Proiect Masini Electrice 2

Proiect realizat de: -> Salajan Bogdan
-> Stan Andrei

Date de intrare

$m := 3$

$P := 90 \quad Kw$

$m_p := 2 \quad \frac{M_p}{M_N}$

$U_N := 415 \quad V$

$n_N := 741 \quad \frac{rot}{min}$

$f_1 := 50 \quad Hz$

$i_p := 6.8 \quad \frac{I_p}{I_N}$

$m_m := 2.2 \quad \frac{M_m}{M_N}$

$n_1 := 750$

Conexiunea Y

Clasa de izolatie: F (max. $120\,°C$)

Grupa de protectie: IP 44

Serviciul: S1 (continuu)

Conditii de functionare: Normale

Capitolul 1

$(1.1) \quad p := \frac{60 \cdot f_1}{n_1}$

$p = 4 \quad rezulta \quad p := 4$ (numar de perechi de poli)

$(1.2) \quad cosf := 0.86$

$\eta := 0.91$

$S_N := \frac{P}{\eta \cdot cosf} \quad S_N = 115.001 \quad (kVA)$

(1.3) $I_N := \frac{S_N \cdot 10^3}{\sqrt{3}\ U_N}$ $I_N = 159.99$ (A)

(1.4) $U_1 := \frac{U_N}{\sqrt{3}}$ $U_1 = 239.6\ V$

(1.6) $k_E := 0.96$

(1.8) $E_1 := k_E \cdot U_1$ $E_1 = 230.016\ V$

(1.13) $S_i := k_E \cdot S_N$ $S_i = 110.401\ V$

(1.16 a) $k_{sd} := 1.3$ $\alpha_i := 0.71$

$k_\omega := 0.92$ $k_B := 1.09$

(1.2) Calculul dimensiunilor principale

(1.18) $C := 200\ \frac{J}{dm^3}$

(1.20) $\lambda := 1.1$

(1.21) $D := \sqrt[3]{\frac{2 \cdot p \cdot 60 \cdot S_i \cdot 10^3}{\pi \cdot \lambda \cdot n_1 \cdot C}} \cdot 10 = 46.758$ (cm)

(tab1.1) $k_D := 1.3$

(1.22 a) $D_e := k_D \cdot D = 60.786$

$D := 460\ (mm)$ (diametrul interior)

(tab1.2) $D_e := 600 (mm)$ (diametrul exterior)

(1.22 b) $D_{rec} := \frac{D_e}{k_D} = 461.538\ (mm)$

(1.22 c) $\tau := \frac{\pi \cdot D}{2 \cdot p} = 180.642\ (mm)$ (pasul polar)

(1.2.3) Calculul lungimii masinii asincrone

$(fig1.11)\quad A := 400 \quad \left(\frac{A}{cm}\right)$

$(fig1.11)\quad B_\delta := 0.76 \quad (T)$

$$(1.23)\quad l_i := \frac{60 \cdot S_i \cdot 10^3 \cdot 10^2}{k_B \cdot k_\omega \cdot \alpha_i \cdot \pi^2 \cdot D^2 \cdot 10^{-4} \cdot n_1 \cdot A \cdot 10^2 \cdot B_\delta} = 0.195 \ (m)$$

$$\lambda := \frac{l_i \cdot 1000}{\tau} = 1.082$$

(1.3) Determinarea latimii intrefierului

$$(1.26)\quad \delta := 3 \cdot \left(4 + 0.7 \cdot \sqrt{D \cdot l_i \cdot 10}\right) \cdot 10^{-2} = 0.75 \qquad deci \qquad \delta := 0.75 \ (mm)$$

(1.4) Solicitarile electromagnetice ale masinii asincrone

In dintii statorului	$B_{d1max} := 1.7$	$B_{d1mad} := 1.5$	$B'_{d1} := 1.4$
In dintii rotorului	$B_{d2max} := 1.7$	$B_{d2mad} := 1.5$	$B'_{d2} := 1.5$

(1.5) Infasurarea si crestaturile statorului

$(1.29)\quad q := 4$

$(1.27)\quad y_\tau := m \cdot q = 12$ (pasul diametral in crestaturi)

$$(1.27)\quad y_1 := \frac{5 \cdot m \cdot q}{6} = 10$$ (pasul principal in crestaturi)

$(1.30)\quad Z_1 := 2 \cdot p \cdot m \cdot q = 96$ (numarul de crestaturi statorice)

$$(1.30)\quad t_1 := \frac{\pi \cdot D}{Z_1} = 15.053 \ (mm)$$ (pasul dentar)

$$(1.12)\quad \phi := \alpha_i \cdot \tau \cdot l_i \cdot \frac{B_\delta}{1000} = 0.019 \quad (Wb)$$

Elementele.infasurarii.statorului

(1.31) $\omega := \frac{E_1}{4 \cdot k_B \cdot k_\omega \cdot f_1 \cdot \alpha_i \cdot \tau \cdot 10^{-3} \cdot l_i \cdot B_\delta} = 60.217$ (tinand cont de 1.8 si 1.11)

(1.32 a) $a_1 := 4$

(1.32) $n_{C1} := \frac{2 \cdot m \cdot a_1 \cdot \omega}{Z_1} = 15.054$ *deci* $n_{C1} := 15$ (numar de conductoare)

$\omega_1 := \frac{Z_1 \cdot n_{C1}}{2 \cdot m \cdot a_1} = 60$ (numar real de spire pe faza)

Verificarea incadrarii in limite a solicitarilor electromagnetice

(1.34) Patura de curent $A := \frac{n_{C1} \cdot I_N}{a_1 \cdot t_1} = 39.856$ $\left(\frac{A}{cm}\right)$

(1.35 a) Fluxul maxim util pentru un pol $\phi := \frac{E_1}{4 \cdot k_B \cdot f_1 \cdot \omega_1 \cdot k_\omega} = 0.019$ (Wb)

