Chapter 5

Simulation and experimental results

The purpose of the simulation is to test and verify the method, sliding mode

estimator for BLDC motor's angular velocity, workable and set up a hardware

environment experiment to realize practically. The simulation items aim at two

different mechanical angular velocity references $\omega_m{}^*$. The simulation and the

hardware experiment results are shown in section 5.1 and 5.2 respectively.

5.1 Simulation results

The simulation items are designed in Table5.1. Each case is composed of two

testing contains, including estimator and sensorless control. The testing estimator is

designed to verify the estimated angular velocity match with the actual one. Note that

the actual angular velocity will be compared with the command one and the actual

angular position will be fed back to the driver.

On the other simulation, sensorless control, the estimated velocity will be fed

back and compared with the command velocity after 0.2 second. Similarly, the

estimated angular position will be fed back to the driver. Besides, the simulations will

be arranged to compare the effects of using different sensorless switching time that is

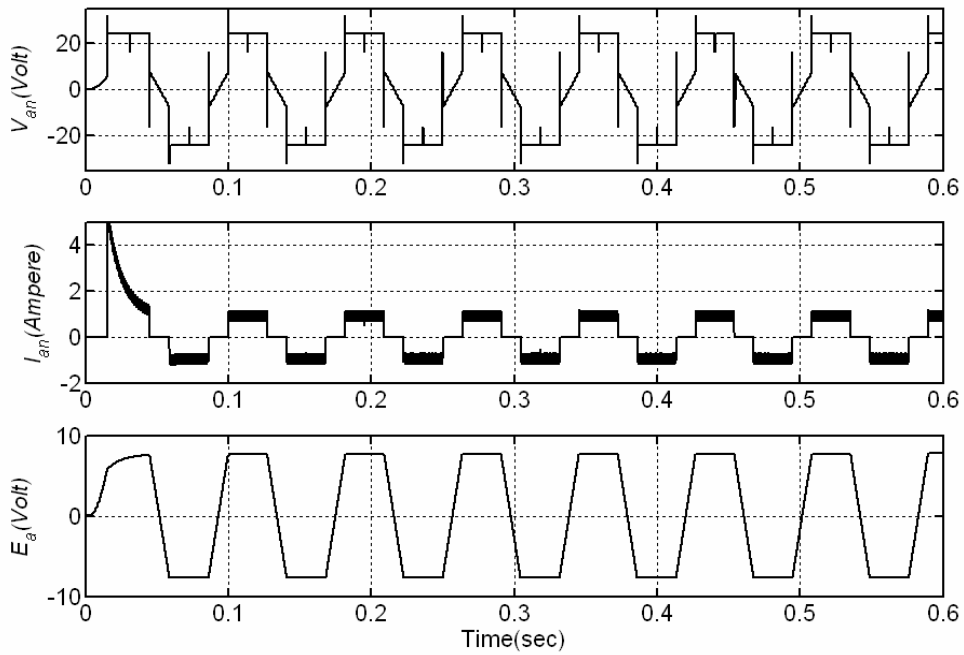turned on after 0.01 second. The block diagram of testing estimator and the sensorless

control will be presented in Figure 5.1 and Figure 5.2.

Table 5.1 The determination values of the simulations.

	ω_m^* (*rad/sec*)	KP	KI
Case 1	10	2	1
Case 2	25	2	1
Case 3	25	8	1

Figure 5.1 The simulated block diagram of testing estimator.

Figure 5.2 The simulated block diagram of sensorless control.

Hence, the simulation results are shown completely as follows. The testing estimator results in the case (1) are presented from Figure 5.3 to Figure 5.10, case (2) are shown from Figure 5.19 to Figure 5.26, case (3) are exhibited from Figure 5.35 to Figure 5.42. The sensorless control results of the case (1) are represented from Figure 5.11 to Figure 5.18, case (2) are shown from Figure 5.27 to Figure 5.34, case (3) are exhibited from Figure 5.43 to Figure 5.50. The failure case results are displayed in Figure 5.51 and Figure 5.52.

