Dynamika asynchronního motoru

Description

Jednoduchý model dynamiky asynchronního motoru.

Náhrada impedance motoru provedena jako:

$$Z_{am} = R_1 + j\ X_{\sigma 1} + \frac{1}{\frac{1}{R_{Fe}} + \frac{1}{j\ X_h} + \frac{1}{\frac{R_2^{/}}{S} + j\ X_{\sigma 2}^{/}}}$$

Což odpovídá velikosti reálné části impedance:

$$R_1 + R_{Fe}\ X_h^2 \cdot \frac{R_2^{/2} + R_2^{/}\ R_{Fe}\ S + S^2\ X_{\sigma 2}^{/2}}{R_2^{/2}\ \left(R_{Fe}^2 + X_h^2\right) + 2\ R_2^{/}\ R_{Fe}\ S\ X_h^2 + S^2\ \left(R_{Fe}^2\ \left(X_h^2 + 2\ X_h\ X_{\sigma 2}^{/} + X_{\sigma 2}^{/2}\right) + X_h^2\ X_{\sigma 2}^{/2}\right)}$$

a záporně vzaté velikosti imaginární části impedance:

$$R_{Fe}^2\ S\ X_h^2 \cdot \frac{2\ R_2^{/}\ R_{Fe}\ X_h + S\ \left(R_{Fe}^2\ \left(X_h + X_{\sigma 2}^{/}\right) - X_h^2\ X_{\sigma 2}^{/}\right)}{\left(R_2^{/2}\ \left(R_{Fe}^2 + X_h^2\right) + 2\ R_2^{/}\ R_{Fe}\ S\ X_h^2 + S^2\ \left(R_{Fe}^2\ \left(X_h^2 + 2\ X_h\ X_{\sigma 2}^{/} + X_{\sigma 2}^{/2}\right) + X_h^2\ X_{\sigma 2}^{/2}\right)\right)\ \left(R_{Fe}^2 + X_h^2\right)} + \frac{X_h^3}{R_{Fe}^2 + X_h^2} - X_h - X_{\sigma 1}$$

Parametry identifikované z chodu naprázdno:

$$R_{Fe} = U_n^2\ [kV]\ \frac{10^6}{dP0\ [W]} \qquad Y_0 = \frac{I_0}{U_n\ [kV]\ \frac{10^3}{\sqrt{3}}} \qquad X_h = \frac{1}{\sqrt{Y_0^2 - \frac{1}{R_{Fe}^2}}}$$

Moment aproximován pomocí Klossova vztahu:

$$M_{am} = 2 \cdot \frac{m_{max}}{\frac{S}{S_{Max}} + \frac{S_{Max}}{S}}\ M_n\ u_p^2$$

Skluz pro bod zvratu a jmenovitý:

$$S_{Max} = S_N\ \left(m_{max} + \sqrt{m_{max}^2 - 1}\right) \qquad S_N = \frac{N_s - N_n}{N_s}$$

Momentová charakteristika zátěže

$$M_p = \left(m_{p0} + \left(\frac{1-S}{1-S_N}\right)^{Exp}\ \left(1 - m_{p0}\right)\right)\ M_n$$

Náhradní reaktance transformátoru:

$$X_t = \frac{u_k[\%]}{100} \cdot \frac{U_n^2\ [kV] \cdot 1000}{S_{nt}\ [kVA]}$$

Poměrné napětí na asynchronním stroji:

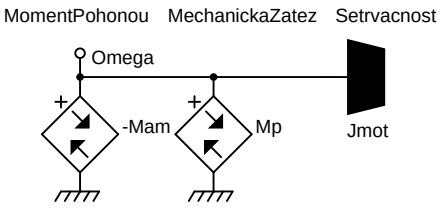
$$u_p = \frac{Z_{am}}{X_t + Z_{am}}$$

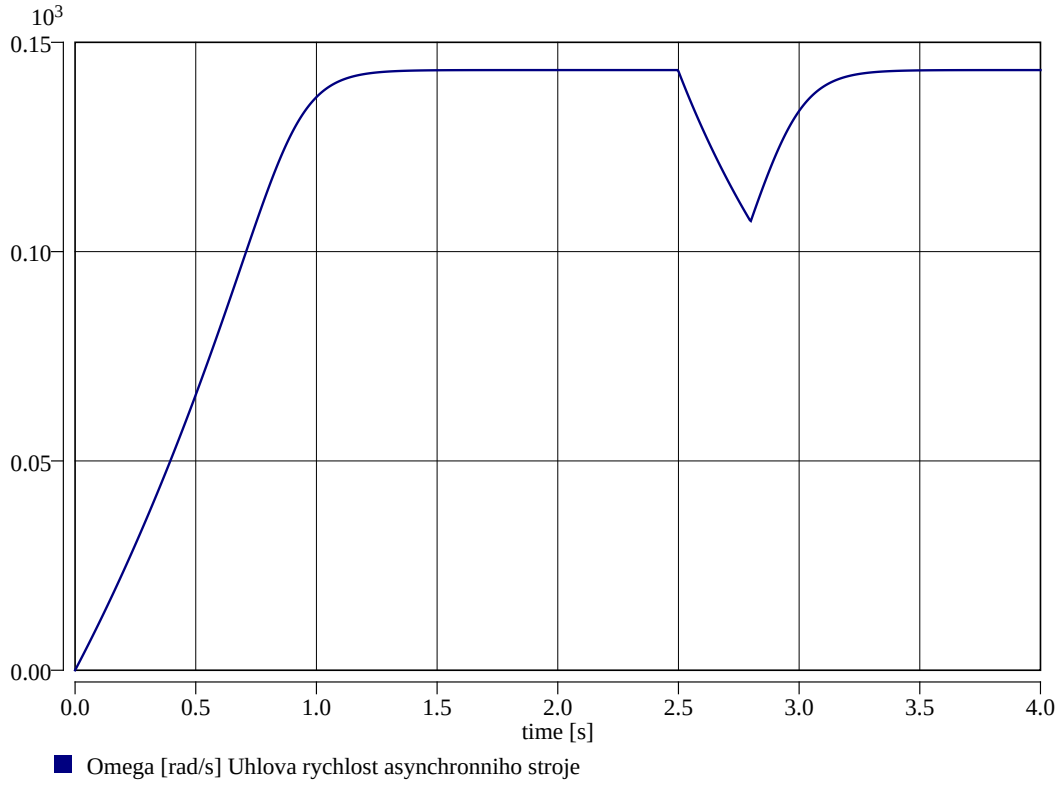
System Parameters

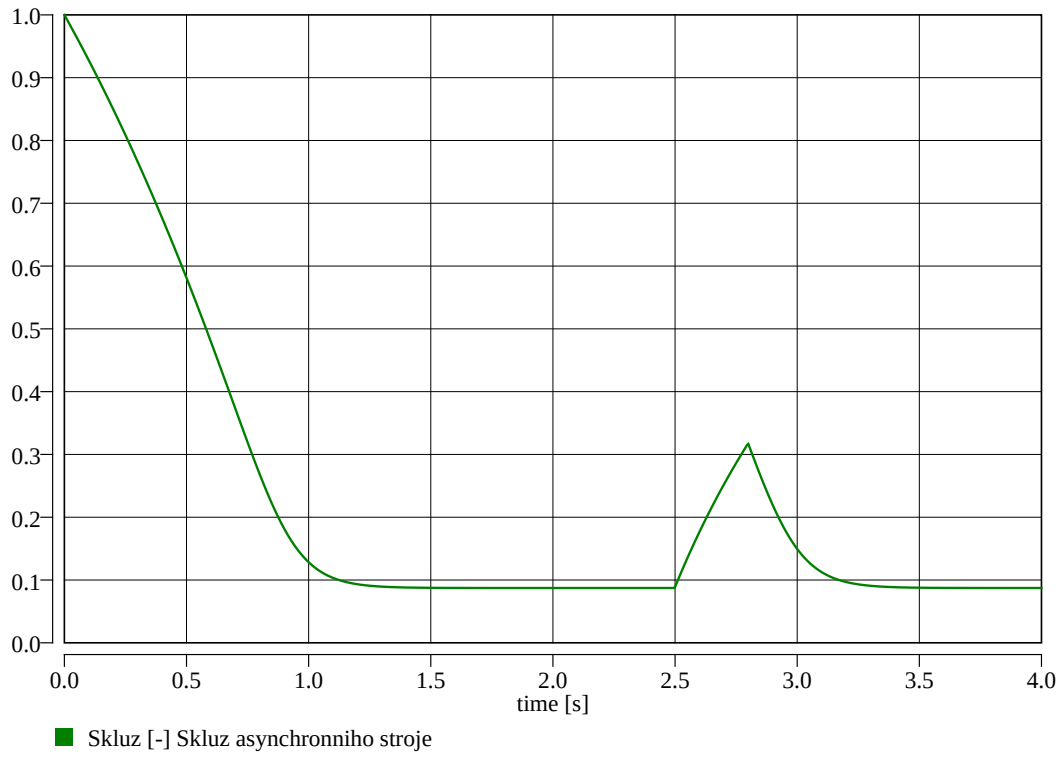
$f_n = 50$	[Hz]	Jmenovitá síťová frekvence
$U_n = 0.4$	[kV]	Jmenovité napětí
$p_p = 2$	[–]	Počet pólpárů
$n_n = 1380;$	[ot./min]	Jmenovité otáčky
$P_n = 1.100$	[kW]	Jmenovitý výkon
$I_n = 2.64$	[A]	Jmenovitý proud
$M_n = 7.6$	[N.m]	Jmenovitý moment
$m_{max} = 2.1$	[–]	Maximální poměrný moment v bodě zvratu
$m_{p0} = 0.2$	[–]	Záběrný poměrný moment zátěže