(1.35 b) Valoarea maxima a inductiei in intrefier $B_\delta := \frac{\phi}{\alpha_i \cdot \tau \cdot l_i \cdot 10^{-3}} = 0.763$ (T)

Dimensionarea conductorului si a crestaturii

(paragraf 1.4.1B) $J_1 := 6$ $\left(\frac{A}{mm^2}\right)$

(1.36) $S_{Cu1} := \frac{I_N}{a_1 \cdot J_1} = 6.666$ $\left(mm^2\right)$

$(tab1.3)$ $n_f := 3$

$$d := \left(\frac{4 \cdot S_{Cu1}}{\pi \cdot n_f}\right)^{\frac{1}{2}} = 1.682$$

$d := 1.7$

(1.38) $k_{Fe} := 0.95$ (coeficientul de impachetare)

(1.4.2B) $B'_{dadm} := 1.7 \quad (T)$

$l_{Fe} := l_i = 0.195 \quad (cm)$ -> Dimensiunea miezului magnetic statoric
$l_g := l_{Fe} \cdot 10^2 = 19.539$ ->

(1.38) $b_d := \frac{t_1 \cdot l_i \cdot B_\delta}{k_{Fe} \cdot l_{Fe} \cdot B'_{dadm}} = 7.11 \quad (mm)$ (latimea constanta a dintelui)

Sectiunea neta a crestaturii

$i_z := 0.045$

$n_f = 3$ $d_{CuN} := 1.7$

(1.39) $d_{iz} := d_{CuN} + 2 \cdot i_z = 1.79 \ (mm)$

$i_z = 0.045$

$k_u := 0.7$ (coeficientul de umplere)

$n_{tot} := n_{C1} \cdot n_f = 45$ (numarul de conductoare elementare in crestatura

$S_{cr} := \frac{n_{tot} \cdot d_{iz}^2}{k_u} = 205.978 \ (mm)^2$

Descrierea istmului crestaturii:

$a_s := d_{iz} + 1.5 = 3.29 \quad (mm)$

$a_s := 3.3$

Dimensionarea analitica a crestaturii statorice de forma trapezoidala:

$g_{iz} := 0.4 \ (mm)$ $h_{pana} := 3 \quad (mm)$ $h_{istml} := 1.5 \ (mm)$

$b_{istml} := d + 2 \cdot g_{iz} = 2.5$

Latimea crestaturii statorice la varful partii trapezoidale:

$$b_{cr1v} := \frac{\pi}{Z_1}\left(D + 2\cdot h_{istml} + 2\cdot h_{pana} + 4\cdot g_{iz}\right) - b_d = 8.291 \quad (mm)$$

Inaltimea partii utile a crestaturii:

$$h_{util} := \frac{\sqrt{\left(b_{cr1v} - 2\cdot g_{iz}\right)^2 + 4\cdot S_{cr}\cdot \tan\left(\frac{\pi}{Z_1}\right)} - \left(b_{cr1v} - 2\cdot g_{iz}\right)}{2\cdot \tan\left(\frac{\pi}{Z_1}\right)} = 24.808\ (mm)$$

$$h_{d1} := h_{util} + h_{istml} + h_{pana} + 4\cdot g_{iz} = 30.908\ (mm)$$

Latimea crestaturii statorice la baza partii trapezoidale:

$$b_{cr1b} := \frac{\pi}{Z_1}\left(D + 2\cdot h_{d1}\right) - b_d = 9.967 \quad (mm)$$

Dimensionarea dintiilor statorici pentru cazul crestaturilor statorice de forma trapez

Latimea dintelui statoric in zona varfului crestaturiii trapezoidale:

$$b_{d1v} := \frac{\pi}{Z_1}\left(D + 2\cdot h_{istml} + 2\cdot h_{pana}\right) - b_{cr1v} = 7.057 \quad (mm)$$

Latimea dintelui statoric in zona bazei crestaturii trapezoidale:

$$b_{d1b} := \frac{\pi}{Z_1}\left(D + 2\cdot h_{d1}\right) - b_{cr1b} = 7.11 \quad (mm)$$

Latimea dintelui statoric in zona medie a inaltimii crestaturii trapezoidale

$$b_{d1m} := \frac{b_{d1b} + b_{d1v}}{2} = 7.083 \quad (mm)$$

Aria sectiunii nete a crestaturilor statorice

$$S_{cr1} := \frac{\left(b_{cr1v} - 2\cdot g_{iz}\right) + \left(b_{cr1b} - 2\cdot g_{iz}\right)}{2}\cdot\left(h_{d1} - h_{istml} - h_{pana} - 2\cdot g_{iz}\right) = 213.283 \quad (mm^2)$$

Verificari necesare

Verificarea paturii de curent:

$$N_1 := Z_1 \cdot n_{C1} = 1.44 \cdot 10^3 \qquad I := \frac{I_N}{a_1} = 39.998 \quad (A)$$

$$A := \frac{N_1 \cdot I}{\pi \cdot D} = 39.856 \quad \left(\frac{A}{mm}\right)$$

Verificarea incadrarii in limite a inductiei jugului statoric:

$$h_{j1} := \frac{D_e - D}{2} - h_{d1} = 39.092 \quad (mm)$$

$$B_{j1} := \frac{\phi}{2 \cdot k_{Fe} \cdot l_{Fe} \cdot h_{j1} \cdot 10^{-3}} = 1.317 \quad (T)$$

Valoarea exacta a densitatii de curent:

$$J_1 := \frac{I_N}{a_1 \cdot S_{Cu1}} = 6 \quad \left(\frac{A}{mm^2}\right)$$

1.6 Infasurarea si crestaturile rotorului:

Numarul de crestaturi:

$2 \cdot p = 8$ *deci* $p = 4$

$Z_1 = 96$

deci $Z_2 := 83$ $m_2 := Z_2$

$\alpha := p \cdot \frac{2 \cdot \pi}{Z_2} = 0.303$ (unghiul de defajaz intre curenti)

