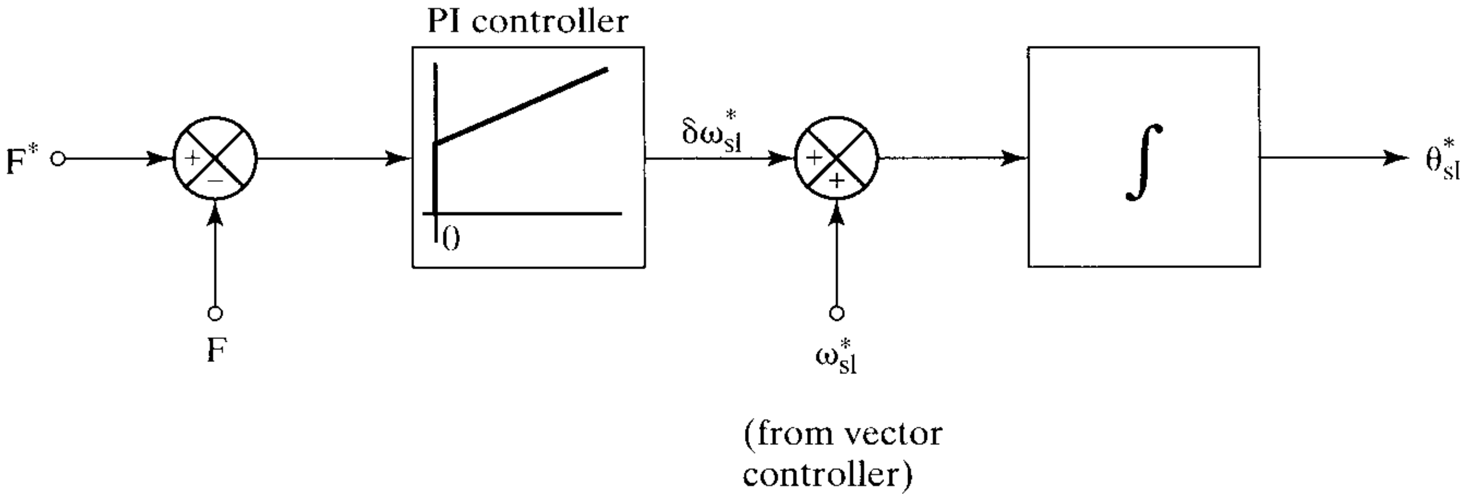


Figure 8.39 Block diagram of the parameter-adaptation with modified-reactive-power feedback control

