Pauta de càlcul de motors síncron amb imants permanents.

Potència nominal $P_2 := 3500$ W

Velocitat nominal $N_N := 250$ rpm

Parell nominal $M_n := \frac{P_2}{2 \cdot \pi \cdot \frac{N_N}{60}}$ $M_n = 133.69$ Nm

Parells de pols $p := 12$

Freqüència $f_s := p \cdot \frac{N_N}{60}$ $f_s = 50$ Hz $\Omega_n := 2 \cdot \pi \cdot f_s$

Rendiment $\eta := 0.90$

Nombre de fases $m := 3$

Factor de potència nominal $cofi_n := 0.8$

Entrada per rectificador trifàsic $U_{red} := 400$ V

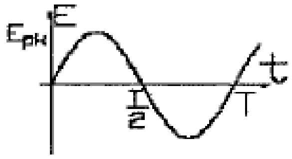
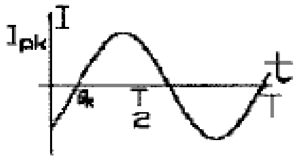
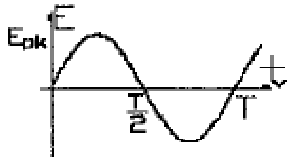
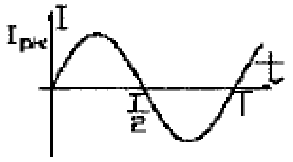
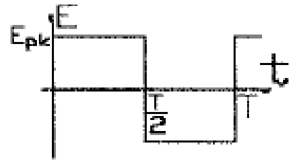
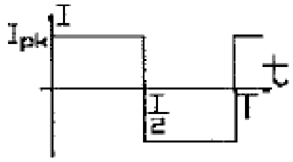
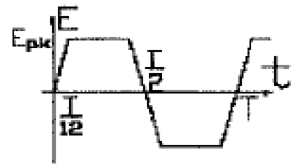
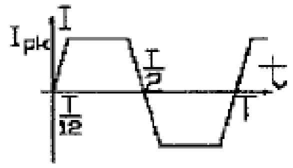
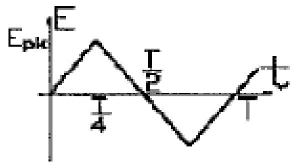
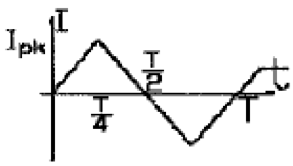
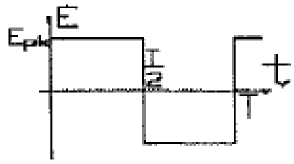
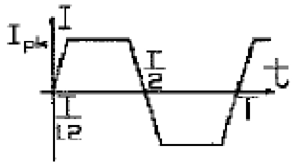
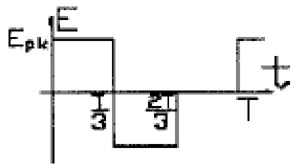
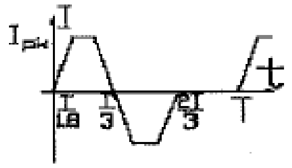
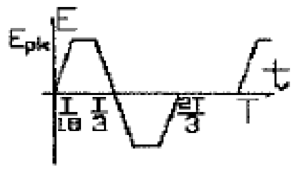
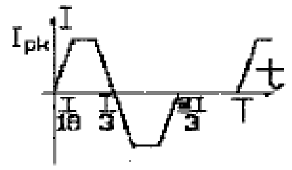
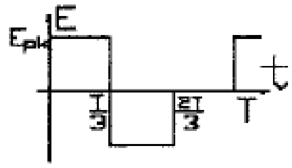
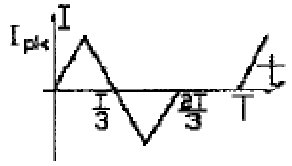
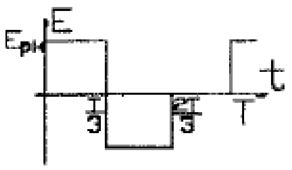
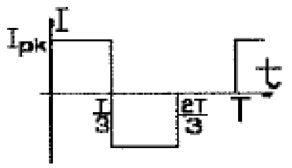
$U_{max} := \sqrt{2} \cdot U_{red}$ $U_{max} = 565.685$

Tensió de fase (rms)

$U := \frac{2 \cdot U_{max}}{\sqrt{2}\,\pi}$ $U = 254.648$ $U_n := 230$ V

Corrent nominal $I_n := \frac{P_2}{m \cdot U_n \cdot \eta \cdot cofi_n}$ $I_n = 7.045$ A

Typical Prototype Waveforms

Model	e(t)	i(t)	K_i	K_p
Sinusoidal waveform			$\sqrt{2}$	$\frac{1}{2}\cos\phi$
Sinusoidal waveform			$\sqrt{2}$	0.5
Rectangular waveform			1	1
Trapezoidal waveform			1.134	0.777
Triangular waveform			$\sqrt{3}$	0.333
Rectangular & Trapezoidal waveform			1.134	0.8
Rectangular & Trapezoidal waveform			1.389	0.556
Trapezoidal waveform			1.389	0.519
Rectangular & Triangular waveform			1.5	0.333
Rectangular waveform			1.225	0.667

Ki relació entre valor máxim del corrent i el seu valor eficaç

Ke relació entre valor máxim i eficaç de la tensió

Kp coeficient de forma de la potència

Depenen de la forma d'ona del corrent, fem i el seu producte.

