第三章直流电机原理习题

3.1 $I_N = \dfrac{P_N}{U_N \eta_N} = \dfrac{17000}{220 \times 0.83} = 93.1\,\mathrm{A}$

$$T_{2N} = \frac{P_N}{\Omega_N} = \frac{17000}{\dfrac{2\pi n_N}{60}} = \frac{17000 \times 60}{2\pi \times 1500} = 108.2\,\mathrm{N \cdot m}$$

$$P_1 = \frac{P_N}{\eta_N} = \frac{17000}{0.83} = 20481.9W = 20.48KW$$

3.3 $n = 1500\,\mathrm{r/min}$

$$E_a = \frac{pN}{60a}\Phi n = \frac{3 \times 398}{60 \times 3} \times 2.1 \times 10^{-2} \times 1500 = 208.95\,\mathrm{V}$$

$n = 500\,\mathrm{r/min}$

$$E_a = \frac{pN}{60a}\Phi n = \frac{3 \times 398}{60 \times 3} \times 2.1 \times 10^{-2} \times 500 = 69.65\,\mathrm{V}$$

$$T_M = C_T \Phi I_a = \frac{pN}{2\pi a}\Phi I_a = \frac{3 \times 398}{2\pi \times 3} \times 2.1 \times 10^{-2} \times 10 = 13.3\,\mathrm{N \cdot m}$$

3.4 $T_{2N} = \dfrac{P_N}{\Omega_N} = \dfrac{6000}{\dfrac{2\pi n_N}{60}} = \dfrac{6000 \times 60}{2\pi \times 1000} = 57.3\,\mathrm{N \cdot m}$

$$P_M = P_2 + p_0 = 6000 + 395 = 6395\,\mathrm{W}$$

$$P_1 = P_M + P_{cua} = 6395 + 500 = 6895\,\mathrm{W}$$

$$T_0 = \frac{p_0}{\Omega_N} = \frac{395 \times 60}{2\pi \times 1000} = 3.77\,\mathrm{N \cdot m}$$

$$\eta_N = \frac{P_N}{P_1} = \frac{6000}{6.895 \times 10^3} = 87\%$$

$$T_N = \frac{P_M}{\Omega_N} = \frac{6395 \times 60}{2\pi \times 1000} = 61\,\mathrm{N \cdot m}$$

$P_1 = U_N I_N$，　　$I_N = \dfrac{P_1}{U_N} = \dfrac{6895}{220} = 31.3\,\mathrm{A}$

$P_{cua} = I_N{}^2 R_a$　　$R_a = \dfrac{P_{cua}}{I_N{}^2} = \dfrac{500}{31.3^2} = 0.51\Omega$

3.6 估算　$E_{aN} = (0.93 \sim 0.97)U_N = 0.95 \times 220 = 209\,\mathrm{V}$

$$C_e\Phi_N = \frac{E_{aN}}{n_N} = \frac{209}{1150} = 0.1817\ \mathrm{V/r \cdot min^{-1}}$$

$$T_N = 9.55 C_e \Phi_N I_N = 9.55 \times 0.1817 \times 270 = 468.6\ \mathrm{N \cdot m}$$

$$n_0 = \frac{U_N}{C_e\Phi} = \frac{220}{0.1817} = 1210\ \mathrm{r/min}$$

两点座标（0，　1210），（468. 6，　1150)可画出固有机械特性曲线。

3. 7 $C_e\Phi_N = \frac{U_N - I_N R_a}{n_N} = \frac{220 - 40 \times 0.5}{1000} = 0.2\ \mathrm{V/r \cdot min^{-1}}$

$$n_0 = \frac{U_N}{C_e\Phi_N} = \frac{220}{0.2} = 1100\ \mathrm{r/min}$$

$$\Delta n_N = n_0 - n_N = 1100 - 1000 = 100\ \mathrm{r/min}$$

$$T_L = 0.5 T_N$$

$$\Delta n_L = n_0 - n_L = \beta T_L = 0.5 \beta T_N = 50\ \mathrm{r/min}$$

$$n = n_0 - \Delta n_L = 1100 - 50 = 1050\ \mathrm{r/min}$$

$$I_a = \frac{T_L}{C_T\Phi_N} = \frac{0.5 T_N}{C_T\Phi_N} = 0.5 I_N = 0.5 \times 40 = 20\ \mathrm{A}$$