Factorul de infasurare:

$$k_i := 0.86$$

Diamestrul exterior al rotorului:

$$\delta := 0.75 \quad (mm)$$

$$D_r := D - 2 \cdot \delta = 458.5 (mm)$$

Pasul dentar al rotorului:

$$t_2 := \frac{\pi \cdot D_r}{Z_2} = 17.354 \ (mm)$$

Tensiunea indusa intr-o bara a coliviei rotorice:

$$b_{i2} := 0.98$$

$$k_{\omega 2} := k_i$$

$$k_{i2} := \frac{D}{p \cdot b_{i2}} \cdot \sin\left(\frac{p \cdot b_{i2}}{D}\right) = 1$$

$$U_{20} := \frac{k_E \cdot U_1 \cdot k_{i2}}{2 \cdot \omega \cdot k_\omega} = 2.076 \ (V)$$

Curentul in rotor:

In barele coliviei rotorice:

$$k_I := 0.9$$

$$I_b := k_I \cdot \frac{2\ m \cdot \omega_1 \cdot k_\omega}{Z_2 \cdot k_i} \cdot I_N = 668.113 \ (A)$$

In inelul de scurtcircuitare:

$$I_i := \frac{I_b}{2 \cdot \sin\left(\pi \cdot \frac{p}{Z_2}\right)} = 2.215 \cdot 10^3 \quad (A)$$

In colivia rotorica:

$$J_{2b} := 3$$

In inelele de scurtcircuitare ale coliviei rotorice:

$$J_{2i} := 0.65 \cdot J_{2b} = 1.95$$

Dimensiunile barelor coliviei si inelelor rotorice:

Sectiunea barei:

$$S_b := \frac{I_b}{J_{2b}} = 222.704 \quad (mm^2)$$

Sectiunea inelului de scurtcircuitare:

$$S_i := \frac{I_i}{J_{2i}} = 1.136 \cdot 10^3 \, (mm^2)$$

Dimensiunile conductorului si ale crestaturii:

Latimea istmului crestaturii:

$$b_{istm2} := 1 \qquad (mm)$$

Inaltimea istmului crestaturii:

$$h_{istm2} := 1 \qquad (mm)$$

Latimea barei coliviei rotorice la varful crestaturii trapezoidale:

$$B_{d2} := 1.7 \quad (T)$$

$$b_{cr2v} := \frac{\pi}{Z_2} \cdot \left(\left(1 - \frac{B_\delta}{k_{Fe} \cdot B_{d2}}\right) \cdot D - 2\,\delta - 2\,h_{istm2}\right) = 9.056 \quad (mm)$$

Inaltimea crestaturii rotorului:

$$h_{cr2} := \frac{Z_2}{2 \cdot \pi} \cdot \left(b_{cr2v} - \sqrt{{b_{cr2v}}^2 - \frac{4 \cdot \pi}{Z_2} \cdot S_b}\right) + h_{istm2} = 28.831 \quad (mm)$$

Latimea barei coliviei rotorice la baza crestaturii trapezoidale:

$$b_{cr2b} := b_{cr2v} - \frac{2 \cdot \pi}{Z_2} \cdot \left(h_{cr2} - h_{istm2}\right) = 6.949 \ (mm)$$

Latimea dintelui rotoric in zona varfului barei coliviei:

$$b_{d2v} := \frac{\pi}{Z_2} \cdot \left(D - 2\ \delta - 2\ h_{istm2}\right) - b_{cr2v} = 8.223 \quad (mm)$$

Latimea dintelui rotoric in zona barei crestaturii trapezoidale:

$$h_{d2} := h_{cr2}$$

$$b_{d2b} := \frac{\pi}{Z_2} \left(D - 2\ \delta - 2\ h_{d2}\right) - b_{cr2b} = 8.223 \quad (mm)$$

$$b_{d2m} := \frac{b_{d2b} + b_{d2v}}{2} = 8.223 \ (mm)$$

$$S_b := \frac{\left(b_{cr2v} + b_{cr2b}\right) \ \left(h_{cr2} - h_{istm2}\right)}{2} = 222.704 \ (mm)^2$$

Verifiare:

$$d_{ax} := 55 + 105 = 160 \ (mm)$$

1.7 Calculul circuitului magnetic si urentului de magnetizare:

Jugul si diametrul interior, ale rotorului:

$$B_{j2} := 1.4$$

$$h_{j2} := \frac{\phi \cdot 10^3}{2 \cdot k_{Fe} \cdot l_{Fe} \cdot B_{j2}} = 36.777 \qquad l_{Fe} = 0.195$$

$$D_{ir} := D_r - 2 \cdot \left(h_{cr2} + h_{j2}\right) = 327.284$$

rezulta

$$D_{ir} := 330$$

$$h_{j2} := \frac{D_r - D_{ir}}{2} - h_{cr2} = 35.419 \quad (mm)$$

$$B_{j2} := \frac{\phi}{2 \cdot k_{Fe} \cdot l_{Fe} \cdot h_{j2} \cdot 10^{-3}} = 1.454 \quad (T)$$

Tensiunea magnetomotoare pe o pereche de poli:

$$a_s := b_{istml} \qquad h_{cr1} := h_{d1}$$

$$a_r := b_{istm2}$$

$$\gamma_1 := \frac{\left(\frac{a_s}{\delta}\right)^2}{5 + \frac{a_s}{\delta}} = 1.333 \qquad \gamma_2 := \frac{\left(\frac{a_r}{\delta}\right)^2}{5 + \frac{a_r}{\delta}} = 0.281$$

Coeficientul lui Carter pentru stator

$$k_{c1} := \frac{t_1}{t_1 - \gamma_1 \cdot \frac{\delta}{10}} = 1.007$$

Coeficientul lui Carter pentru rotor

$$k_{c2} := \frac{t_2}{t_2 - \gamma_2 \cdot \frac{\delta}{10}} = 1.001$$

Coeficientul lui Carter

$$k_c := k_{c1} \cdot k_{c2} = 1.008$$

Tensiunea magnetica a intrefierului

$$\mu_0 := 4 \cdot \pi \cdot 10^{-7}$$

$$U_{m\delta} := 2 \cdot \frac{B_\delta}{\mu_0} \cdot k_c \cdot \delta \cdot 10^{-3} = 917.673$$