$K_e := \sqrt{2}$ $\qquad K_i := \sqrt{2}$ $\qquad K_p := 0.5$

Relació Longitud/Diàmetre:

$$K_l := \frac{\pi \cdot p^{\left(\frac{-2}{3}\right)}}{2} \qquad K_l = 0.3$$

Capa de corrent (750.....35000 A/m)

$A_s := 18000 \quad \frac{A}{m}$

imant $\qquad B_r := 1.17 \quad T$

$H_c := 860000 \quad \frac{A}{m}$

$\mu_0 := 4\frac{\pi}{10000000} \quad \frac{H}{m}$

$$\mu_r := \frac{B_r}{\mu_0 \cdot H_c} \qquad \mu_r = 1.083$$

$H_{c125} := 350000$

Inducció en l'entreferro (aproximació) $\quad B_e := 0.75 \cdot B_r \qquad B_e = 0.877 \quad T$

$$D_e := \sqrt[3]{2 \cdot p \cdot \frac{P_2}{\pi \cdot m \cdot A_s \cdot K_e \cdot K_i \cdot K_p \cdot K_l \cdot \eta \cdot B_e \cdot f_s}}$$

$D_e = 0.347 \quad m \qquad d_e := 1000 \cdot D_e$

$d_e = 347.166 \quad mm$

$D_e := 0.425 \quad m$

$$L := \frac{2 \cdot p P_2}{\eta \cdot m \cdot K_p \cdot K_e \cdot B_e \cdot f_s \cdot D_e^2 \cdot K_i \cdot A_s \cdot \pi}$$

$L = 0.069 \qquad m$

$L := 0.070 \quad m$

$D_{eje} := 0.080 \quad m$

Inducció màxima a l'entreferro

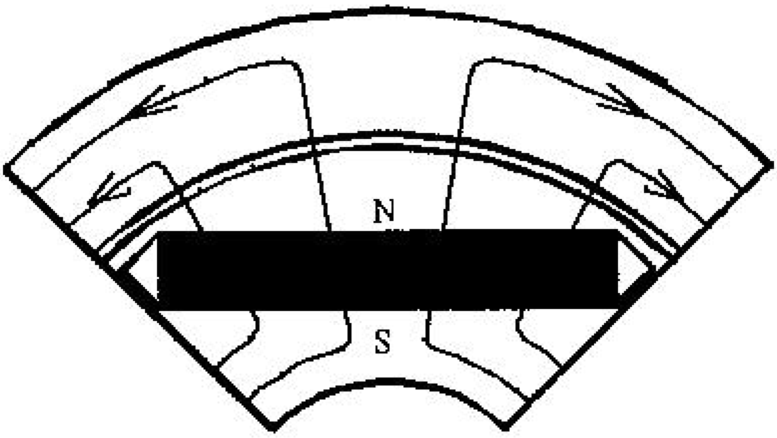
$B_{max} := 2$ T

Ponts al ferro (x, y, y.2)

$x := 2$ mm

Inducció a l'entreferro

Tipo c)



$b_m := 30$ mm $\quad x = 2$

$D := 1000 \cdot D_e \quad D_e = 0.425$

$K_c := 1.21$

$g_g := 1 \quad \mu_r = 1.083 \quad g_c := K_c \cdot g_g \quad D = 425 \quad B_r = 1.17$

$h_m := 10 \quad x = 2 \quad \mu_r = 1.083 \quad B_{max} = 2$

Factor de recubriment polar $\quad \alpha := \frac{76}{90} \quad p = 12 \quad g_c = 1.21$

$$B_e := \frac{\left(B_r - B_{max} \cdot \frac{2x}{b_m}\right)}{g_c \cdot \frac{\mu_r}{h_m} + \frac{\alpha \pi D}{2p \cdot b_m}} \qquad B_e = 0.532$$

T

Debanat

$Q := 72$ ranures $\quad q := \frac{Q}{2 \cdot p \cdot m} \quad q = 1$

Nombre total de conductors $\quad A_s = 1.8 \times 10^4 \ \frac{A}{m}$

$$Z_t := \pi \cdot D_e \cdot \frac{A_s}{I_n} \qquad Z_t = 3.411 \times 10^3$$

Nombre de conductors per ranura

$Z_r := \frac{Z_t}{Q}$ $\quad Z_r = 47.38$

$Z_r := 48$ $\quad Z_t := Z_r \cdot Q$ $\quad Z_t = 3.456 \times 10^3$ $\quad N_f := \frac{Z_t}{2 \cdot m}$

$A_s := Z_t \cdot \frac{I_n}{\pi \cdot D_e}$ $\quad A_s = 1.824 \times 10^4$ $\quad N_f = 576$

$I_n = 7.045$

Secció conductorsr:

Densidat de corrent $\quad \Delta := 6 \frac{A}{mm^2}$

Fils en paral·lel $\quad aa := 5$ $\quad I_n = 7.045$

$s_c := \frac{I_n}{aa \cdot \Delta}$ $\quad d_c := \sqrt{4 \cdot \frac{s_c}{\pi}}$ $\quad d_c = 0.547 \ mm$

$d_c := 0.95$ $\quad d_{ca} := d_c + 0.053$ $\quad d_{ca} = 1.003$ $\quad S_c := \pi \cdot \frac{aa\, d_c^{\,2}}{4}$

$\Delta_{real} := \frac{I_n}{S_c}$ $\quad \Delta_{real} = 1.988 \frac{A}{mm^2}$ $\quad S_c = 3.544 \ mm^2$