第四章他励直流电动机的运行习题参考解

4.1 解：（1）$I_S = \frac{U_N}{R_a} = \frac{220}{0.147} = 1496.6\ \mathrm{A}$

(2)电枢回路串电阻起动

应串电阻$R_S = \frac{U_N}{I_S} - R_a = \frac{220}{2 \times 90} - 0.147 = 1.075\Omega$

降压起动

起动电压$U_S = I_S R_a = 2 \times 90 \times 0.147 = 26.46\ \mathrm{V}$

注：起动电流I_S=$2I_N$

4.2　解：（1）

$$U = E + I_a R_a$$

$$E = 220 - 41 \times 0.376 = 204.6\text{V}$$

$u \downarrow 150V$时，n来不及变　$E = 204.6\text{V}$

$$I_a = \frac{150 - 204.6}{0.376} = -145.2\text{A}$$

$$T = 9.55 C_e \Phi I_a = 9.55 \frac{E}{n} I_a = 9.55 \times \frac{204.6}{1500} \times (-145.2) = -189.1\text{N} \cdot \text{m}$$

$$T_L = T_N = 9.55 C_e \Phi_N I_N = 9.55 \times \frac{204.6}{1500} \times 41 = 53.4\text{N} \cdot \text{m}$$

动转矩$T - T_L = -189.1 - 53.4 = -242.5\text{N} \cdot \text{m}$

(2)

$\because T_L$不变

$T = 955 C_e \Phi I_a$故I_a不变

$$\therefore n = \frac{U - I_a R_a}{C_e \Phi} = \frac{150 - 41 \times 0.376}{\frac{204.6}{1500}} = 986.7\text{r/min}$$

4.3

解 (1)

$$T_L = 0.5 T_N = 0.5 \times 53.4 = 26.7\text{N} \cdot \text{m}$$

$$C_e \Phi = \frac{E}{n} = \frac{204.6}{1500} = 0.1364$$

$$T = T_L = 9.55 C_e \Phi I_a = 26.7$$

也即$9.55 \times 0.8 \times 0.1364 \times I_a = 26.7\text{N} \cdot \text{m}$

算得$I_a = 25.62\text{A}$

$$n = \frac{U - I_a R_a}{C_e \Phi} = \frac{220 - 25.62 \times 0.376}{0.8 \times 0.1364} = 1927.8\text{r/min}$$

（2）

$$T_L = T_N = 53.4\text{N} \cdot \text{m}$$

$$T_L = 9.55 C_e \Phi I_a$$

$$I_a = \frac{T_L}{9.55 C_e \Phi} = \frac{53.4}{9.55 \times 0.8 \times 0.1364} = 51.24\text{A}$$

$$n = \frac{U - I_a R_a}{C_e \Phi} = \frac{220 - 51.24 \times 0.376}{0.8 \times 0.1364} = 1839.6\text{r/min}$$

4.4 解：

$$C_e\Phi=\frac{U_N-I_{aN}R_a}{n_N}=\frac{220-68.7\times0.224}{1500}=0.1364\text{韦伯}$$

$$n_0=\frac{U_N}{C_e\Phi}=\frac{220}{0.1364}=1613\text{r/min}$$

$$\delta=\frac{n_0-n_{\min}}{n_0}$$

$$(1)n_{\min}=n_0(1-\delta)=1613(1-0.3)=1129\text{r/min}$$

$$(2)D=\frac{n_{\max}}{n_{\min}}=\frac{1500}{1129}=1.33$$

$$(3)\Delta n_N=n_0-n_N=1613-1500=113$$

$$\Delta n=n_0-n_{\min}=1613-1129=484$$

$$\frac{R_{\max}+R_a}{R_a}=\frac{\Delta n}{\Delta n_N}\qquad R_{\max}=\frac{\Delta n}{\Delta n_n}R_a-R_a=\frac{484}{113}\times0.224-0.224=0.735\Omega$$

$$(4)T_2=9.55\frac{P_N}{n_N}=9.55\frac{13000}{1500}=82.77N\cdot m$$

$$P_2=T_2\Omega=T_2\frac{2\pi}{60}n=82.77\times\frac{2\pi}{60}1129=9780.8W$$

$$P_1=U_NI_N=220\times68.7=15115\text{W}$$

$$\eta=\frac{P_2}{P_1}=\frac{9780.8}{15115}=64.7\%$$

$$I_{aN}{}^2R_{\max}=68.7^2\times0.735=3470\text{W}$$

4.5 解

$$\Delta n_{\text{N}}=n_0-n_{\text{N}}=1613-1500=113\text{r/min}$$

$$n_{0\min}=\frac{\Delta n_{\text{N}}}{\delta}=\frac{113}{0.3}=376.7\text{r/min}$$