Tensiunea magnetica a dintilor statorului, pentru o pereche de poli:

$$B'_{dadm} = 1.7$$

Din anexa 2 avem:

$$h_{cr1} = 30.908$$

$$H_{d1} := 53$$

$$U_{md1} := 2\,\frac{h_{cr1}}{10}\cdot H_{d1} = 327.627$$

Tensiunea magnetica a dintilor rotorului, pentru o pereche de poli:

$$h_{d2} := h_{cr2}$$

$$b_{d2min} := t_1 - b_{istml} = 12.553 \qquad b_{d2med} := \frac{\pi\cdot\left(D + h_{cr2}\right)}{Z_1} - b_{istml} = 13.497$$

$$b_{d2max} := \frac{\pi\cdot\left(D + 2\cdot h_{cr2}\right)}{Z_1} - b_{istml} = 14.44$$

$$B`_{d2min} := \frac{t_2\cdot l_i\cdot B_\delta}{k_{Fe}\cdot l_{Fe}\cdot b_{d2max}} = 0.965 \quad (T)$$

$$B`_{d2med} := \frac{t_2\cdot l_i\cdot B_\delta}{k_{Fe}\cdot l_{Fe}\cdot b_{d2med}} = 1.032 \quad (T)$$

$$B`_{d2max} := \frac{t_2\cdot l_i\cdot B_\delta}{k_{Fe}\cdot l_{Fe}\cdot b_{d2min}} = 1.11 \quad (T)$$

Din anexa 2 avem:

$$B_{d2} = 1.7$$

$$H_{d2} := 53$$

$$U_{md2} := 2\cdot\frac{h_{d2}}{10}\cdot H_{d2} = 305.605$$

Tensiunea magnetica a jugului statoric, pentru o pereche de poli:

$$L_{j1} := \frac{\pi\cdot\left(D_e - h_{j1}\right)}{2\cdot p} = 220.268$$

$$H_{j1} := 5 \qquad \left(\frac{A}{cm}\right)$$

$$\zeta_1 := 0.48$$

$$B_{j1} = 1.317 \qquad (T)$$

$$U_{mj1} := \zeta_1\cdot L_{j1}\cdot H_{j1}\cdot 10^{-1} = 52.864$$

Tensiunea magnetica a jugului rotoric, pentru o pereche de poli:

$$L_{j2} := \frac{\pi \cdot (D_{ir} - h_{j2})}{2 \cdot p} = 115.682$$

$$H_{j2} := 10 \quad \left(\frac{A}{cm}\right)$$

$$\zeta_2 := 0.51$$

$$B_{j2} = 1.454 \quad (T)$$

$$U_{mj2} := \zeta_2 \cdot L_{j2} \cdot H_{j2} \cdot 10^{-1} = 58.998$$

Tensiunea magneto-motoare a circuituluii magnetic, pe o pereche de poli:

$$U_{mtotal} := U_{m\delta} + U_{md1} + U_{md2} + U_{mj1} + U_{mj2} = 1.663 \cdot 10^3$$

$$k_s := \frac{U_{mtotal}}{U_{m\delta}} = 1.812$$ (Coeficient total de saturatie magnetica)

Curentul de magnetizare

$$I_N = 159.99$$

$$I_\mu := \frac{p \cdot U_{mtotal}}{0.9 \cdot m \cdot \omega \cdot k_\omega} = 44.465$$

$$I_\mu := \frac{I_\mu}{I_N} \cdot 100 = 27.792$$ (Viteza de rotatie mica)

1.8 Parametrii infasurarilor masinii asincrone

1.8.1 Tipuri de obine si dimensiunile lor

$$\beta_1 := \frac{h_{d1} \cdot 10}{\tau \cdot 10} = 0.171$$

$$h_c := \beta_1 \cdot \tau \cdot 10^{-1} = 3.091 \quad (mm)$$

$$\Delta iz := 5 \quad (mm)$$

$$A := 50 \quad (mm)$$

$q = 4$

$t_{1med} := \frac{\pi \cdot (D + h_c)}{Z_1} = 15.155 \quad (mm)$

$l_{med} := (2 \cdot q + 1) \cdot t_{1med} = 136.392 \quad (mm)$

$R_m := y_1 \cdot \frac{t_{1med}}{2} = 75.773 \quad (mm)$

$l_{fmed} := \pi \cdot R_m + A = 288.048 \quad (mm)$

1.8.2 Determinarea rezistentelor infasurarilor

A.Rezistenta pe faza statorului

$l_g := l_i \cdot 10^3 = 195.39$ (mm)

$l_f := l_{fmed}$

$l_{wmed} := l_g + l_f = 483.438$ (mm)

Lungimea totala a conductoarelor unei faze si a unei cai de curent in paralel (in mm)

$\omega_1 = 60$

$L_1 := 2 \cdot \omega_1 \cdot \frac{l_{wmed}}{1000} = 58.013 \quad (m)$

Clasa de izolare (F)

$\theta := 115$ (Grade Celsius)

$\rho_{20} := \frac{1}{56} \quad \left(\frac{\Omega mm^2}{m}\right)$

$\rho_\theta := 1.38 \cdot \rho_{20} = 0.025 \quad \left(\frac{\Omega mm^2}{m}\right)$

$S_{Cu1} = 6.666$

$k_r := 1$

$R_1 := k_r \cdot \rho_\theta \cdot \frac{L_1}{S_{Cu1} \cdot a_1} = 0.054 \quad (\Omega)$