$s_{ocupadaambaillament} := \frac{aa \cdot 4}{\pi} Z_r \cdot \pi \cdot \frac{d_{ca}^{\,2}}{4}$ $\quad s_{ocupadaambaillament} = 241.442$

$s_{ocupada} := aa \cdot Z_r \cdot \pi \cdot \frac{d_c^{\,2}}{4}$ $\quad s_{ocupada} = 170.117 \ mm^2$

Secció ranura: $\quad S_r := 449.2 \ mm^2$

Factor d'ocupació (màxim 0.4)

$F_o := \frac{s_{ocupada}}{S_r}$ $\quad F_o = 0.379$ $\quad$ OK

$F_o := \frac{s_{ocupadaambaillament}}{S_r}$ $\quad F_o = 0.537$

Dimensionat dels imants

Factor de dispersió $\quad \sigma_0 := 1.2$ $\quad$ (1.2.....1.5)

corrent màxim en pu

$K_m := 3$ $\quad$ (2...6)

Factor de utilizació del imant

$$\xi_m := 0.6 \qquad (0.5....0.81)$$

Factor de recubriment polar:

$$\alpha := \frac{12}{15} \qquad (0.6....0.85) \qquad \alpha = 0.8$$

Factor de reacció

$$K_f := \frac{4}{\pi} \sin\left(\alpha \cdot \frac{\pi}{2}\right)$$

$$K_{ad} := \frac{1}{K_f} \qquad K_{ad} = 0.826$$

DIMENSIONAT DELS IMANTS

$$\delta := 50$$

$$C_v := \frac{0.2 \cdot \sigma_0 \cdot K_m \cdot K_{ad} \cdot \tan\left(\delta \cdot \frac{\pi}{180}\right)}{\xi_m} \qquad C_v = 1.181 \qquad (0.5.......2)$$

Volum del imant

$$V_m := C_v \cdot \frac{\frac{P_2}{\eta}}{f_s \cdot B_r \cdot H_c} \qquad V_m = 9.129 \times 10^{-5} \quad m^3$$

$$V_{mm3} := V_m \cdot 10^9 \qquad V_{mm3} = 9.129 \times 10^4 \quad mm^3$$

Volum per pol

$$SmLm := \frac{V_{mm3}}{2 \cdot p} \qquad SmLm = 3.804 \times 10^3 \quad mm^3$$

Desmagnetizació

$$K_m = 3$$

$$I_{max} := K_m \cdot I_n \sqrt{2} \qquad I_{max} = 29.89 \quad A$$

Factor de debanat

$$k_w := 0.95$$

$$D = 425 \quad mm$$

$$A_{max} := Z_t \cdot \frac{I_{max}}{\pi \cdot D} \qquad A_{max} = 77.367 \quad \frac{A}{mm} \qquad Z_t = 3.456 \times 10^3$$

$$\tau_p := \pi \cdot \frac{D}{2 \cdot p} \qquad \tau_p = 55.632 \quad mm$$

$$FMM_{desmag} := A_{max} \cdot \frac{\tau_p}{2} \qquad FMM_{desmag} = 2.152 \times 10^3 \quad A$$

Altura mínima del imant:

$$h_m(FMM_{desmag}, H_{c125}) := \frac{FMM_{desmag}}{H_{c125}}$$

$$H_{c125} = 3.5 \times 10^5 \quad \frac{A}{m}$$

$$h_m(FMM_{desmag}, H_{c125}) = 6.149 \times 10^{-3}$$

S'escull: $l_{mag} := 0.010 \quad m$

Longitud. Els imants poden tenir una longitud diferent.

$L_{fe} := 0.070 \quad m \qquad L = 0.07$

$k_l := 1.0 \qquad L_{fe} = 0.07$

$L_m := k_l \cdot L_{fe} \qquad L_m = 0.07$

$\pi \cdot D_e = 1.335 \quad m$

pas polar

$D_e = 0.425$

$$\tau_p := \pi \cdot \frac{D_e}{2 \cdot p} \qquad \tau_p = 0.056 \quad m$$

Ample màxim del imant

$b_p := \alpha \cdot \tau_p \qquad b_p = 0.045 \quad m$

Altura màxima del imant

$$H_{max} := \frac{(D_e - D_{eje})}{2}$$

Altura del imant

$H_{max} = 0.172$

$$b_m := \frac{V_m}{2 \cdot p \cdot l_{mag} \cdot L_m} \qquad 1000 \cdot b_m = 5.434 \quad mm$$

$b_m := 30 \qquad h_m := 1000 \cdot l_{mag} \qquad h_m = 10$

$$B_e := \frac{\left(B_r - B_{max} \cdot \frac{2x}{b_m}\right)}{g_c \cdot \frac{\mu_r}{h_m} + \frac{\alpha \pi D}{2p \cdot b_m}}$$

$g_c = 1.21 \qquad D = 425$

$B_e = 0.56 \quad T$

Constant de parell
Condueixen 2 fases a la vegada! $M_n = 133.69 \quad Nm$

$k_t := 2Z_t \cdot D_e \cdot L_{fe} \cdot B_e \cdot \frac{k_w}{2m}$

$$E_n := \left(\frac{\pi}{2 \cdot p}\right) \cdot \left(\frac{4}{\pi}\right) \cdot \left(2 \cdot \frac{\sqrt{2}}{\pi} B_e \cdot \sin\left(\alpha \cdot \frac{\pi}{2}\right)\right) \cdot k_w \cdot \left(\frac{Z_t}{2 \cdot m}\right) \cdot \left(\frac{D}{1000} \cdot \frac{L_{fe}}{2}\right) \cdot 2 \cdot \pi \cdot f_s$$