$$(1)n_{\min}=n_{0\min}-\Delta n_{\text{N}}=376.7-113=264\text{r/min}$$

$$(2)D=\frac{n_{\text{N}}}{n_{\min}}=\frac{1500}{264}=5.68$$

(3)$\frac{u_N}{u_1}=\frac{n_0}{n_{0\min}}\qquad u_1=\frac{n_0}{n_{0\min}}u_N=\frac{376.7}{1613}220=51.4\text{V}$

(4)$T_2=9.55\frac{P_N}{n_N}=9550\frac{13000}{1500}=82.77N\cdot m$

$P_2=T_2\Omega=T_2\frac{2\pi}{60}n=82.77\times\frac{2\pi}{60}264=2287\text{W}$

$P_1=U_1I_N=51.4\times68.7=3531\text{W}$

$\eta=\frac{P_2}{P_1}=\frac{2287}{3531}=64.8\%$

$I_{aN}{}^2R_{\max}=68.7^2\times0.735=3470\text{W}$

4.6

解：（1）

$T_L=T_N,\ \Phi=\frac{1}{3}\Phi_N$

$I_a=3I_{aN}=309\text{A}$

$C_e\Phi_N=\frac{U-I_NR_a}{n_N}=\frac{220-103\times0.18}{500}=0.4029$韦伯

$n=\frac{U-I_aR_a}{\frac{1}{3}C_e\Phi_N}=\frac{220-309\times0.18}{\frac{1}{3}\times0.4029}=1223.98\text{r/min}$

不能长期运行，因为I_a太大

(2)

$P_L=P_N,\ \Phi=\frac{1}{3}\Phi_N$

$P_M=EI_a=C$

$I_a=I_{aN},\ E=C$

$n=\frac{E}{C_e\Phi}=\frac{U-I_{aN}R_a}{\frac{1}{3}C_e\Phi_N}=\frac{220-103\times0.18}{\frac{1}{3}\times0.4029}=1500\text{r/min}$

能长期运行，因为$I_a=I_{aN}$，$n=n_{\max}$。

4.7

解：

(1)$E_N = U_N - I_N R_a = 440 - 76 \times 0.376 = 411.4\text{V}$

$$C_e\Phi_N = \frac{E_N}{n_N} = \frac{411.4}{1000} = 0.4114\text{韦伯}$$

$$n_0 = \frac{U_N}{C_e\Phi_N} = \frac{440}{0.4114} = 1069.5\text{r/min}$$

$$\Delta n = n_0 - n_N = 1069.5 - 1000 = 69.5\text{r/min}$$

$$n_{\min} = n_{0\text{-min}} - \Delta n = 250 - 69.5 = 180.5\text{r/min}$$

$$\delta_{\max} = \frac{\Delta n_N}{n_{0\text{-min}}} = \frac{69.5}{250} = 0.278 = 27.8\%$$

(2)恒功率负载$I_a = I_N$=76A

$$C_e\Phi = \frac{U_N}{n_{0-\max}} = \frac{440}{1500} = 0.2933\text{韦伯}$$

$$n_{\max} = \frac{U - I_a R_a}{C_e\Phi} = \frac{440 - 76 \times 0.376}{0.2933} = 1402.7\text{r/min}$$

$$(3)D = \frac{n_{\max}}{n_{\min}} = \frac{1402.7}{180.5} = 7.77$$

4.8

解：$E_a = 0.94 \times U_N = U_N - I_{aN} R_a$，$R_a = \frac{U_N - E_{aN}}{I_{aN}} = \frac{110 - 0.94 \times 110}{185} = 0.0357\Omega$

$$C_e\Phi_N = \frac{E_{aN}}{n_N} = \frac{0.94 \times 110}{1000} = 0.103\text{ 韦伯}$$

$$(1)R_{\text{能串}} = \frac{-E_N}{-I_{\max}} - R_a = \frac{U_N - 0.8 \times I_{aN} \times R_a}{I_{\max}} - R_a = \frac{110 - 0.8 \times 185 \times 0.0357}{1.8 \times 185} - 0.0357 = 0.279\Omega$$

$$(2)R_{\text{反串}} = \frac{-U_N - (U_N - 0.8 \times I_{aN} \times R_a)}{-I_{\max}} - R_a = \frac{-110 - (110 - 0.8 \times 185 \times 0.0357)}{-1.8 \times 185} - 0.0357 = 0.609\Omega$$

$$(3)T_{\text{能}} = T_{\text{反}} = 9.55 C_e\Phi_N I_{\max} = 9.55 \times 0.103 \times (-1.8 \times 185) = -327.6\text{N} \cdot \text{m}$$