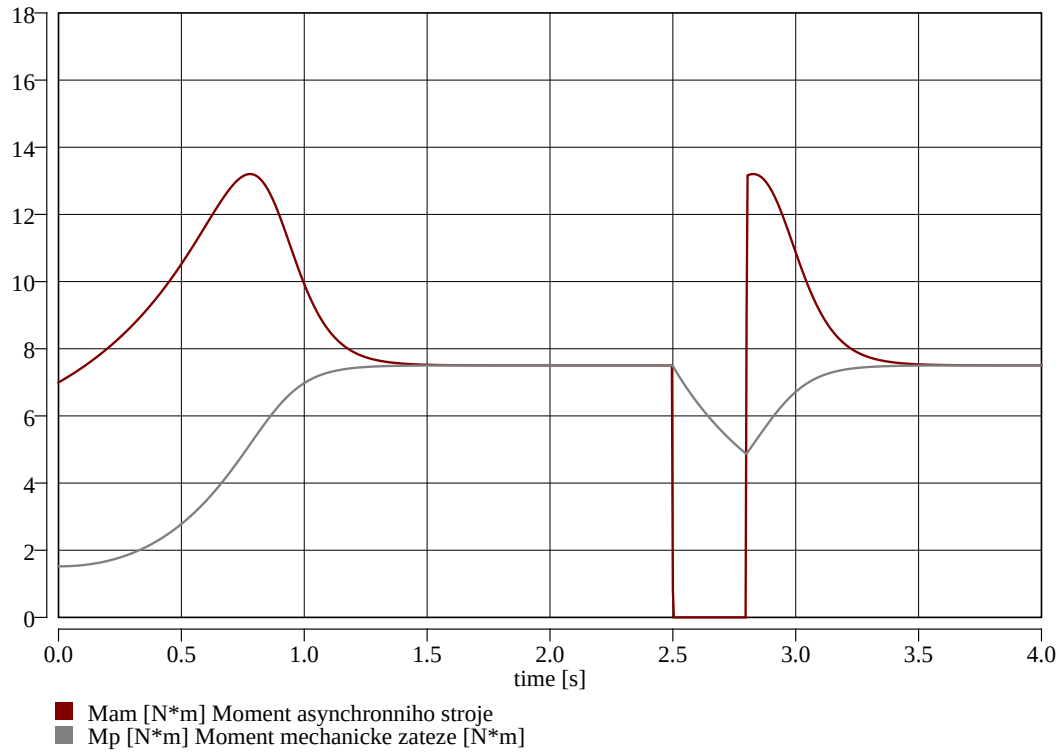
$N = 2$	[–]	Exponent charakteristiky moment zátěže
$J_{mot} = 50\text{m}$	$[\text{kg.m}^2]$	Moment setrvačnosti soustrojí
$R_1 = 9.5$	[Ω]	Statorový činný odpor
$R_2^{/} = 5.8$	[Ω]	Rotorový činný odpor přepočtený
$X_{\sigma 1} = 8.1$	[Ω]	Statorová rozptylová reaktance
$X_{\sigma 2}^{/} = 8.7$	[Ω]	Rotorová rozptylová reaktance přepočtená
$\Delta P_0 = 50$	[W]	Ztráty naprázdno
$I_0 = 1.4$	[A]	Proud naprázdno
$S_{nt} = 5$	[kVA]	Jmenovitý výkon transformátoru
$u_k = 10$	[%]	Napětí nakrátko transformátoru

