Errata

Chapter 1.

At page 15

\[ J = \begin{bmatrix} J_{xx} & -J_{xy} & -J_{xz} \\ -J_{xy} & J_{xx} & -J_{yz} \\ -J_{xz} & -J_{yz} & J_{yy} \end{bmatrix} \]

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At page 15

In (1-23) \( F \) stands for external force acting on a rigid body, \( M \), for mass of a rigid body.

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Page 16.

\[ f_i = (f_i, 0, 0) \quad i = 1, 2 \quad f_i = (f_i, 0, 0) \quad i = 3, 4 \quad f_i = (f_i, 0, 0) \quad i = 5, 6, 7 \]

\[ [T_{e_x} \quad T_{e_y} \quad T_{e_z}] = \sum_{i=1}^{7} \mathbf{r}_i \times f_i \]

\[ f_i = (f_i, 0, 0) \quad i = 1, 2 \quad f_i = (0, f_i, 0) \quad i = 3, 4 \quad f_i = (0, 0, f_i) \quad i = 5, 6, 7 \]

\[ [T_{e_x} \quad T_{e_y} \quad T_{e_z}] = \sum_{i=1}^{7} \mathbf{r}_i \times f_i \]

Page 24.

Problems

1. Exercise Problem 1. Calculate the moment of inertia of rotating cylinder as shown in Fig.p.1.1. The density of the cylinder is \( \rho \). Describe how to maximize the ratio, \( J/M \), between the inertia, \( J \), and the mass of the cylinder, \( M \), under the condition of \( r_1+2r_2=\text{constant} \).

2. As shown in Fig.p.1.2, a disk is rotating regarding z axis. The origin of the Cartesian coordinate is apart from the center of the mass, \( G \), by \( 2(\text{mm}), 2(\text{mm}), 1(\text{mm}) \) as shown in the figure. The ‘G’ can be represented by \( (-2 \ \text{mm}, -2 \ \text{mm}, -1\text{mm}) \) in the coordinate. The radius of the disk is, \( r \), \( 100(\text{mm}) \), and thickness of the disk is \( 10(\text{mm}) \). The density of the disk is \( 8000 \text{kg/m}^3 \).
3. As shown in Fig.1.13, there is a rigid body moving by seven forces. The body is not constraint in any axis of motion. The gravitational force is acting in the direction of z axis. At the starting instant, 

$\rightarrow$ As shown in Fig.1.13, there is a rigid body moving by seven forces. The body is not constraint in any axis of motion. The gravitational force is acting in the direction of $-z$ axis. At the starting instant,

At page 27, problem 5. Figure P1.4

At page 30, problem 8.

In Fig. P1.29, a conceptual $\rightarrow$ In Fig. P1.9, a conceptual $\rightarrow$

Chapter 2.

At page 68, Fig.2.36
At page 75, equation (2.50)

\[
P_{\text{copper}} = 3 \left( R_s \| \| ^2 + \frac{R_s}{S} \| \| ^2 \right) \quad \Rightarrow \quad P_{\text{copper}} = 3 \left( R_s \| \| ^2 + R_s \| \| ^2 \right)
\]
For the control system shown in Fig.2.60, prepare the $V_f$ table of the figure in the frequency range from 0 to $360\pi$(rad/s) for the induction machine, whose parameters are given as followings.

Rated power: 22kW, Rated voltage(line to line rms): 220V, Rated speed: 1755r/min.
Base frequency: 60Hz, Number of pole: 4, Inertia of the machine itself: 0.122 kg m$^2$, Rated current: 75A

\[ R_s = 0.044\Omega, \quad R_r = 0.0252\Omega, \quad L_m = 0.55mH, \quad L_n = 0.47mH, \quad L_m = 12.90mH \]

A 22kW induction machine, whose parameters and limiting conditions are given in followings, are driven by 280Hz voltage source. The machine is generating the available maximum torque as a motor in the steady state keeping the limiting conditions.