Figure 5.3 The phase voltage, current and back-EMF of phase *a* in testing estimator of case (1).
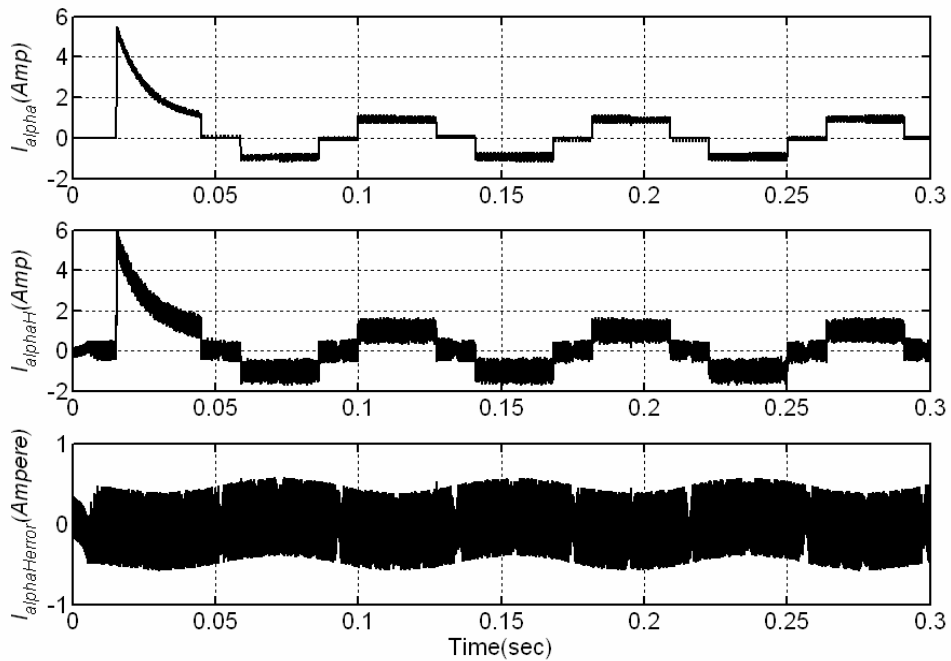
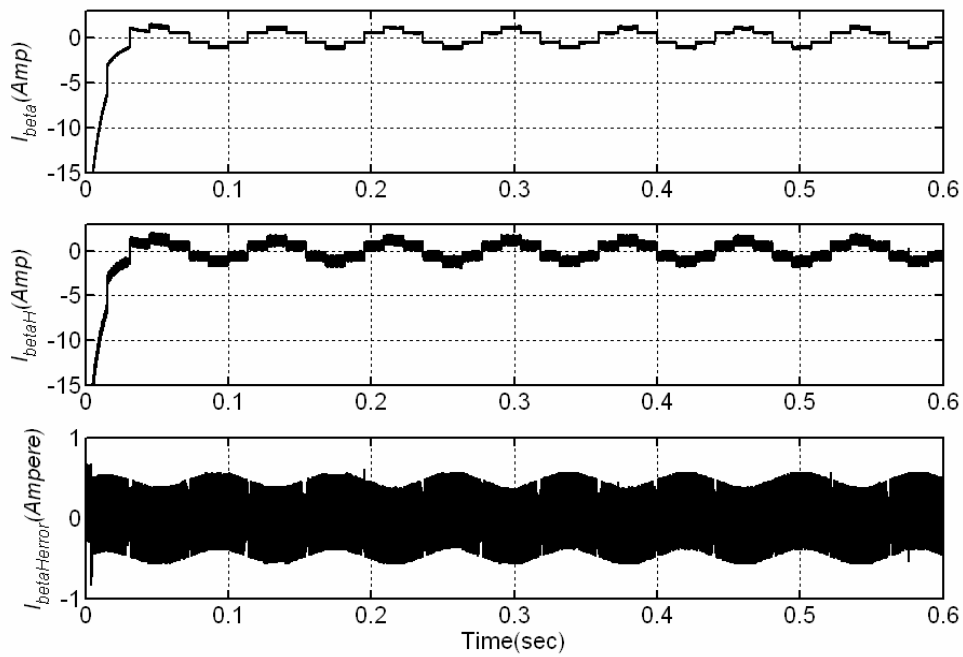Figure 5.4 The information of the α-axis current in testing estimator of case (1).
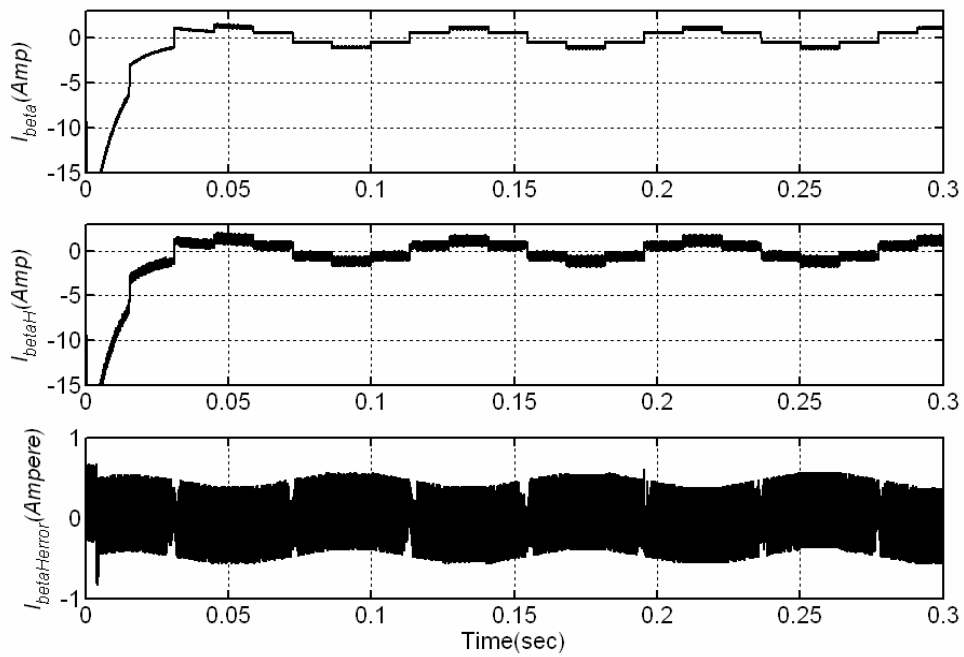
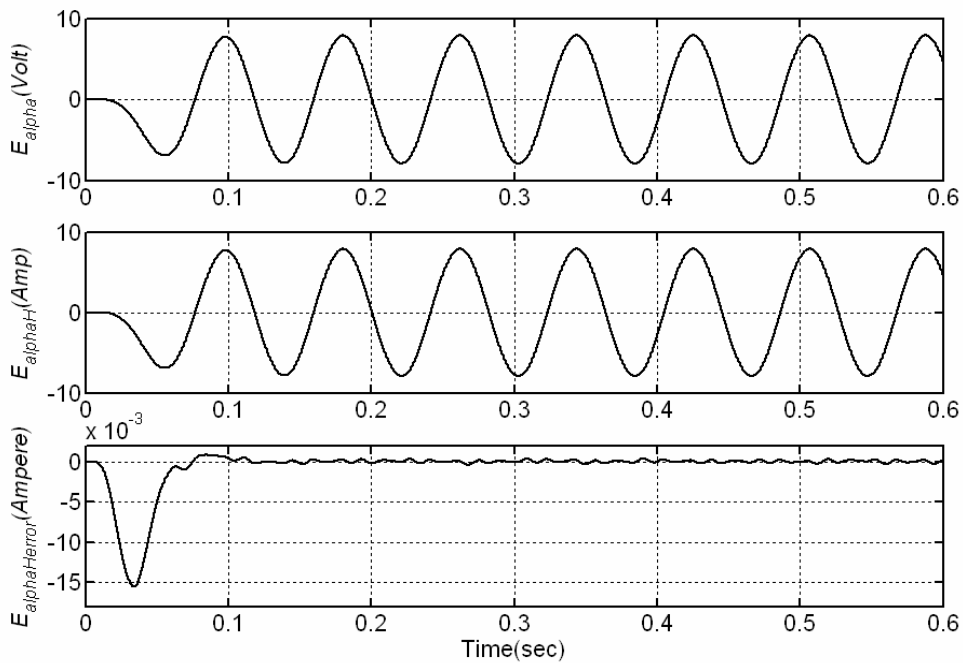Figure 5.5 The information of the β-axis current in testing estimator of case (1).
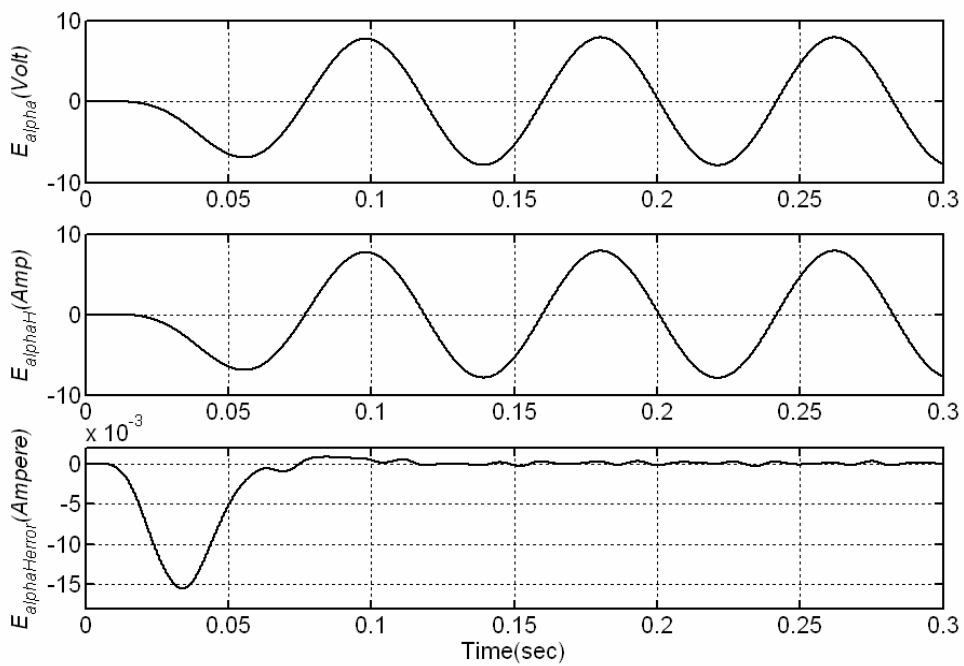
Figure 5.6 The information of the α-axis back-EMF in testing estimator of case (1).
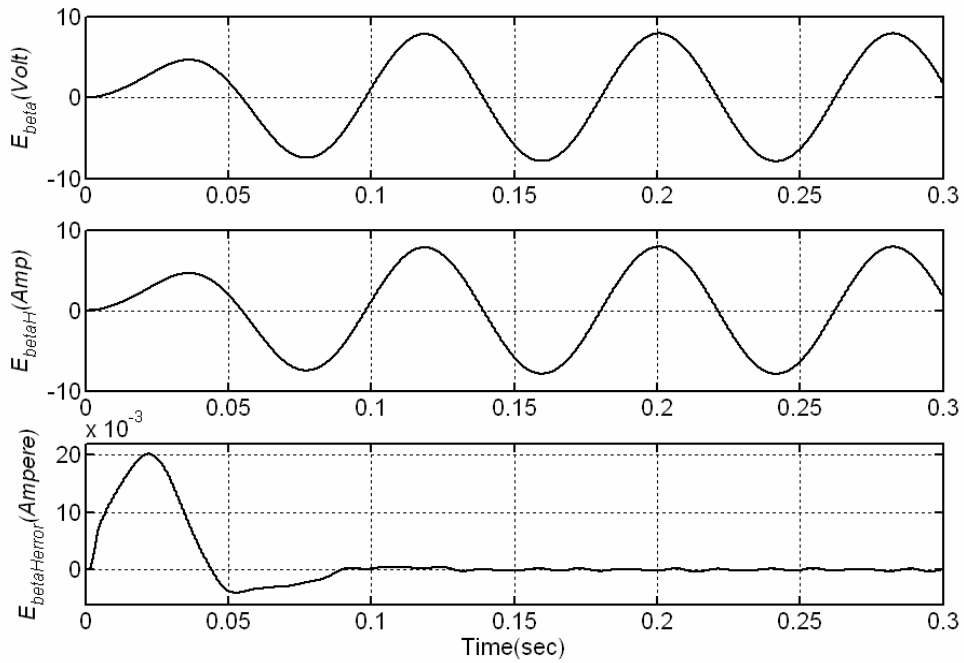
Figure 5.7 The information of the β-axis back-EMF in testing estimator of case (1).
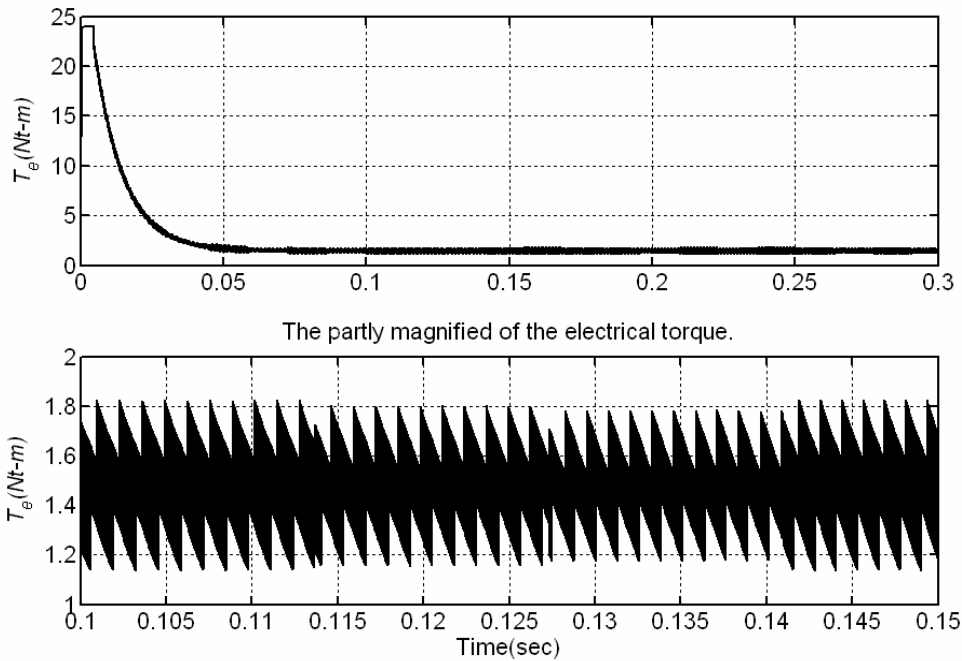
Figure 5.8 The information of the electrical torque in testing estimator of case (1).