(4)对能耗制动$n = 0, T = 0$

对反接制动$n = 0, E_a = 0$

$$I = \frac{-U_N}{R_a + R_{\text{反串}}} = \frac{-110}{0.0357 + 0.609} = -170.6\text{A}$$

$$T = 9.55 C_e\Phi_N I = 9.55 \times 0.103 \times (-170.6) = -167.8\text{ N} \cdot \text{m}$$

4.9

解：

$$C_e\Phi_N=\frac{U_N-I_{aN}R_a}{n_N}=\frac{220-68.7\times0.195}{1500}=0.1377\text{韦伯}$$

$$n=\frac{U_N}{C_e\Phi_N}-\frac{(R_a+R)I_{aN}}{C_e\Phi_N};\ \ n=0;\ \ U_N=(R_a+R)I_{aN};T=C_e\Phi_NI_{aN}=T_N$$

$$R=\frac{U_N}{I_{aN}}-R_a=\frac{220}{68.7}-0.195=3\Omega$$

4.10

解：倒拉反接制动运行状态。

$$C_e\Phi_N=\frac{U_N-I_aR_a}{n_N}=\frac{220-158\times0.069}{1000}=0.2091\text{韦伯}$$

第四象限，制动状态，$T_L=0.7T_N\rightarrow I_a=0.7I_N=110.6\text{A}$

$$E_a=C_e\Phi_Nn=0.2091\times(-550)=-115\text{V},\ \ R_{串}=\frac{U_N+E_a}{I}-R_a=\frac{220+115}{110.6}-0.069=2.96\Omega$$

4.11

解：

$$C_e\Phi_N=\frac{U_N-I_{aN}R_a}{n_N}=\frac{440-29.5\times1.05}{730}=0.56\text{韦伯}$$

(1)求$U_N=-U_N,R=0$时的n

$$I_a=0.8I_{aN}=23.6\text{A}$$

$$n=\frac{-U_N}{C_e\Phi_N}-\frac{-I_aR_a}{C_e\Phi_N}=\frac{-440-23.6\times1.05}{0.56}=-830\text{r/min}$$

(2)能耗制动放下重物

$$|n|=\left|\frac{-0.8I_NR_a}{C_e\Phi_N}\right|=\left|\frac{-0.8\times29.5\times1.05}{0.56}\right|=44.25\text{r/min}$$

(3)

$n=-380\text{r/min}$下放

能耗：$E=C_e\Phi_Nn=0.56\times(-380)=-212.8\text{v}$

$$R=\frac{-E}{I_a}-R_a=\frac{212.8}{23.6}-1.05=8\Omega$$

倒拉反转

$$R=\frac{U_N-(-E)}{I_a}-R=\frac{440+212.8}{23.6}-1.05=26.6\Omega$$

4.12

解：

$$(1)C_e\Phi_N=\frac{U_N-I_NR_a}{n_N}=\frac{440-76.2\times0.393}{1050}=0.3905\text{韦伯}$$

$$E_N=U_N-I_{aN}R_a=440-76.2\times0.393=410\text{V}$$

$$n=\frac{-U_N}{C_e\Phi_N}-\frac{I_aR_a}{C_e\Phi_N}=\frac{-440-60\times0.393}{0.3905}=-1187\text{r/min}$$

$$T=9.55C_e\Phi_NI_a=9.55\times0.3905\times60=223.8N\cdot m$$

$$E=C_e\Phi_Nn=0.3905\times(-1187)=-463.5\text{v}$$

$$|P_1|=U_NI_a=440\times60=26.4\text{KW}$$

(2)