Rated power: 22kW, Rated voltage(line to line rms): 220V, Rated speed: 1755r/min.
Base frequency: 60Hz, Number of pole: 4, Inertia of the machine itself: 0.122 kg m$^2$, Rated current: 75A

Chapter 4.

Fig.4.19 at page 178 should be changed as followings!
Chapter 5

Equation (5-70) at page 256

\[
L_q^2 \left( i_{s_{\text{max}}}^2 - i_{d_{\text{st}}}^2 \right)^2 - L_d^2 \left( i_{d_{\text{st}}}^2 + \frac{\lambda_f}{L_d - L_q} \right) \left( i_{d_{\text{st}}}^2 + \frac{\lambda_f}{L_d} \right) = 0
\]

\[
L_q^2 \left( i_{s_{\text{max}}}^2 - i_{d_{\text{st}}}^2 \right) - L_d^2 \left( i_{d_{\text{st}}}^2 + \frac{\lambda_f}{L_d - L_q} \right) \left( i_{d_{\text{st}}}^2 + \frac{\lambda_f}{L_d} \right) = 0
\]

Problems

8. A four pole induction machine with following parameters is controlled in the rotor flux linkage oriented vector control mode by a PWM inverter with an ideal current regulation loop. The machine is running in the steady state, \( i_{d_{\text{st}}} = 7 \text{ A} \). And the frequency of the stator current is 55Hz. At \( t = 0 \text{ s} \), when the direction of the rotor flux linkage coincides with that of magnetic axis of ‘a’ phase winding, the input contactor of the machine is opened as shown in Fig.5.4. After \( t = 0^+ \), find the line to line voltage between ‘a’ and ‘b’ phase of the machine through following procedures. The current to the machine is immediately zero after the opening of the contactor.

\( R_s = 0.55 \Omega, R_r = 0.36 \Omega \)

\( L_{d_r} = 1.8 \text{ mH}, L_{n_r} = 1.8 \text{ mH} \)

\( L_m = 59 \text{ mH}, \text{Inertia of motor itself; } J_M = 0.04 \text{ kg m}^2 \)

Rated power of the induction machine is 5Hp and the inertia of the load is 9 times of the machine inertia, \( J_M \).
And the friction coefficient, \( B_{M+L} \), of the drive system is 0.1 N-m/(rad/s).

1) Just after the opening of the switch, find rotor angular speed, \( \omega_r \left( 0^+ \right) \), d-q axis stator flux linkage, \( \lambda_{d_{\text{st}}} \left( 0^+ \right) \), \( \lambda_{q_{\text{st}}} \left( 0^+ \right) \), in the rotor reference frame.
2) Find the rotor angular speed $\Omega_\theta (t), \ t > 0^+$ in electric angle.

3) Find $\lambda'_{d}, \ t > 0^+.$

4) Find ‘a’ phase voltage, $V_{a}(t), \ t > 0^+.$

5) Find ‘b’ phase voltage, $V_{b}(t), \ t > 0^+.$

6) Find line to line voltage $V_{ab}(t), \ t > 0^+.$

3) In the case of problem 2), calculate $V_{ds}^r$ and $V_{qs}^r.$ At that instant, the speed of SMPMSM was 600r/min. In this part of problem, it is assumed that SMPMSM is running in the steady state.

15. Figure p5.8b
Chapter 6

At page 300

The figure 6.8 has some glitches. The figure should be revised as followings.

At page 301

\[
\left( s^2 + 2\zeta_s \omega_{s}^2 s + \omega_{s}^2 \right) \left( s^2 + 2\zeta_q \omega_{q}^2 s + \omega_{q}^2 \right) = 0 \]  

(6-66)

\[
\Rightarrow \left( s^2 + 2\zeta_s \omega_{s}^2 s + \omega_{s}^2 \right) \left( s^2 + 2\zeta_q \omega_{q}^2 s + \omega_{q}^2 \right) = 0 \]  

(6-66)

At page 311.