B.Rezistenta pe faza infasurarii rotorului:

$$D_i := D_r = 458.5 \quad (mm)$$

$$L_i := \frac{\pi \cdot D_i}{Z_2} = 17.354 \quad (mm)$$

$$R_i := \rho_\theta \cdot \frac{L_i}{S_i \cdot 1000} = 3.765 \cdot 10^{-7} \quad (\Omega)$$

$$S_b = 222.704$$

$$L_b := l_g = 195.39$$

$$R_b := \rho_\theta \cdot \frac{L_b}{S_b \cdot 1000} = 2.162 \cdot 10^{-5} \quad (\Omega)$$

$$R_2 := R_b + \frac{R_i}{2 \cdot \left(\sin\left(\frac{\pi \cdot p}{Z_2}\right)\right)^2} = 2.99 \cdot 10^{-5} \quad (\Omega)$$

1.8.3 Determinarea reactantelor infasurarilor

$$\beta_y := \frac{y_1}{y_\tau} = 0.833 \quad \text{(2/3<=By<1)} \quad \text{rezulta} \quad k'_\beta := \frac{1 + 3\,\beta_y}{4} = 0.875$$

$$k_\beta := \frac{1}{4} + \frac{3}{4} \cdot k'_\beta = 0.906$$

$$L := \lambda \cdot \pi \cdot \frac{D}{2 \cdot p} = 195.39$$

$$h_0 := 2 \quad (mm) \quad h_1 := 10 \quad (mm) \quad h_2 := 0 \quad (mm) \quad h_3 := 4.9 \quad (mm)$$

$$b := 3.5 \quad (mm) \quad b_0 := 1 \quad (mm)$$

$$\lambda_{c1} := \frac{h_1}{3 \cdot b} \cdot k_\beta + \left(\frac{h_2}{b} + \frac{3 \cdot h_3}{b + 2 \cdot a_s} + \frac{h_0}{a_s}\right) \cdot k'_\beta = 3.076 \quad (1.86)$$

$$\lambda_{c2} := \left(\frac{h_1}{3 \cdot b}\right) \cdot \left(1 - \frac{\pi \cdot b^2}{8 \cdot S_b}\right)^2 + 0.66 - \frac{b_0}{2 \cdot b} + \frac{h_0}{b_0} = 3.429 \quad (1.88)$$

$$\frac{a_s}{\delta} = 3.333 \quad \frac{a_r}{\delta} = 1.333 \quad \frac{a_s}{t_1} = 0.166 \quad \frac{a_r}{t_1} = 0.066 \quad (1.96\ b)$$

(unde a s/r sunt deschiderile crestaturilor statorului/rotorului)

1.8.4 Determinarea parametrilor rotorului masinii asincrone cu influenta refularii curentului

Coeficienti care depind de deschiderea crestaturilor,de latimea intrefierului si de pasii dentari:

$$k_{01} := 1 - 0.033 \cdot \frac{a_s^{\,2}}{\delta \cdot t_1} = 0.982$$

$$k_{02} := 1 - 0.033 \cdot \frac{a_r^{\,2}}{\delta \cdot t_2} = 0.997$$

Coeficientii de amortizare a campului armonicilor superioare:

$$\rho_{d1} := 0.11 \qquad \frac{Z_2}{6\ p} = 3.458$$

$$\rho_{d2} := 1 \qquad q_2 := \frac{Z_2}{6\ p}$$

$$\sigma_{d1} := 0.004 \qquad t_2 := t_2 = 17.354$$

$$\sigma_{d2} := 0.006 \qquad k_{\omega 2} = 0.86$$

$$\lambda_{d1} := 0.9 \cdot \frac{t_1 \cdot \left(q \cdot k_\omega\right)^2 \cdot \rho_{d1} \cdot k_{01}}{k_c \cdot \delta} \cdot \sigma_{d1} = 0.105$$

$$\lambda_{d2} := 0.9 \cdot \frac{t_2 \cdot \left(q_2 \cdot k_{\omega 2}\right)^2 \cdot \rho_{d2} \cdot k_{02}}{k_c \cdot \delta} \cdot \sigma_{d1} = 0.729$$

$$\lambda_{z1} := 0$$

$$\lambda_{z1} := 0$$

$$\Delta := 2 \cdot \sin\left(\pi \cdot \frac{p}{Z_2}\right) = 0.302$$

Permeanța specifica a scaparilor in partile frontale ale infasurarilor:

$$l_i = 0.195 \qquad d_{iz} = 1.79$$

$$h_{d1} = 30.908$$

$$\lambda_{f1} := 0.34 \cdot \frac{q}{l_i} \cdot \left(\frac{l_{fmed}}{100} - \frac{\tau}{100} \cdot \beta_y \right) = 9.572$$

$$\lambda_1 := \lambda_{c1} + \lambda_{d1} + \lambda_{f1} = 12.753$$

$$l_i = 0.195$$

$$h := h_{d1} - d_{iz} = 29.118$$

Reactanta de dispersie pe faza

$$X_{\sigma 1} := 0.158 \cdot \left(\frac{f_1}{100} \right) \cdot \left(\frac{\omega_1}{100} \right)^2 \cdot \frac{l_i \cdot 100}{p \cdot q} \cdot \lambda_1 = 0.443$$

Determinarea parametrilor electromagnetici ai infasurarii rotorice

Factorul de raportare a infasurarii rotorice in scurtcircuit la stator:

$$K := \frac{12 \cdot \left(k_\omega \cdot \omega_1 \right)^2}{Z_2 \cdot {k_{i2}}^2} = 440.547$$

Rezistivitatea electrica a materialului coliviei rotorice:

$$\rho_2 := \frac{1}{19} = 0.053 \qquad \left(\frac{\Omega mm^2}{m} \right)$$

Inaltimea inelului de scurtcircuitare al coliviei rotorice:

$$h_{isc} := h_{d2} + 5 = 33.831 \qquad (mm)$$

Latimea inelului de scurtcircuitare al coliviei rotorice:

$$b_{isc} := \frac{S_i}{h_{isc}} = 33.574 \qquad (mm)$$

Valoarea raportata la stator a reactantei de dispersie a crestaturii rotorice:

$$b_{cr1m} := \left(\frac{1}{2} \cdot \left(b_{cr1v} \right)^2 + \left(b_{cr1b} \right)^2 \right)^{\frac{1}{2}} = 11.563 \qquad (mm)$$

$$\lambda_{cr2} := \frac{h_{cr2} - h_{istm2}}{3 \cdot b_{cr1m}} = 0.802$$

$$X'_{\sigma 2cr} := K \cdot \mu_0 \cdot 2 \cdot \pi \cdot f_1 \cdot L \cdot \lambda_{cr2} \cdot 10^{-3} = 0.027$$