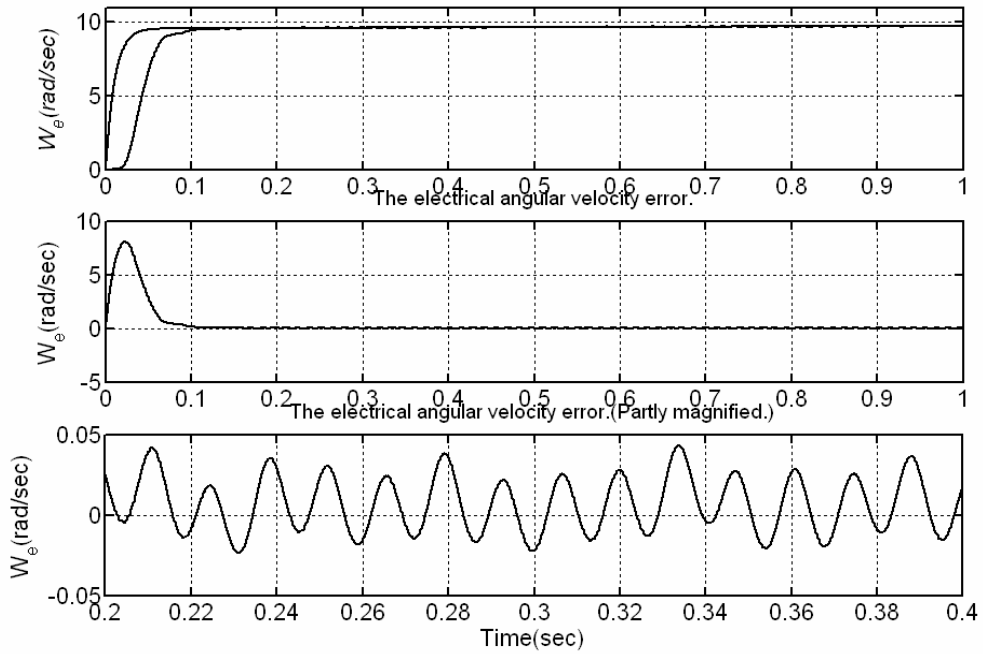
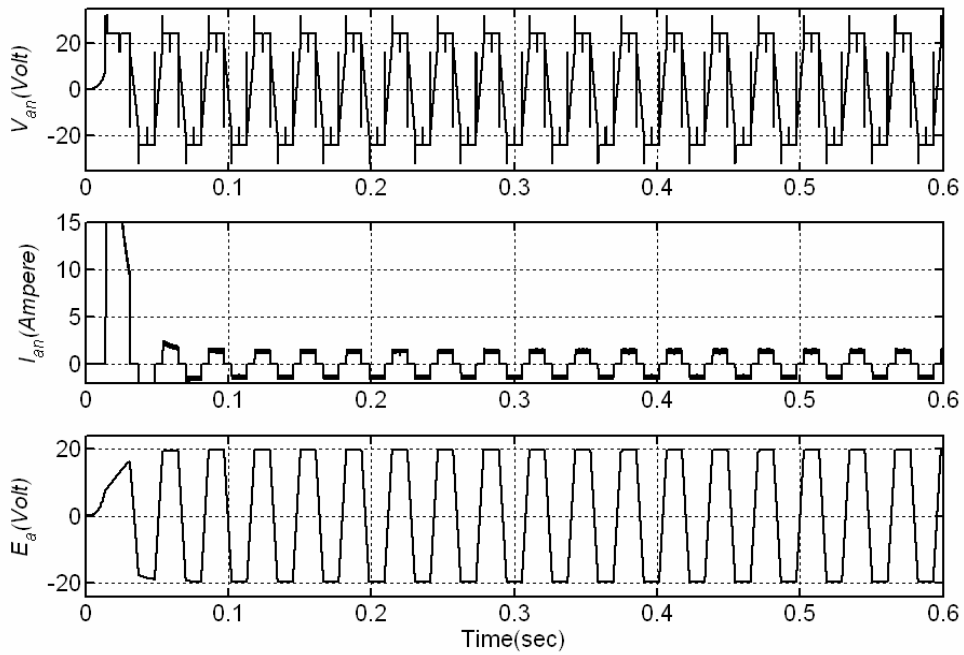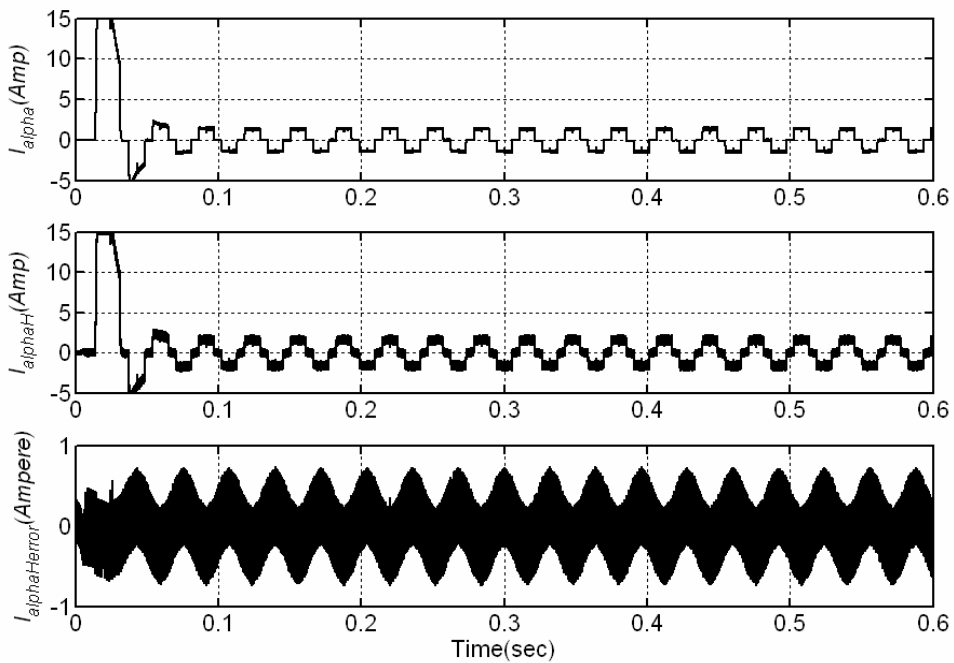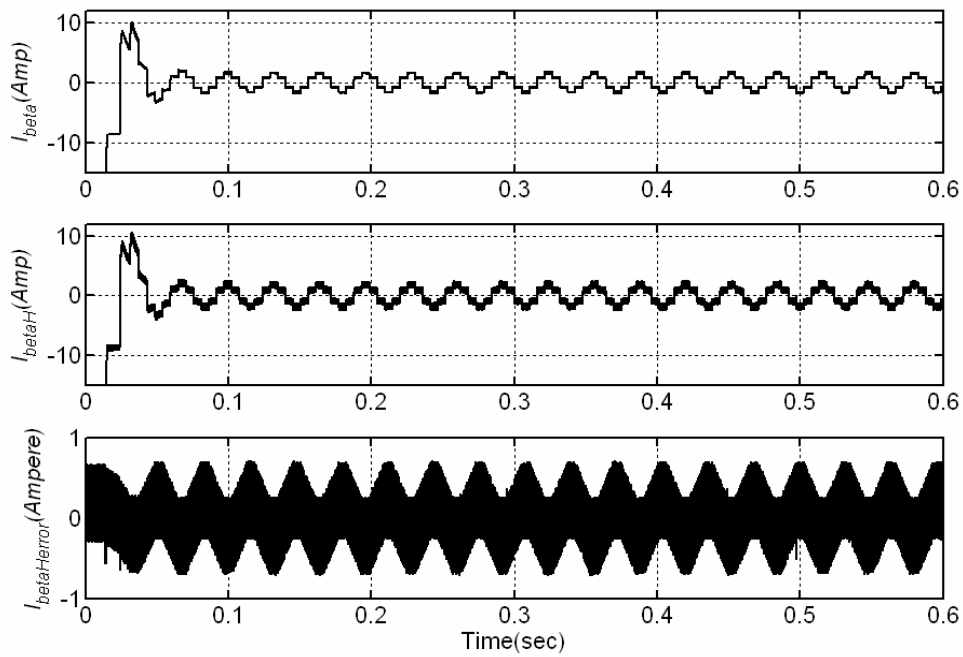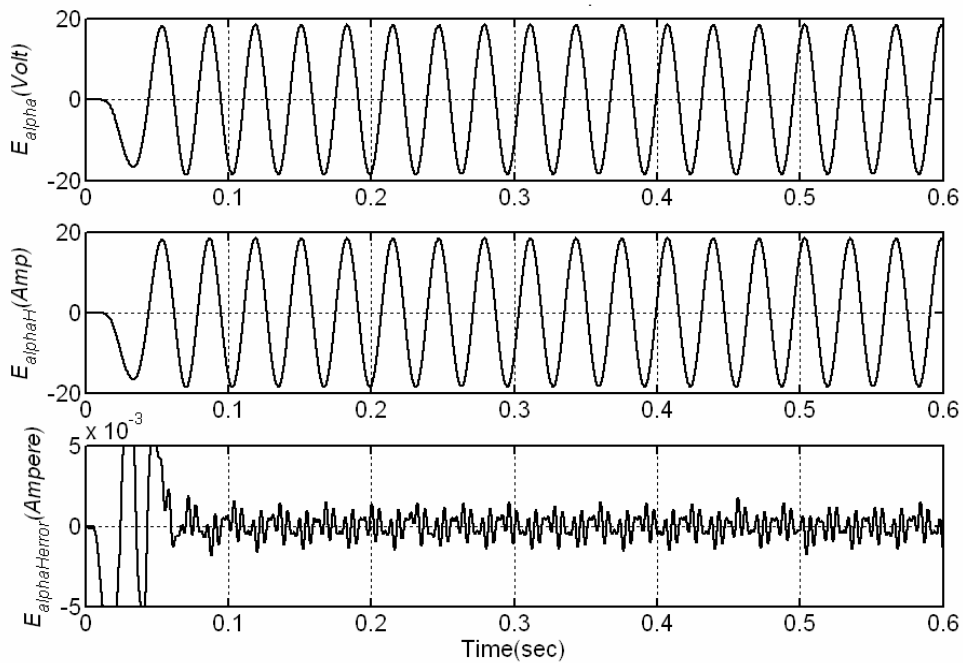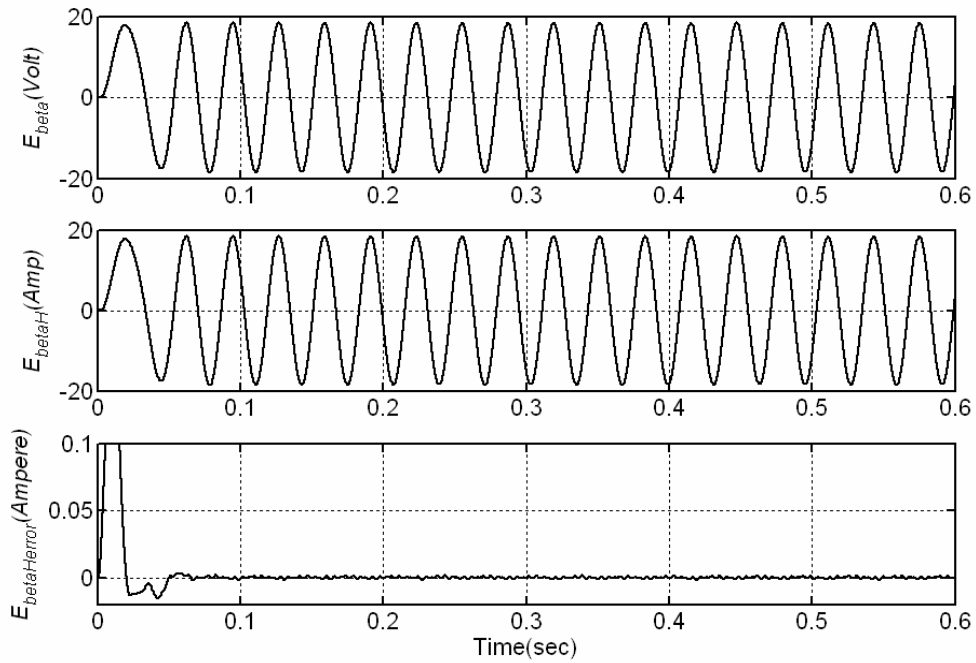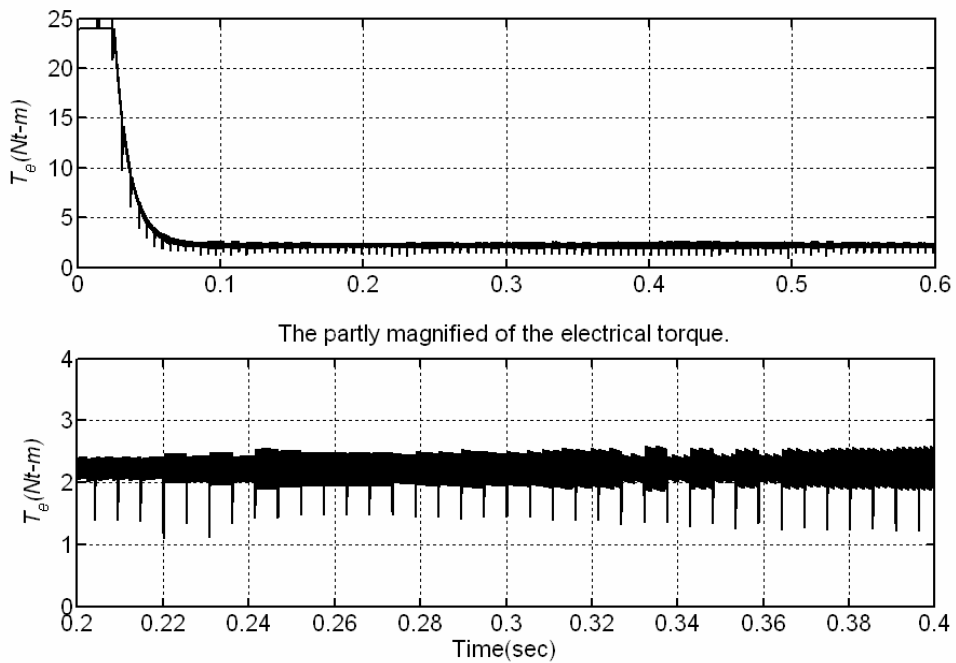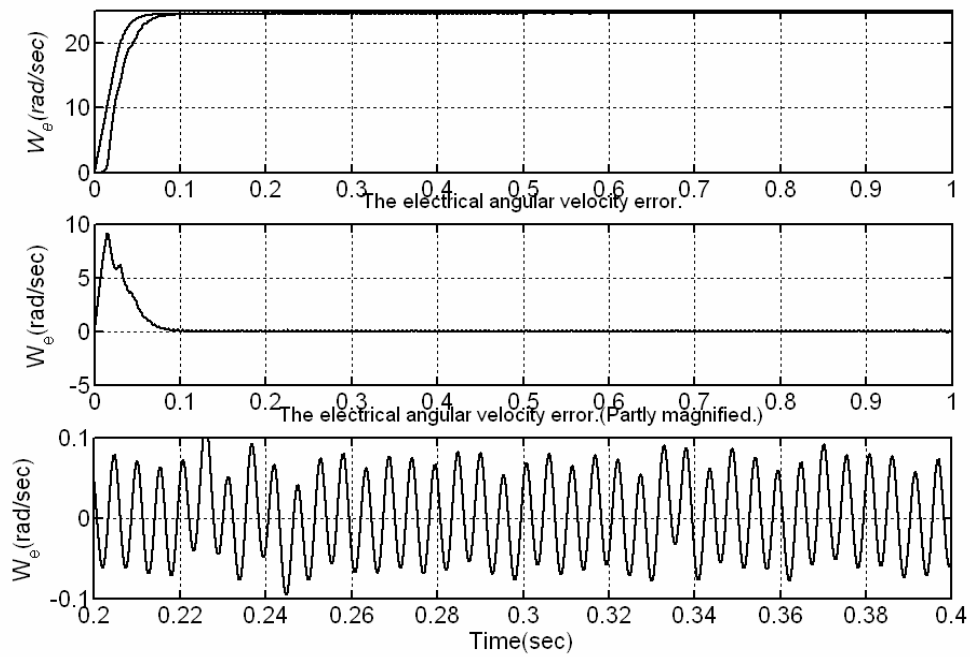Figure 5.9 The electrical angular velocity of the BLDC motor in testing estimator of case (1).
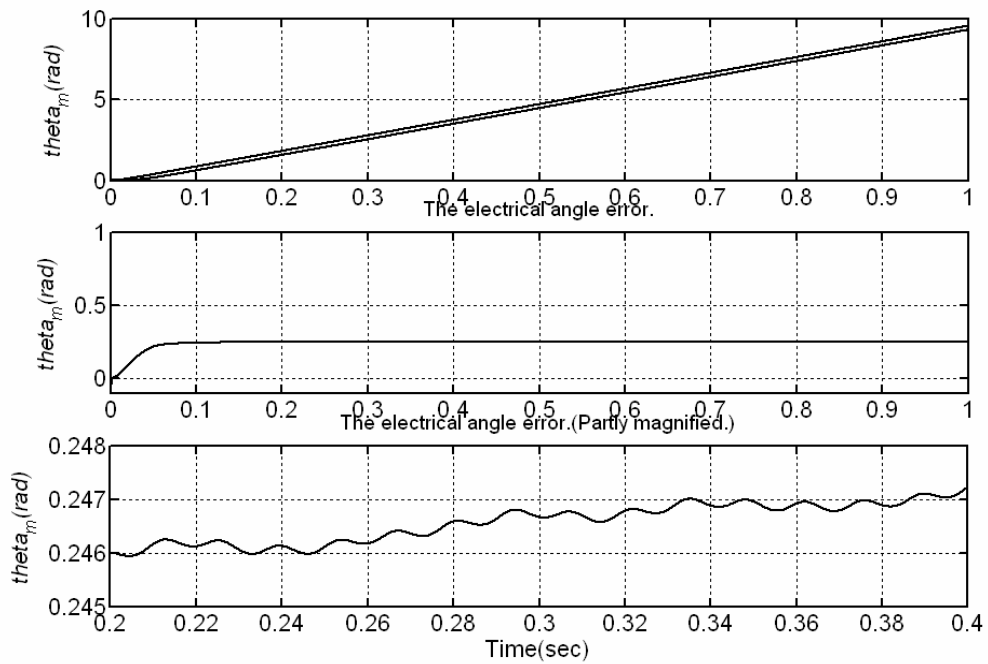
Figure 5.10 The angular position of the BLDC motor in testing estimator of case
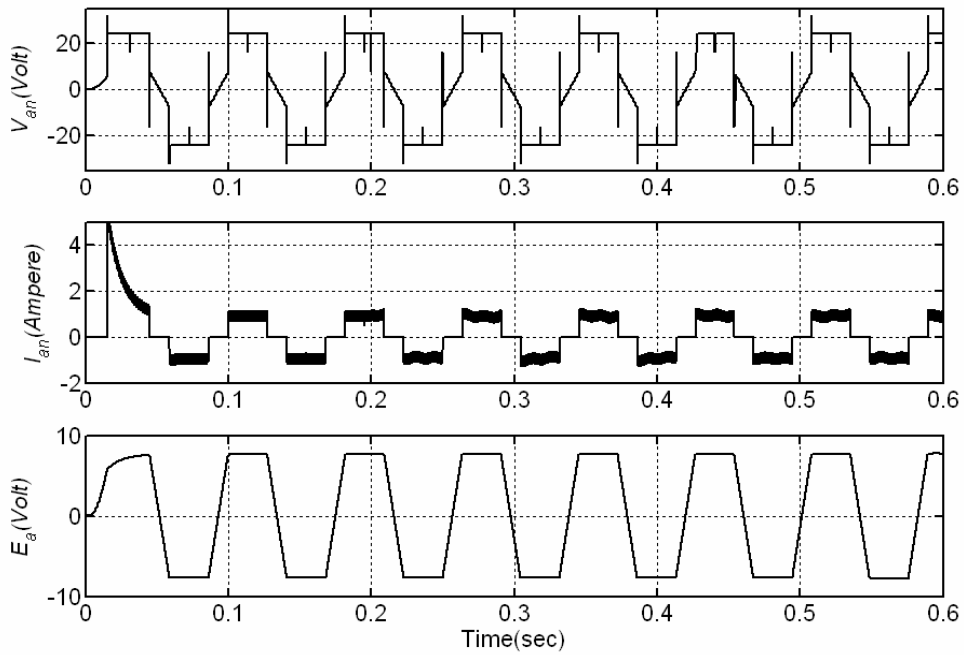
Figure 5.11 The phase voltage, current and back-EMF of phase *a* in sensorless control of case (1).
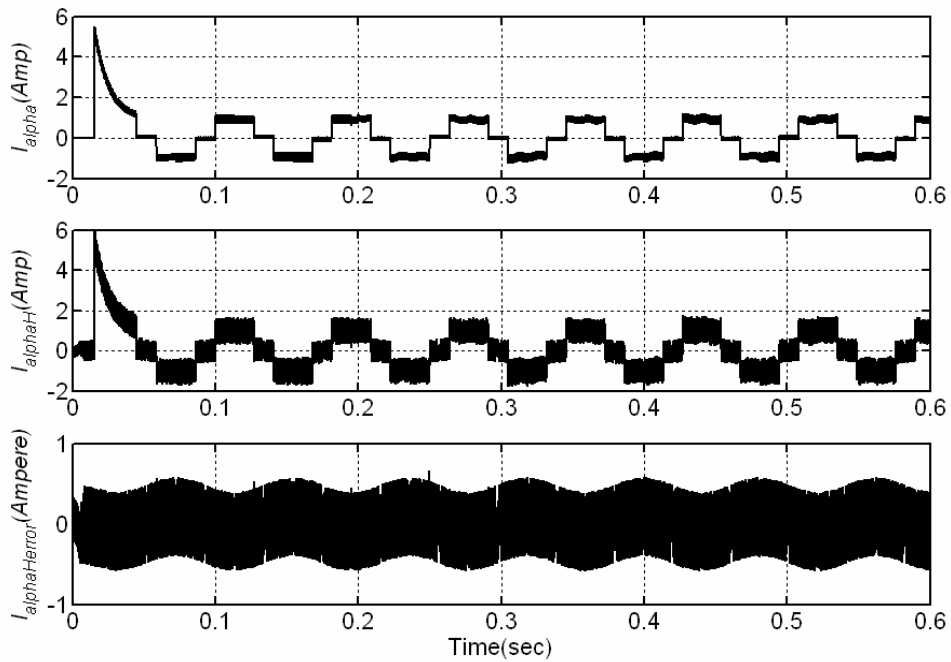
Figure 5.12 The information of the α-axis current in sensorless control of case (1).