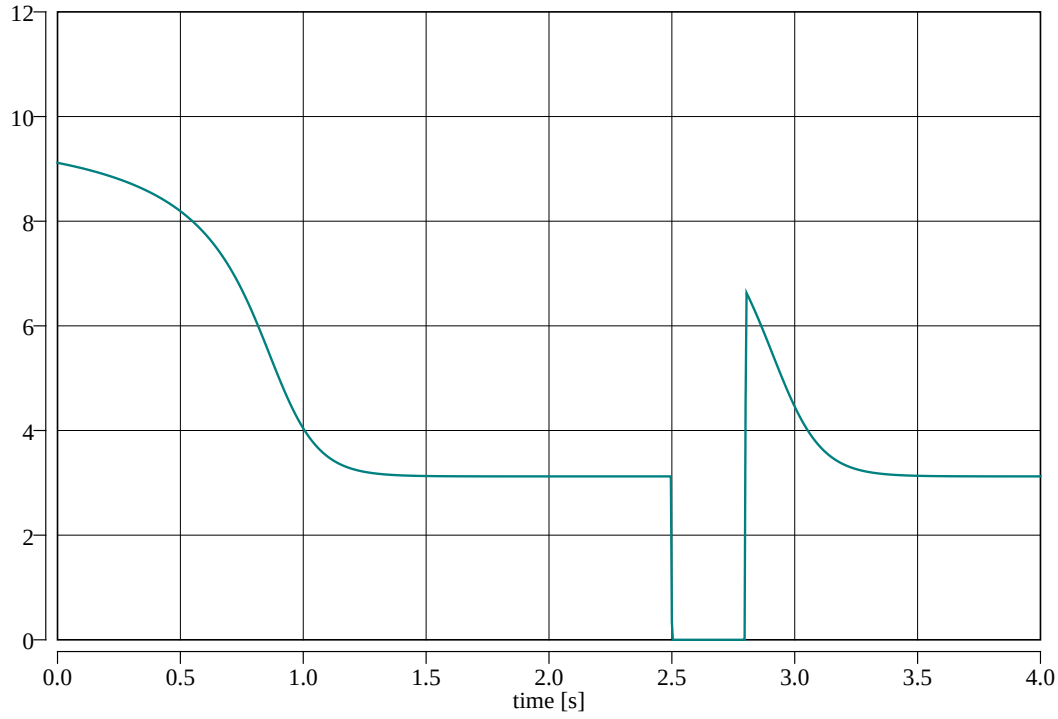
Model

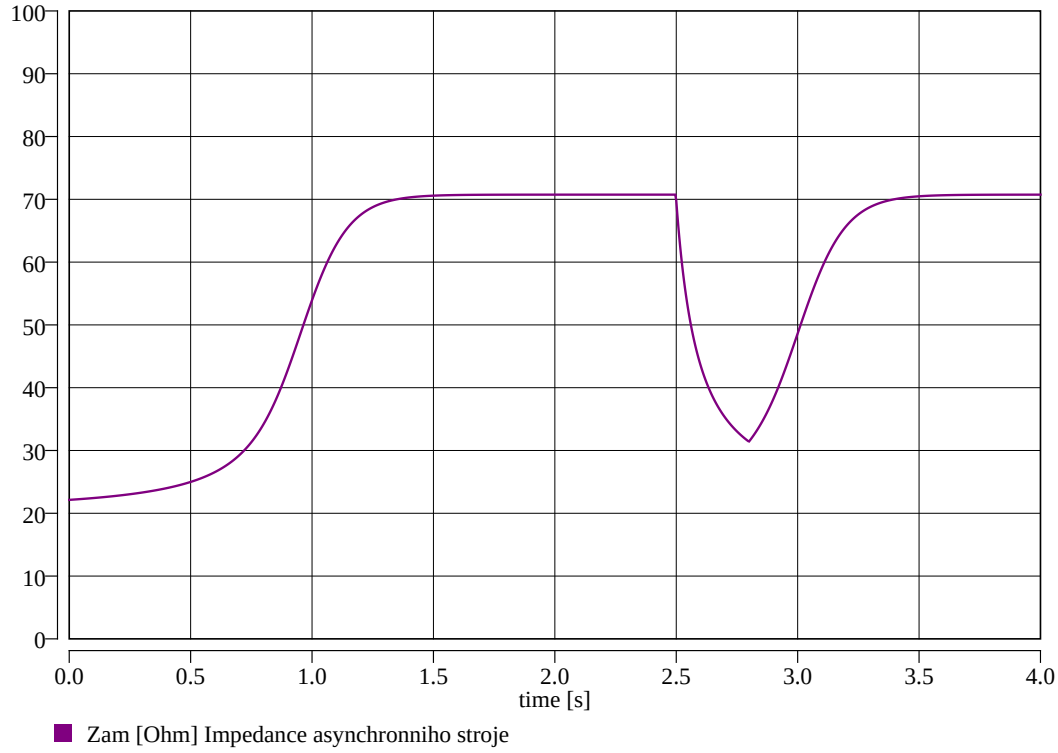


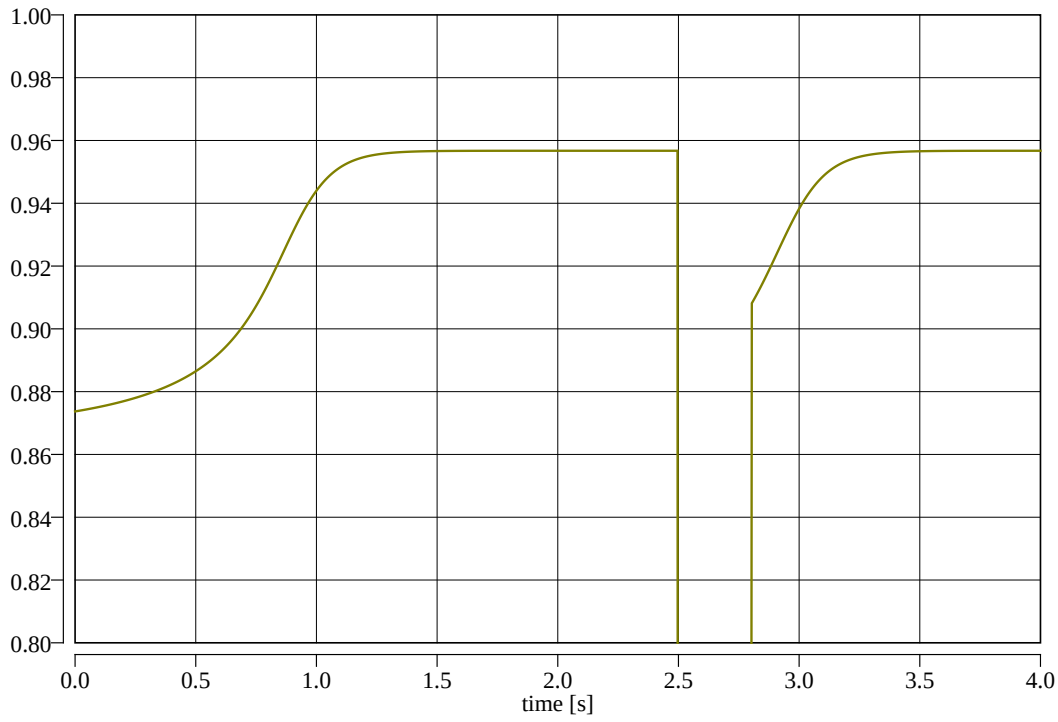


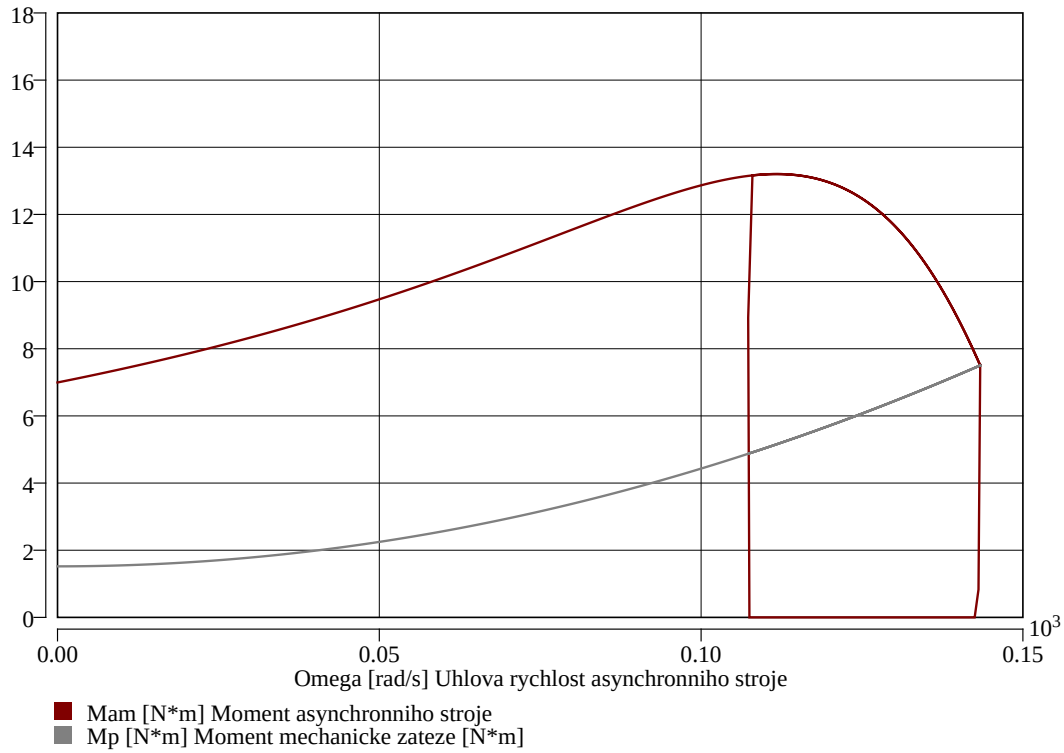

1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
time [s]
Skluz [-] Skluz asynchronniho stroje

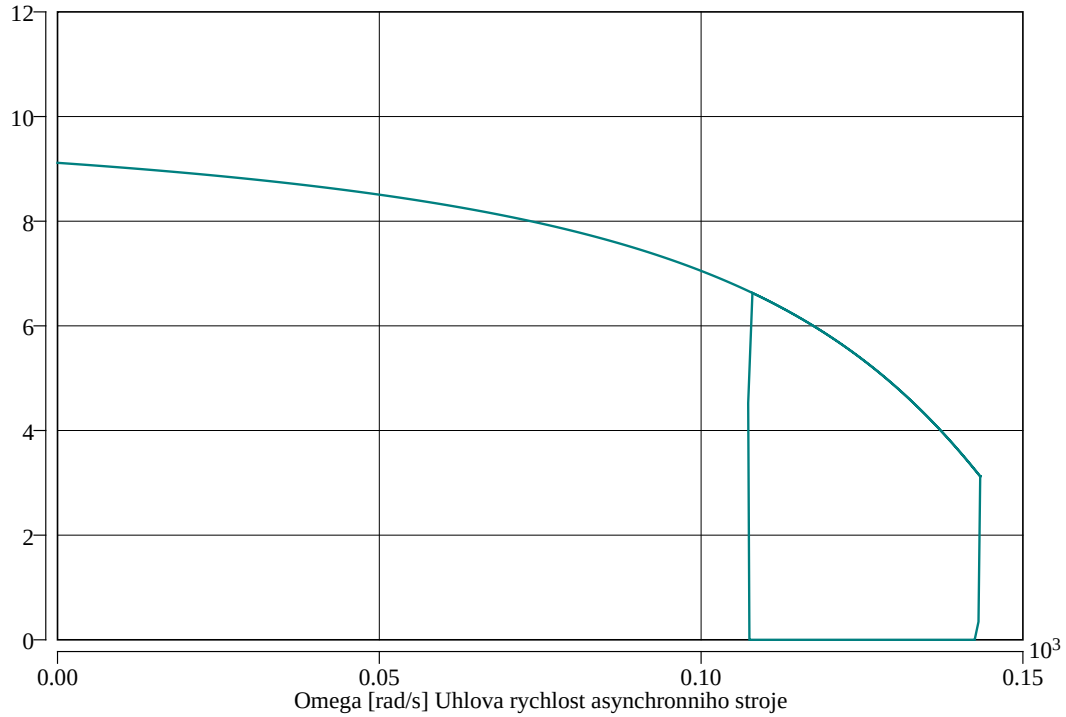

18
16
14
12
10
8
6
4
2
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
time [s]
Mam [N*m] Moment asynchronniho stroje
Mp [N*m] Moment mechanicke zateze [N*m]

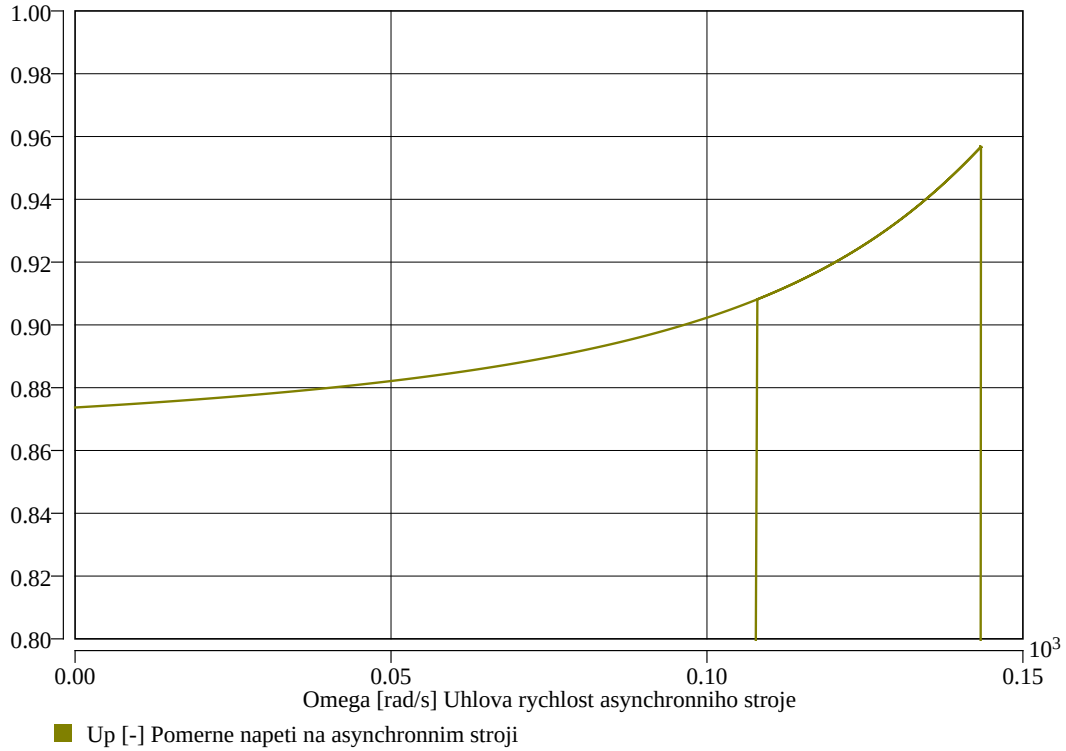

12
10
8
6
4
2
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
time [s]
Is [A] Proud asynchronniho stroje


100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
time [s]
Zam [Ohm] Impedance asynchronniho stroje


1.00
0.98
0.96
0.94
0.92
0.90
0.88
0.86
0.84
0.82
0.80
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
time [s]
Up [-] Pomerne napeti na asynchronnim stroji


18
16
14
12
10
8
6
4
2
0
0.00
0.05
0.10
0.15
10^3
Omega [rad/s] Uhlova rychlost asynchronniho stroje
Mam [N*m] Moment asynchronniho stroje
Mp [N*m] Moment mechanicke zateze [N*m]


12
10
8
6
4
2
0
0.00
0.05
0.10
0.15
10^3
Omega [rad/s] Uhlova rychlost asynchronniho stroje
Is [A] Proud asynchronniho stroje


1.00
0.98
0.96
0.94
0.92
0.90
0.88
0.86
0.84
0.82
0.80
0.00
0.05
0.10
0.15
10^3
Omega [rad/s] Uhlova rychlost asynchronniho stroje
Up [-] Pomerne napeti na asynchronnim stroji

Start of induction motor with quadratic loading torque

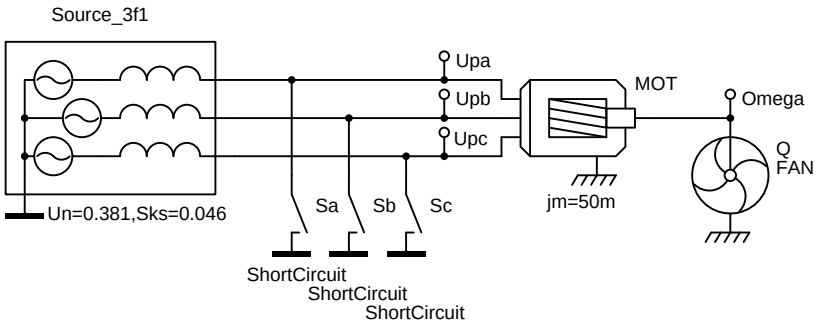
Description

Model of engine start and short supply lost later.

