Investigation of a three-phase, two pole, 18 slot, two-layer fractional pitch distributed coil winding.

ORIGIN := 1

$N := 60$ Number of turns per winding.

$N_{slots} := 18$ Number of slots

$\sigma := \frac{2 \cdot \pi}{N_{slots}}$ Slot pitch in radians. $\sigma = 0.349$ $\sigma = 20 \cdot deg$

$\beta := 0.5\sigma$ Slot opening in radians. $\beta = 0.175$ $\beta = 10 \cdot deg$

$N_{poles} := 2$ Number of poles

$N_{phases} := 3$ Number of phases

$N_{coilspppp} := \frac{N_{slots}}{N_{poles} \cdot N_{phases}}$ Number of coils per phase per pole $N_{coilspppp} = 3$

$N_{cp} := \frac{N}{N_{coilspppp}}$ Number of turns per coil pair $N_{cp} = 20$

$CP_{slots} := 8$ Coil pitch in slots

$N_{slotspppp} := N_{coilspppp}$ $N_{slotspppp} = 3$ Number of slots per pole per phase

$$\psi := \frac{CP_{slots}}{\frac{N_{slots}}{2}} \cdot \pi$$ Coil pitch in radians $\psi = 2.793$ $\psi = 160 \cdot deg$

$\gamma := \pi - \psi$ $\gamma = 0.349$ $\gamma = 20 \cdot deg$

$N_{harmonics} := 101$

$h := 1, 3 .. N_{harmonics}$ Harmonic number

$$a_{c_h} := \frac{2 \cdot N_{cp}}{\pi \cdot h} \cdot \sin\left(h \cdot \frac{\pi}{2}\right)$$ F.S. cefficient of a full pitch concentrated coil winding.

$$k_{p_h} := \cos\left[h \cdot \left(\frac{\gamma}{2}\right)\right]$$ Pitch factor

$$k_{d_h} := \operatorname{sinc}\left(h \cdot \frac{\beta}{2}\right)$$ Distribution factor

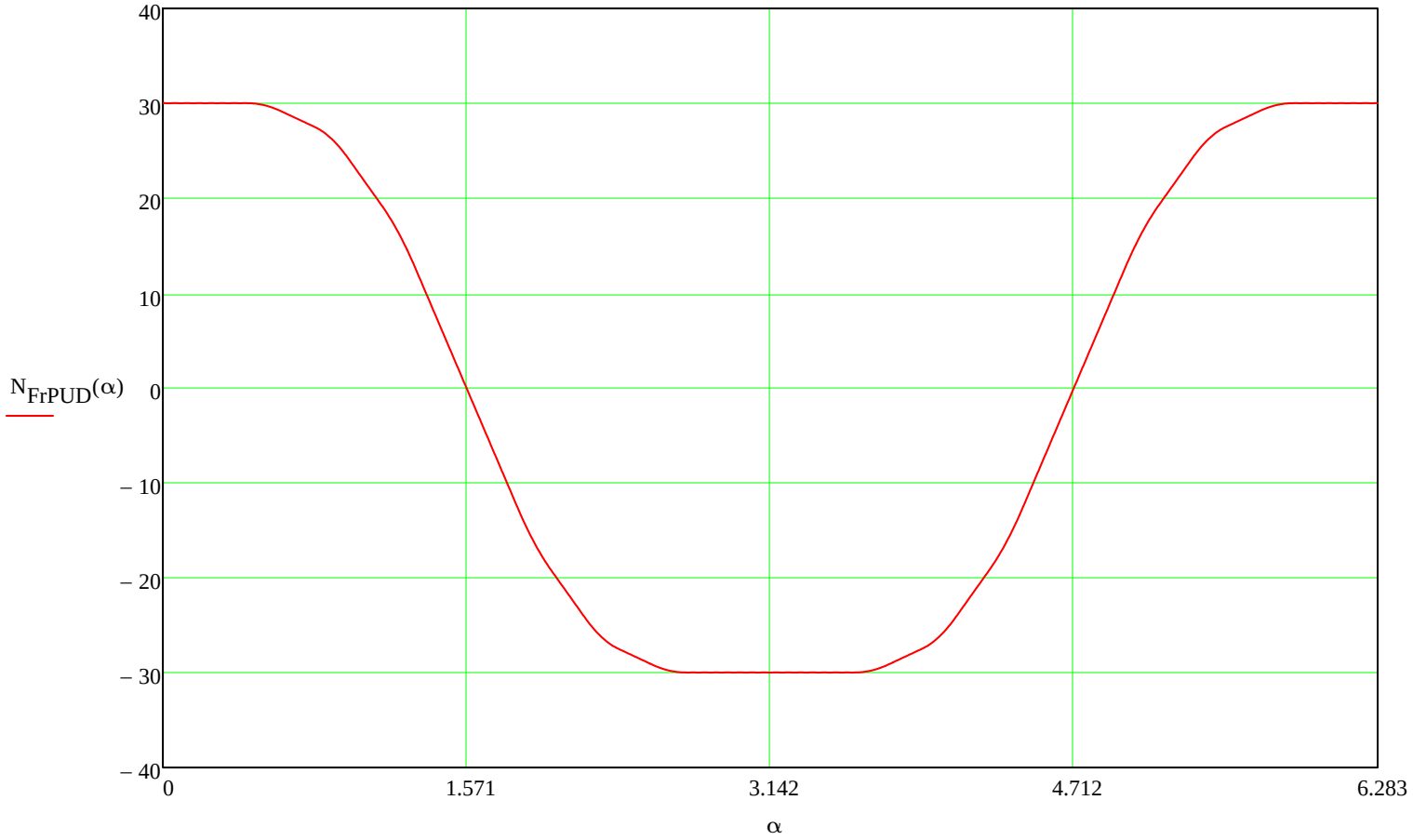
$k_{m_h} := 1 + 2 \cdot \cos(h \cdot \sigma)$ Multi-coil winding factor only works 3 coils