Figure 5.13 The information of the β-axis current in sensorless control of case (1).

Figure 5.14 The information of the α-axis back-EMF in sensorless control of case (1).
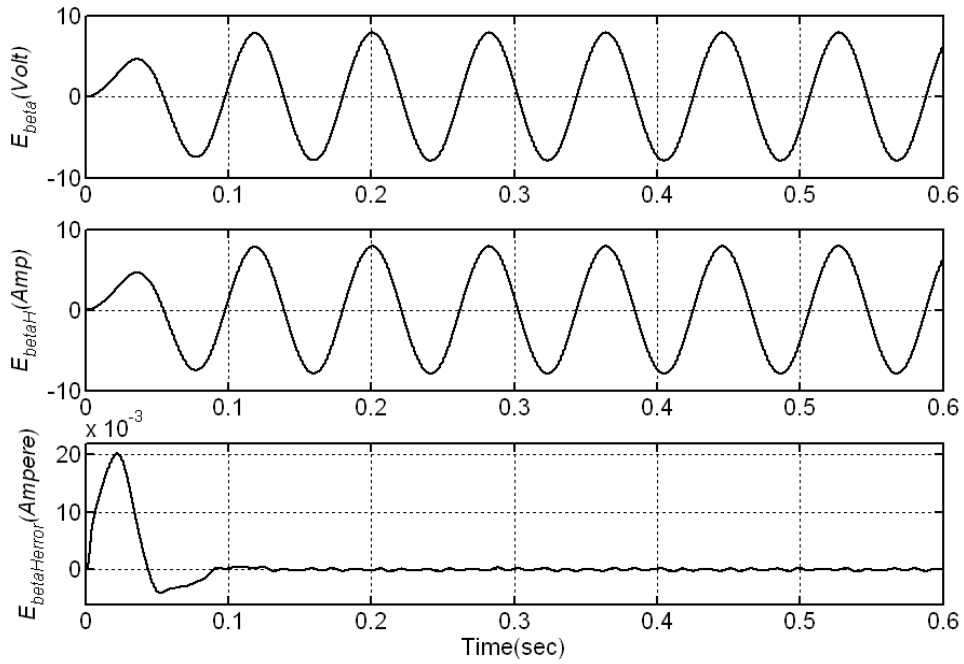
Figure 5.15 The information of the β-axis back-EMF in sensorless control of case (1).
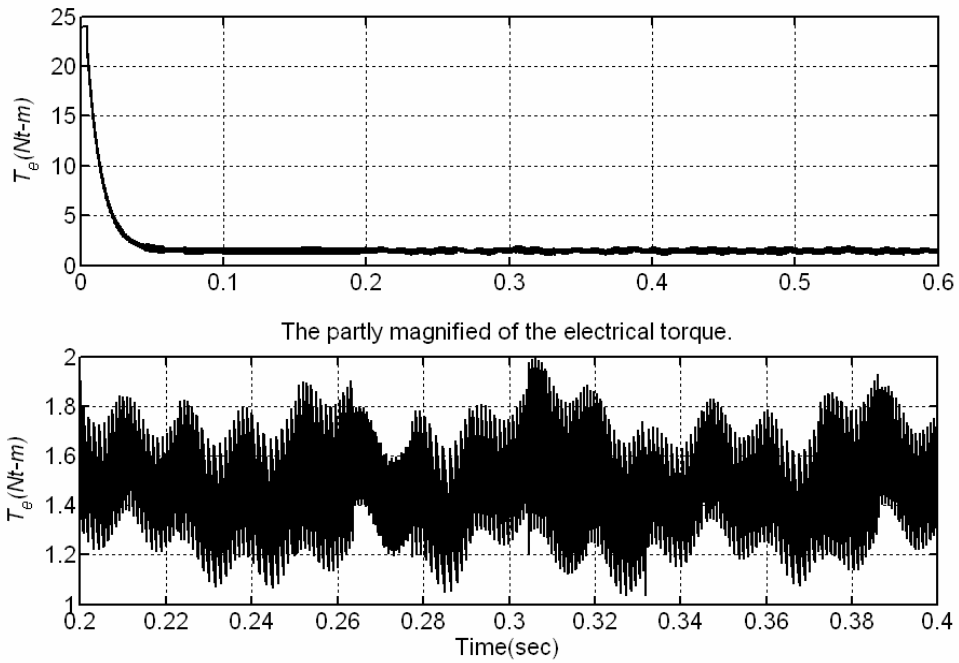
Figure 5.16 The information of the electrical torque in sensorless control of case (1).
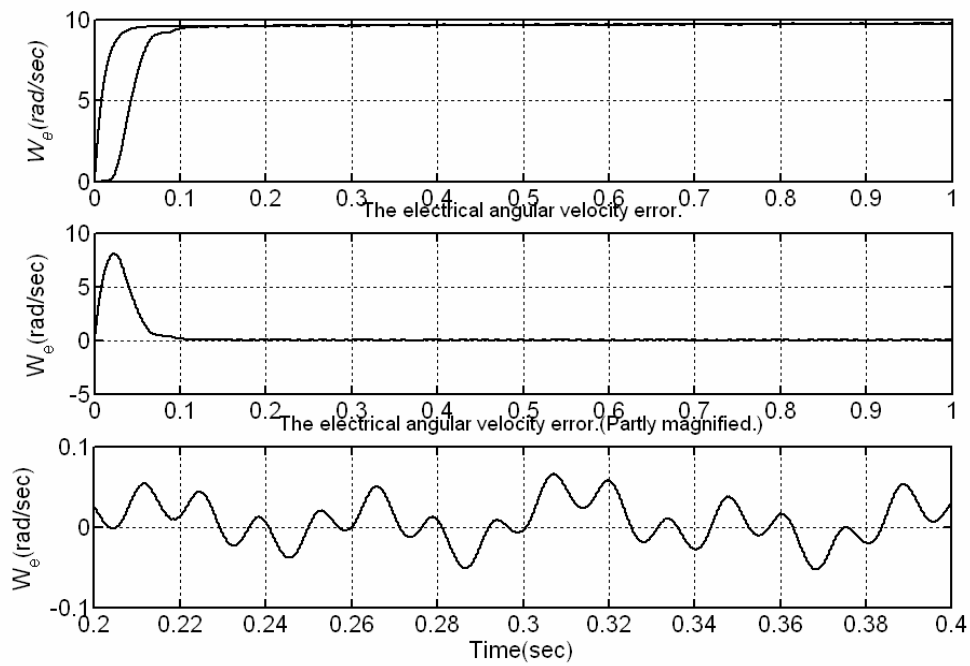
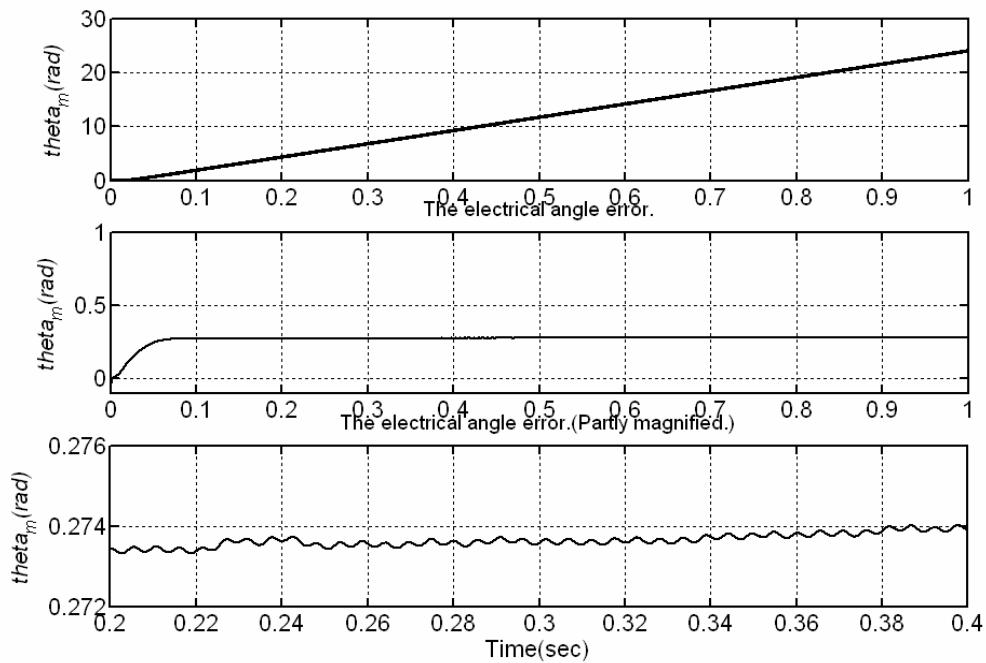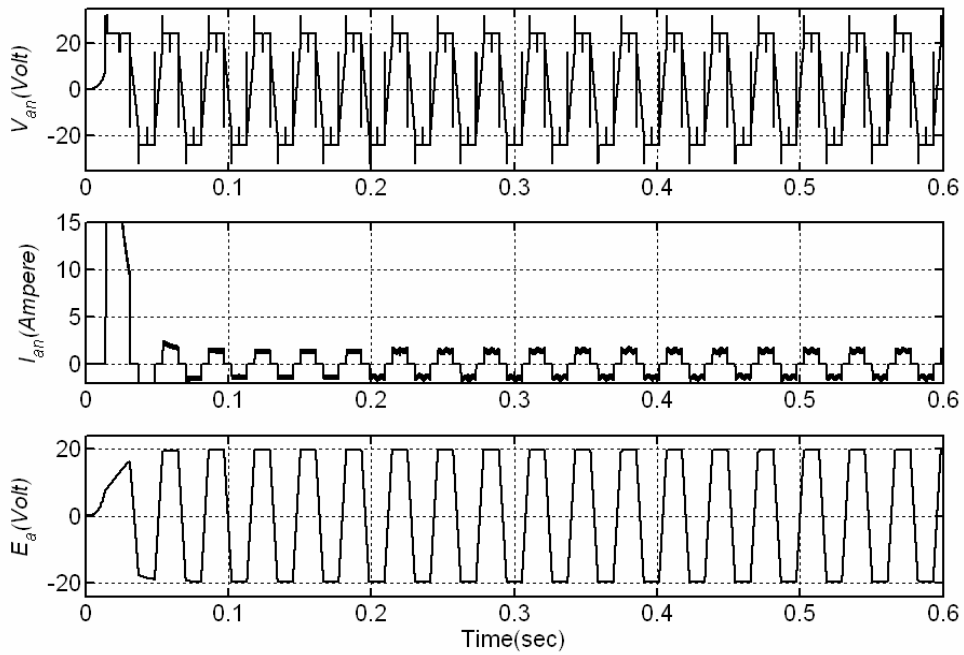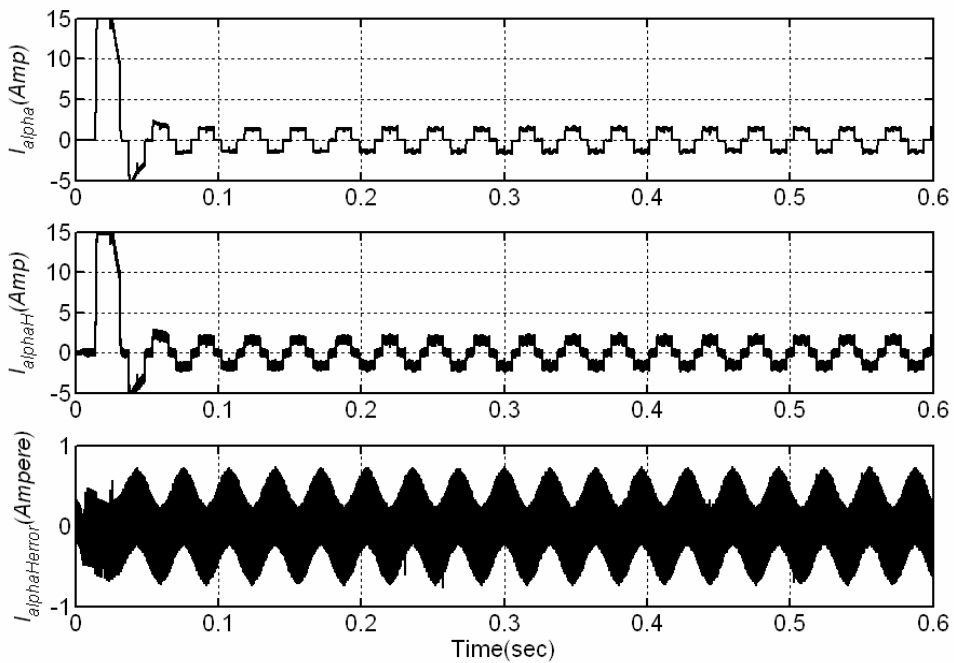Figure 5.17 The electrical angular velocity of the BLDC motor in sensorless control of case (1)
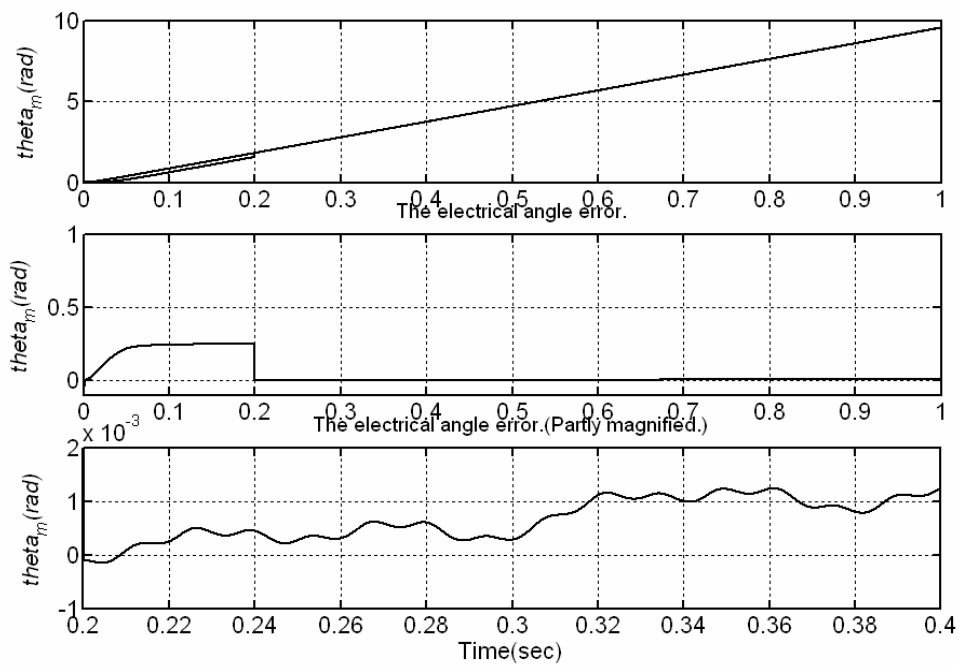
Figure 5.18 The angular position of the BLDC motor in sensorless control of case (1).

Figure 5.19 The phase voltage, current and back-EMF of phase *a* in testing estimator of case (2).

Figure 5.20 The information of the α-axis current in testing estimator of case (2).

Figure 5.21 The information of the β-axis current in testing estimator of case (2).

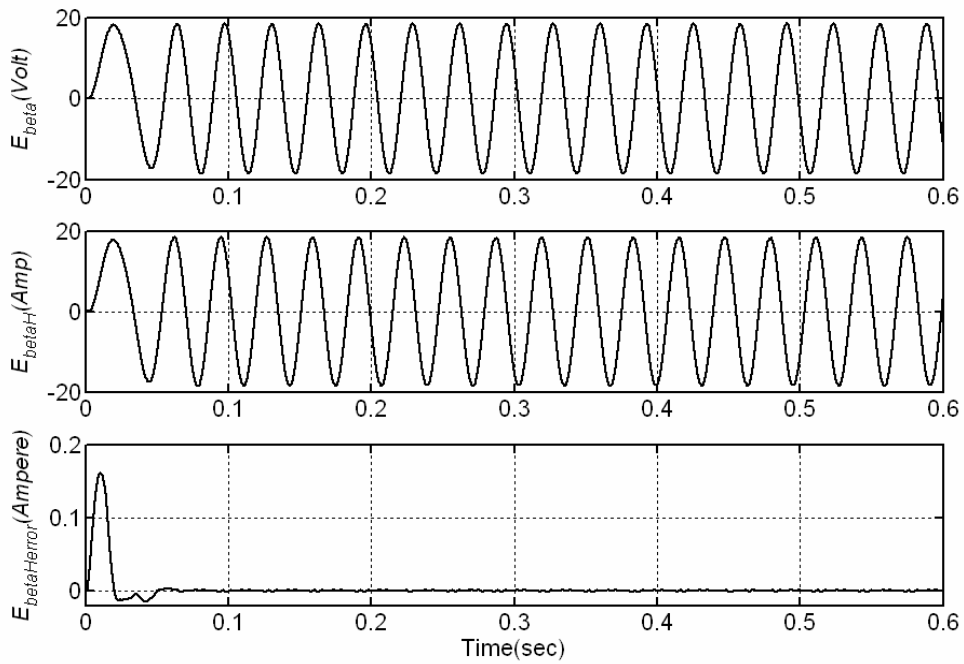Figure 5.22 The information of the α-axis back-EMF in testing estimator of case (2).

Figure 5.23 The information of the β-axis back-EMF in testing estimator of case (2).

Figure 5.24 The information of the electrical torque in testing estimator of case (2).

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Figure 5.25 The electrical angular velocity of the BLDC motor in testing estimator of case (2).

Figure 5.26 The angular position of the BLDC motor in testing estimator of case (2).

Figure 5.27 The phase voltage, current and back-EMF of phase *a* in sensorless control of case (2).

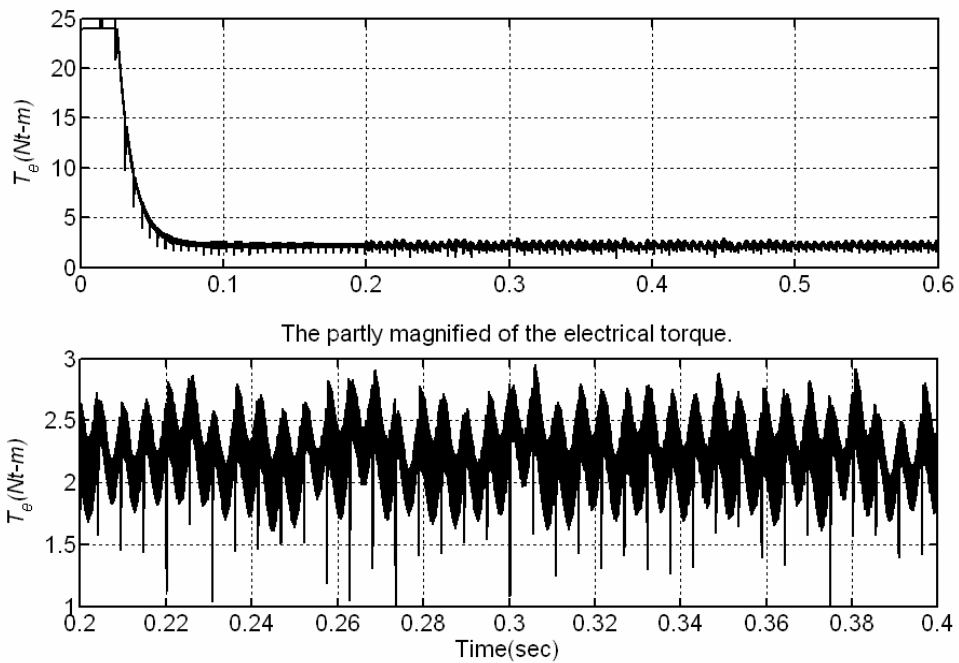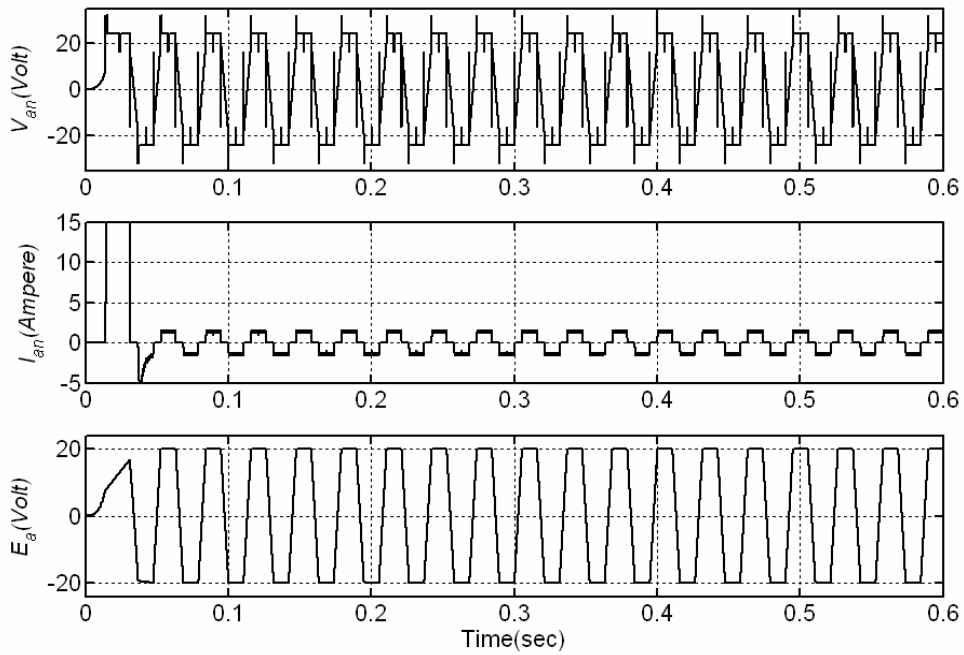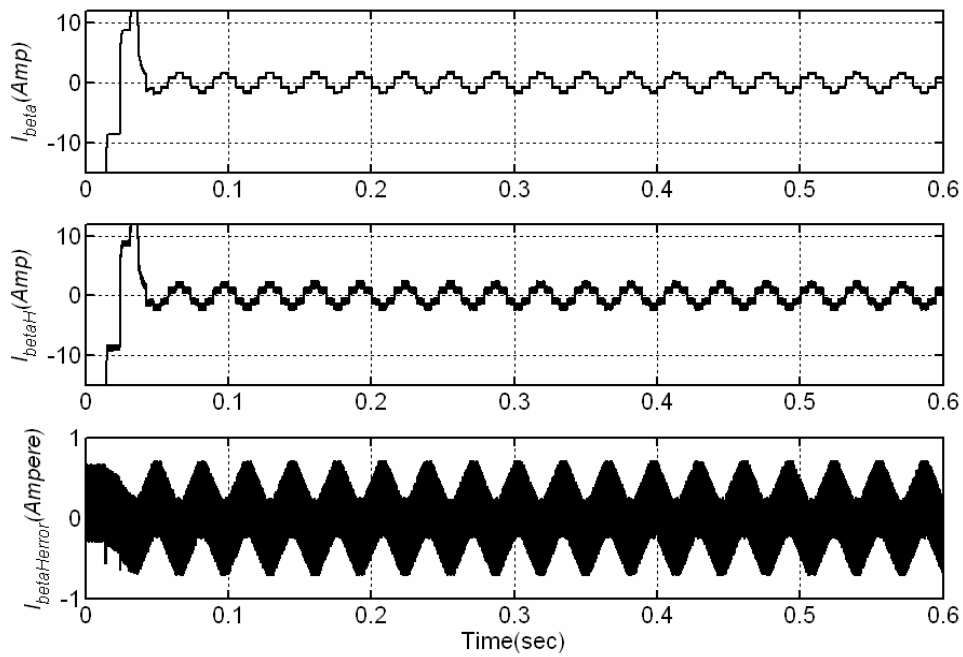Figure 5.28 The information of the β-axis current in sensorless control of case (2).
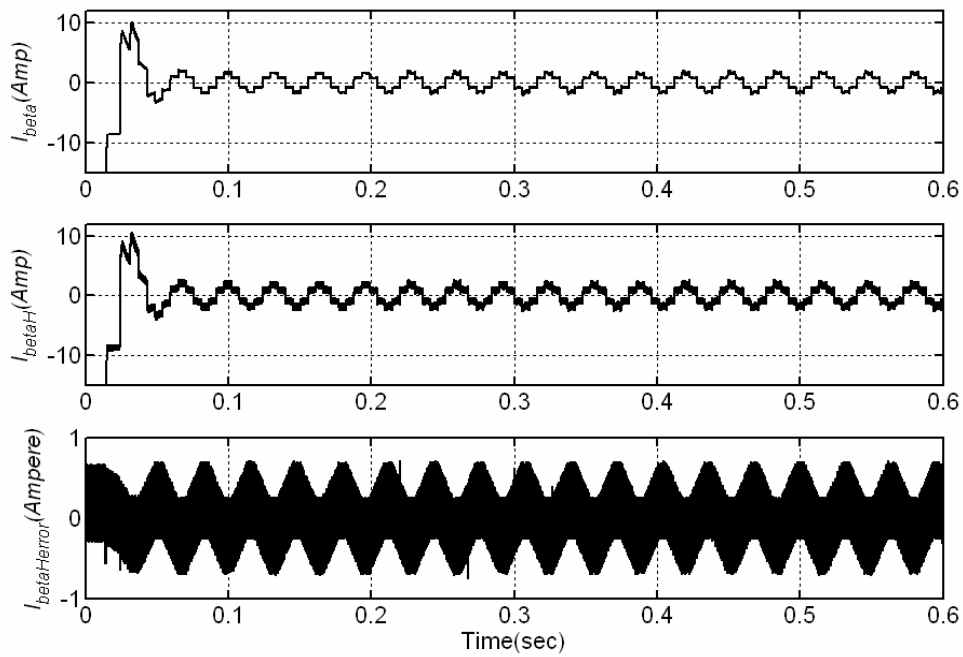
Figure 5.29 The information of the β-axis current in sensorless control of case (2).
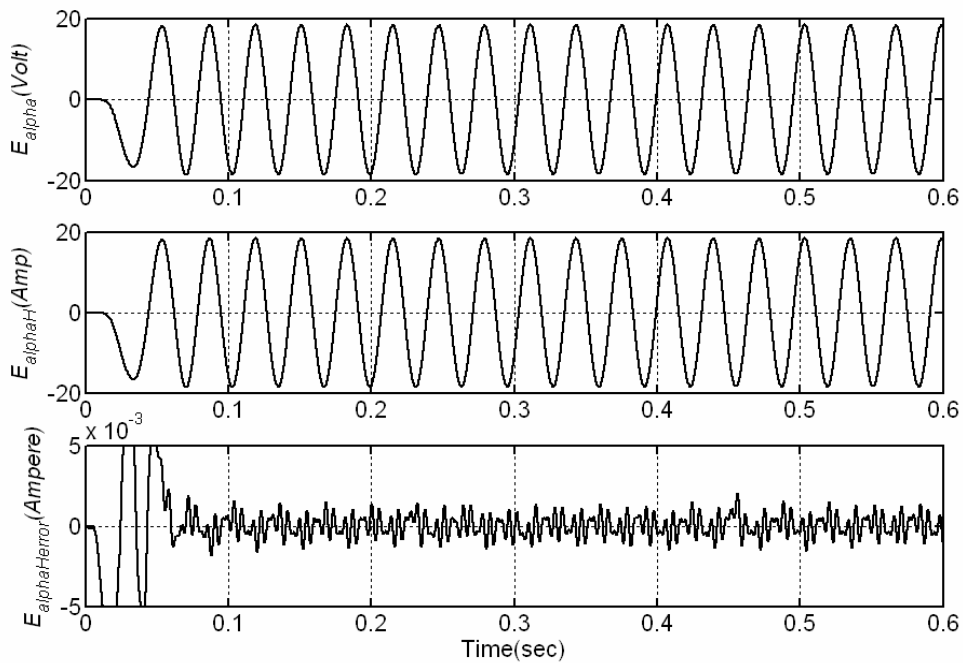
Figure 5.30 The information of the αβ-axis back-EMF in sensorless control of case (2).