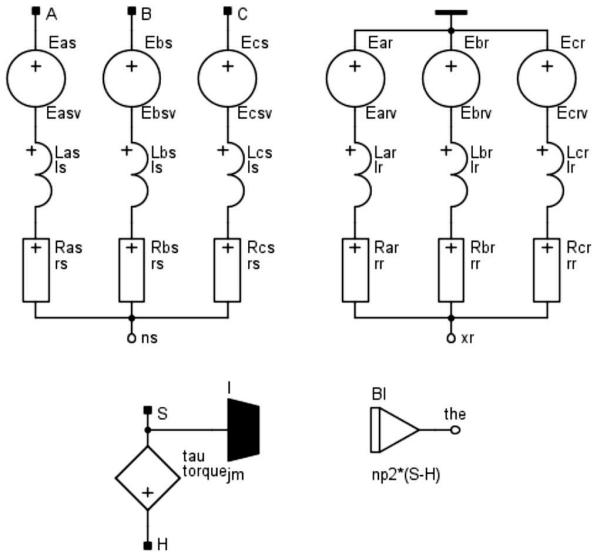
System Parameters

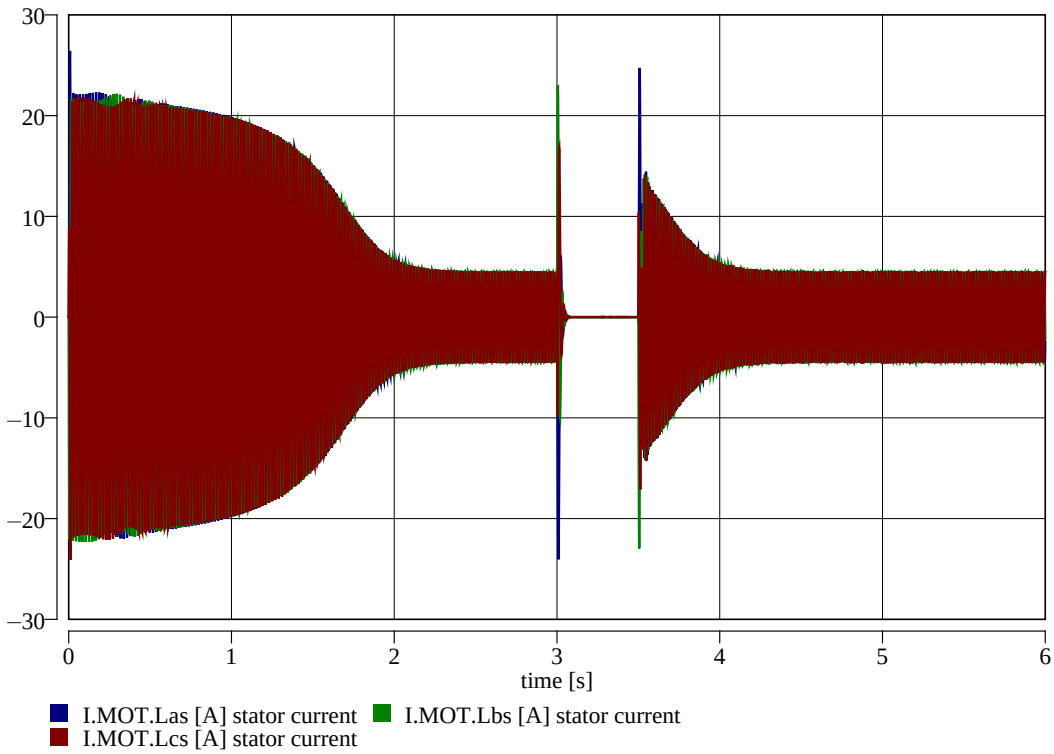
$Q = 57.83\mu$ [–] damper constant

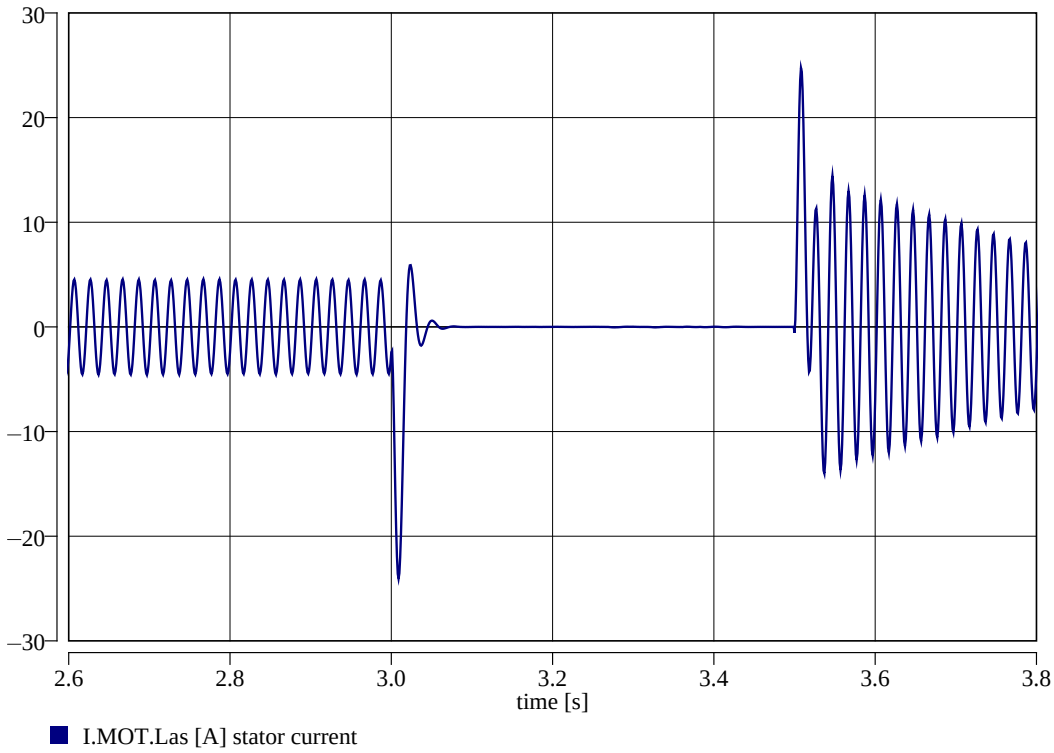
Model

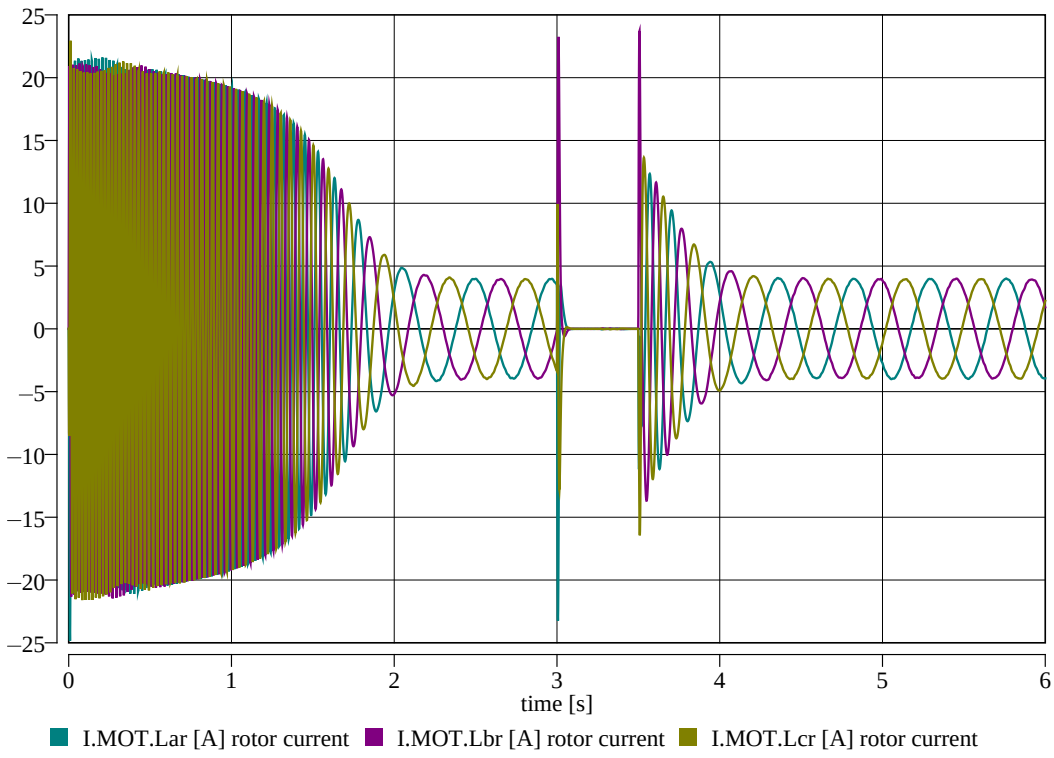


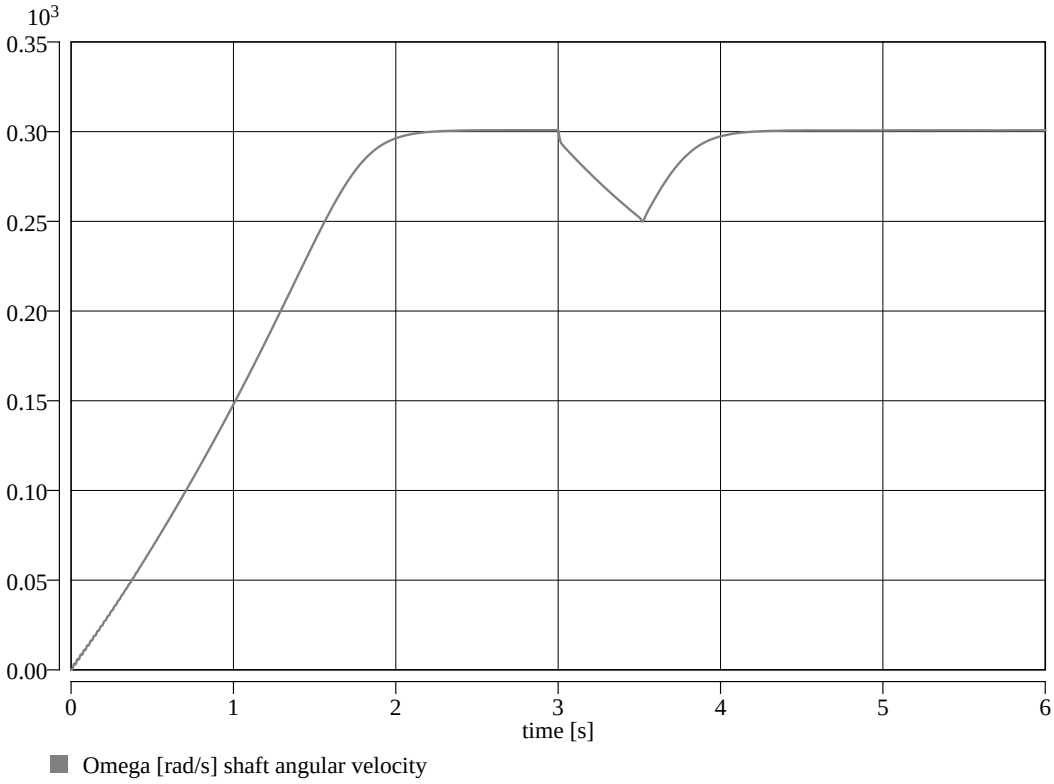
Induction motor model:

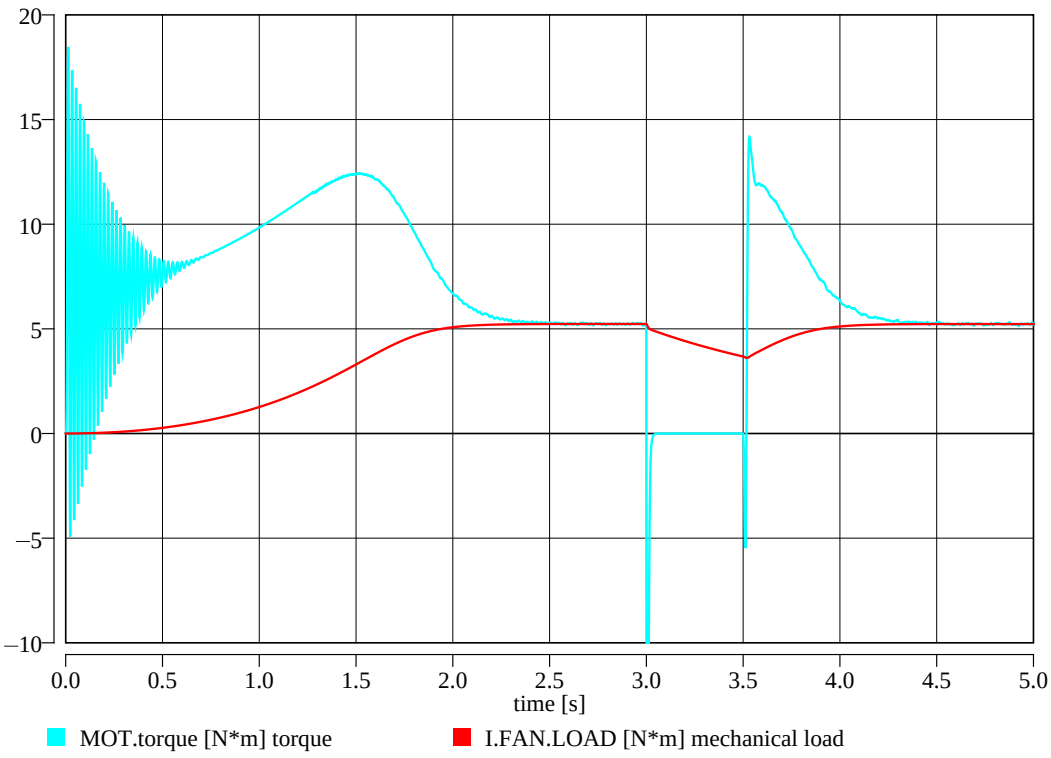