$k_t = 18.217 \quad \frac{Nm}{A}$

$I_n \cdot \sqrt{2} = 9.963$ $\qquad E_n = 204.177 \quad V$

$M := k_t \cdot \sqrt{2} I_n \qquad M = 181.496$ $\qquad f_s = 50$

$M_{sin} := 3 \cdot E_n \cdot \frac{I_n}{2 \cdot \pi \cdot \frac{N_N}{60}}$

$k_e := k_t$

$M_{sin} = 164.833$

$k_e = 18.217 \quad \frac{V}{\frac{rad}{s}}$

Atenció és la fem de línea (2E)

$N_N = 250$

$E_{nL} := k_e \cdot 2 \cdot \pi \cdot \frac{N_N}{60} \qquad E_{nL} = 476.908 \quad V \qquad E_{nBDC} := \frac{E_{nL}}{2}$

màxim permés: $\qquad U_{max} = 565.685 \qquad$ OK

Inductància principal

$\beta := (\alpha) \cdot \pi \qquad \beta = 2.513 \quad rad$

$k_q := \frac{(\beta - \sin(\beta))}{\pi} \qquad k_q = 0.613$

$$k_d := \left[\frac{\left(\sin\left(\frac{\beta}{2}\right)\right)^2}{\frac{\beta}{2} + p \cdot g_c \cdot \mu_r \cdot \frac{b_m}{h_m \cdot D}}\right] \cdot \frac{4}{\pi} - k_q$$

$D = 425 \qquad b_m = 30 \qquad g_c = 1.21$

$k_d = 0.229$

$\xi := \frac{k_q}{k_d} \qquad \xi = 2.674$

$N_s := \frac{Z_t}{2 \cdot m}$

$k_{sat} := 1$

$$L_m := \left(\frac{3}{\pi}\right) \cdot \mu_0 \cdot \left(\frac{N_s \cdot k_w}{p}\right)^2 \cdot \frac{D \cdot L_{fe}}{k_{sat} \cdot g_c}$$

$L_m = 0.061 \quad H$

$L_{mq} := L_m \cdot k_q \qquad L_{mq} = 0.038 \quad H$

$L_{md} := L_m \cdot k_d \qquad L_{md} = 0.014 \quad H$

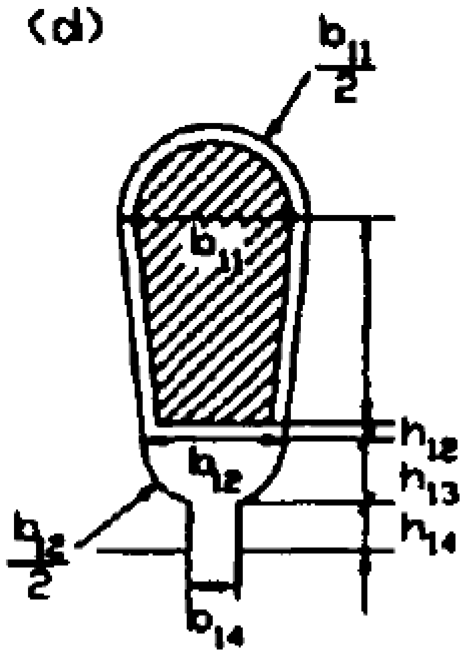
Longitud mitja d'una espira:

$l_{av} := 2L_{fe} + 2.3 \cdot \tau_p + 0.$ $\qquad l_{av} = 0.268 \quad m$ $\qquad k_{long} := \frac{l_{av}}{2 \cdot L_{fe}} \qquad k_{long} = 1.914$

$2.3 \cdot \tau_p = 0.128$

$2 \cdot L_{fe} = 0.14$

Inductància de dispersió



$h_{11} := 35.5$

$h_{12} := 0$

$h_{13} := 1.5$

$h_{14} := 2.5$

$b_{11} := 12.2$

$b_{12} := 7.1$

$b_{14} := 4.1$

Inductància de dispersió diferencial

$\alpha_{us} := \frac{p \cdot 2\pi}{Q}$ $\qquad \alpha_{us} = 1.047$

$$k_{\delta 1} := \sum_{k=1}^{300} \left[\frac{\sin\left[(1+2\cdot k\cdot m)\cdot\frac{\pi}{2}\right]\cdot\frac{\sin\left[(1+2\cdot k\cdot m)\cdot q\cdot\frac{\alpha_{us}}{2}\right]}{q\cdot\sin\left[(1+2\cdot k\cdot m)\cdot\frac{\alpha_{us}}{2}\right]}}{(1+2\cdot k\cdot m)\cdot k_w} \right]^2$$

$k_{\delta 1} = 0.04$

$$k_{\delta 12} := \sum_{k=-1}^{-300} \left[\frac{\sin\left[(1+2\cdot k\cdot m)\cdot\frac{\pi}{2}\right]\cdot\frac{\sin\left[(1+2\cdot k\cdot m)\cdot q\cdot\frac{\alpha_{us}}{2}\right]}{q\cdot\sin\left[(1+2\cdot k\cdot m)\cdot\frac{\alpha_{us}}{2}\right]}}{(1+2\cdot k\cdot m)\cdot k_w} \right]^2$$

$k_{\delta 12} = 0.066$

$\sigma_{\delta s} := k_{\delta 1} + k_{\delta 12}$ $\qquad \sigma_{\delta s} = 0.107$

$L_{\delta s} := \sigma_{\delta s} \cdot L_m$ $\qquad L_{\delta s} = 6.556 \times 10^{-3}$ H