Figure 5.31 The information of the β-axis back-EMF in sensorless control of case (2).

Figure 5.32 The information of the electrical torque in sensorless control of case (2).
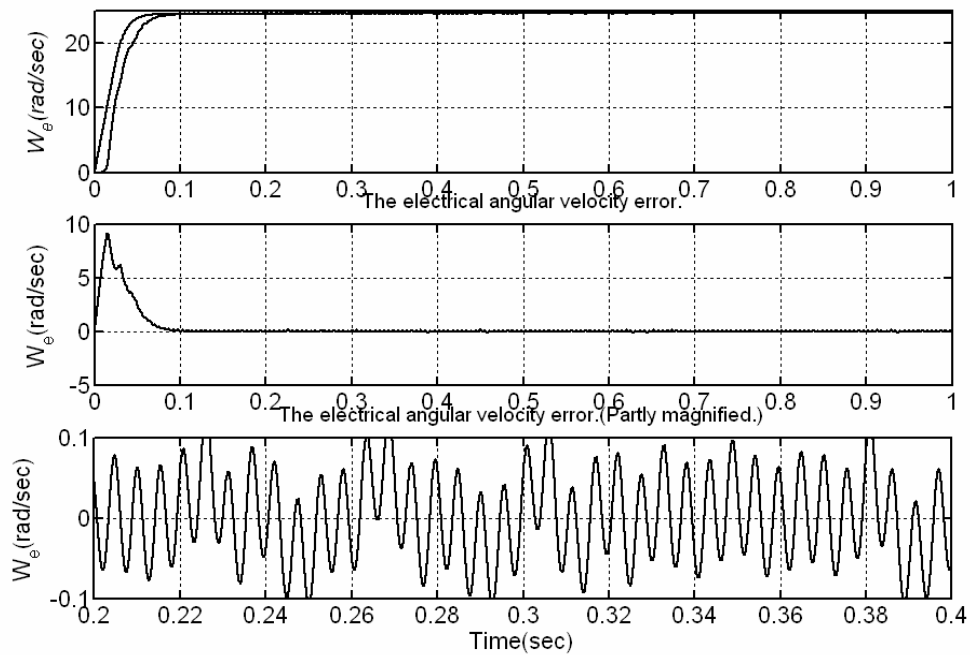
Figure 5.33 The angular position velocity of the BLDC motor in sensorless control of case (2).
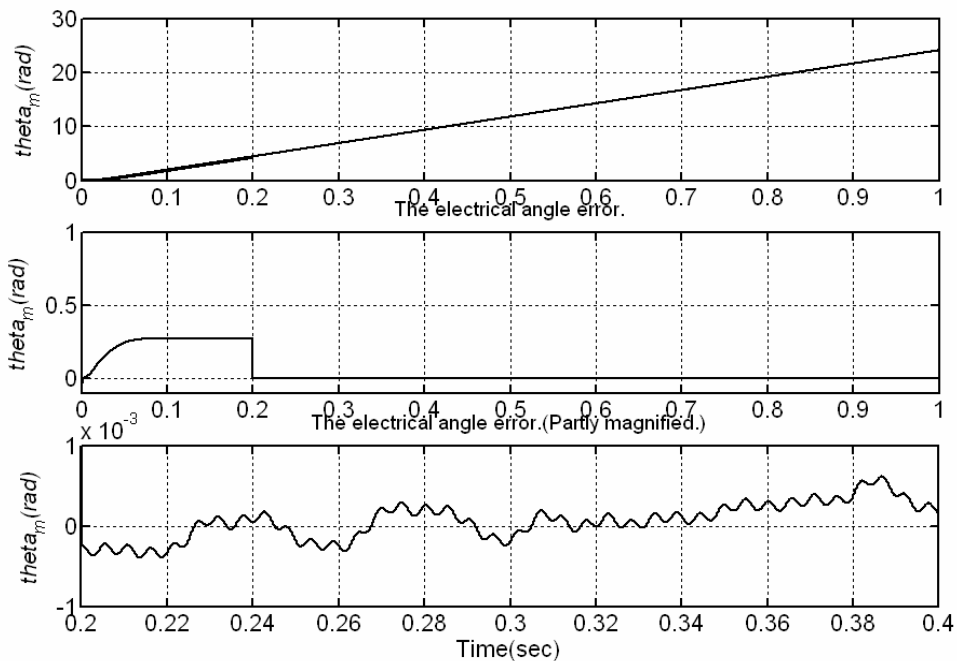
Figure 5.34 The electrical angle of the BLDC motor in sensorless control of case (2).

Figure 5.35 The phase voltage, current and back-EMF of phase *a* in testing estimator of case (3).
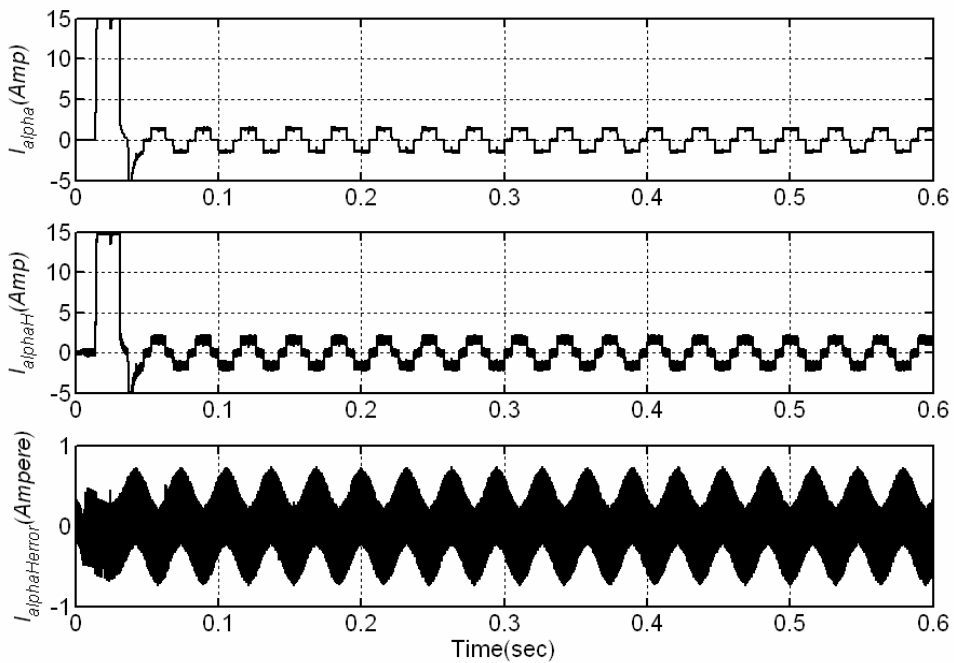
Figure 5.36 The information of the α-axis current in testing estimator of case (3).

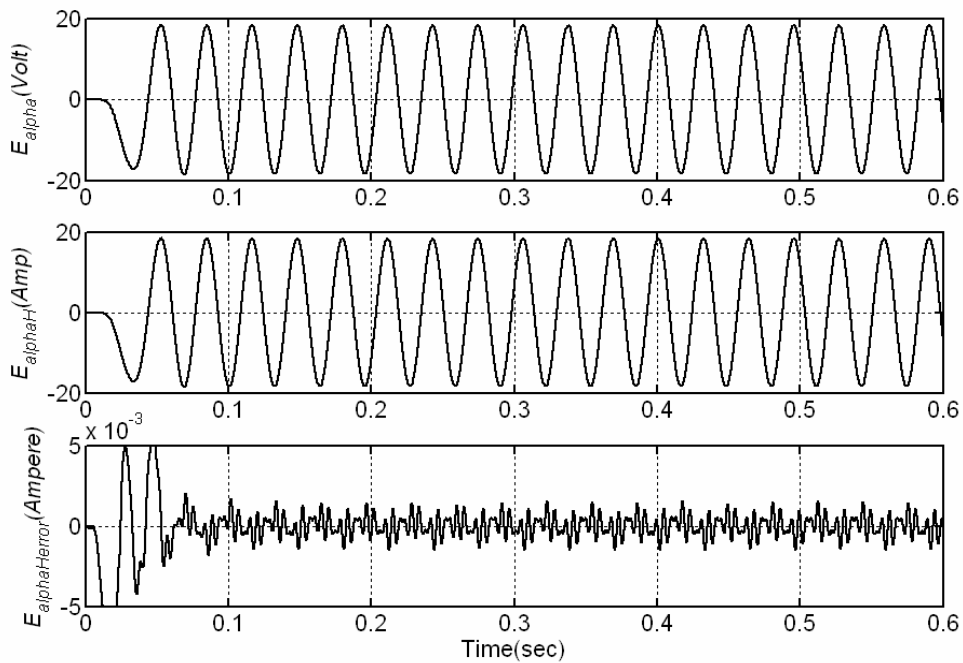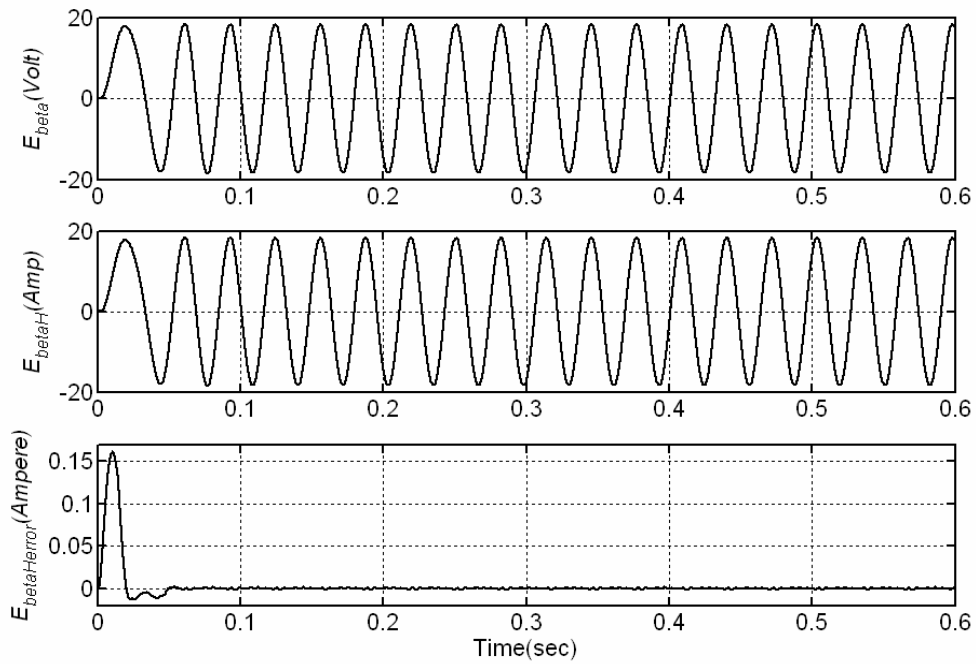Figure 5.37 The information of the β-axis current in testing estimator of case (3).

Figure 5.38 The information of the α-axis back-EMF in testing estimator of case (3).

