

$$T_{em} = k_t \Phi I_a = C_t \Phi I_a$$

$$E_a = k_e \omega = C_e \Phi n$$

第一章作业 直流电动机及其控制

6. 已知一台直流电动机，其电枢额定电压 $U_a = 110V$ ，额定运行时的电枢电流 $I_a = 0.4A$ ，转速 $n = 3600r/min$ ，电枢电阻 $R_a = 50\Omega$ ，空载阻转矩 $T_0 = 0.015N \cdot m$ ，该电动机额定负载转矩是多少？

6. 转矩平衡方程: $T_{em} = T_0 + T_L$, T_{em} 为电磁转矩 $\omega = \frac{2\pi}{60} n = 120\pi \text{ rad/s}$ 指 T_L

由 $U_a = R_a I_a + E_a = R_a I_a + k_e \omega$ 知 $k_e = k_t = \frac{U_a - R_a I_a}{\omega}$

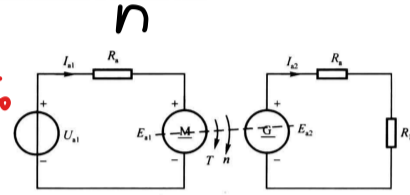
故 $T_L = T_{em} - T_0 = k_t I_a - T_0 = \frac{U_a - R_a I_a}{\omega} I_a - T_0 = \frac{110 - 50 \times 0.4}{120\pi} \times 0.4 - 0.015 = 0.08 N \cdot m$

7. 用一对完全相同的直流电机组成电动机-发电机组，它们的激磁电压均为 $110V$ ，电枢电阻 $R_a = 75\Omega$ 。当发电机不接负载，电动机电枢加 $110V$ 电压时，电动机的电枢电流为 $0.12A$ ，机组的转速为 $4500r/min$ 。问：

1) 发电机空载时的电枢电压为多少？

电动机 $U_{a1} = I_{a1} R_{a1} + E_{a1}$, $T_{em1} = T_0 + T_L$

发电机 $E_{a2} = U_{a2} + I_{a2} R_{a2}$, $T_L = T_{em2} + T_0 \Rightarrow T_{em1} = T_{em2} + 2T_0$



2) 电动机的电枢电压仍为 $110V$ ，而发电机接上 $0.5k\Omega$ 的负载时，机组的转速 n 是多少？

1) $E_{a1} = E_{a2} = k_e \omega$

2) $T_{em1} = T_{em2} + 2T_0$

7. 解. 设电动机下标1, 发电机下标2, 已知 $U_{f1} = U_{f2} = 110V$, $R_{a1} = R_{a2} = 75\Omega$

1) 发电机空载时 $I_{a2} = 0$, $U_{a2} = E_{a2} = k_e \omega$. $U_{a1} - R_{a1} I_{a1} = k_e \omega$, 由于 $k_e = k_t$ 有

$U_{a2} = k_e \frac{U_{a1} - R_{a1} I_{a1}}{k_e} = U_{a1} - R_{a1} I_{a1} = 101V$ ✓ $k_e = k_t = \frac{U_{a2}}{\omega} = \frac{101}{\frac{2\pi}{60} \times 4500} \approx 0.2143 \text{ Vs rad}^{-1}$ ✓

发电机 $T_{em} = k_t I_a = T_L - T_0 = 0$, 电动机 $k_t I_{a1} = T_L + T_0 = 2T_0 \Rightarrow T_0 = \frac{k_t I_{a1}}{2} = 0.0129 N \cdot m$

2) $U_{a1} = 110V$, 发电机电枢 $R_{a2}' = R_a + 0.5k\Omega = 575\Omega$, $U_{a2} = 0$

$U_{a2} + R_{a2}' I_{a2} = k_e \omega = U_{a1} - R_{a1} I_{a1}$

$k_t I_{a1} - T_0 = k_t I_{a2} + T_0$

联合有

$$\begin{cases} 575 I_{a2} = 110 - 75 I_{a1} \\ I_{a1} = I_{a2} + \frac{2T_0}{k_t} = I_{a2} + 0.12 \end{cases} \Rightarrow \begin{cases} I_{a1} = 0.275 A \\ I_{a2} = 0.155 A \\ \omega = 417 \text{ rad/s} \end{cases}$$

$n = \frac{60}{2\pi} \omega = 3982.6 (r/min)$

答: 1). $101V$ 2) 约为 $3980r/min$ ✓

16. 已知一台直流伺服电动机在 $U_{a1} = 110V$ 时，空载电流 $I_{a1} = 0.055A$ ，空载转速 $n_{01} = 4600r/min$, $R_a = 80\Omega$ 。

1) 电枢电压为 $70V$ 时，理想空载转速 n_{02} 是多大？堵转时的电磁转矩是多少？

2) 驱动它的功率放大器内阻 $R_i = 50\Omega$ ，当功放的开路电压为 $70V$ 时理想空载转速和启动转矩是多少？

3) 在上述两种情况下，折合到电动机上的总阻转矩 $T_c = T_0 + T_L$ 由 $0.03N \cdot m$ 增大到 $0.04N \cdot m$ 时，转速各为多少？