- Parameter compensation with air gap-power feedback control

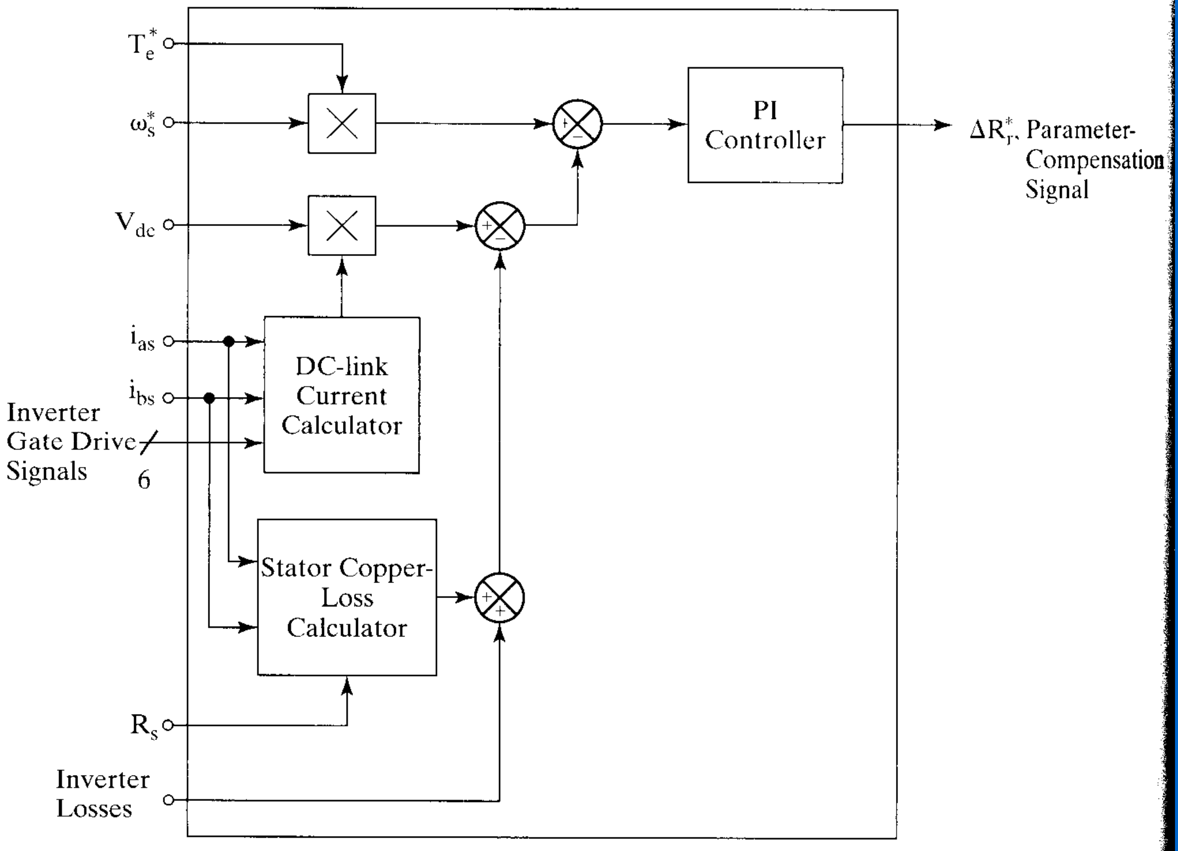


Figure 8.41 Parameter-compensation signal generation with air gap-power feedback control

• Parameter-compensated indirect vector-controlled induction motor drive

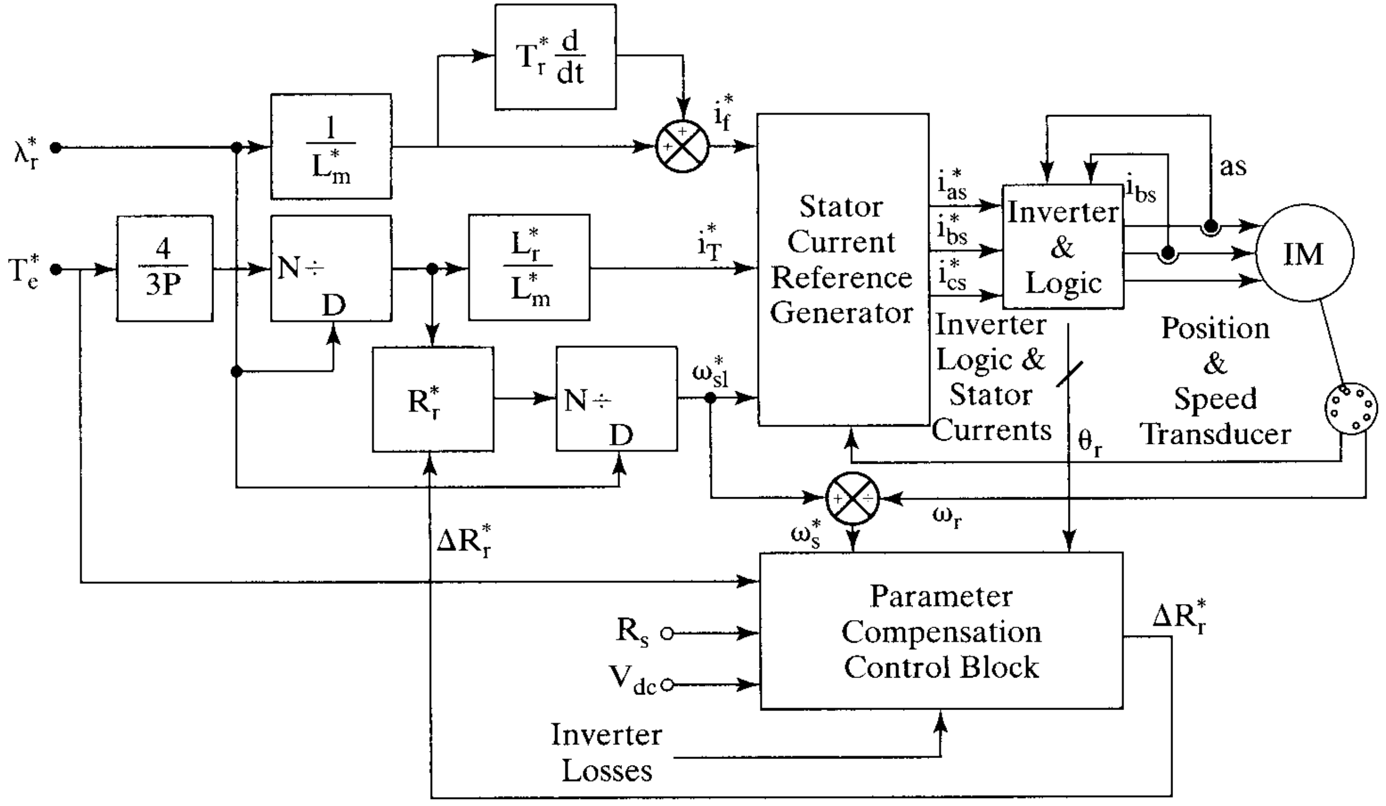


Figure 8.42 Parameter-compensated indirect vector-controlled induction motor drive

