第五章 三相异步电动机拖动基础

5.1

解:

$$S_N = \frac{750 - 735}{750} = 0.02$$

$$T_N = \frac{9550 \times 260}{735} = 3378 \quad (N \cdot m)$$

(1) $S_{cr} = S_N(\lambda_T + a_T + \sqrt{\lambda^2 - 1})$=0.04×(2.13+$\sqrt{2.13^2 - 1}$)=0.08

(2)

$$T_e = \frac{2T_m}{S/S_{cr} + S_{cr}/S} = \frac{2 \times 2.13 \times 3378}{0.04/0.08 + 0.08/0.04} = 5756(N \cdot M)$$

5.2

解:

$$\begin{cases} S_n = \dfrac{1500 - 1440}{1500} = 0.04 \\ T_N = \dfrac{9550 \times 5.5}{1440} = 36.48(N \cdot m) \end{cases}$$

(1)

$$\begin{cases} S_{Cr} = 0.04 \times \left(2 + \sqrt{2^2 - 1}\right) = 0.149 \\ T_m = \lambda_T \cdot T_N = 2 \times 36.48 = 72.95(N \cdot m) \end{cases}$$

(2)

$$\begin{cases} S = 1 \\ T_{st} = \dfrac{2 \times 2 \times 36.48}{1/0.149 + 0.149/1} = 21.27(N \cdot m) \end{cases}$$

(3)

$$\begin{cases} S = 0.5 \\ T_e = \dfrac{2 \times 2 \times 36.48}{0.5/0.149 + 0.149/0.5} = 40(N \cdot m) \end{cases}$$

图略

5.3

解:

$$K = \frac{I_{st}}{I_{st}'} = 4$$

$$I_N = \frac{40000}{\sqrt{3} \times 380 \times 0.91 \times 0.9} = 74.2\ (A)$$

$$Z_K = \frac{380}{\sqrt{3} \times 5.5 \times 74.2} = 0.538\ (\Omega)$$

$$Y_K = Z_K \cdot \cos\varphi_{1ST} = 0.538 \times 0.3 = 0.16(\Omega)$$

$$X_K = Z_K \cdot \sin\varphi_{1st} = 0.538 \times 0.954 = 0.51(\Omega)$$

$$x_{ST} = \sqrt{K^2 {X_K}^2 + (K^2 - 1){Y_K}^2} - X_K = \sqrt{4^2 \times 0.51^2 + (4^2 - 1) \times 0.16^2} - 0.51 = 1.62(\Omega)$$

5.4

解

$$I_{st} = K_I I_N = 6.7 \times 527 = 3530.9\ A > 1800\ A$$

$$T_{st} = K_T T_N = \frac{1.5 \times 9550 \times 300}{1475} = 2913.56\ \ N \cdot m > 1000\ N \cdot m$$

(1)串X_{st}：$K = \frac{I_{st}}{I_{st}'} = \frac{3530.9}{1800} = 1.962$

$$T_{st}' = \frac{T_{st}}{K^2} = \frac{2913.56}{1.962^2} = 756.88 < 1000 N \cdot m$$

不可

(2) Y-△:因 Y 接，不能作 Y-△XX

(3)自耦变压器（$\frac{1}{K} = 55\%$，64%，73%）

$$\frac{I_{st}'}{I_{st}} \geq \frac{1}{K^2} \qquad \frac{1}{K} \leq \sqrt{\frac{I_{st}'}{I_{st}}} = \sqrt{\frac{1800}{3530.9}} = 71.4\%$$

所以选 64%抽头。

校核：$T_{st}' = \frac{1}{K^2} T_{st} = (\frac{64}{100})^2 \times 2913.56 = 1193.4 > 1000 N \cdot m$