$$E=C_e\Phi_Nn=0.3905\times(-300)=-117.15\text{v}$$

$$R=\frac{-E}{-I_a}-R_a=\frac{117.15}{60}-0.393=1.56\Omega$$

$$P_{\text{cuR}}=I_a{}^2R=60^2\times1.56=5.616\text{KW}$$

(3)

$$E=C_e\Phi n=0.3905\times(-850)=-332\text{v}$$

$$R=\frac{U-(-E)}{-I_a}-R_a=\frac{440+332}{60}-0.393=12.47\Omega$$

$$P_1=UI=440\times60=26.4\text{KW}$$

$$P_{\text{cuR}}=I_a{}^2R=60^2\times12.47=44.89\text{KW}$$

4.13　　能耗制动

$$Ce\Phi_N=\frac{U_N-I_NR_a}{n_N}=\frac{110-185\times0.035}{1000}=0.1035\text{V/r}\cdot\text{min}^{-1}$$

$T_{L=0.85}\ T_N$　　$I_a=0.85I_N$

$$n_{F0}=\frac{U_N-0.85I_NR_a}{Ce\Phi_N}=\frac{110-0.85\times185\times0.035}{0.1035}=1009.6\text{r/min}$$

制动前电动机电枢感应电动势为

$$E_a=Ce\Phi n=0.1035\times1009.6=104.5\text{V}$$

制动时电枢回路总电阻为

$$R_a+R=\frac{-E_a}{-1.8\times I_N}=\frac{-104.5}{-1.8\times185}=0.314\Omega$$

虚稳态点的转速为

$$n_L=\frac{U}{Ce\Phi_N}-\frac{R_a+R}{Ce\Phi_N}I_a=0-\frac{0.314}{0.1035}\times0.85\times185=-477\text{r/min}$$

$$T_M=\frac{GD^2}{375}\frac{R+R_a}{9.55(Ce\Phi)^2}=\frac{1.25\times30}{375}\times\frac{0.314}{9.55\times0.1035^2}=0.307s$$

$$t_0=T_M In\frac{n_{F0}-n_L}{-n_L}=0.307\times In\frac{1009.6+477}{477}=0.349s$$

$$(\text{或}t_0=T_M In\frac{I_{\max}-I_a}{-I_a}=0.307\times In\frac{-1.8I_N-0.85I_N}{-0.85I_N}=0.349s)$$

反接制动

制动时电枢回路总电阻为

$$R_a+R=\frac{-U_N-E_a}{-1.8\times I_N}=\frac{-110-104.5}{-1.8\times185}=0.644\Omega$$

虚稳态点的转速为

$$n_L=\frac{U}{Ce\Phi_N}-\frac{R_a+R}{Ce\Phi_N}I_a=\frac{-110}{0.1035}-\frac{0.644}{0.1035}\times0.85\times185=-2041.2\text{r/min}$$

$$T_M=\frac{GD^2}{375}\frac{R+R_a}{9.55(Ce\Phi)^2}=\frac{1.25\times30}{375}\times\frac{0.644}{9.55\times0.1035^2}=0.6295s$$

$$t_0=T_M In\frac{n_{F0}-n_L}{-n_L}=0.6295\times In\frac{1009.6+2041.2}{2041.2}=0.253s$$

$$(\text{或}:n=0\qquad I_a=\frac{U}{R+R_a}=\frac{-110}{0.644}=-170.8A$$

$$t_0=T_M In\frac{I_{\max}-I_a}{-I_a}=0.6295\times In\frac{-1.8I_N-0.85I_N}{-170.8-0.85I_N}=0.253s)$$

第五章变压器习题参考解

5.1 $I_{1N}=\frac{S_N}{\sqrt{3}U_{1N}}=\frac{100\times10^3}{\sqrt{3}\times35000}=1.65A$

$$I_{2N}=\frac{S_N}{\sqrt{3}U_{2N}}=\frac{100\times10^3}{\sqrt{3}\times400}=144.3A$$

5.2 (1) $U_{1N}/U_{2N}=3300/220$ 的单相变压器 $\quad k=\frac{U_{1N}}{U_{2N}}=\frac{3300}{220}=15$

(2) $U_{1N}/U_{2N}=10000/400$ Y,y接法的三相变压器 $k=\frac{E_1}{E_2}=\frac{10000/\sqrt{3}}{400/\sqrt{3}}=25$

(3) $U_{1N}/U_{2N}=10000/400$ Y,d接法的三相变压器 $k=\frac{E_1}{E_2}=\frac{10000/\sqrt{3}}{400}=14.43$