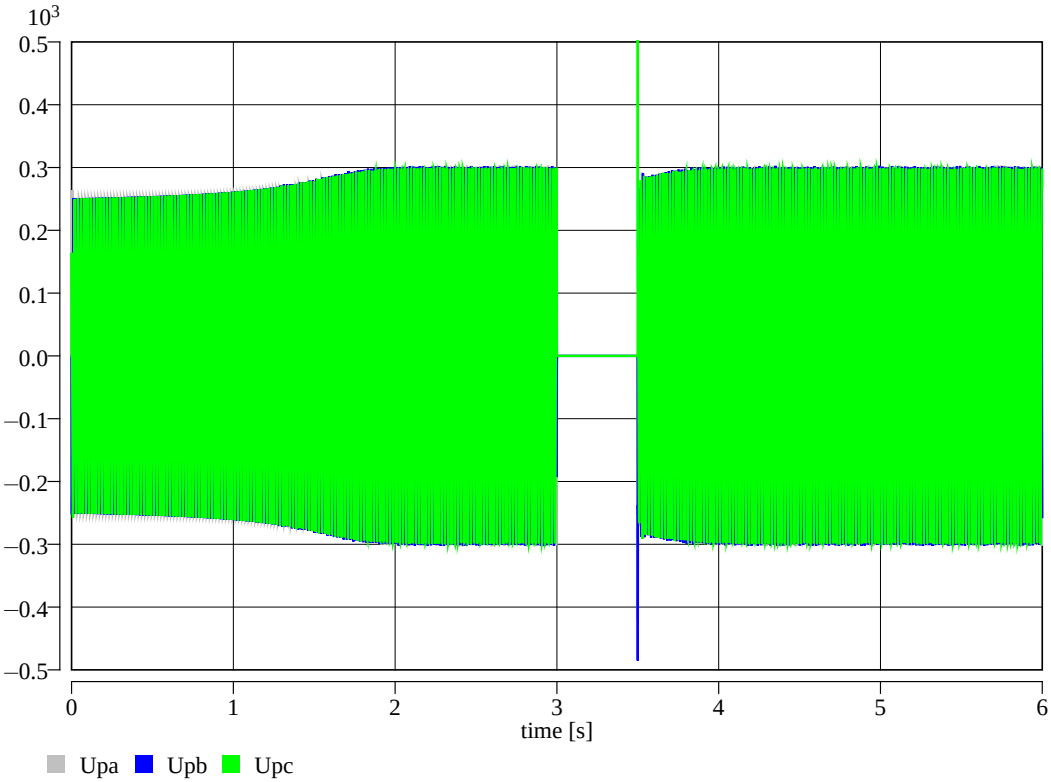

30
20
10
0
–10
–20
–30
0
1
2
3
4
5
6
time [s]
I.MOT.Las [A] stator current
I.MOT.Lbs [A] stator current
I.MOT.Lcs [A] stator current

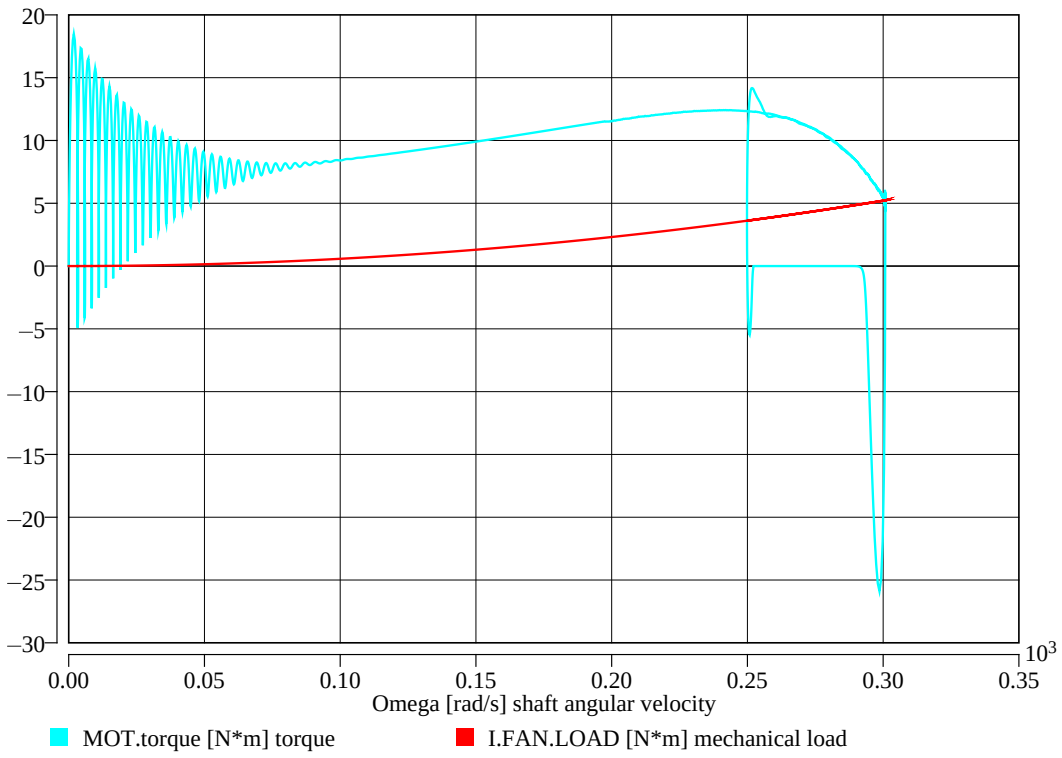

30
20
10
0
–10
–20
–30
2.6
2.8
3.0
3.2
3.4
3.6
3.8
time [s]
I.MOT.Las [A] stator current