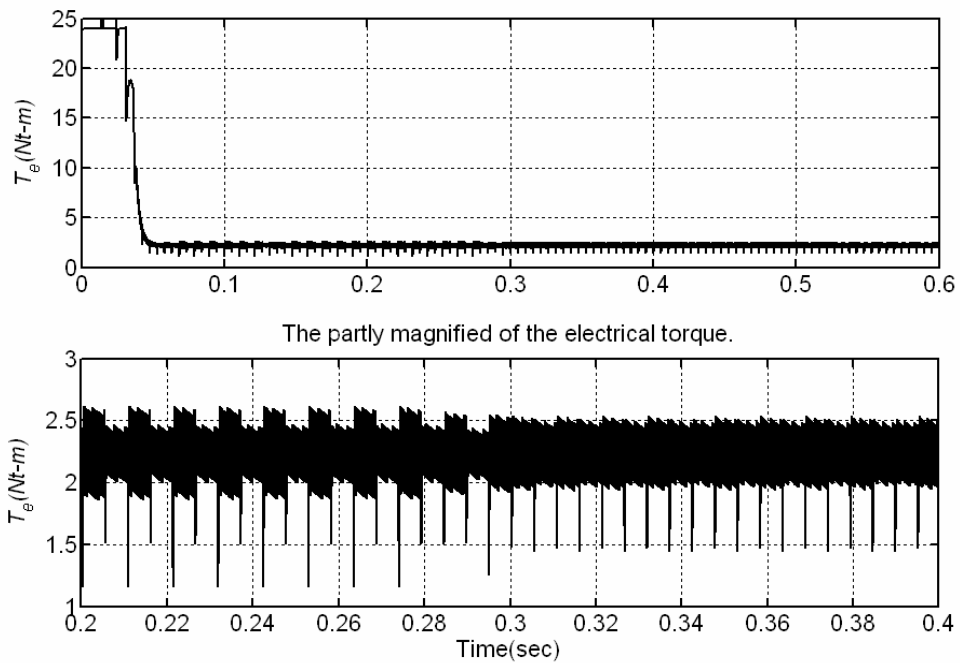Figure 5.39 The information of the β-axis back-EMF in testing estimator of case
(3).

Figure 5.40 The information of the electrical torque in testing estimator of case
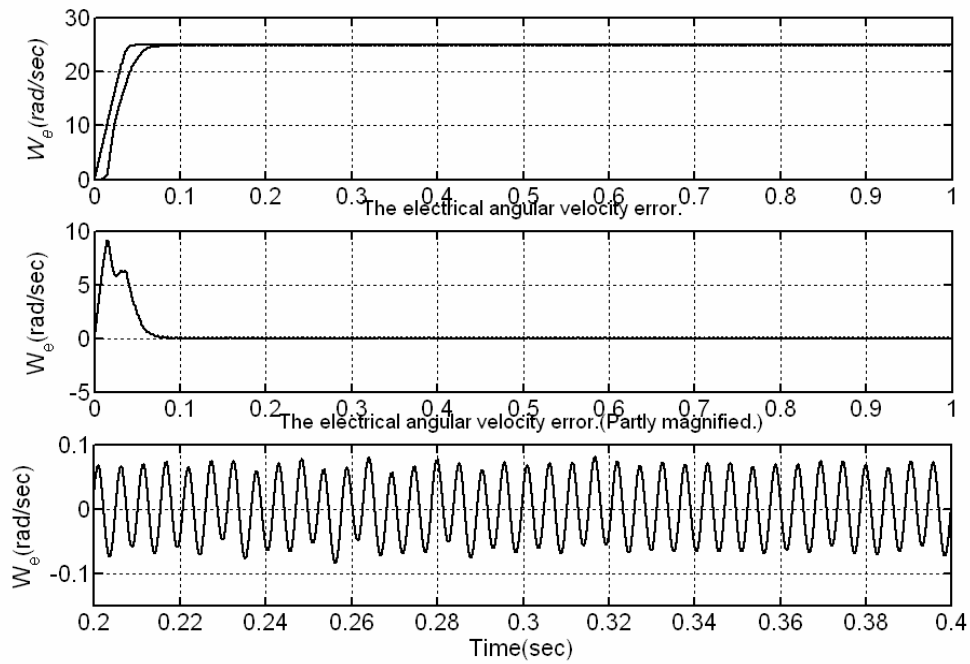(3).

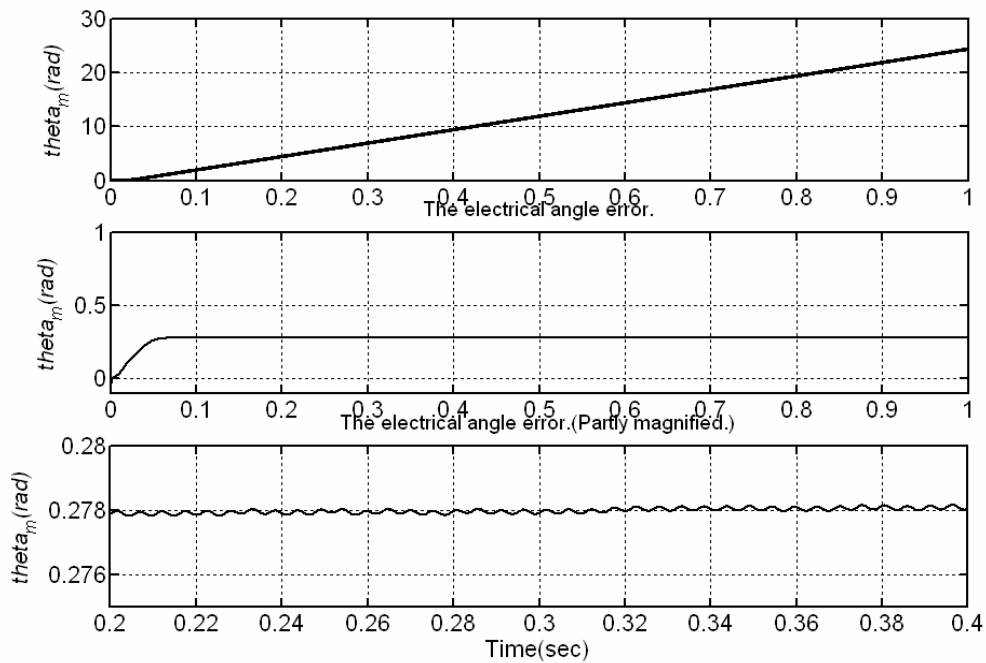Figure 5.41 The electrical angular velocity of the BLDC motor in testing estimator of case (3).

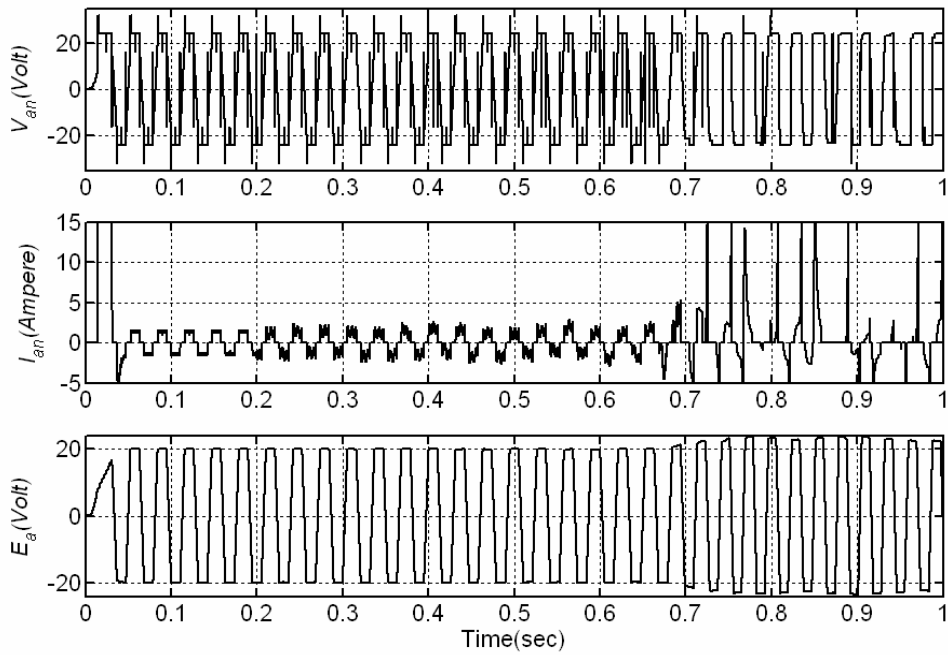Figure 5.42 The angular position of the BLDC motor in testing estimator of case (3).

Figure 5.43 The phase voltage, current and back-EMF of phase *a* in sensorless control of case (3).
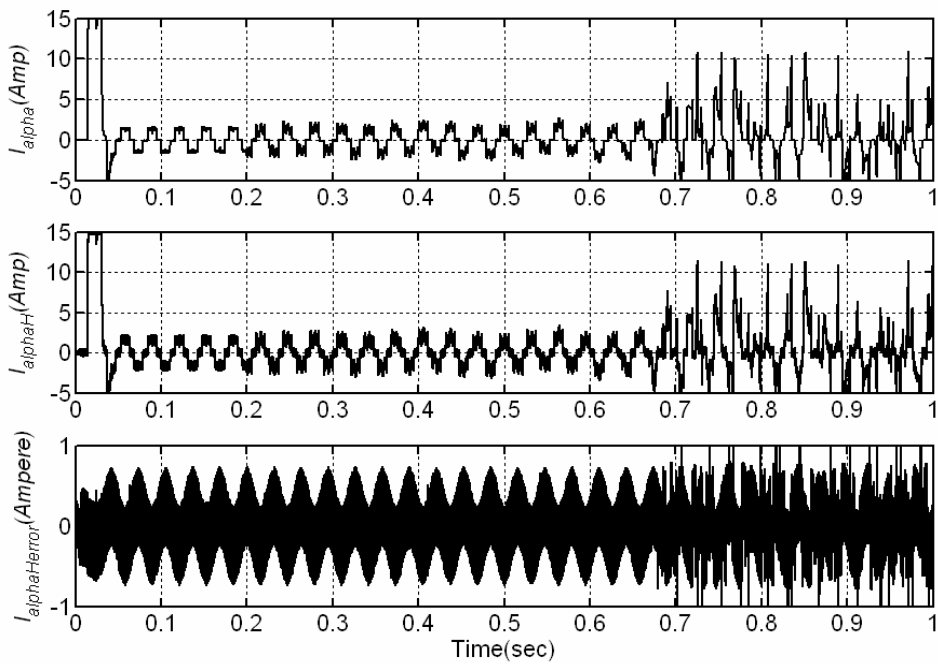

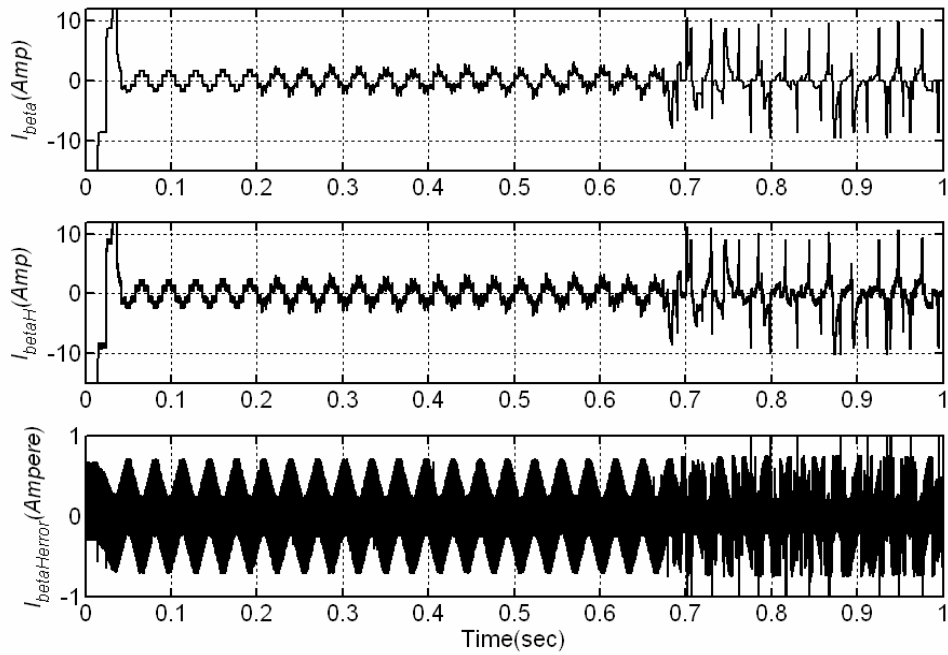Figure 5.44 The information of the α-axis current in sensorless control of case (3).

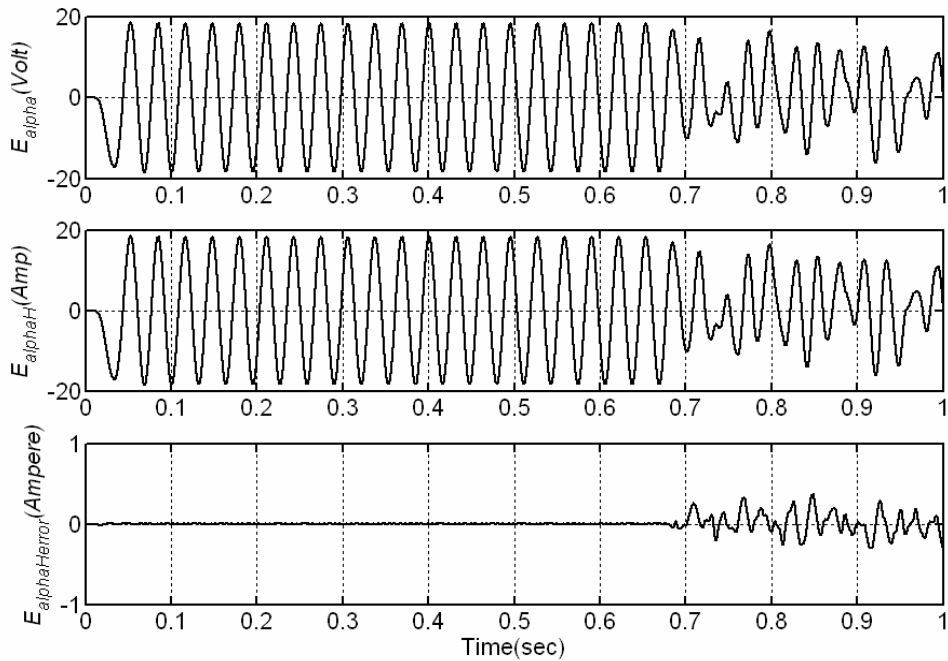Figure 5.45 The information of the β-axis current in sensorless control of case (3).

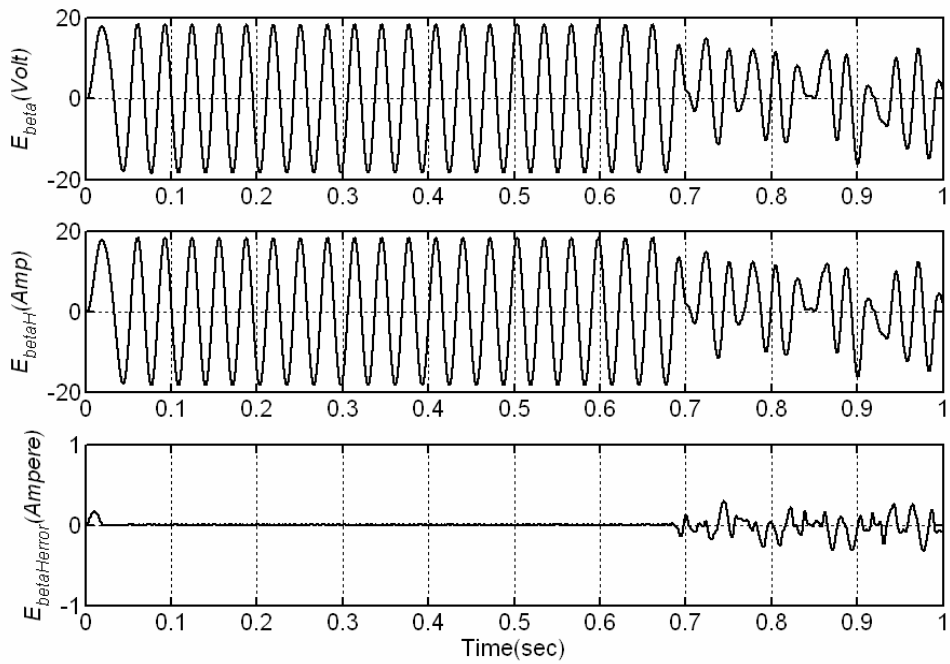Figure 5.46 The information of the α-axis back-EMF in sensorless control of case (3).