5.4 $\dot{E}_1 = -j4.44 f\omega_1\phi_m$ $\dot{E}_2 = -j4.44 f\omega_2\phi_m$

$U_1 = -\dot{E}_1$ $U_2 = -\dot{E}_2$

U_1、U_2超前ϕ 90° E_1、E_2滞后ϕ 90°

5.5 漏阻抗忽略，故$U_1 = E_1$，$U_2 = E_2$则

$$W_1 = \frac{E_1}{4.44 fBS} = \frac{1000}{4.44\times 50\times 90\times 1.2\times 10^{-4}} = 417 \text{匝}$$

$$W_2 = \frac{E_2}{4.44 fBS} = \frac{220}{4.44\times 50\times 90\times 1.2\times 10^{-4}} = 92 \text{匝}$$

5.9 $k = \dfrac{U_{1N}/\sqrt{3}}{U_{2N}/\sqrt{3}} = \dfrac{1000}{400} = 2.5$

$Z_L = 0.96 + j0.48 = 1.07\angle 26.5°$

$Z_L' = k^2 Z_L = 1.07\times 2.5^2\angle 26.5° = 6.69\angle 26.5° = 5.98 + j2.98$

忽略I_0 采用简化等值电路

$Z = Z_k + Z_L' = 0.15 + j0.35 + 5.98 + j2.98 = 6.13 + j3.33 = 6.98\angle 28.5°$

原边电流 $I_1 = \dfrac{U_{1N}/\sqrt{3}}{Z} = \dfrac{1000/\sqrt{3}}{6.98} = 82.7A$

副边电流 $I_2 = kI_1 = 2.5\times 82.7 = 206.75A$

副边电压（线值） $U_2 = \sqrt{3} I_2 Z_L = \sqrt{3}\times 206.75\times 1.07 = 383V$

$\varphi_1 = 28.5°$ $\cos\varphi_1 = 0.879$

输入有功功率 $P_1 = \sqrt{3} U_{1N} I_1 \cos\varphi_1 = \sqrt{3}\times 1000\times 82.7\times 0.879 = 125.9KW$

输入无功功率 $Q_1 = \sqrt{3} U_{1N} I_1 \sin\varphi_1 = \sqrt{3}\times 1000\times 82.7\times 0.4772 = 68.4KVar$

输入视在功率 $S_1 = \sqrt{P_1^2 + Q_1^2} = \sqrt{125.9^2 + 68.4^2} = 143.3KVA$

副边功率因数 $\varphi_2 = \varphi_L = 26.5°$

$$P_2 = \sqrt{3} U_2 I_2 \cos\varphi_2 = \sqrt{3}\times 383\times 206.7\times \cos 26.5° = 122.7KW$$

$$Q_2 = \sqrt{3}U_2 I_2 \sin\varphi_2 = 61.2KVar$$

$$S_2 = \sqrt{P_2^{\ 2} + Q_2^{\ 2}} = 137.1KVA$$

5.10 $U_{1N\phi} = \dfrac{10000}{\sqrt{3}} = 5773.5V$

$$I_{1N} = \frac{1000000}{\sqrt{3}U_{1N}} = \frac{1000000}{\sqrt{3}\times 10000} = 57.735A$$

$$Z_{1N} = \frac{U_{1N\varphi}}{I_{1N\varphi}} = \frac{5773.5}{57.735} = 100\Omega$$

$$Z_k = \underline{Z_k} Z_{1N} = (0.15 + j0.053)\times 100 = 1.5 + j5.3 = 5.51\angle 74.2°$$

$$k \approx \frac{U_{1N\phi}}{U_{2N\phi}} = \frac{10000/\sqrt{3}}{3300} = 1.75$$

$$Z_L^{\ '} = k^2 Z_L = 1.75^2(50 + j85) = 153.13 + j260.3 = 302\angle 59.5°$$

$$Z_1 = Z_k + Z_L^{\ '} = 1.5 + j5.3 + 153.13 + j260.3 = 154.63 + j265.6 = 307.3\angle 59.8°$$

$$\dot{I}_1 = \frac{U_{1N\phi}}{Z_1} = \frac{10000/\sqrt{3}}{307.3\angle 59.8°} = 18.8\angle -59.8°A$$

$$\dot{I}_2 = \sqrt{3}\dot{I}_{2\phi} = \sqrt{3}k\dot{I}_1 = \sqrt{3}\times 1.75\times 18.8\angle -59.8° = 56.98\angle -59.8°A$$

$$U_2 = U_{2\phi} = I_{2\phi} Z_L = 1.75\times 18.8\times\sqrt{50^2 + 85^2} = 3244.4V$$