Valoarea raportata la stator a reactantei corespunzatoare fluxului magnetic de dispersie prin istmul (superior) de la carful crestaturii rotorice:

$$\lambda_{cr2istm} := \frac{h_{istm2}}{b_{istm2}} = 1$$

$$X'_{\sigma 2istm} := K \cdot \mu_0 \cdot 2 \cdot \pi \cdot f_1 \cdot L \cdot \lambda_{cr2istm} \cdot 10^{-3} = 0.034$$

Valoarea raportata la stator a reactantei de dispersie diferentiala a rotorului:

$$\lambda_{d2} := \frac{1}{119} \cdot \frac{t_2}{k_c \cdot \delta} = 0.193$$

$$X'_{\sigma 2d} := K \cdot \mu_0 \cdot 2 \cdot \pi \cdot f_1 \cdot L \cdot \lambda_{d2} \cdot 10^{-3} = 0.007$$

Valoarea raportata la stator a reactantei de dispersie a partii frontale a rotorului:

$$\frac{D_i}{h_{isc} + b_{isc}} = 6.802 \qquad D_i = 458.5 \qquad h_{isc} + b_{isc} = 67.405$$

$$\lambda_{f2} := 2.3 \cdot \frac{D_i}{Z_2 \cdot L \cdot \Delta^2} \cdot \log\left(4.7 \cdot \frac{D_i}{h_{isc} + b_{isc}}\right) = 1.075$$

$$\lambda_2 := \lambda_{c2} + \lambda_{d2} + \lambda_{f2} = 4.697$$

$$X_{\sigma 2} := 7.9 \cdot f_1 \cdot l_i \cdot 100 \cdot 10^{-8} \cdot \lambda_2 = 3.625 \cdot 10^{-4} \quad (\Omega)$$

$$X'_{\sigma 2f} := K \cdot \mu_0 \cdot 2 \cdot \pi \cdot f_1 \cdot L \cdot \lambda_{f2} \cdot 10^{-2} = 0.365 \quad (\Omega)$$

Valoarea raportata la stator a reactantei de dispersie a coliviei rotorice:

$$X'_{\sigma 2} := X'_{\sigma 2cr} + X'_{\sigma 2istm} + X'_{\sigma 2d} + X'_{\sigma 2f} = 0.433 \quad (\Omega)$$

Reactanta utila sau de inmagazinare:

$$X_m := \frac{U_1 - I_\mu \cdot X_{\sigma 1}}{I_\mu} = 8.178 \quad (\Omega)$$

Verificare:

$$X_{\sigma 1ver} := 4 \cdot \pi \cdot f_1 \cdot \mu_0 \cdot l_i \cdot \lambda_1 \cdot \frac{{\omega_1}^2}{p \cdot q} = 0.443 \quad (\Omega)$$

$$X_{h\sigma} := 2 \cdot \pi \cdot f_1 \cdot \mu_0 \cdot l_i \cdot \lambda_2 = 3.623 \cdot 10^{-4} \quad (\Omega)$$

Raportarea parametrilor rotorului la stator:

$$R'_2 := R_2 \cdot \frac{4 \cdot m \cdot \left(\omega_1 \cdot k_\omega\right)^2}{Z_2} = 0.013$$

Parametrii masinii asincrone, in unitati relative:

$$Z_N := \frac{U_1}{I_N} = 1.498 \quad (\Omega)$$

pentru stator:

$$r_1 := \frac{R_1}{Z_N} = 0.036$$

$$x_{\sigma 1} := \frac{X_{\sigma 1}}{Z_N} = 0.296$$

$$x_m := \frac{X_m}{Z_N} = 5.461$$

pentru rotor:

$$r'_2 := \frac{R'_2}{Z_N} = 0.009$$

$$x'_{\sigma 2} := \frac{X'_{\sigma 2}}{Z_N} = 0.289$$

Calculul caracteristicilor masinii asincrone cu parametrii constanti:

$$R_0 := \frac{R_m \cdot X_m}{{R_m}^2 + {X_m}^2} = 0.107 \qquad I_{0r} := I_\mu$$

$$X_0 := \frac{R_m^{\,2} \cdot X_m}{R_m^{\,2} + X_m^{\,2}} = 8.084$$

$$I_0 := I_{0r}$$

$$P_{e10} := m \cdot R_1 \cdot I_0^{\,2} \cdot 10^{-3} = 0.124$$

Pierderi principale in fier:

$$D_{ej1} := D_e = 600 \quad (mm)$$

$$D_{ij1} := D + 2 \cdot h_{d1} = 521.816 \quad (mm)$$

$$\gamma_{Fe} := 7.8 \quad \left(\frac{kg}{dm^3}\right) \qquad l_{Fe} = 0.195$$

$$G_{j1} := \gamma_{Fe} \cdot \frac{\pi}{4} \cdot \left(\left(D_{ej1} \cdot 10^{-3}\right)^2 - \left(D_{ij1} \cdot 10^{-3}\right)^2\right) \cdot k_{Fe} \cdot l_{Fe} \cdot 1000 = 99.735 \quad (kg)$$

$$P_{10.50} := 2.4 \quad \left(\frac{w}{kg}\right)$$

$$P_{j1} := P_{10.50} \cdot \left(\frac{f_1}{50}\right)^{1.3} \cdot B_{j1}^{\,2} = 4.163 \quad \left(\frac{w}{kg}\right)$$

$$k_j := 1.3$$

$$P_{j1} := k_j \cdot P_{j1} \cdot G_{j1} = 539.815 \quad (W)$$

$$P_{d1} := P_{10.50} \cdot \left(\frac{f_1}{50}\right)^{1.3} \cdot B'_{d1}{}^{2} = 4.704 \quad \left(\frac{w}{kg}\right)$$