25
20
15
10
5
0
−5
−10
−15
−20
−25
0
1
2
3
4
5
6
time [s]
I.MOT.Lar [A] rotor current
I.MOT.Lbr [A] rotor current
I.MOT.Lcr [A] rotor current


10^3
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
1
2
3
4
5
6
time [s]
Omega [rad/s] shaft angular velocity


20
15
10
5
0
−5
−10
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
time [s]
MOT.torque [N*m] torque
I.FAN.LOAD [N*m] mechanical load


10^3
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
0
1
2
3
4
5
6
time [s]
Upa
Upb
Upc



Origin

Karel Noháč KEE, FEL, WBU in Pilsen

Last Update

March 24, 2015

Start of two induction motors

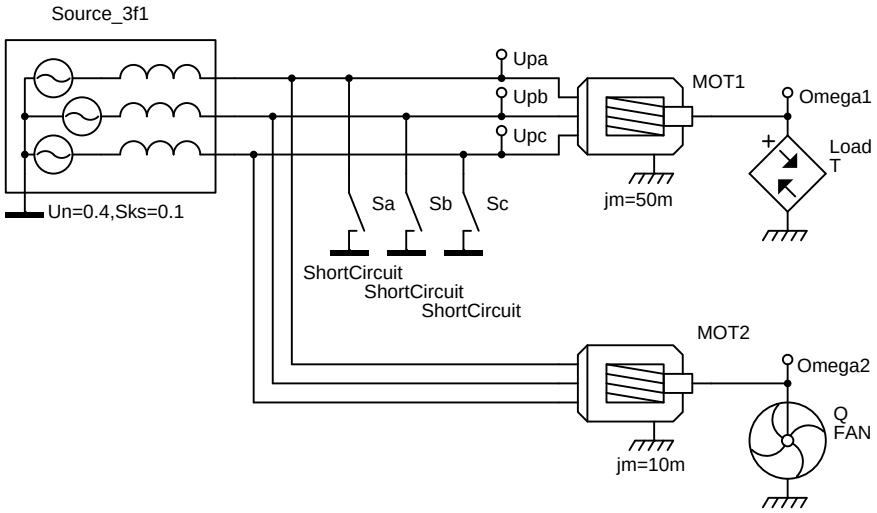
Description

Model of two engines start with different load and friction.

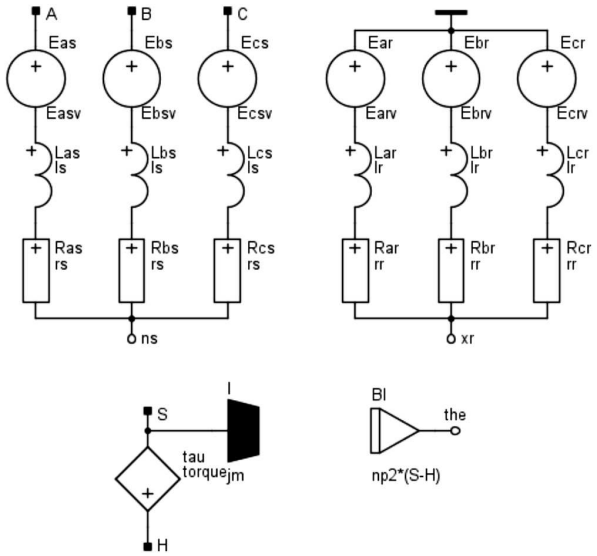
System Parameters

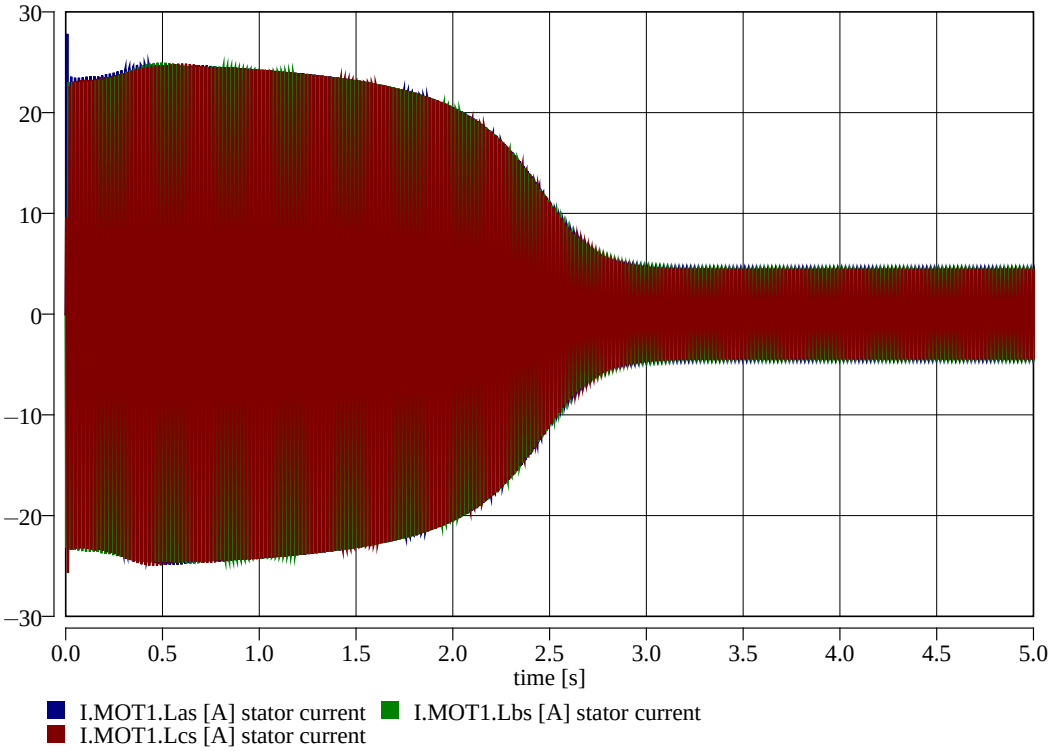
$T = 5.26$	[Nm]	Constant load torque
$Q = 107.83\mu$	[–]	Fan damper constant