可以

5.5

解：(1)

$$I_{st} = 6.06 I_N = 6.06 \times 100 = 606(A)$$

$$T_{st} = 1.1 T_N = \frac{1.1 \times 9550 \times 55}{1475} = 391.7(N \cdot m)$$

(2)要求

$$T_{st}^{\cdot} \geq 0.7T_N, 即 \frac{T_{st}^{\cdot}}{T_{st}} = \frac{1}{K^2} \geq \frac{0.7T_N}{1.1T_N}$$

$$\frac{1}{K} \geq \sqrt{\frac{0.7}{1.1}} = 0.798$$

$$I_{st}^{\cdot} = \frac{1}{K} I_{st} = 0.798 \times 606 = 483.6(A)$$

(3)

$$\frac{1}{K} \geq \sqrt{\frac{0.7}{1.1}} = 0798 \quad 选\ 0.8$$

$$I_{st}^{\cdot} = \frac{1}{K^2} I_{st} = 0.8^2 \times 606 = 387.8(A)$$

(4) Y-△:

$$I_{st}^{\cdot} = \frac{1}{3} I_{st} = \frac{1}{3} \times 606 = 202\ A$$

$$T_{st}^{\cdot} = \frac{1}{3} \times 1.1T_N = 0.37T_N < 0.7T_N$$

不能满足要求

5.6

解:

$$S_N = \frac{600 - 580}{600} = 0.0333$$

$$Y_2 = \frac{S_N E_{2N}}{\sqrt{3} I_{2N}} = \frac{0.0333 \times 212}{\sqrt{3} \times 159} = 0.0257\ (\Omega)$$

$$\beta = \frac{T_{st}}{T_2} = \frac{1.8T_{eN}}{0.8T_N} = 2.25 = \sqrt[m]{\frac{T_N}{S_N T_{st}}} = \sqrt[m]{16.68} = 2.25$$

$$m = 3.47 \qquad 取\ m = 4$$

检验：T_2 $\qquad \beta = \sqrt[4]{16.68} = 2.021$

$$T_2 = \frac{T_{st}}{\beta} = \frac{1.8T_N}{2.021} = 0.89T_N$$

$$R_{st1} = (\beta - 1)Y_2 = (2.021 - 1) \times 0.0257 = 0.0262 \quad (\Omega)$$

$$R_{st2} = \beta r_{st1} = 2.021 \times 0.0262 = 0.053 \quad (\Omega)$$

$$R_{st3} = \beta r_{st2} = 2.021 \times 0.053 = 0.107 \quad (\Omega)$$

$$R_{st4} = \beta r_{st3} = 2.021 \times 0.107 = 0.216 \quad (\Omega)$$

5.7 图略

解:

$$S_N = 0.0333$$

$$S_a = 0.9S_N = 0.03 \begin{cases} 0.9T_N = \dfrac{2T_m}{S_{cra}} S_a \\ T_N = \dfrac{2T_m}{S_{cra}} S_N \end{cases}$$

$$n_a = (1 - S_a)n_s = (1 - 0.03) \times 600 = 582(\mathrm{r/min})$$

(1)

$$S_b = -S_a = -0.03$$

$$n_b = (1 - S_b)n_s = (1 + 0.03)(-600) = -618(\mathrm{r/min})$$

(2)

$$S_{crb} = -S_N\left(\lambda_T + \sqrt{\lambda_T{}^2 - 1}\right) = -0.0333(2.3 + \sqrt{2.3^2 - 1}) - 0.1456$$

$$S_{crc} = \frac{r_2 + R_{st}}{r_2}(-s_{crb}) = \frac{0.0257 + 0.4022}{0.0257}(-0.1456) = -2.4242$$

$$S_c = -S_{crc}\left[\frac{2.3T_N}{0.9T_N} \pm \sqrt{\left(\frac{2.3}{0.9}\right)^2 - 1}\right] = -2.4242\left[\frac{2.3}{0.9} \pm \sqrt{\left(\frac{2.3}{0.9}\right)^2 - 1}\right]$$

$$= \begin{matrix} -0.494 \\ -11.9 \end{matrix} \quad (> S_{crc}\text{舍去})$$

$$n_c = -600(1 + 0.494) = -896.4 \text{ rpm}$$

简化式:

$$\frac{S_C}{S_N} = \frac{r_2 + R_{st}}{r_2} \cdot \frac{0.9T_N}{T_N}$$

$$S_C = \frac{0.0257 + 0.4022}{0.0257} \times 0.9 \times (-0.0333) = -0.499$$

$$n_C = -600(1 + 0.499) = -899.4 \left(\frac{r}{\min}\right)$$

(3)

$$S_d = \frac{-600 - 582}{-600} = 1.97$$

$$T_b = \frac{2T_m}{\frac{S_d}{S_{crc}} + \frac{S_{crc}}{S_d}} = \frac{2 \times 2.3T_N}{\frac{1.97}{-2.4242} - \frac{2.4242}{1.97}} = -2.25T_N$$

简化式

$$\frac{S_d}{S_N} = \frac{-S_{crc}}{S_{cra}} \cdot \frac{T_b}{T_N} = -\frac{r_2 + R_{st}}{r_2} \cdot \frac{T_b}{T_N}$$

$$T_b = \frac{S_b}{S_N}\left(-\frac{r_2}{r_2 + R_{st}}T_N\right) = \frac{1.97}{0.0333}\left(\frac{0.0257}{0.0257 + 0.4022}T_N\right) = -3.55T_N$$

所以，按线性计算，故计算结果大于 $2.25T_N$，X 制动瞬时只在非线性进行对应 $R_{st} = 0.402\Omega$的特性，曲线的$S_{crd} = S_d\left(\frac{2.3}{0.9} - \sqrt{\left(\frac{2.3}{0.9}\right)^2 - 1}\right) = 0.405 < S_d = 1.97$

故不能用简化公式计算。

5.8 （图略）

解：

$$S_{cr1.2} = 1 \times \left[\frac{2.4}{1.2} \pm \sqrt{(\frac{2.4}{1.2})^2 - 1}\right] = \begin{matrix} 3.732 = S_{cr2} \\ 0.268 = S_{cr1} \end{matrix}$$

$$R_{st1} = \left(\frac{S_{cr1}}{S_{cr}} - 1\right) r_2 = \left(\frac{0.268}{0.1833} - 1\right) \times 0.02236 = 0.01(\Omega)$$

$$R_{st2} = \left(\frac{S_{cr2}}{S_{cr}} - 1\right) r_2 = 0.433(\Omega)$$

$$S_1 = S_{cr1}\left(\lambda_T - \sqrt{{\lambda_T}^2 - 1}\right) = 0.268\left(2.4 - \sqrt{2.4^2 - 1}\right) = 0.0585$$

$$S_2 = S_{cr2}\left(\lambda_T - \sqrt{{\lambda_T}^2 - 1}\right) = 3.732\left(2.4 - \sqrt{2.4^2 - 1}\right) = 0.8145$$

$$n_1 = 750(1 - 0.0585) = 706(\mathrm{r/min})$$

$$n_2 = 750(1 - 0.8145) = 139(\mathrm{r/min})$$

简化式：

$$\frac{S_{st}}{S_N} = \frac{r_2 + R_{st}}{r_2} \cdot \frac{1.2T_N}{T_N}$$

$$R_{st2} = \left(\frac{1}{0.04 \times 1.2} - 1\right) \times 0.02236 = 0.443(\Omega)$$

显然不会有R_{st1}

$$S_2 = \frac{r_2 + R_{st2}}{r_2} S_N = \frac{0.02236 + 0.443}{0.02236} \times 0.04 = 0.8325$$

$$n_2 = (1 - 0.8325) \times 750 = 125.6(\mathrm{r/min})$$

(2)

$$S_b = \frac{-750 - 720}{-750} = 1.96$$

$$S_{crb} = 1.96\left[\frac{2.4T_N}{1.2T_N} \pm \sqrt{\left(\frac{2.4}{1.2}\right)^2 - 1}\right] = \begin{matrix} 3.652 = S_{crb1} \\ 1.052 = S_{crb2} \end{matrix}$$

$$R_{b1} = \left(\frac{3.652}{0.1833} - 1\right) \times 0.02236 = 0.423(\Omega)$$

$$R_{b2} = \left(\frac{1.052}{0.1833} - 1\right) \times 0.02236 = 0.106(\Omega)$$

$$T_{e1} = \frac{2 \times 2.4}{\frac{1}{3.652} + \frac{3.652}{1}} T_N = 1.22T_N > T_N \text{ 按反向起动}$$