Pierderile principale in dintii statorului:

$$G_{d1} := h_{d1} \cdot 10^{-3} \cdot b_d \cdot l_{Fe} \cdot k_{Fe} \cdot Z_1 \cdot \gamma_{Fe} = 30.543 \quad (kg)$$

$$k_D = 1.3$$

$$P_{d1} := k_D \cdot P_{d1} \cdot G_{d1} = 186.777 \quad (W)$$

Pierderile principale totale in fier:

$P_{Fepr} := P_{j1} + P_{d1} = 726.593 \quad (kW)$

Pierderile de suprafata ale statorului:

$k_0 := 1.6$ Tabla silicioasa laminata la rece (tabelul 2.1/pag 196)

$\frac{a_s}{\delta} = 3.333$

$\beta_{01} := 0.28$ (pagina 195, fig 2.5)

$B_{01} := \beta_{01} \cdot k_c \cdot B_\delta = 0.215 \quad (T)$

$P_{supr1} := 0.5 \cdot k_0 \cdot \left(\frac{Z_2 \cdot n_1}{10^4}\right)^{1.5} \cdot \left(10 \cdot B_{01} \cdot \frac{t_2}{1000}\right) = 0.464 \quad \left(\frac{W}{m^2}\right)$

$P_{supr1} := 2 \cdot p \cdot \left(\frac{t_1 \cdot 10^{-2} - a_s \cdot 10^{-3}}{t_1 \cdot 10^{-3}}\right) \cdot \tau \cdot 10^{-2} \cdot l_{Fe} \cdot k_{Fe} \cdot P_{supr1} = 12.244 \quad \left(\frac{W}{m^2}\right)$

Pierderile de suprafata ale rotorului:

$k_0 := 1.9$

$\frac{a_r}{\delta} = 1.333$

$\beta_{02} := 0.19$

$B_{02} := \beta_{02} \cdot k_c \cdot B_\delta = 0.146 \quad (T)$

$P_{supr2} := 0.5 \cdot k_0 \cdot \left(\frac{Z_1 \cdot n_1}{10^4}\right)^{1.5} \cdot \left(10 \cdot B_{02} \cdot \frac{t_1}{100}\right)^2 = 0.887 \quad \left(\frac{W}{m^2}\right)$

$P_{supr2} := 2 \cdot p \cdot \left(\frac{t_2 \cdot 10^{-2} - a_r \cdot 10^{-3}}{t_2 \cdot 10^{-2}}\right) \cdot \tau \cdot 10^{-2} \cdot l_{Fe} \cdot k_{Fe} \cdot P_{supr2} = 2.367 \quad (W)$

Pierderile de pulsatie in dintii statorului:

$$B_{puls1} := \frac{\gamma_2 \cdot \delta \cdot 10^{-3}}{2 \cdot t_1 \cdot 10^{-2}} \cdot B'_{d1} = 9.79 \cdot 10^{-4} \quad (T)$$

$$P_{puls1} := k_0 \cdot \left(\frac{Z_2 \cdot n_1}{10^4} \cdot 10 \cdot B_{puls1} \right)^2 \cdot G_{d1} = 0.216$$

Pierderile de pulsatie in dintii rotorului:

$$B_{puls2} := \frac{\gamma \cdot \frac{\delta}{100}}{2 \cdot \frac{t_2}{100}} \cdot B'_{d2} = 0.019 \quad (T)$$

$$h_{d2} = 28.831$$

$$G_{d2} := h_{d2} \cdot 10 \cdot 10^{-3} \cdot b_{d2min} \cdot 10 \cdot 10^{-3} \cdot l_{Fe} \cdot k_{Fe} \cdot Z_2 \cdot \gamma_{Fe} \cdot 10 = 43.493 \quad (Kg)$$

$$P_{puls2} := k_0 \cdot \left(\frac{Z_1 \cdot n_1}{10^4} \cdot 10 \cdot B_{puls2} \right)^2 \cdot G_{d2} = 149.946 \quad (W)$$

Pierderile totale in fier la functionarea in gol:

$$P_{Fe} := P_{Fepr} + P_{supr1} + P_{supr2} + P_{puls1} + P_{puls2} = 891.365 \quad (W)$$

Pierderile electrice principale:

Pierderile in infasurarea statorului:

$$P_{e11} := m \cdot R_1 \cdot {I_N}^2 = 4.117 \cdot 10^3 \quad (W)$$

Pierderile in infasurarea rotorului:

$$I_2 := I_b$$

$$m_2 := Z_2 \qquad I_2 = 668.113$$

$$P_{e12} := m_2 \cdot R_2 \cdot {I_2}^2 = 1.108 \cdot 10^3 \quad (W)$$

Pierderile electrice principale totale:

$$P_{e1} := P_{e11} + P_{e12} = 5.225 \cdot 10^3 \quad (W)$$

Pierderile mecanice:

$$P_{mec} := p \cdot \left(\frac{n_1}{1000}\right)^2 \cdot \left(\frac{D_e \cdot 10}{1000}\right)^4 = 2.916 \cdot 10^3 \quad (W)$$