Eq.(6.81) should be revised as followings.

\[
v_{dph} = \begin{bmatrix} V_p \cos \omega_p t \\ 0 \end{bmatrix}
\]

\[
\Rightarrow \dot{v}_{dph} = \begin{bmatrix} V_p \cos \omega_p t \\ 0 \end{bmatrix}
\]

Problems

4. An eight-pole … in Fig.6.5. The current regulator can be assumed as ideal one, which means that the transfer function of the regulator is unity. The bandwidth of the speed …. → An eight-pole … in Fig.6.5. The bandwidth of the current regulator is 400Hz and its control block diagram is shown in Fig. 4.18. The output of the regulator is not bounded. The bandwidth of the speed …. 
(1) If the speed reference, \( \omega_{\text{ref}}^* \), and the load torque, \( T_L \), are followings, plot speed reference, actual speed, actual torque, the d-q axis current, \( i_{ds} \), \( i_{qs} \), with their references, and error between estimated rotor position and actual position along with time from 0 to 5s. It is assumed that PWM inverter is ideal and the output of the current regulator is directly applied to SMPMSM without any delay or distortion. The exact parameters of SMPMSM have been known to the controller. And all control is done in analog domain.

\[
\omega_{\text{ref}}^* = \begin{cases} 
0s \leq t < 1s & (\text{Starting}) \\
1s \leq t < 3s & \frac{500}{\text{r/min}} \\
3s \leq t < 5s & \frac{50}{\text{r/min}} 
\end{cases} \\
T_L = \begin{cases} 
0s \leq t < 2s & 0\text{N-m} \\
2s \leq t < 2.5s & 60\text{N-m} \\
2.5s \leq t < 4s & 0\text{N-m} \\
4s \leq t < 4.5s & 60\text{N-m} \\
4.5s \leq t < 5s & 0\text{N-m}
\end{cases}
\]

\[
\Rightarrow \omega_{\text{ref}}^* = \begin{cases} 
0s \leq t < 1s & (\text{Starting}) \\
1s \leq t < 3s & \frac{500}{\text{r/min}} \\
3s \leq t < 5s & \frac{50}{\text{r/min}}
\end{cases} \\
T_L = \begin{cases} 
0s \leq t < 2s & 0\text{N-m} \\
2s \leq t < 2.5s & 60\text{N-m} \\
2.5s \leq t < 4s & 0\text{N-m} \\
4s \leq t < 4.5s & 60\text{N-m} \\
4.5s \leq t < 5s & 0\text{N-m}
\end{cases}
\]

5. An eight-pole IPMSM with … in Fig.6.8. The current regulator can be assumed as ideal one, which means that the transfer function of the regulator is unity. The bandwidth of the speed … An six-pole IPMSM with… in Fig.6.8. The bandwidth of the current regulator is 400Hz and its control block diagram is shown in Fig. 4.18. The output of the regulator is not bounded. The bandwidth of the speed …. 

\[
\omega_{\text{ref}}^* = \begin{cases} 
0s \leq t < 2s & \frac{500}{\text{r/min}} \\
2s \leq t < 3s & \frac{50}{\text{r/min}} \\
3s \leq t < 5s & -\frac{50}{\text{r/min}}
\end{cases} \\
T_L = \begin{cases} 
0s \leq t < 1s & 0\text{N-m} \\
1s \leq t < 2.5s & 60\text{N-m} \\
2.5s \leq t < 4s & 0\text{N-m} \\
4s \leq t < 4.5s & 60\text{N-m} \\
4.5s \leq t < 5s & 0\text{N-m}
\end{cases}
\]

\[
\Rightarrow \omega_{\text{ref}}^* = \begin{cases} 
0s \leq t < 3s & \frac{500}{\text{r/min}} \\
3s \leq t < 5s & \frac{50}{\text{r/min}}
\end{cases} \\
T_L = \begin{cases} 
0s \leq t < 1s & 0\text{N-m} \\
1s \leq t < 2.5s & 60\text{N-m} \\
2.5s \leq t < 4s & 0\text{N-m} \\
4s \leq t < 4.5s & 60\text{N-m} \\
4.5s \leq t < 5s & 0\text{N-m}
\end{cases}
\]

Chapter7
At page 340.