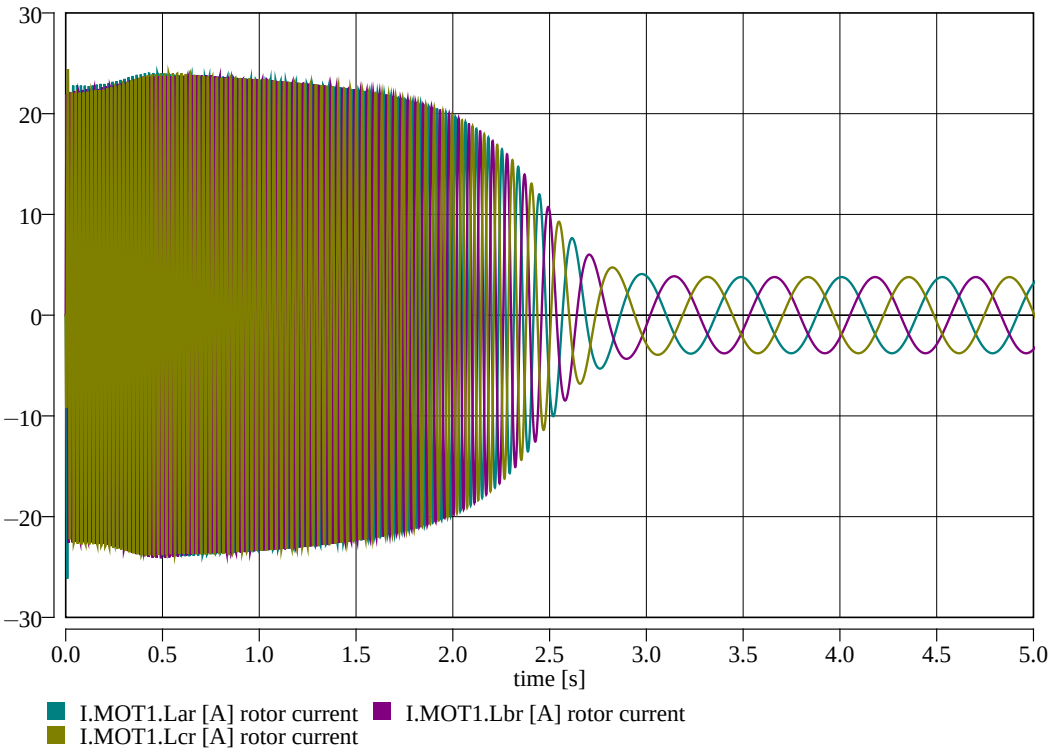
Model

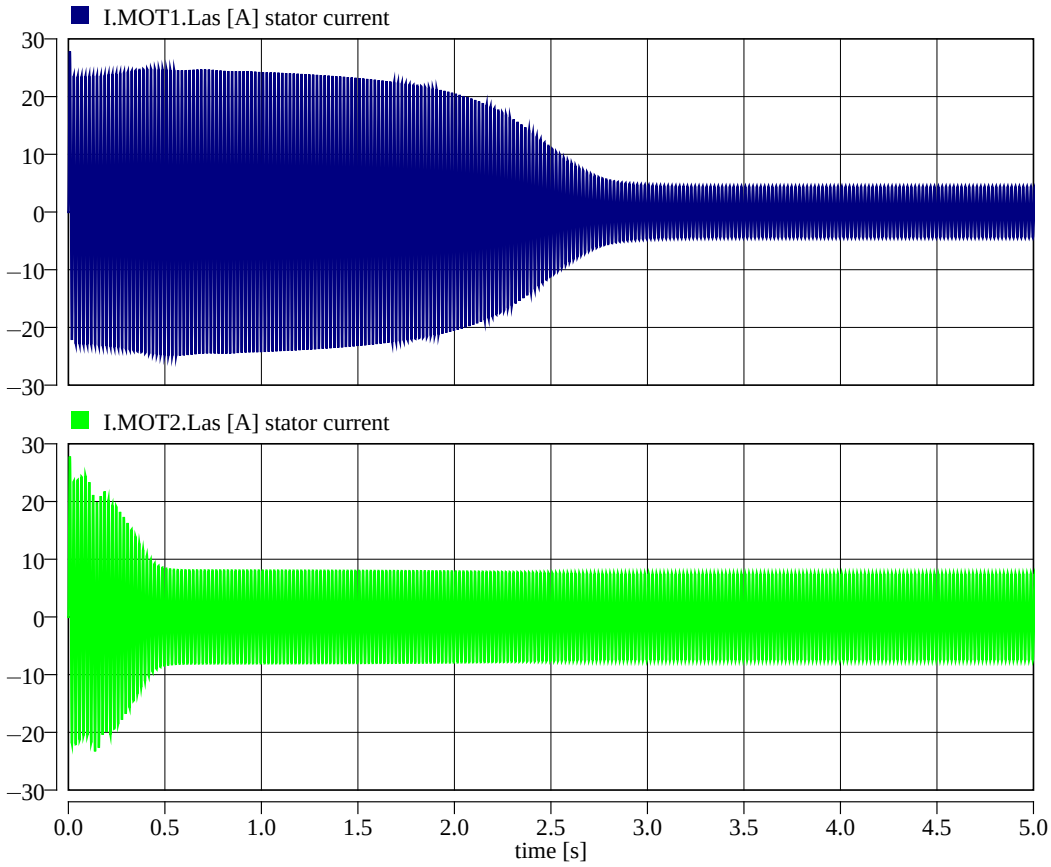


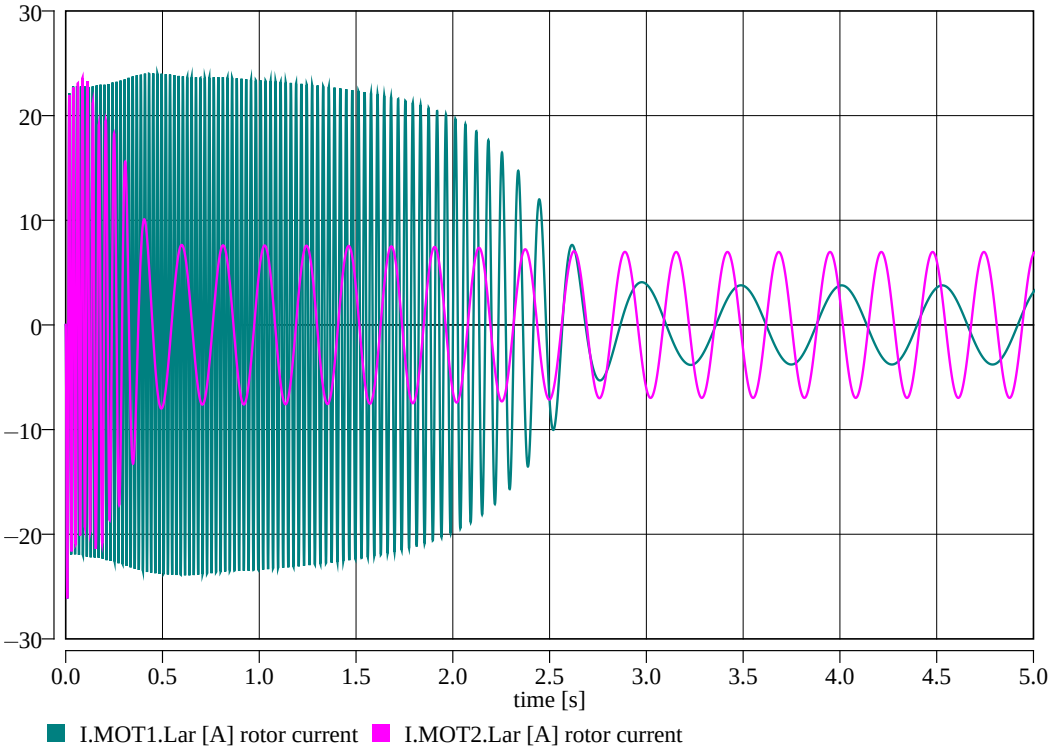
Induction motor model:

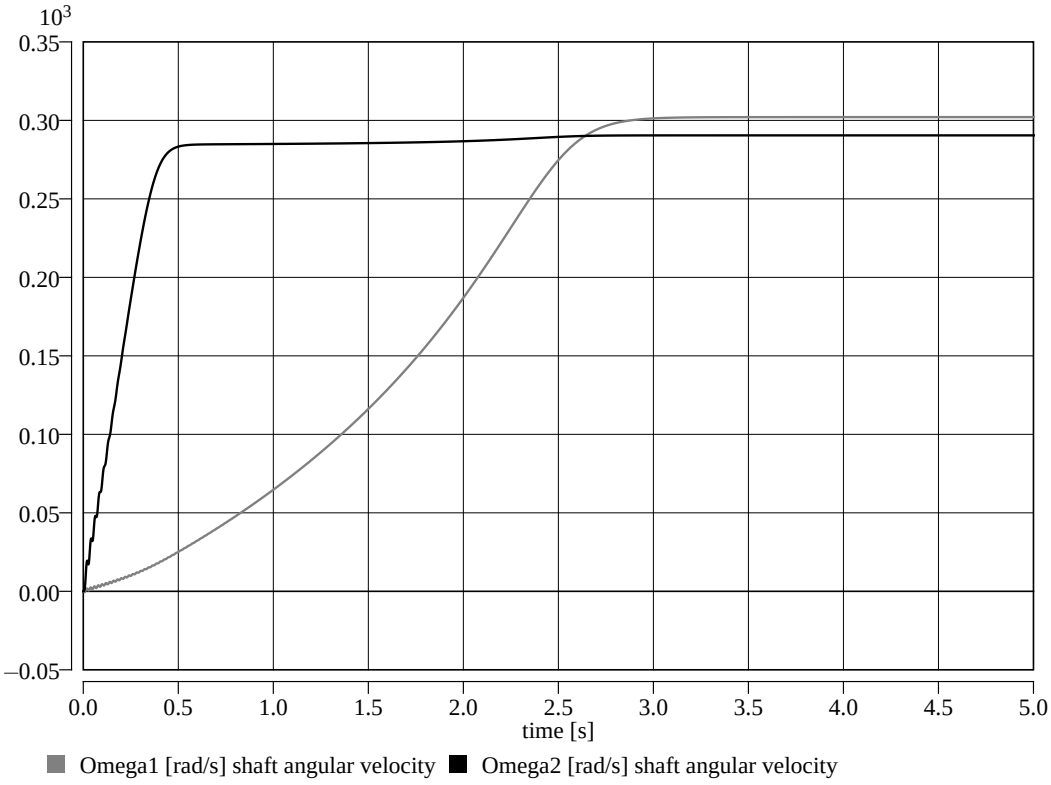


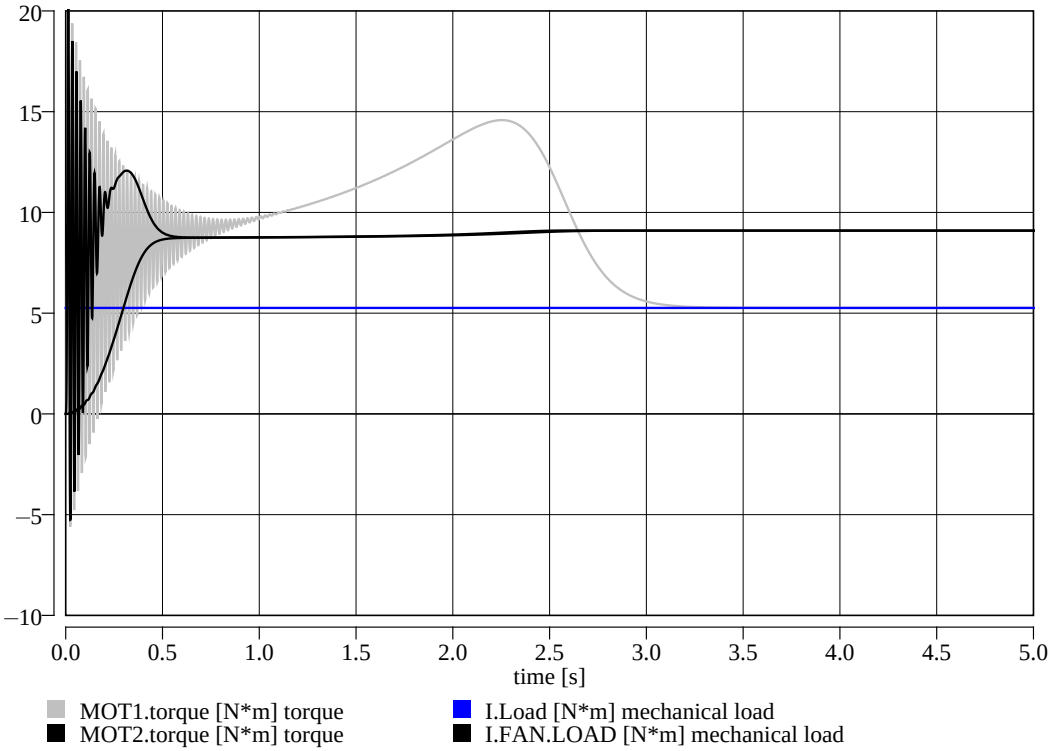

30
20
10
0
–10
–20
–30
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
time [s]
I.MOT1.Las [A] stator current
I.MOT1.Lbs [A] stator current
I.MOT1.Lcs [A] stator current