（串电阻R_{b2}X 能反向起动：$T_{e1} = \frac{2 \times 2.4}{\frac{1}{1.052} + \frac{1.052}{1}} T_N = 2.4T_N > T_N$ ）

简化式：

$$\frac{S_b}{S_N} = \frac{r_2 + R_{b1}}{r_2} \cdot \frac{T_e}{T_N}$$

$$R_{b1} = \left(\frac{1.96}{0.04 \times 2} - 1\right) \times 0.02236 = 0.525(\Omega)$$

$$\frac{1}{S_N} = \frac{r_2 + R_{b1}}{r_2} \cdot \frac{T_C}{T_N}$$

$$T_C = \frac{r_2}{S_N(r_2 + R_{b1})} T_N = \frac{0.02236}{0.04(0.02236 + 0.525)} T_N = 1.02T_N \text{ 能反向起动}$$

5.9

解：

$$S_a = S_N = \frac{600 - 577}{600} = 0.03833$$

$$r_2 = \frac{0.03833 \times 253}{\sqrt{3} \times 160} = 0.035$$

$$S_{cra} = S_{cr} = 0.03833\left(2.9 + \sqrt{2.9^2 - 1}\right) = 0.2155$$

(1)

$$n_b = 35.4\frac{转}{m} \times \frac{8m}{分} = 283.2r/min$$

$$S_b = \frac{600 - 283.2}{600} = 0.528$$

$$S_{crb} = 0.528\left(2.9 + \sqrt{2.9^2 - 1}\right) = 2.968$$

$$R_b = \left(\frac{2.968}{0.2155} - 1\right) \times 0.035 = 0.447(\Omega)$$

(2)

$$S_C = 1$$

$$S_{crc} = 1 \times \left[\frac{2.9}{0.4} \pm \sqrt{(\frac{2.9}{0.4})^2 - 1}\right] = 14.43$$

$$R_c = \left(\frac{14.43}{0.2155} - 1\right) \times 0.035 = 2.31(\Omega)$$

简化式：

$$R_c = \left(\frac{1}{0.4 \times 0.03833} - 1\right) \times 0.035 = 2.25(\Omega)$$

(3)

$$S_d = S_{crc}\left[\frac{2.9}{0.8} \mp \sqrt{(\frac{2.9}{0.8})^2 - 1}\right] = 14.43[3.625 \mp 3.484] = \begin{matrix}2.03\\102.6\end{matrix} > 14.43 \text{ 舍去}$$

$$n_d = 600(1 - 2.03) = -618(r/min)$$

简化式：

$$S_d = \frac{r_2 + R_c}{r_2} S_N \frac{0.8}{1} = \frac{0.035 + 2.25}{0.035} \times 0.03833 \times \frac{0.8}{1} = 2$$

$$n_d = 600(1 - 2) = -600(r/min)$$

(4)

$$S_e = -0.2155\left[\frac{2.9}{0.8} \pm \sqrt{(\frac{2.9}{0.8})^2 - 1}\right] = \begin{matrix}-0.03\\-15.32\end{matrix}$$

$$|-15.32| > |-0.2155| \text{ 舍去}$$

$$n_e = -600(1 + 0.03) = -618(r/min)$$

简化式：

$$S_e = -0.8S_N = -0.0306$$

$$n_e = -600(1 + 0.0306) = -618.4(r/min)$$

(图略)

5.10 (图略)