Inductància de dispersió de ranura

$E_{scurçat} := 1$

$\varepsilon := 1 - E_{scurçat}$ $\qquad \varepsilon = 0$

$$t := \frac{b_{11}}{b_{12}} \qquad k_1 := 3 \cdot \frac{\left[4 \cdot t^2 - t^4 \cdot (3 - 4 \cdot \ln(t)) - 1\right]}{4 \cdot \left(t^2 - 1\right)^2 \cdot (t - 1)} \qquad k_1 = 0.968$$

$$\lambda_{us} := 0.1424 + \frac{h_{11} \cdot k_1}{3 \cdot b_{12}} + \frac{h_{12}}{b_{12}} + 0.5 \cdot \operatorname{asin}\left[\sqrt{1 - \left(\frac{b_{14}}{b_{12}}\right)^2}\right] + \frac{h_{14}}{b_{14}} \qquad \lambda_{us} = 2.843$$

$$L_{us} := \frac{4m}{Q} \cdot \mu_0 \cdot L_{fe} \cdot N_s^2 \cdot \lambda_{us} \qquad L_{us} = 0.014 \quad \text{H}$$

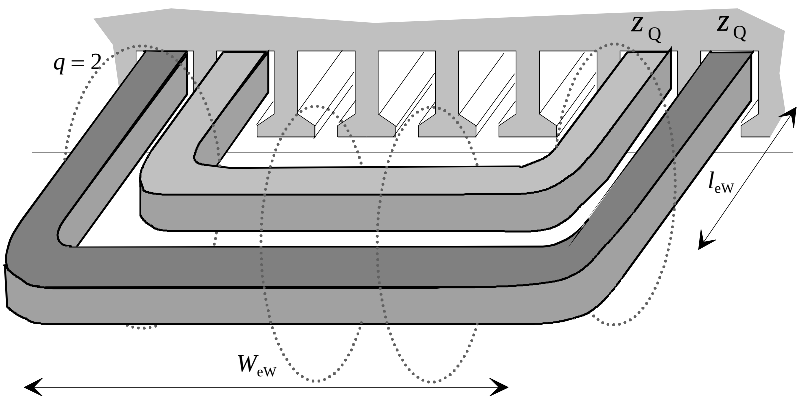
Inductància de cap de dent (zig-zag)

$$k_2 := 1 - \frac{3}{4} \cdot \varepsilon \qquad k_2 = 1$$

$$\lambda_{ds} := k_2 \cdot \frac{5 \cdot \frac{g_c}{b_{14}}}{5 + 4 \cdot \frac{g_c}{b_{14}}} \qquad \lambda_{ds} = 0.239$$

$$L_{\sigma ds} := \frac{4m}{Q} \cdot \mu_0 \cdot L_{fe} \cdot \lambda_{ds} \cdot N_s^2 \qquad L_{\sigma ds} = 1.161 \times 10^{-3} \quad \text{H}$$

inductància de cap de debanat



$$l_{ew} := 0.020 \quad \text{m} \qquad l_w := \frac{l_{av}}{2} - L_{fe} \qquad l_w = 0.064 \quad \text{m}$$

$$W_{ew} := l_w - 2l_{ew} \qquad W_{ew} = 0.024 \quad \text{m}$$

Factors de permeabilitat

$$\lambda_{lew} := 0.5 \qquad \lambda_W := 0.2$$

$$\lambda_{ws} := \frac{2 \cdot l_{ew} \cdot \lambda_{lew} + W_{ew} \cdot \lambda_W}{l_w} \qquad \lambda_{ws} = 0.388$$

$L_{ws} := \frac{4m}{Q} \cdot q \cdot N_s^2 \cdot \mu_0 \cdot l_w \cdot \lambda_{ws}$ $L_{ws} = 1.723 \times 10^{-3}$ H

Inductància total de dispersió

$L_{s\sigma} := L_{\delta s} + L_{us} + L_{\sigma ds} + L_{ws}$ $L_{s\sigma} = 0.023$ H

Inductància total

$L_d := L_{md} + L_{s\sigma}$ $L_d = 0.037$ H

$L_q := L_{mq} + L_{s\sigma}$ $L_q = 0.061$ H

$\xi_{corr} := \frac{L_q}{L_d}$ $\xi_{corr} = 1.631$

Resistència per fase

Longitud d'una espira: $l_{av} = 0.268$ m

Conductividad del coure a 100 º C (Θ = 80 K)

$\Theta := 80$ $\sigma_{Cu20C} := 57 \cdot 10^6$ $\alpha_{Cu} := 3.81 \cdot 10^{-3}$

$\sigma_{Cu} := \frac{\sigma_{Cu20C}}{1 + \Theta \cdot \alpha_{Cu}}$ $\sigma_{Cu} = 4.368 \times 10^7$ S /m

resistència per fase $N_s = 576$ $S_c = 3.544$

$R_s := \frac{N_s \cdot l_{av} \cdot 10^6}{\sigma_{Cu} \cdot S_c}$ $R_s = 0.997$ W