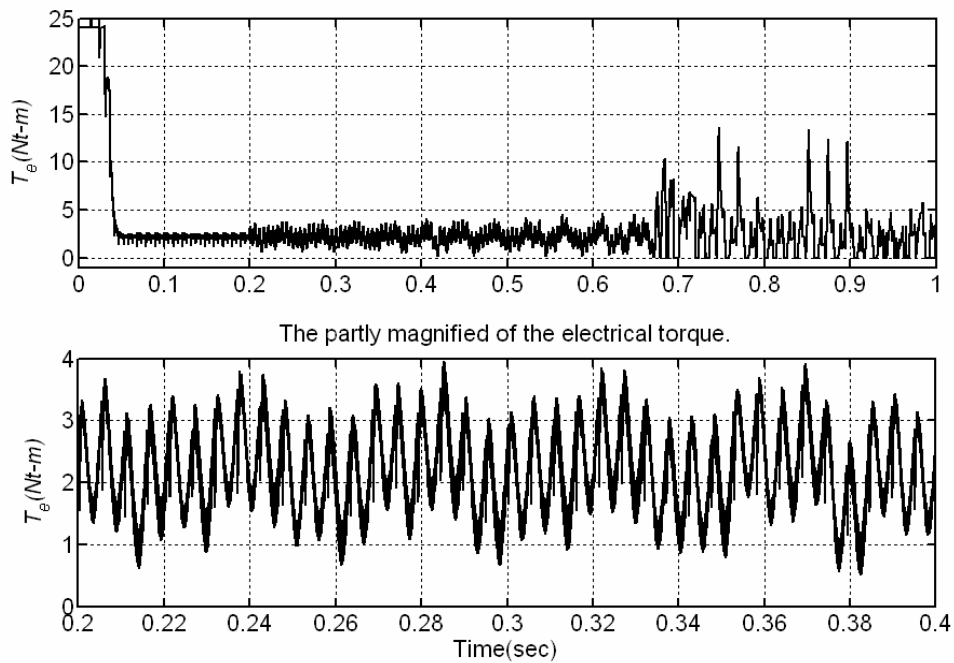Figure 5.47 The information of the β-axis back-EMF in sensorless control of case
(3).

Figure 5.48 The information of the electrical torque in sensorless control of case
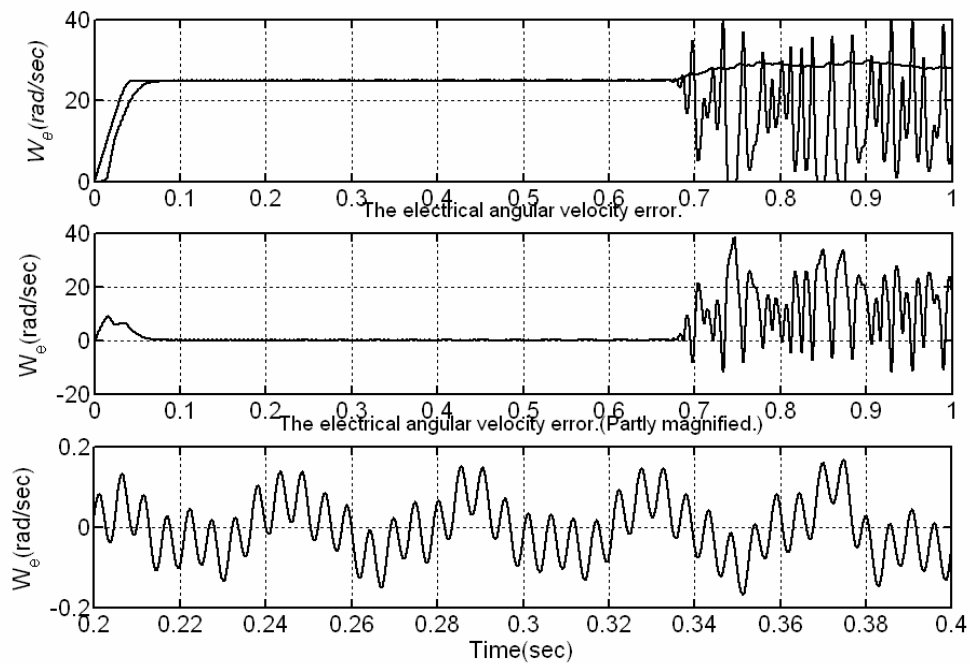(3).

Figure 5.49 The electrical angular velocity of the BLDC motor in sensorless control of case (3).
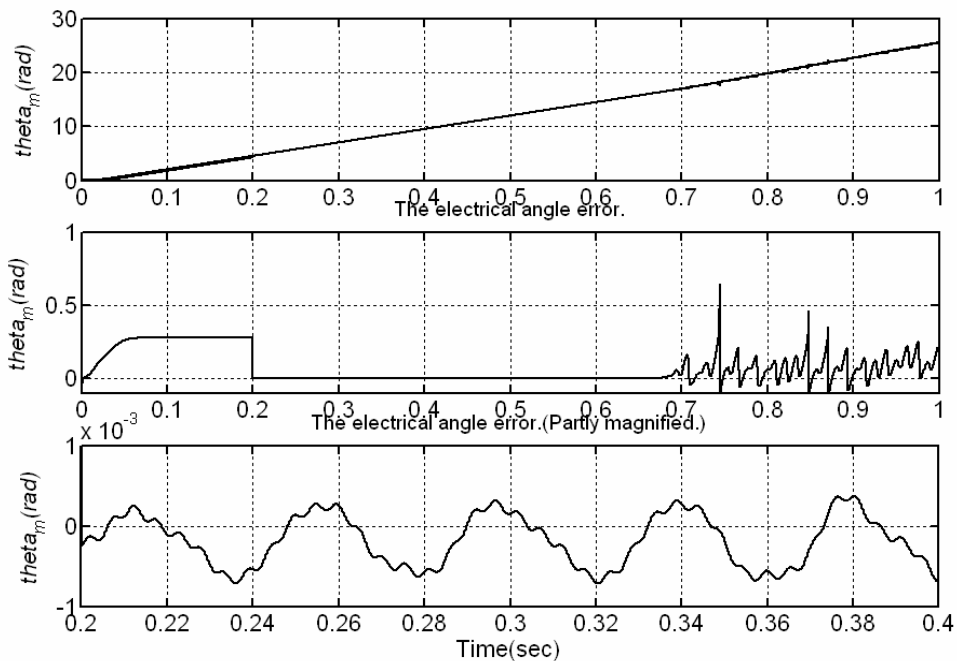

Figure 5.50 The angular position of the BLDC motor in sensorless control of case (3).
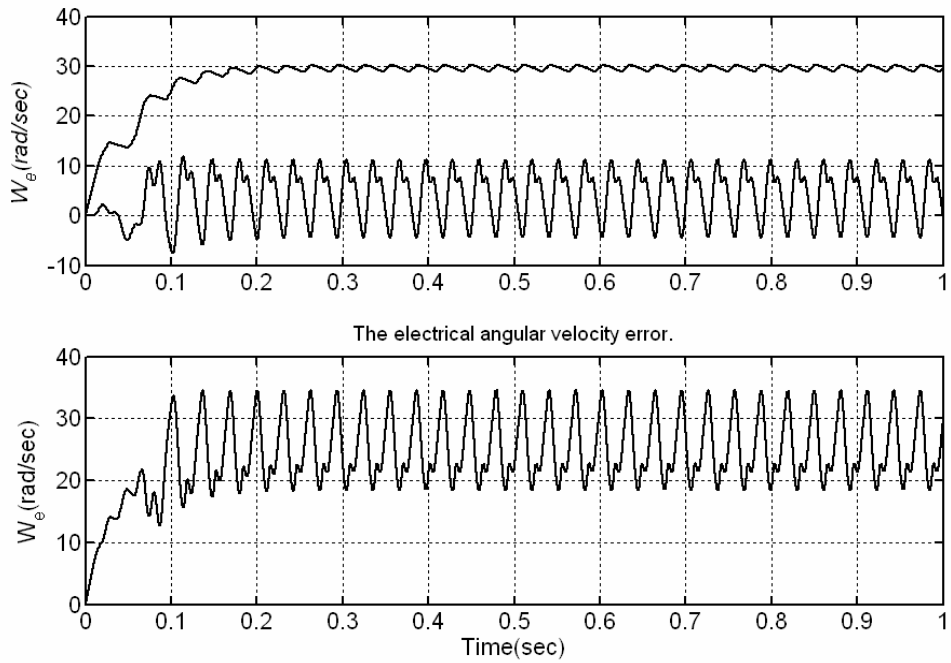
Figure 5.51 The electrical angular velocity of the BLDC motor in failure case.
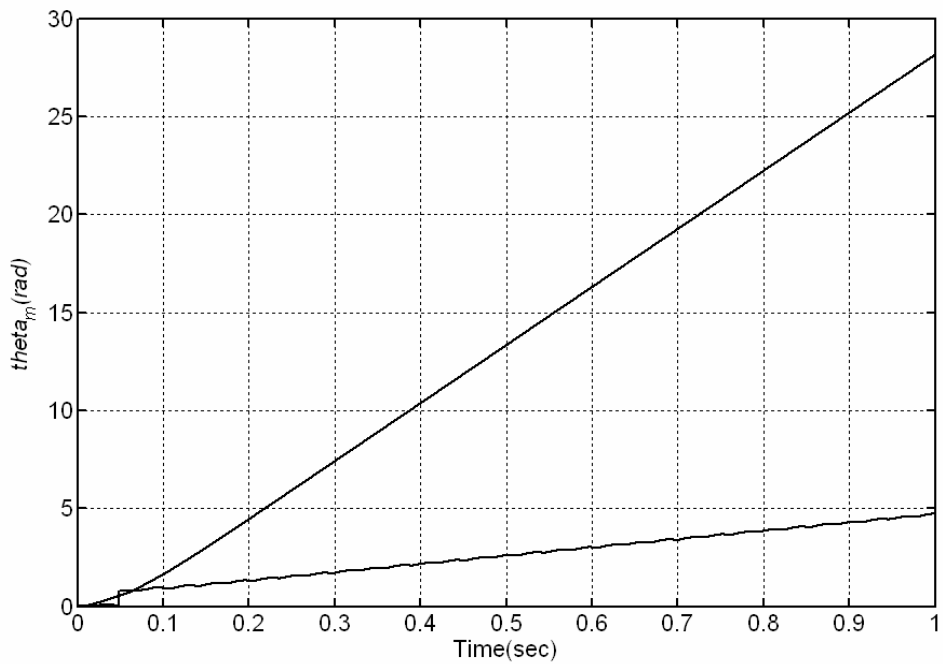

Figure 5.52 The angular position of the BLDC motor in failure case.

5.2 Hardware experiment results

The purpose of the hardware experiments are planned in testing estimator only. The experiment results in high angular velocity (about 172rpm) without loading torque presented from Figure 5.53 to Figure 5.57; and a low angular (about 95.5rpm) velocity without loading torque is shown from Figure 5.58 to Figure 5.62. The total experimental results are shown as follows.
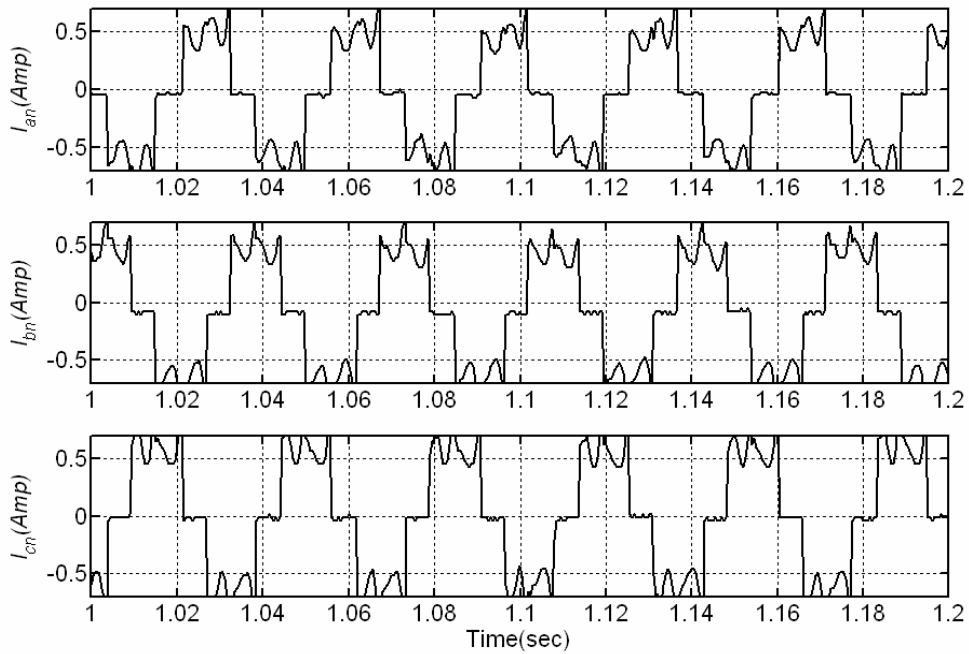

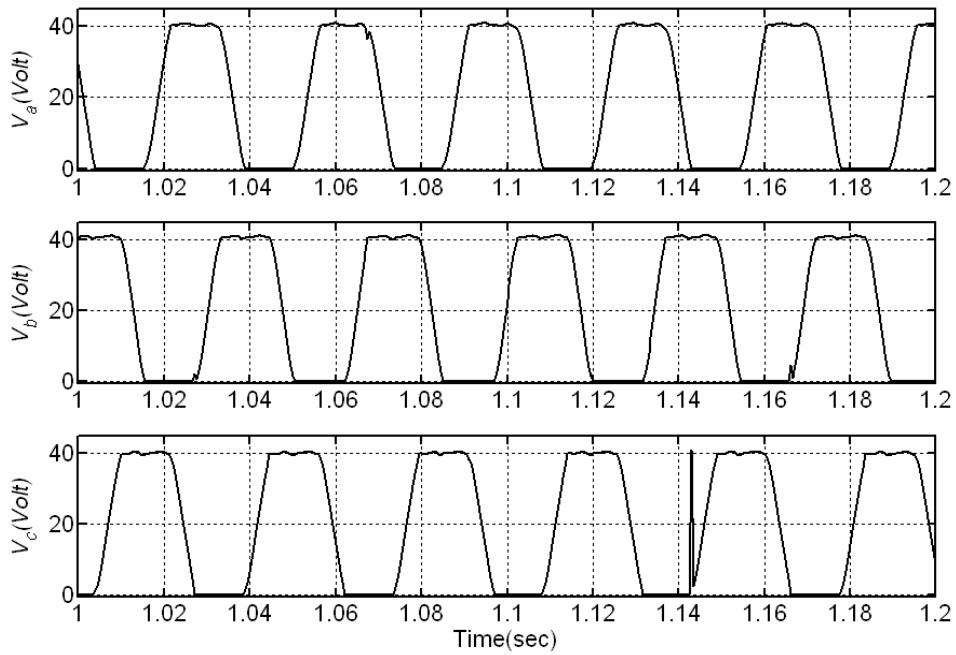Figure 5.53 The three terminal phase currents in a high angular velocity.