解：

$$S_N = \frac{1000 - 960}{1020} = 0.04$$

$$S_{cr} = 0.04\left(2.5 + \sqrt{(2.5)^2 - 1}\right) = 0.19165$$

$$r_2 = \frac{0.04 \times 200}{\sqrt{3} \times 195} = 0.02369\ (\Omega)$$

$$T_N = 9550\frac{60}{960} = 596.875(N \cdot m)$$

(1)

$$S_a = 0.19165\left[\frac{2.5 \times 596.875}{461 + 69} \mp \sqrt{(\frac{2.5 \times 596.875}{461 + 69})^2 - 1}\right]$$

$$= \begin{matrix} 0.035 \\ 1.044 > 0.19165\ 舍去 \end{matrix}$$

$$n_a = 1000(1 - 0.035) = 965(r/min)$$

简化式：

$$S_a = \frac{T_e}{T_N}S_N = \frac{530}{596.875} \times 0.04 = 0.0355$$

$$n_a = 1000(1 - 0.0355) = 964.5(r/min)$$

(2)

$$T_e = T_L - \Delta T = 461 - 69 = 392(N \cdot m)$$

$$S_B = -0.19165\left[\frac{2.5 \times 596.875}{392} \mp \sqrt{(\frac{2.5 \times 596.875}{392})^2 - 1}\right]$$

$$= \begin{matrix} -0.0256 \\ -7.4795 > 0.19165\ 舍去 \end{matrix}$$

$$n_b = -1000(1 - 0.0256) = -1025.6(r/min)$$

简化式：

$$S_b = \frac{392}{596.875} \times 0.04 = -0.02627$$

$$n_b = -1000(1 + 0.02627) = -1026(r/min)$$

(3)

$$S_C = \frac{1000 + 280}{1000} = 1.28$$

$$S_{crc} = 1.28\left[\left[\frac{2.5 \times 596.875}{392} \pm \sqrt{\left(\frac{2.5 \times 596.875}{392}\right)^2 - 1}\right] = \begin{matrix} 0.17 < 0.19165 \text{ 舍去} \\ 9.57376 \end{matrix}\right.$$

$$R_C = \left(\frac{9.57376}{0.19165} - 1\right) \times 0.02369 = 1.16(\Omega)$$

简化式：

$$R_C = \left(\frac{1.28}{0.04} \times \frac{596.875}{392} - 1\right) \times 0.02369 = 1.13(\Omega)$$

(4)

$$S_{crd} = 1 \times \left[\frac{2.5 \times 596.875}{1.392} + \sqrt{(\frac{2.5 \times 596.875}{392})^2 - 1}\right] = 7.4795$$

$$R_c = \left(\frac{7.4795}{0.19165} - 1\right) \times 0.02369 = 0.9(\Omega)$$

简化式：

$$R_d = \left(\frac{1}{0.04} \times \frac{596.875}{392} - 1\right) \times 0.02369 = 0.878(\Omega)$$

$$S_{cre} = 1 \times \left[\frac{2.5 \times 596.875}{461 + 69} + \sqrt{(\frac{2.5 \times 596.875}{530})^2 - 1}\right] = 5.447$$

$$R_e = \left(\frac{7.47955.447}{0.19165} - 1\right) \times 0.02369 = 0.665(\Omega)$$

简化式：

$$R_e = \left(\frac{1}{0.04} \times \frac{596.875}{530} - 1\right) \times 0.02369 = 0.64(\Omega)$$