Pèrdues per efecte Joule en CN: $I_n = 7.045$

$P_{joule} := 3 \cdot R_s \cdot I_n^2$ $P_{joule} = 148.436$ W

Pèrdues en el ferro, aproximació

$P_{fe} := \left(\frac{1}{3}\right) \cdot P_{joule}$

Pèrdues totals: $P_{totales} := P_{joule} + P_{fe}$

Escalfament

Superfície de ventilació aproximada: $D_{outs} := 580$ mm

Carcassa gruix de carcassa $g_{car} := 30$

$l_{ew} = 0.02$

$L_{car} := L_{fe} + 2 \cdot l_{ew}$ $L_{car} = 0.11$

DIàmetre exterior: $D_o := D_{outs} + 2 \cdot g_{car}$

$D_o = 640$

$S_v := \pi \cdot D_o \cdot \frac{L_{car}}{1000}$ $S_v = 0.221$ m^2

Convecció natural

$deltaT := 265.2$

$D = 425$ $k_v := 1.32 \cdot \sqrt[4]{\frac{1000deltaT}{D}}$ $k_v = 6.597$ $\frac{W}{m^2 ºC}$

$\Theta_{max} := \frac{P_{totales}}{k_v \cdot S_v}$ $\Theta_{max} = 135.639$ ºC

Convecció forzada

$v := 1$ $\frac{m}{s}$ $k_v := 3.89 \cdot \sqrt{\frac{v}{L_{car}}}$ $k_v = 11.729$ $\frac{W}{m^2 ºC}$

$\Theta_{max} := \frac{P_{totales}}{k_v \cdot S_v}$ $\Theta_{max} = 76.296$ ºC

Amb una carcassa amb aletes, la superfície de ventilació fàcilmente es duplica:

$S_v := 2 \cdot S_v$ $S_v = 0.442$

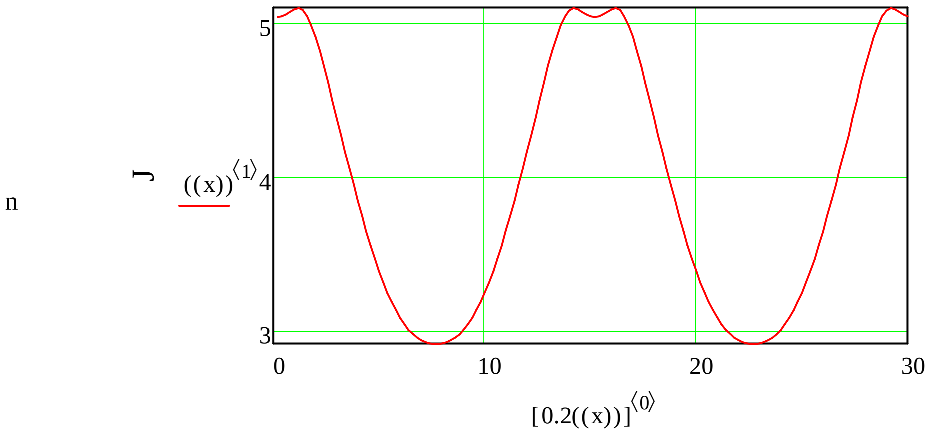
$\Theta_{max} := \frac{P_{totales}}{k_v \cdot S_v}$ $\Theta_{max} = 38.148$ ºC

Relació de inductàncies

llegeix els resultats del fitxer;

$x :=$ ...\resultEnergy4p.txt

Energia



Angle,graus

$L = 0.07$

Valors màxim i mínim

$E_{max} := max\left[(x)^{\langle 1\rangle}\right]$ $E_{max} = 5.101$

$E_{min} := min\left[(x)^{\langle 1\rangle}\right]$ $E_{min} = 2.912$

$\xi_{calc} := \frac{E_{max}}{E_{min}}$ $\xi_{calc} = 1.752$

$I_n := 7.045$

$L_{qcalc} := 2\cdot\frac{E_{max}}{3\cdot I_n^2}$ $L_{qcalc} = 0.069$

$L_{dcalc} := 2\cdot\frac{E_{min}}{3\cdot I_n^2}$ $L_{dcalc} = 0.039$

Característica M(N) i P(N) de la màquina

$m := 3$ $L_d = 0.037$ $\omega_n := 2\cdot\pi\cdot f_s$

$p := 12$ $L_q = 0.061$ $f := 10$

$\lambda := \frac{E_n}{\omega_n}$ $I_n := 2$

$\lambda = 0.65$ $\xi := \frac{L_q}{L_d}$ $\xi = 1.631$

$M(I_d, I_q) := (m)\cdot p\cdot\left[\lambda\cdot I_q + (L_d - L_q)\cdot I_d\cdot I_q\right]$

$$\omega(f) := 2\pi\cdot f$$

$$Vol(f) := \text{if}\left(f < 50, \frac{230\cdot f}{50}, 230\right)$$

$$P(I_d, I_q, f) := M(I_d, I_q)\cdot\frac{\omega(f)}{p}$$

$$N(f) := 60\cdot\frac{f}{p}$$

Parell i Velocitat qualsevol

Volem un parell de: $M_a := 150$

i una velocitat de: $N_a := 250$ $\qquad f := p\cdot\frac{N_a}{60}$ $\qquad f = 50$

$$E_n = 204.177 \ \text{V} \qquad \omega(f) := 2\pi\cdot f$$

$$I_d := -.4 \qquad I_q := .1 \qquad I_a := 1 \qquad Vol(f) := \text{if}\left(f < 50, \frac{230\cdot f}{50}, 230\right)$$

$$Vol(f) = 230 \qquad \omega(f) = 314.159$$

Dado

$$I_d^{\,2} + I_q^{\,2} = I_a^{\,2}$$

$$\left(\lambda + L_d\cdot I_d\right)^2 + \left(L_q\cdot I_q\right)^2 = \left(\frac{Vol(f)}{\omega(f)}\right)^2$$

$$(m)\cdot p\cdot\left[\lambda\cdot I_q + \left(L_d - L_q\right)\cdot I_d\cdot I_q\right] = M_a$$

$$\begin{pmatrix} I_d \\ I_q \\ I_a \end{pmatrix} := \text{Find}(I_d, I_q, I_a) \qquad \begin{pmatrix} I_d \\ I_q \\ I_a \end{pmatrix} = \begin{pmatrix} -0.664 \\ 6.26 \\ 6.296 \end{pmatrix}$$

Característica sencera.