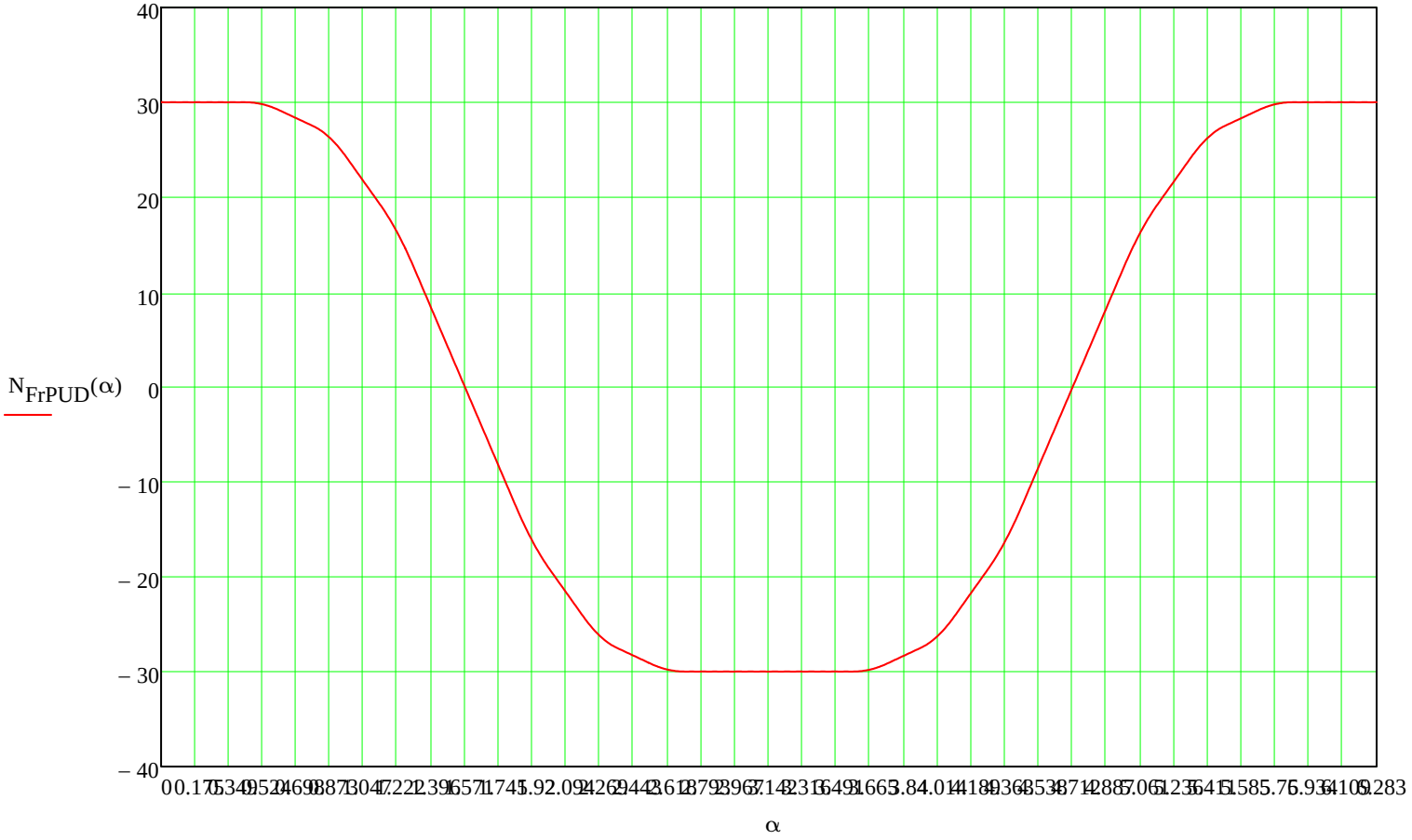
$k_{m_1} = 2.879$ $k_{m_3} = 2$ $k_{m_5} = 0.653$ $k_{m_7} = -0.532$ $k_{m_9} = -1$