$0.65 < R_2 < 0.9$　简化式：$0.64 < R < 0.878$

5.11

解:

$$S_N = \frac{1000 - 976}{1000} = 0.024$$

$$r_2 = \frac{0.02 \times 238}{\sqrt{3} \times 210} = 0.0157(\Omega)$$

$$S_{cr} = 0.024\left(2.05 + \sqrt{(2.05)^2 - 1}\right) = 0.092$$

(1)

$$S_{cr3} = \frac{0.0157 + 0.2}{0.0157} \times 0.092 = 1.264$$

$$S_3 = 1.264\left(2.05 - \sqrt{2.05^2 - 1}\right) = 0.329$$

$$n_3 = 1000(1 - 0.329) = 671(r/min)$$

$$D = \frac{976}{671} = 1.45$$

简化式:

$$S_3 = \frac{0.0157 + 0.2}{0.0157} \times 0.024 = 0.33$$

$$n_3 = 1000(1 - 0.33) = 670(r/min)$$

$$D = \frac{976}{670} = 1.46$$

(2)

$$S_{max} = \frac{1000 - 671}{1000} 32.9\%$$

简化式:

$$S_{max} = \frac{1000 - 670}{1000} 33\%$$

(3) $n_3 = 671(r/min)$

$$S_{cr} = \frac{0.0157 + 0.1}{0.0157} \times 0.092 = 0.678$$

$$S_2 = 0.678\left(2.05 - \sqrt{2.05^2 - 1}\right) = 0.1766$$

$$n_2 = 1000(1 - 0.1766) = 823.4(r/min)$$

简化式:

$$S_2 = \frac{0.0157 + 0.1}{0.0157} \times 0.024 = 0.177$$

$$n_2 = 1000(1 - 0.1766) = 823.4(r/min)$$

$$S_{cr} = \frac{0.0157 + 0.1}{0.0157} \times 0.092 = 0.385$$

$$S_1 = 0.385\left(2.05 - \sqrt{2.05^2 - 1}\right) = 0.1$$

$$n_1 = 1000(1 - 0.1) = 900(r/min)$$

简化式：

$$S_1 = \frac{0.0157 + 0.05}{0.0157} \times 0.024 = 0.1$$

$$n_1 = 900(r/min)$$

5-12

解：(1) $n_{min} = \frac{n_{min}}{D} = \frac{980}{1.46} = 671\ (r/min)$

$\Delta n = 1000 - 980 = 20\ (r/min)$

$n_{0min} = n_{min} + \Delta n = 691(r/min)$

$S_{max} = \frac{\Delta n}{n_{0min}} = \frac{20}{691} = 2.9\%$

(2) $n_{01} = \frac{60f_1}{p} = \frac{60\times40}{3} = 800(r/min)$

$n_1 = n_{01} - \Delta n_N = 800 - 20 = 780(r/min)$

$n_{02} = \frac{60f_2}{p} = \frac{60 \times 30}{3} = 600(r/min)$

$n_2 = n_{02} - \Delta n_N = 600 - 20 = 580(r/min)$

5-13

解：$S_N = \frac{1500-1450}{1500} = 0.0333$

$r_2 = \frac{0.0333 \times 371}{\sqrt{3} \times 72} = 0.099$

$S_{cr} = 0.0333\left(2 + \sqrt{4 - 1}\right) = 0.1244$

$$S_b = \frac{1500 - 1050}{1500} = 0.3$$

$S_{crb} = 0.3\left(\frac{2}{0.8} \pm \sqrt{\frac{2}{0.8}^2 - 1}\right) = 0.1437$ 或 0.0626

$$R_b = \left(\frac{1.4374}{0.1244} - 1\right) \times 0.99 = 1.045\Omega$$

降压$S_{cr} = 0.1244$，而$S_b = 0.3 > S_{cr}$，在非线性域，故不能稳定运行

为了工作在直线域：$n = 1500(1 - 0.1244) = 1313.4(r/min)$，

即在 $1313(r/min)$以上运行方可调压

$$S_a = 0.8S_N = 0.8 \times 0.0333 = 0.0267$$

$$n_a = (1 - 0.0267) \times 1500 = 1460(r/min)$$

$$\Delta n = 1500 - 1460 = 40\ (r/min)$$

$$n_{01} = 1050 + 40 = 1090(r/min)$$

$$f_1 = \frac{2 \times 1090}{60} = 36.33\ (Hz)$$

$$U_1 = \frac{36.33}{50} \times 380 = 276\ (V)$$