Eq.(7.31) should be revised as followings.

$$\begin{align*}
\delta i_{dqs} &= i_{dqs,AD} - i_{dqs} = (i_{dqs,AD} - i_d^*_{dqs}) + j(i_{dqs,AD} - i_q^*_{dqs}) = \delta i^*_d + j\delta i^*_q \\
&= \left(\frac{k_a-1}{k_a}\right) I \cos(\phi) - \left(\frac{k_a-k_b}{k_a k_b}\right) \frac{I}{\sqrt{3}} \left[ \sin \left(2\omega t - \frac{2\pi}{3} + \phi\right) - \sin \left(\phi - \frac{2\pi}{3}\right) \right] \\
&+ j \left[ \left(\frac{k_a-1}{k_a}\right) I \sin(\phi) - \left(\frac{k_a-k_b}{k_a k_b}\right) \frac{I}{\sqrt{3}} \left[ \cos \left(2\omega t - \frac{2\pi}{3} + \phi\right) + \cos \left(\phi - \frac{2\pi}{3}\right) \right] \right]
\end{align*}$$

$$\begin{align*}
\delta i_{dqs} &= i_{dqs,AD} - i_{dqs} = (i_{dqs,AD} - i_d^*_{dqs}) + j(i_{dqs,AD} - i_q^*_{dqs}) = \delta i^*_d + j\delta i^*_q \\
&= \left(1 - \frac{k_a+k_b}{2k_a k_b}\right) I \cos(\phi) - \left(\frac{k_a-k_b}{k_a k_b}\right) \frac{I}{\sqrt{3}} \left[ \sin \left(2\omega t + \frac{\pi}{3} + \phi\right) - \frac{1}{2} \sin(\phi) \right] \\
&+ j \left[ \left(1 - \frac{k_a+k_b}{2k_a k_b}\right) I \sin(\phi) - \left(\frac{k_a-k_b}{k_a k_b}\right) \frac{I}{\sqrt{3}} \left[ \cos \left(2\omega t + \frac{\pi}{3} + \phi\right) - \frac{1}{2} \cos(\phi) \right] \right]
\end{align*}$$

Eq.(7.32) should be revised as followings.

$$\begin{align*}
\delta T_e &= T_e^* - T_e = \frac{3 P}{2 L_r} \left( \delta i^*_d I_q^* - \delta i^*_q I_d^* \right) \\
&\approx \frac{3 P}{2 L_r} L^2_m \left( \delta^*_d i_d^* q^* + \delta^*_q i_q^* d^* \right) \\
&= \frac{3 P}{2 L_r} L^2_m \left( \delta^*_d I_q^* \sin(\phi) + \delta^*_q I_d^* \cos(\phi) \right)
\end{align*}$$

$$\begin{align*}
\delta T_e &= T_e^* - T_e = \frac{3 P}{2 L_r} \left( \delta i^*_d I_q^* - \delta i^*_q I_d^* \right) \\
&\approx \frac{3 P}{2 L_r} L^2_m \left( \delta^*_d i_d^* q^* + \delta^*_q i_q^* d^* \right) \\
&= \frac{3 P}{2 L_r} L^2_m \left( \delta^*_d I_q^* \sin(\phi) + \delta^*_q I_d^* \cos(\phi) \right)
\end{align*}$$

Problem 6

(3) ....

In the measurement of the phase current, there is white noise, \( \eta(t) \), whose rms magnitude is 4% of rated rms phase current. Only, ‘a’ and ‘b’ phase currents are measured and ‘c’ phase current is calculated using the measured currents. The sampling frequency of the white noise is 100 \( \mu s \) and also the measured currents have offset, \( \delta i^*_d, \delta i^*_q \), whose magnitude is 1% of 0.1% of rated rms current. And ‘a’ and ‘b’ phase current measurement system had 1% scale difference. And, the measured current can be represented as follows.