Pierderile suplimentare in fier:

$$P_{sFe} := 0.005 \cdot P \cdot 10^3 = 450 \quad (W)$$

$$P_i := P_{Fe} + P_{e1} + P_{sFe} = 6.566 \cdot 10^3 \quad (W)$$

Randamentul masinii la functionarea nominala:

$$\eta_N := \frac{P \cdot 10^3}{P \cdot 10^3 + P_i} = 0.932$$

Curentul de functionare in gol:

$$I_{0a} := \frac{P_{Fe} + P_{mec} + P_{e10} \cdot 10^3}{m \cdot U_1} = 5.47 \quad (A)$$

$$I_0 := \sqrt{{I_{0a}}^2 + {I_{0r}}^2} = 28.325 \quad (A)$$

$$cos\varphi_0 := \frac{I_{0a}}{I_0} = 0.193$$

$$c_1 := 1 + \frac{X_{\sigma 1}}{X_m} = 1.054$$

$$R_k := c_1 \cdot R_1 + {c_1}^2 \cdot R'_2 = 0.071 \quad (\Omega)$$

$$X_k := c_1 \cdot X_{\sigma 1} + {c_1}^2 \cdot X'_{\sigma 2} = 0.948 \quad (\Omega)$$

$$I''_{2k} := \frac{U_1}{\sqrt{R_k^{\,2} + X_k^{\,2}}} = 251.949 \quad (A)$$

$$I'_{2k} := c_1 \cdot I''_{2k} = 265.594 \quad (A)$$

Componentele curentului secundar:

Componenta activa:

$$cos\varphi_{2k} := \frac{R_k}{\sqrt{R_k^{\,2} + X_k^{\,2}}} = 0.075$$

$$I'_{2ka} := I'_{2k} \cdot cos\varphi_{2k} = 19.872 \quad (A)$$

Componenta reactiva:

$$sin\varphi_{2k} := \frac{X_k}{\sqrt{R_k^{\,2} + X_k^{\,2}}} = 0.997$$

$$I'_{2kr} := I'_{2k} \cdot sin\varphi_{2k} = 264.85 \quad (A)$$

$$I_{1k} := \sqrt{\left(I_{0a} + I'_{2ka}\right)^2 + \left(I_\mu + I'_{2kr}\right)^2} = 293.737 \quad (A)$$

Defazajul:

$$cos\varphi_k := \frac{I_{0a} + I'_{2ka}}{I_{1k}} = 0.086$$

$$s := \frac{n_1 - n_N}{n_1} = 0.012 \qquad (alunecarea)$$

Curent absorbit:

Componenta activa:

$$I'_{2a} := \frac{U_1 \cdot \left(R_1 + c_1 \cdot \frac{R'_2}{s}\right)}{\left(R_1 + c_1 \cdot \frac{R'_2}{s}\right)^2 + \left(X_{\sigma 1} + c_1 \cdot X'_{\sigma 2}\right)^2} = 127.509 \quad (A)$$

Componenta reactiva:

$$I'_{2r} := \frac{U_1 \cdot \left(X_{\sigma 1} + c_1 \cdot X'_{\sigma 2}\right)}{\left(R_1 + c_1 \cdot \frac{R'_2}{s}\right)^2 + \left(X_{\sigma 1} + c_1 \cdot X'_{\sigma 2}\right)^2} = 94.753 \quad (A)$$

$$I_{1s} := \sqrt{\left(I_{0a} + I'_{2a}\right)^2 + \left(I_{\mu} + I'_{2r}\right)^2} = 180.833 \quad (A)$$

$$I'_2 := \frac{U_1}{\sqrt{\left(R_1 + c_1 \cdot \frac{R'_2}{s}\right)^2 + \left(X_{\sigma 1} + c_1 \cdot X'_{\sigma 2}\right)^2}} = 158.86 \quad (A)$$

Cuplu electromagnetic:

$$\omega_1 := 2 \cdot \pi \cdot f_1 = 314.159 \quad \left(\frac{rad}{s}\right) \quad \text{(pulsatia curentului de alimentare)}$$

$$\Omega_1 := \frac{\omega_1}{p} = 78.54 \quad \text{(viteza unghiulara a campului invartitor)}$$

$$M := \frac{m \cdot p \cdot U_1^{\,2} \cdot \frac{R'_2}{s}}{\omega_1 \cdot \left(\left(R_1 + c_1 \cdot \frac{R'_2}{s}\right)^2 + \left(X_{\sigma 1} + c_1 \cdot X'_{\sigma 2}\right)^2\right)} = 1.058 \cdot 10^3 \quad (Nm)$$

$$P_{Cu2} := s \cdot M \cdot \Omega_1 = 997.13$$

$$P_M := M \cdot \Omega_1 = 8.309 \cdot 10^4 \quad (VA)$$

Cuplul de pornire:

$$M_p := \frac{m \cdot 4 \cdot p \cdot U_1^{\,2} \cdot R'_2}{\omega_1 \cdot \left(\left(R_1 + c_1 \cdot R'_2\right)^2 + \left(X_{\sigma 1} + c_1 \cdot X'_{\sigma 2}\right)^2\right)} = 141.947 \quad (Nm)$$

Alunecare critica:

$$s_m := \frac{c_1 \cdot R'_2}{\sqrt{R_1^{\,2} + \left(X_{\sigma 1} + c_1 \cdot X'_{\sigma 2}\right)^2}} = 0.015$$

Cuplul maxim:

$$M_m := \frac{2 \cdot p \cdot m \cdot {U_1}^2}{2 \cdot c_1 \cdot 1.5 \cdot \omega_1 \cdot \left(R_1 + \sqrt{{R_1}^2 + \left(X_{\sigma 1} + c_1 \cdot X'_{\sigma 2}\right)^2}\right)} = 1.452 \cdot 10^3$$

Alunecare nominala:

$$S_N := \frac{P_{Cu2}}{P_M} = 0.012$$

Factorul de putere nominal:

$$I'_{2aN} := I'_{2a} = 127.509 \quad (A) \qquad M_N := \frac{60 \cdot P \cdot 10^3}{2 \cdot \pi \cdot n_N} = 1.16 \cdot 10^3 \quad (Nm)$$

$$I_{1N} := I_{1s} = 180.833 \quad (A)$$

$$cos\varphi_N := \frac{I_{0a} + I'_{2aN}}{I_{1N}} = 0.735$$

$$m_p := \frac{M_p}{M_N} = 0.122$$

$$m_m := \frac{M_m}{M_N} = 1.252$$

$$n_N := \left(1 - S_N\right) \cdot n_1 = 741$$