Corrent de curtcircuit:

$$I_{pk} := \frac{\lambda}{L_d} \qquad I_{pk} = 17.41$$

Com es major que In la velocitat màxima és (si fos menor la velocitat màxima, en teoria, és infinta):

$$f_n := 10$$

$$I_n := 16 \qquad \omega_{max} := \frac{Vol(f_n)}{\lambda - L_d\cdot I_n}$$

$$Vol(f_n) = 46 \qquad \omega_{max} = 873.71$$

$$I_d := -.1 \qquad I_q := .1 \qquad f_{max} := \frac{\omega_{max}}{2\cdot\pi}$$

$$I_a := 3 \qquad f_{max} = 139.055 \ \ \text{Hz}$$

$$M_b(f) := \text{if}\left[f < 50, 150, 11.25 + 140\cdot\frac{50^2}{\left(f^2\right)}\right]$$

Dado

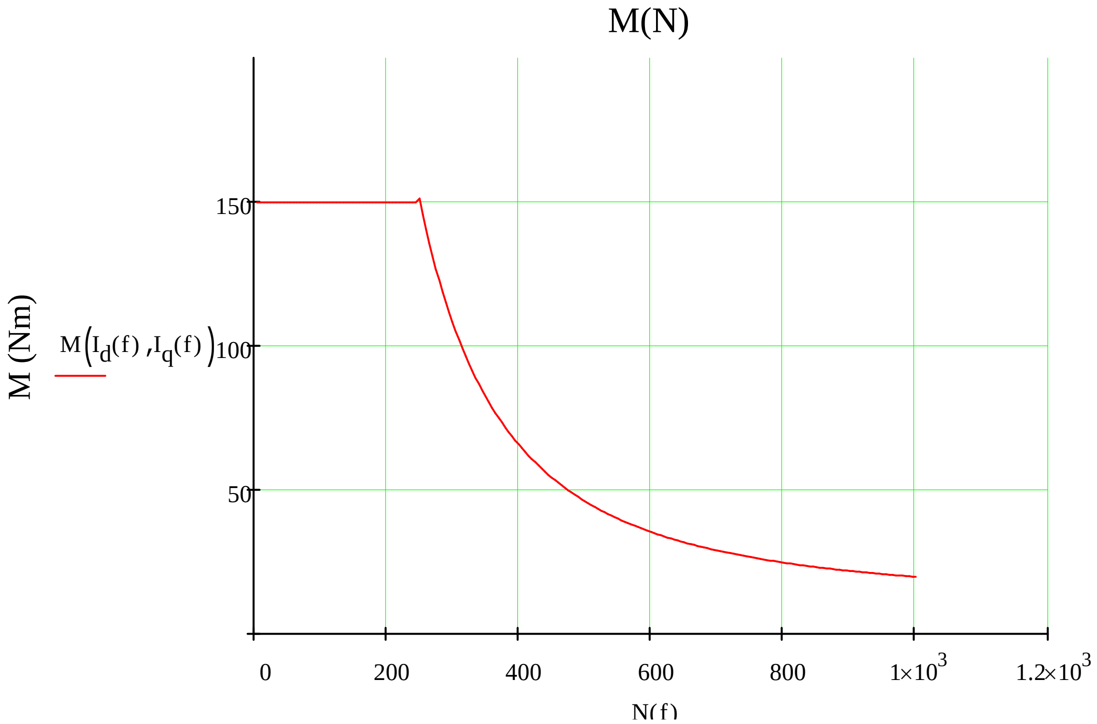
$$\left(\lambda + L_d\cdot I_d\right)^2 + \left(L_q\cdot I_q\right)^2 = \left(\frac{Vol(f)}{\omega(f)}\right)^2$$

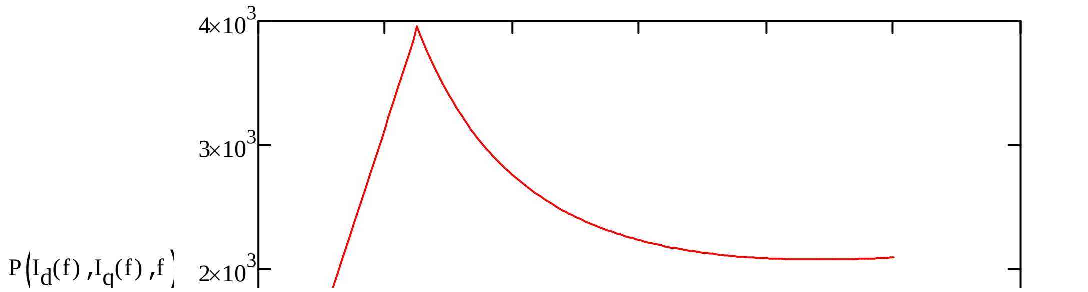
$$(m)\cdot p\cdot\left[\lambda\cdot I_q + \left(L_d - L_q\right)\cdot I_d\cdot I_q\right] = M_b(f)$$