5.11 (1) $I_{1N} = \dfrac{S_N}{U_{1N}} = \dfrac{600\times 10^3}{35\times 10^3} = 17.14A$

$$I_{1N} Z_k = 0.065\times U_{1N} = 0.065\times 35\times 10^3 = 2275V$$

$$Z_k = \frac{2275}{I_{1N}} = 132.7\Omega$$

$$P_{cu} = I_{1N}^{\ 2} r_k \qquad r_k = \frac{P_{cu}}{I_{1N}^{\ 2}} = \frac{9.5\times 10^3}{17.14^2} = 32.34\Omega$$

$$X_k = \sqrt{Z_k^{\ 2} - r_k^{\ 2}} = \sqrt{132.7^2 - 32.34^2} = 128.7\Omega$$

$$I_0 = 0.055\times I_{1N} = 0.055\times 17.14 = 0.94A$$

$$Z_0 \approx Z_m = \frac{U_{1N}}{I_0} = \frac{35\times10^3}{0.94} = 37234\Omega$$

$$r_m = Z_m \cos\varphi \ = 37234\times0.1 = 3723.4\Omega$$

$$X_m = \sqrt{Z_m{}^2 - r_m{}^2} = \sqrt{37234^2 - 3723.4^2} = 37047.4\Omega$$

(2) $k \approx \frac{U_{1N}}{U_{2N}} = \frac{35}{6.3} = 5.56$

$$Z_L{}' = k^2 Z_L = 5.56^2 \times 80\angle 40° = 1894.5 + j1589.7$$

$$Z_1 = Z_k + Z_L{}' = 32.34 + j128.7 + 1894.5 + j1589.7 = 2581.8\angle 41.7°$$

$$\dot{I}_1 = \frac{U_{1N}}{Z_1} = \frac{35\times10^3}{2581.8} = 13.6A$$

$$\dot{I}_2 = k\dot{I}_1 = 5.56\times13.6 = 75.6A$$

$$U_2 = \dot{I}_2 Z_L = 75.6\times80 = 6048V$$

5.12 (1) $I_{1N} = I_{1N\phi} = \frac{S_N}{\sqrt{3}U_{1N}} = \frac{750\times10^3}{\sqrt{3}\times10000} = 43.3A$

$$I_{2N\phi} = I_{2N}/\sqrt{3} = \frac{S_N}{\sqrt{3}U_{2N}\times\sqrt{3}} = \frac{750\times10^3}{3\times400} = 625A$$

$$k = \frac{U_{1N}/\sqrt{3}}{U_{2N}} = \frac{10000/\sqrt{3}}{400} = 14.43$$

$$Z_0 = \frac{U_{20}}{I_0} = \frac{400}{65/\sqrt{3}} = 10.66\Omega$$

$$Z_m \approx Z_0{}' = k^2 Z_0 = 14.43^2\times10.66 = 2220\Omega$$

$$P_0 = 3I_0{}^2 r_0 \qquad r_0 = \frac{3.7\times10^3}{3(65/\sqrt{3})^2} = 0.876\Omega$$

$$r_m \approx r_0{}' = 14.43^2\times0.876 = 182.4\Omega$$

$$X_m = \sqrt{Z_m{}^2 - r_m{}^2} = \sqrt{2220^2 - 182.4^2} = 2212.5\Omega$$

(2) $Z_k = \frac{U_{1k}/\sqrt{3}}{I_{1k}} = \frac{450/\sqrt{3}}{35} = 7.42\Omega$

$$P_k = 3I_{1k}{}^2 r_k \qquad r_k = \frac{P_k}{3I_{1k}{}^2} = \frac{7.5\times10^3}{3\times35^2} = 2.04\Omega$$

$$X_k = \sqrt{Z_k{}^2 - r_k{}^2} = \sqrt{7.42^2 - 2.04^2} = 7.13\Omega$$

$$r_{k75°c} = \frac{234.5+75}{234.5+\theta} r_k = \frac{234.5+75}{234.5+30}\times 2.04 = 2.387\Omega$$

$$Z_{k75°c} = \sqrt{X_k{}^2 + r_{k75°c}{}^2} = \sqrt{7.13^2 + 2.387^2} = 7.52\Omega$$

$$X_1 = X_2{}' = \frac{1}{2}X_k = 3.565\Omega \qquad r_1 = r_2{}' = \frac{1}{2}r_k = 1.19\Omega$$