$$k_{s_h} := \operatorname{sinc}\left(h \cdot \frac{3.0\sigma}{2}\right) \qquad a_h := k_{m_h} \cdot k_{s_h} \cdot k_{p_h} \cdot k_{d_h} \cdot a_{c_h} \qquad N_{FrPUD}(\alpha) := \sum_h \left(a_h \cdot \cos(h \cdot \alpha)\right)$$

Slots skewed one slot pitch.

h =	a_h =
1	34.434
3	-4.627
5	0.198
7	-0.042
9	0
11	0.016
13	-0.024
15	0.138
17	-0.08
19	-0.057
21	0.05
23	$-4.354 \cdot 10^{-3}$
25	$1.329 \cdot 10^{-3}$
27	0
29	$-5.963 \cdot 10^{-4}$
...	...


40
30
20
10
0
– 10
– 20
– 30
– 40
$N_{FrPUD}(\alpha)$
0
1.571
3.142
4.712
6.283
α


40
30
20
10
0
– 10
– 20
– 30
– 40
$N_{FrPUD}(\alpha)$
0
0.175
0.349
0.524
0.698
0.873
1.047
1.222
1.396
1.571
1.745
1.92
2.094
2.269
2.443
2.618
2.793
2.967
3.142
3.316
3.491
3.665
3.84
4.014
4.189
4.363
4.538
4.712
4.887
5.061
5.236
5.411
5.585
5.76
5.934
6.109
6.283
α

$\mu_0 := 4\cdot\pi\cdot 10^{-7}$ $r := 0.2$ $l_{eff} := 0.6042$ $N_f := 200$ $g := 0.004$ $\omega := 377$