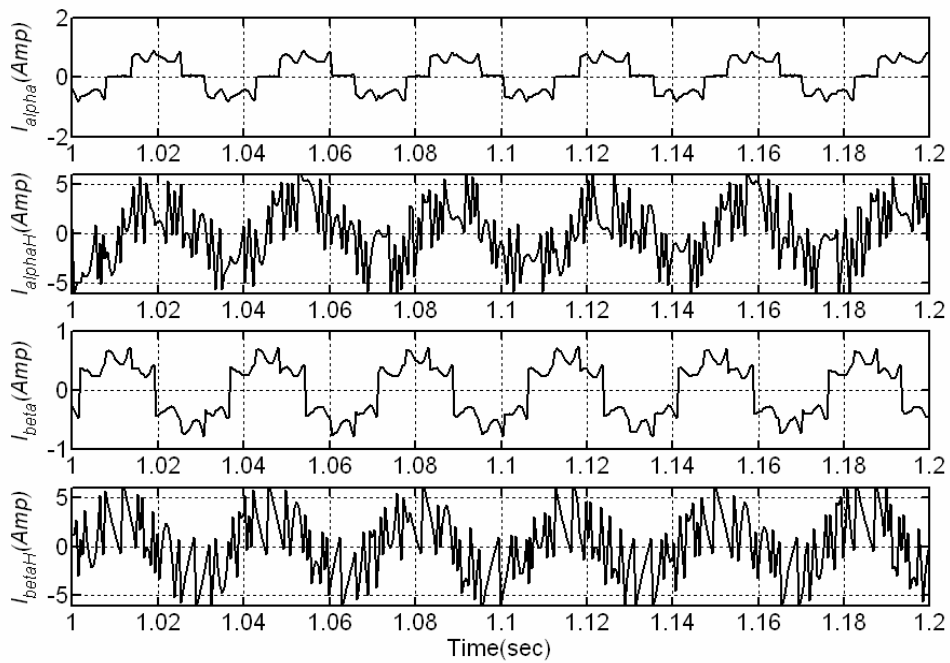Figure 5.54 The three terminal-ground voltages in a high angular velocity.

Figure 5.55 The actual and estimated currents of αβ axis in a high angular velocity.
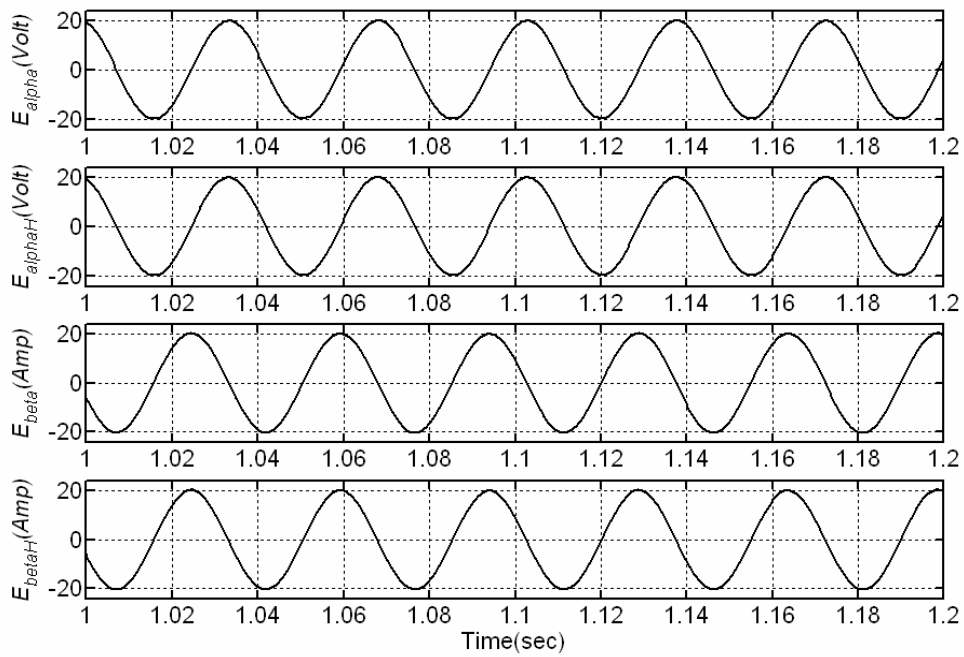
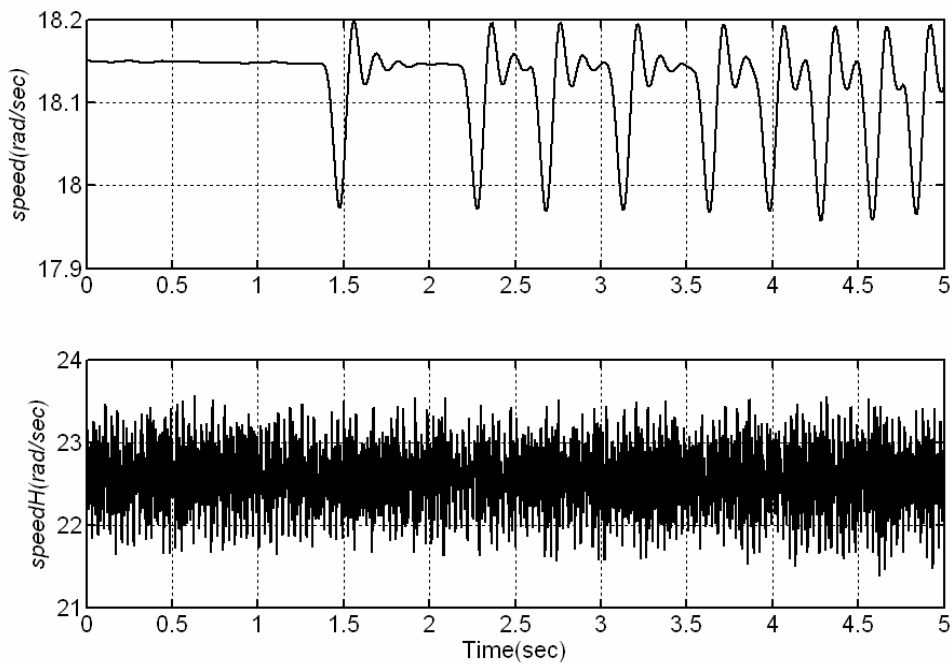Figure 5.56 The actual and estimated back-EMFs of αβ axis in a high angular velocity.

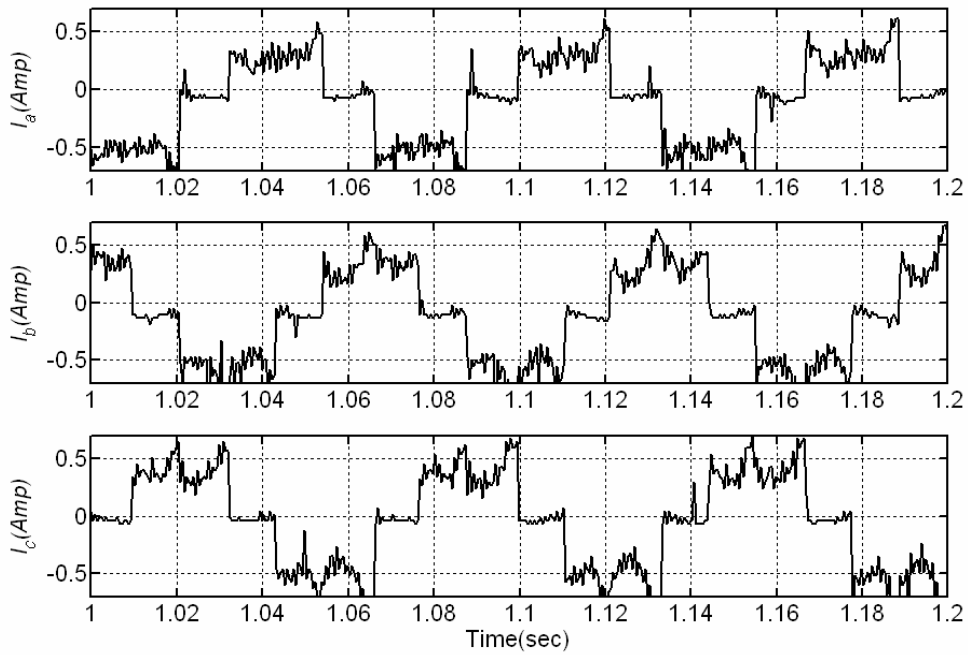Figure 5.57 The actual and estimated angular velocity in a high angular velocity.

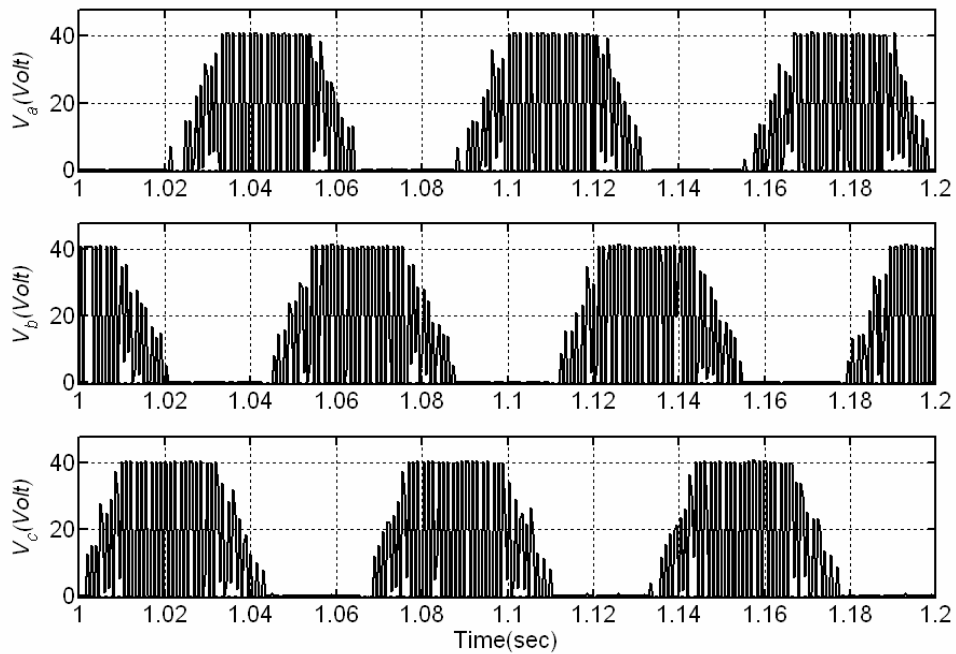Figure 5.58 The three terminal currents in a low angular velocity.

Figure 5.59 The three terminal-ground voltages in a low angular velocity.
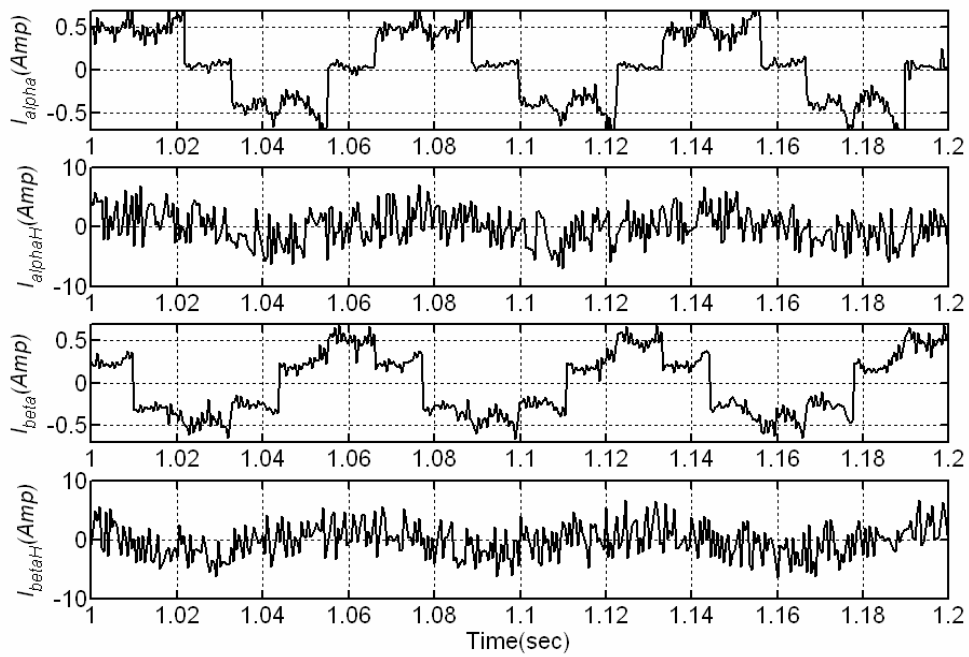
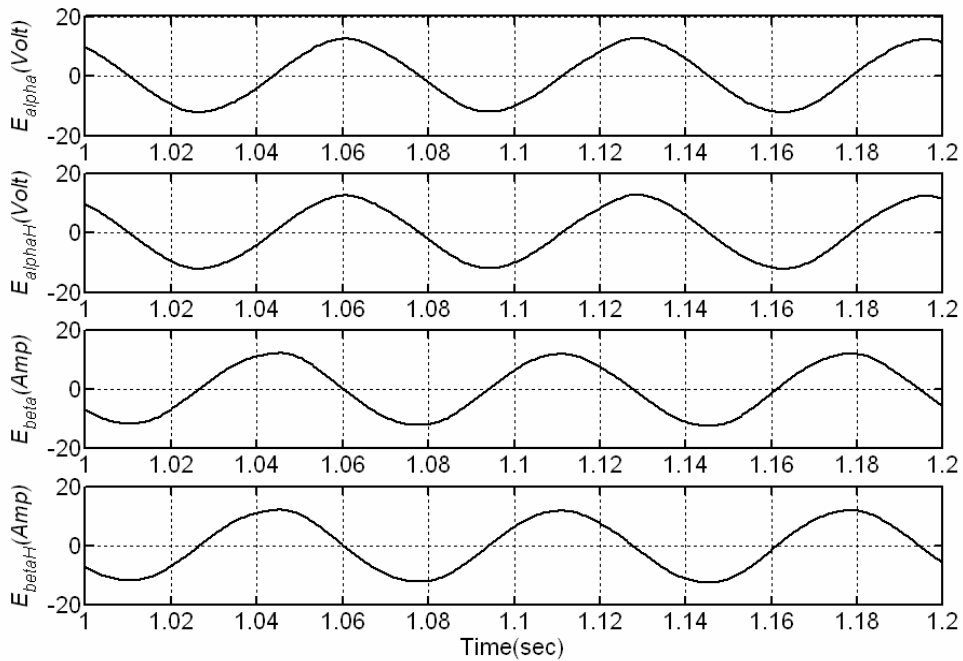Figure 5.60 The actual and estimated currents of αβ axis in a low angular velocity.

Figure 5.61 The actual and estimated back-EMFs of αβ axis in a low angular velocity.
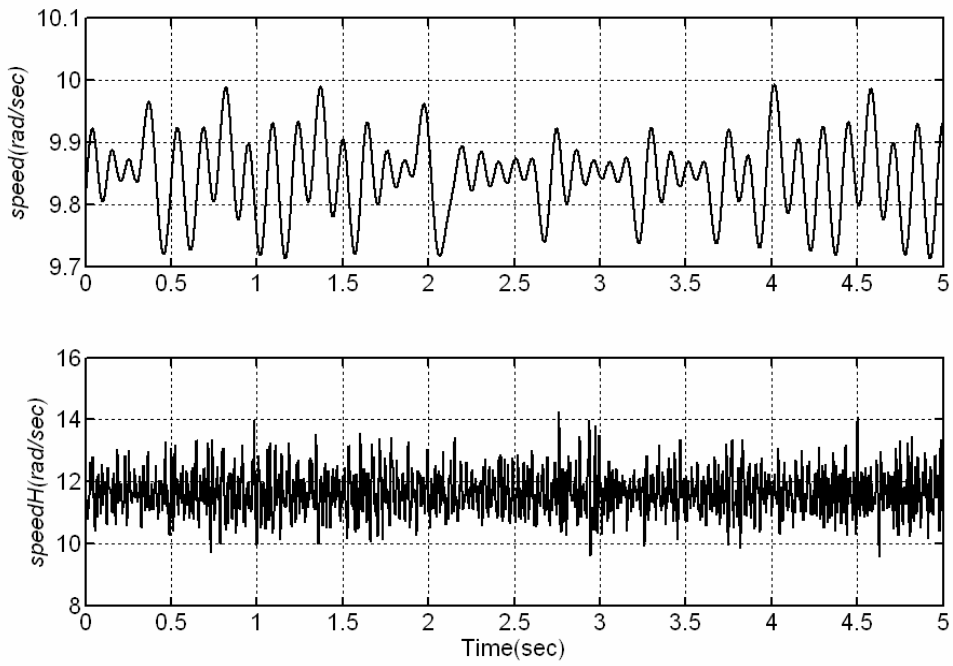
Figure 5.62 The actual and estimated angular velocity in a low angular velocity.