5.13 (1)带感性负载

$$\Delta u\% = \beta \frac{I_{1N}(r_k\cos\varphi_2 + X_k\sin\varphi_2)}{U_{1N}/\sqrt{3}} = 1\times 43.3\frac{2.38\times0.8+7.13\times0.6}{10000/\sqrt{3}} = 0.046 = 4.6\%$$

$$U_2 = (1-\Delta u\%)U_{2N} = 381.6V$$

$$P_{kN} = 3I_{1N}{}^2 r_k = 3\times43.3^2\times2.38 = 13386.7\text{W} \approx 13.4\text{KW}$$

$$\eta = 1 - \frac{P_0+\beta^2 P_{kN}}{\beta S_N\cos\varphi_2 + P_0 + \beta^2 P_{kN}} = 1 - \frac{3.7+13.4}{1\times750\times0.8+3.7+13.4} = 97.2\%$$

(2)带容性负载

$$\Delta u\% = \beta \frac{I_{1N}(r_k\cos\varphi_2 + X_k\sin\varphi_2)}{U_{1N}/\sqrt{3}} = 1\times 43.3\frac{2.38\times0.8+7.13\times(-0.6)}{10000/\sqrt{3}} = -1.8\%$$

$$U_2 = (1-\Delta u\%)U_{2N} = 407.2V$$

η 不变

5.16 $k = \dfrac{6000/\sqrt{3}}{400} = 8.66 \qquad Z_L = 0.1 + j0.06 = 0.117\angle30.96°$

$$Z_L{}' = k^2 Z_L = 8.66^2\times0.117\angle30.96° = 8.77\angle30.96° = 7.52 + j4.5$$

$$I_{1N\phi} = I_{1N} = \frac{S_N}{\sqrt{3}U_{1N}} = \frac{5600\times10^3}{\sqrt{3}\times6000} = 538.9A$$

$$Z_k = \frac{U_k/\sqrt{3}}{I_k} = \frac{280/\sqrt{3}}{538.9} = 0.3\Omega \qquad r_k = \frac{P_{kN}}{3I_{1N}{}^2} = \frac{56\times10^3}{3\times538.9^2} = 0.064\Omega$$

$$X_k = \sqrt{Z_k{}^2 - r_k{}^2} = \sqrt{0.3^2 - 0.064^2} = 0.29\Omega$$

$$\dot{I}_1 = \frac{\dot{U}_{1N\phi}}{Z_L{}' + Z_k} = \frac{6000/\sqrt{3}}{7.52 + j4.5 + 0.064 + j0.29} = 386.2\angle -32.3° A$$

$$\dot{I}_2 = \sqrt{3}k\dot{I}_1 = \sqrt{3}\times 8.66 \times 386.2 = 5793A$$

$$U_2 = (I_2/\sqrt{3})Z_L = 5793\times 0.117/\sqrt{3} = 391.3V$$

$$I_{2N} = \frac{S_N}{\sqrt{3}U_{2N}} = \frac{5600\times 10^3}{\sqrt{3}\times 400} = 8082.9A \qquad \beta = \frac{I_2}{I_{2N}} = 0.72$$

$$\varphi_2 = \varphi_L = 30.96°$$

$$\eta = 1 - \frac{P_0 + \beta^2 P_{kN}}{\beta S_N \cos\varphi_2 + P_0 + \beta^2 P_{kN}} = 1 - \frac{18 + 0.72^2\times 56}{0.72\times 5600\times 0.858 + 18 + 0.72^2\times 56} = 98.66\%$$

$$\beta_m = \sqrt{\frac{P_0}{P_{kN}}} = \sqrt{\frac{18}{56}} = 0.57$$

$$\eta = 1 - \frac{P_0 + \beta^2 P_{kN}}{\beta S_N \cos\varphi_2 + P_0 + \beta^2 P_{kN}} = 1 - \frac{18 + 0.57^2\times 56}{0.57\times 5600\times 0.858 + 18 + 0.57^2\times 56} = 98.7\%$$