空载 $T_L = 0, T_{em} = T_0$

理想空载 $T_{em} = 0$

1) 由 $T_{em} = C_t \Phi I_a = T_0 + T_L$, $E_a = k_e \omega = C_e \Phi n = U_a - I_a R_a$ 知 $n = \frac{U_a - I_a R_a}{C_e \Phi}$

先算电动机的 k_e $n_{01} = 4600r/min$ 时 $k_e = \frac{U_a - I_a R_a}{\omega} = \frac{110 - 0.055 \times 80}{\frac{2\pi}{60} \times 4600} = 0.219 \text{ Vs rad}^{-1}$

空载时 $T_L = 0, T_0 = T_{em} = k_t I_a = k_e I_a = 0.012 N \cdot m$

理想空载时 $T_{em} = 0 \Rightarrow I_{a2} = 0$

$\frac{n_{02}}{n_{01}} = \frac{U_{a2} - I_{a2} R_{a2}}{U_{a1} - I_{a1} R_{a1}} = \frac{70}{110 - 0.055 \times 80} = 0.663 \Rightarrow n_{02} = 0.663 n_{01} \approx 3050r/min$ ✓

再算堵转时 $\omega = 0, I_a' = \frac{U_a}{R_a} = \frac{70}{80} = 0.875$, 堵转电磁转矩 $T_s = k_e I_a' = 0.192 N \cdot m$ ✓

2) 理想空载时 $T_{em} = 0, I_{a2} = 0, R_i$ 相当于被短路, $U_a = U_i = 70V$ 不变, 由 $n = \frac{U_a - I_a R_a}{C_e \Phi} \approx n \approx 3050r/min$ ✓

启动时 $n = \omega = 0$, 由 $T_{em} = C_t \Phi I_a = C_t \Phi \cdot \frac{U_a}{R_a + R_i} = k_e \frac{U_i}{R_a + R_i} = 0.118 N \cdot m$, ✓

$E_a = 0$

★启动转矩指的是 T_{em}

$$T_{em} = k_t \bar{I}_a = C_t \Phi \bar{I}_a$$

$$E_a = k_e \omega = C_e \Phi n$$

$$1) \text{ 当 } T_{em} = T_0 + T_L = 0.03 \text{ N}\cdot\text{m} \text{ 时, } \bar{I}_a = \frac{T_{em}}{k_t} = 0.137 \text{ A}$$

$$\text{由 } U_a = \bar{I}_a R_a + E_a = \bar{I}_a R_a + k_e \omega \text{ 知, } \omega = \frac{U_a - \bar{I}_a R_a}{k_e} = \frac{70 - 0.137 R_a}{0.219}$$

$$\text{当 } R_a = 80 \Omega \text{ 时, } \omega = 269.6 \text{ rad/s} \Rightarrow n = 2574.4 \text{ r/min} \checkmark$$

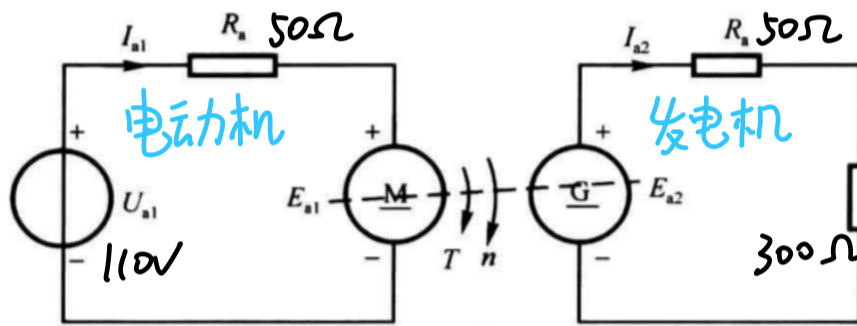
$$\text{当 } R_a = 130 \Omega \text{ 时, } \omega = 238.3 \text{ rad/s} \Rightarrow n = 2275.7 \text{ r/min} \checkmark$$

$$2) \text{ 当 } T_{em} = T_0 + T_L = 0.04 \text{ N}\cdot\text{m} \text{ 时, } \bar{I}_a = \frac{T_{em}}{k_t} = 0.1826 \text{ A}$$

$$\text{当 } R_a = 80 \Omega \text{ 时, } \omega = 252.9 \text{ rad/s} \Rightarrow n = 2413.9 \text{ r/min} \checkmark$$

$$\text{当 } R_a = 130 \Omega \text{ 时, } \omega = 211.24 \text{ rad/s} \Rightarrow n = 2014.9 \text{ r/min} \checkmark$$

18. 已知某永磁直流电机电枢电阻 $R_a = 50 \Omega$, 作电动机运行时的空载转矩为 $T_0 = 0.025 \text{ N}\cdot\text{m}$, 相应的空载电流为 $I_0 = 0.1 \text{ A}$ 。现在将两台参数完全相同的该型电机组成电动机-发电机组, 其中发电机作为电动机的机械负载, 如图 1-53 所示。