Speed controller design

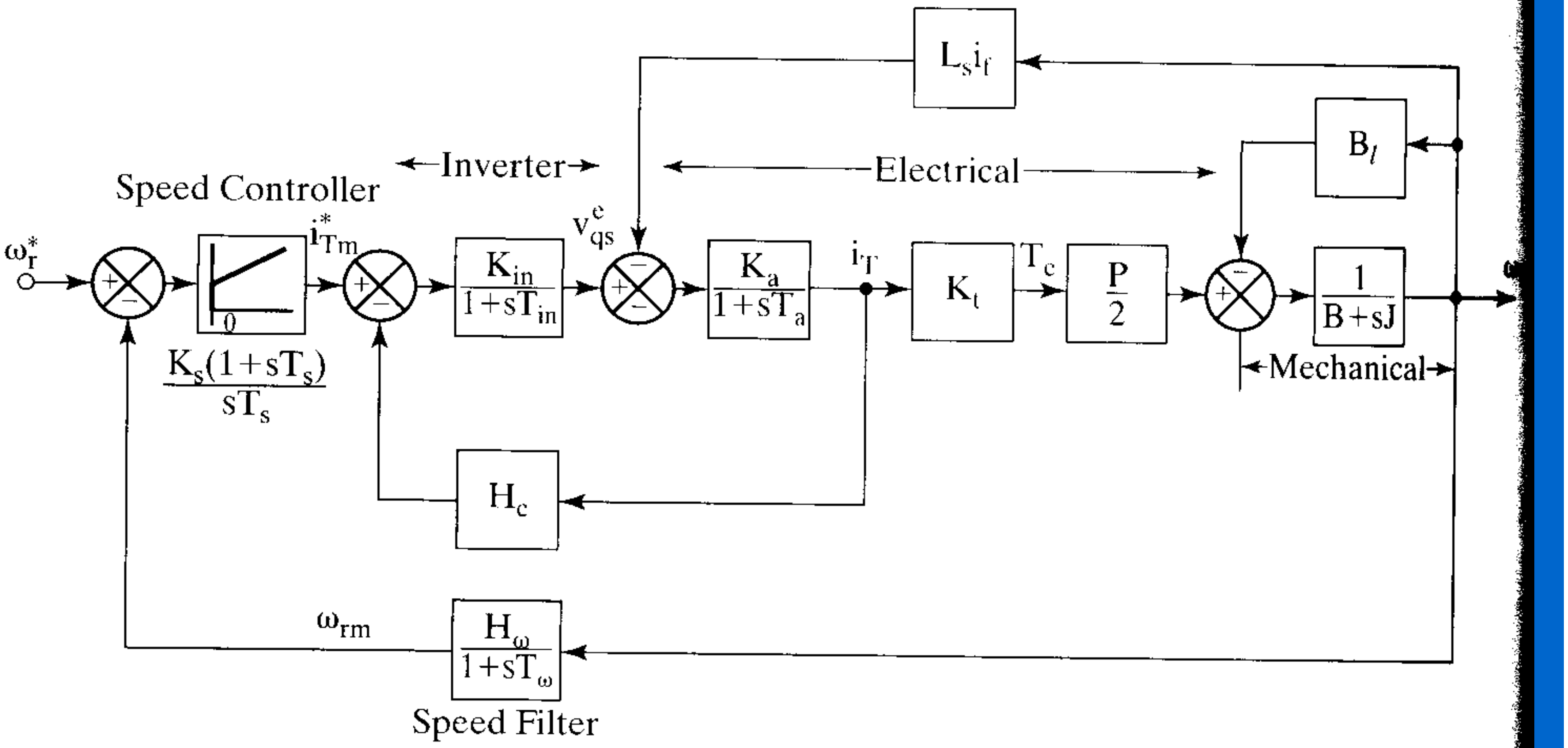


Figure 8.51 Block diagram of the vector-controlled induction motor with constant rotor flux linkages