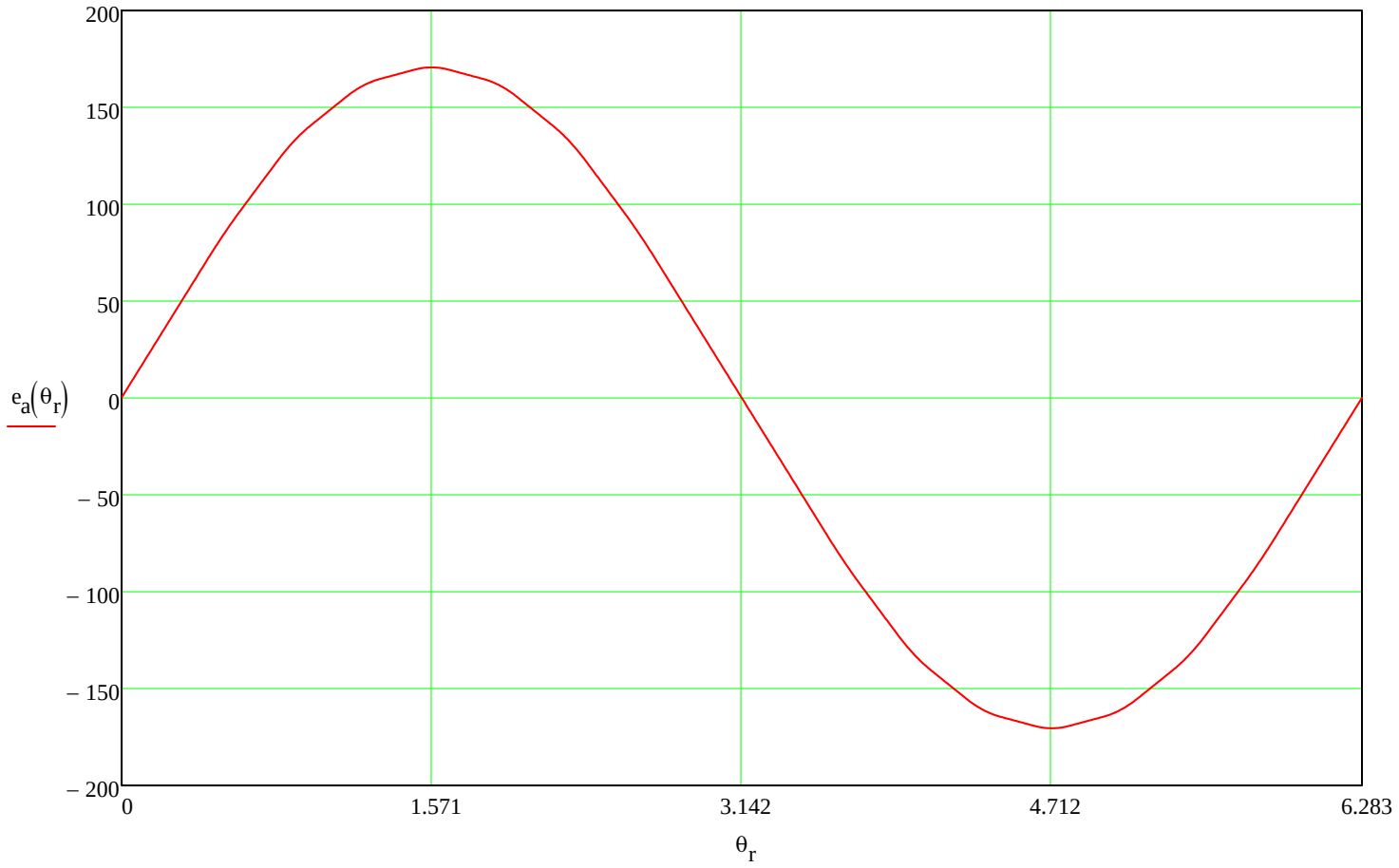
$$k_9 := \frac{\mu_0 \cdot r \cdot l_{eff} \cdot N_f}{g} \qquad k_9 = 7.593 \times 10^{-3}$$

$$k_{Lc_h} := 2\cdot\omega\cdot k_9 \cdot \left(\sin\left(h\cdot\frac{4\cdot\pi}{3}\right)\right) \qquad k_{v_h} := k_{Lc_h}\cdot a_h$$

$120\cdot\sqrt{2} = 169.706$

$$e_a(\theta_r) := -\sum_h \left(k_{v_h}\cdot\sin(h\cdot\theta_r)\right)$$

h =	k_{v_h} =	$\left\lvert\frac{k_{v_h}}{k_{v_1}}\right\rvert\cdot 100$ =
1	-170.716	100
3	0	0
5	0.98	0.574
7	0.21	0.123
9	0	0
11	0.077	0.045
13	0.12	0.07
15	0	0
17	-0.397	0.233
19	0.284	0.167
21	0	0
23	-0.022	0.013
25	$-6.59\cdot10^{-3}$	$3.86\cdot10^{-3}$
27	0	0
29	$-2.956\cdot10^{-3}$	$1.732\cdot10^{-3}$
…	…	…


200
150
100
50
0
– 50
– 100
– 150
– 200
$e_a(\theta_r)$
0
1.571
3.142
4.712
6.283
θ_r