(1) (2)
电动机与发电机的外部联系
1) $E_{a1} = E_{a2} = k_e \omega$
2) $T_{L1} = T_{L2} \Rightarrow T_{em1} = T_{em2} + 2T_0$
相当于: 传力矩时会损失 $2T_0$

图 1-53 习题 18 附图

1) 分别写出两台电机的电压平衡方程式和转矩平衡方程式。

2) 当发电机负载电阻 $R_L = 300 \Omega$, 电动机外加电压 $U_{a1} = 110 \text{ V}$ 时, 两台电机的电磁转矩各为多少? 机组的共同转速为多少?

指 ω/n

1) 电动机 $U_{a1} = \bar{I}_{a1} R_a + E_{a1}$, $T_{em1} = T_0 + T_L$, 其中 $E_{a1} = k_e \omega$, $T_{em1} = k_t \bar{I}_{a1}$
发电机 $E_{a2} = \bar{I}_{a2} (R_a + R_L)$, $T_1 = T_{em2} + T_0$, 其中 $E_{a2} = k_e \omega$, $T_{em2} = k_t \bar{I}_{a2}$
 \Rightarrow 有 $T_{em1} = T_{em2} + 2T_0$

空载时, $T_{em} = T_0 = 0.025 \text{ N}\cdot\text{m}$, $I_0 = 0.1 \text{ A}$, 故 $k_e = k_t = \frac{T_{em}}{I_0} = 0.25 \text{ N}\cdot\text{m}\cdot\text{A}^{-1}$

2) 已知 $R_L = 300 \Omega$, $U_{a1} = 110 \text{ V}$, $T_0 = 0.025 \text{ N}\cdot\text{m}$ $k_e = k_t = 0.25 \text{ N}\cdot\text{m}\cdot\text{A}^{-1}$

有 $\begin{cases} T_{em1} = T_{em2} + 0.05 \\ E_{a1} = E_{a2} = 0.25 \omega \end{cases}$, 联立, 得 $\begin{cases} T_{em1} = T_{em2} + 0.05 \\ 110 = 20 T_{em1} + 140 T_{em2} \end{cases}$

$\Rightarrow T_{em1} = 0.1125 \text{ N}\cdot\text{m}$, $T_{em2} = 0.0625 \text{ N}\cdot\text{m} \Rightarrow \bar{I}_{a1} = \frac{T_{em1}}{k_t} = 0.45 \text{ A}$, $E_{a1} = 110 - 50 \bar{I}_{a1} = 87.5 \text{ V}$

$\Rightarrow \omega = 4 E_{a1} = 350 \text{ rad/s}$ $n = 3342.3 \text{ r/min}$

19. 一台直流伺服电动机, 额定电压 $U_n = 24V$, 额定电流 $I_n = 0.5A$, 电磁转矩的额定值 $T_m = 0.015N \cdot m$, 空载摩擦转矩 $T_f = 0.003N \cdot m$, 额定转速 $\omega_n = 300rad/s$ 。求

$$T_m = k_t \bar{I}_a = C_t \Phi \bar{I}_a$$

$$E_a = k_e \omega = C_e \Phi n$$

1) 电枢电压 $U_a = 18V$ 时, 启动输出转矩 是多少? 空载转速 是多少?

2) 要求电磁转矩 $T_e = 0.02N \cdot m$, 转速为 $250 rad/s$, 电枢电压是多少? 电机输出的机械转矩是多少?

解 当 $U_a = 24V, \bar{I}_a = 0.5A, T_m = 0.015N \cdot m, T_0 = 0.003N \cdot m, \omega = 300rad/s$ 时

$$\text{有 } k_e = k_t = \frac{T_m}{I_a} = 0.03N \cdot m \cdot A^{-1}, \text{ 由 } R_a = \frac{U_a - k_e \omega}{I_a} \text{ 得 } R_a = 30\Omega$$

1) 当 $U_a = 18V$ 时,

① 启动时, $\omega = n = 0, I_a = \frac{U_a}{R_a} = 0.6A$, 输出转矩 $T_m = k_t \bar{I}_a = 0.018N \cdot m$

② 空载时, $T_L = 0, T_m = T_0 = 0.003N \cdot m, I_a = \frac{T_m}{k_t} = 0.1A, \omega = \frac{U_a - R_a I_a}{k_e} = 500rad/s$

故空载转速 $n = 4774 r/min$

2) 已知 $T_m = 0.02N \cdot m, \omega = 250rad/s$, 求 U_a 与 T_L

$$T_L = T_m - T_0 = 0.017N \cdot m$$

$$I_a = \frac{T_m}{k_t} = \frac{0.02}{0.03} = \frac{2}{3}A, U_a = k_e \omega + R_a I_a = 27.5V$$

即电枢电压 $U_a = 27.5V$, 机械转矩为 $0.017N \cdot m$