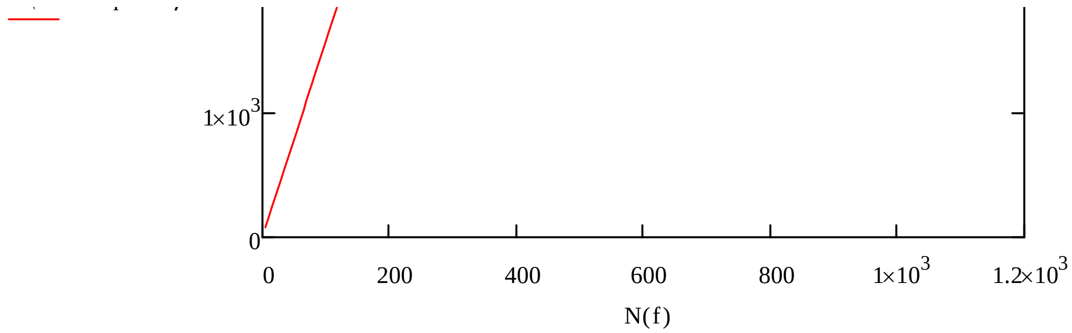
$aa(f) := \mathrm{Find}\left(I_d, I_q\right)$ $\qquad I_d(f) := aa(f)_0 \qquad I_q(f) := aa(f)_1$

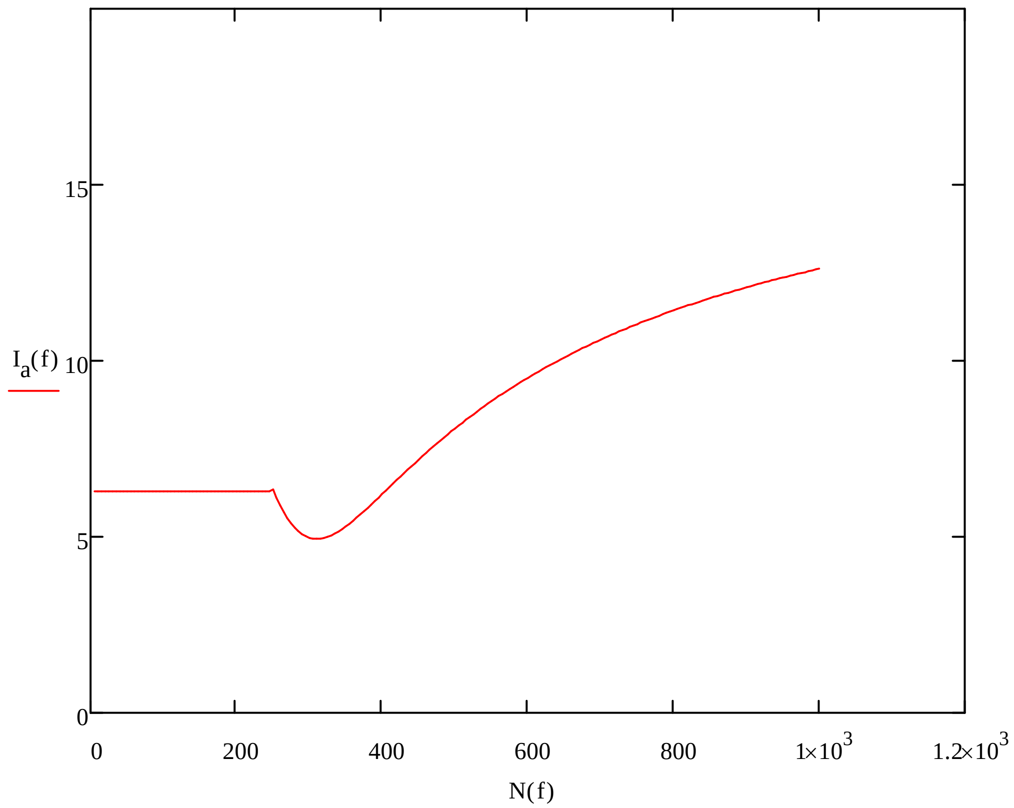
$f := 1, 2 .. 200$ $\qquad I_a(f) := \sqrt{I_d(f)^2 + I_q(f)^2}$

f =	$I_d(f)$ =	$I_q(f)$ =	$I_a(f)$ =	$P\left(I_d(f), I_q(f), f\right)$ =	N(f) =	$M\left(I_d(f), I_q(f)\right)$ =
1	-0.664	6.26	6.296	78.54	5	150
2	-0.664	6.26	6.296	157.08	10	150
3	-0.664	6.26	6.296	235.619	15	150
4	-0.664	6.26	6.296	314.159	20	150
5	-0.664	6.26	6.296	392.699	25	150
6	-0.664	6.26	6.296	471.239	30	150
7	-0.664	6.26	6.296	549.779	35	150
8	-0.664	6.26	6.296	628.319	40	150
9	-0.664	6.26	6.296	706.858	45	150
10	-0.664	6.26	6.296	785.398	50	150
11	-0.664	6.26	6.296	863.938	55	150
12	-0.664	6.26	6.296	942.478	60	150
13	-0.664	6.26	6.296	$1.021\cdot10^3$	65	150
14	-0.664	6.26	6.296	$1.1\cdot10^3$	70	150
15	-0.664	6.26	6.296	$1.178\cdot10^3$	75	150
...	...	...	...	...	...	...









$I_{centrifugat} := I_a(200)$ $\qquad I_{centrifugat} = 12.615 \quad A$ $\qquad S_c = 3.544 \quad mm^2$

$\Delta_{cent} := \dfrac{I_{centrifugat}}{S_c}$ $\qquad \Delta_{cent} = 3.56 \quad \dfrac{A}{mm^2}$