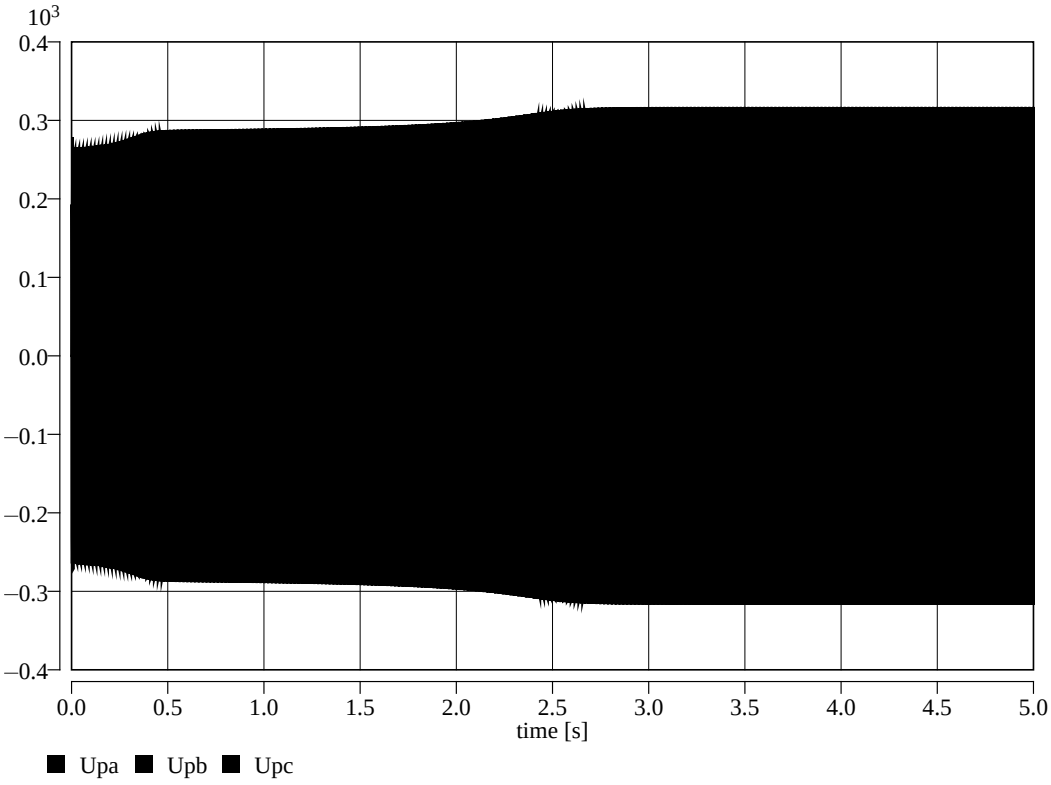

30
20
10
0
–10
–20
–30
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
time [s]
I.MOT1.Lar [A] rotor current
I.MOT1.Lbr [A] rotor current
I.MOT1.Lcr [A] rotor current

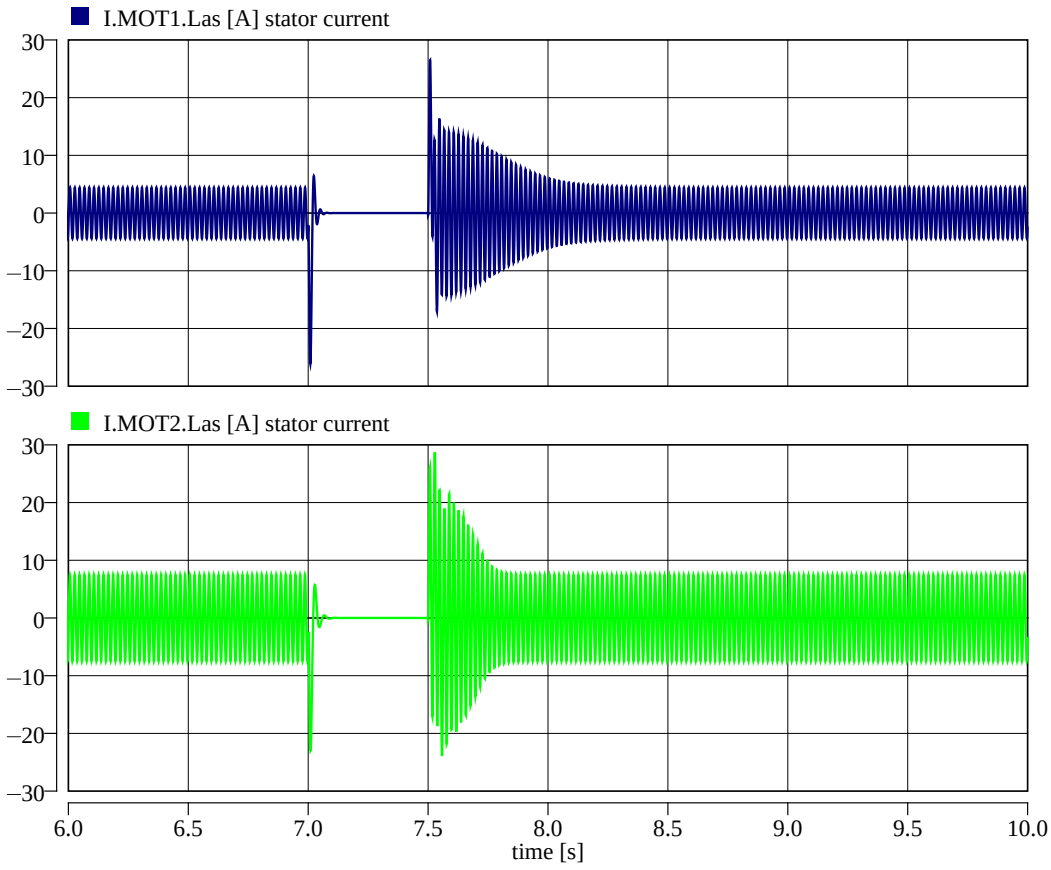

I.MOT1.Las [A] stator current
30
20
10
0
−10
−20
−30
I.MOT2.Las [A] stator current
30
20
10
0
−10
−20
−30
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
time [s]

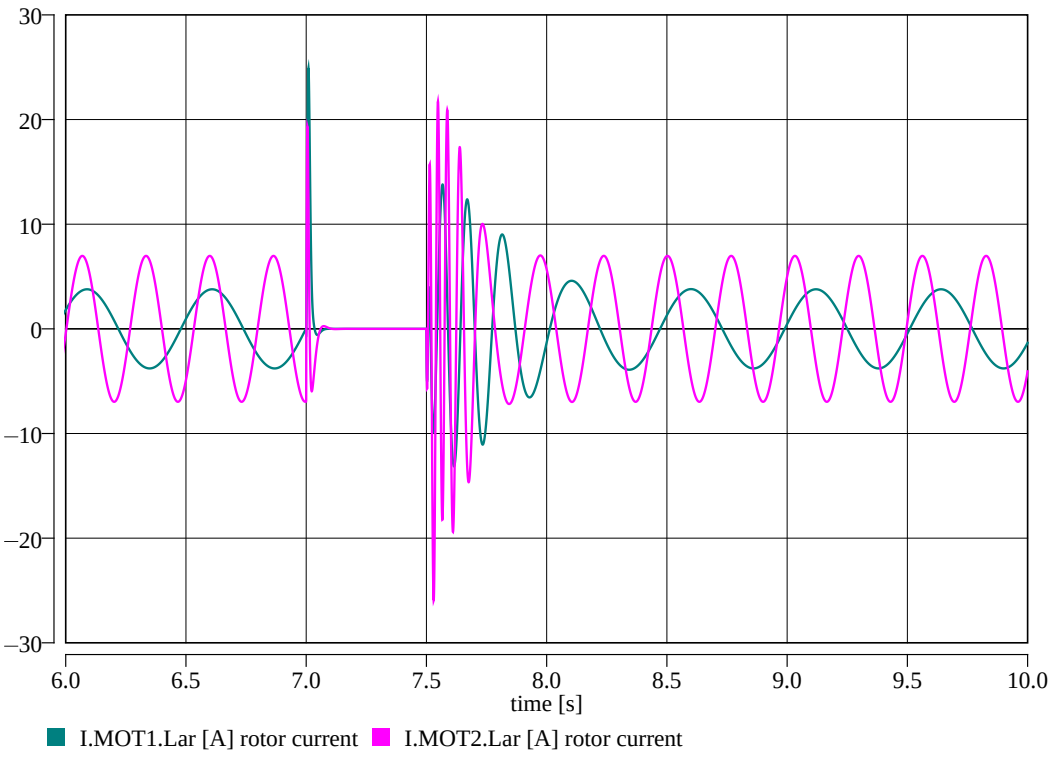

30
20
10
0
−10
−20
−30
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
time [s]
I.MOT1.Lar [A] rotor current
I.MOT2.Lar [A] rotor current

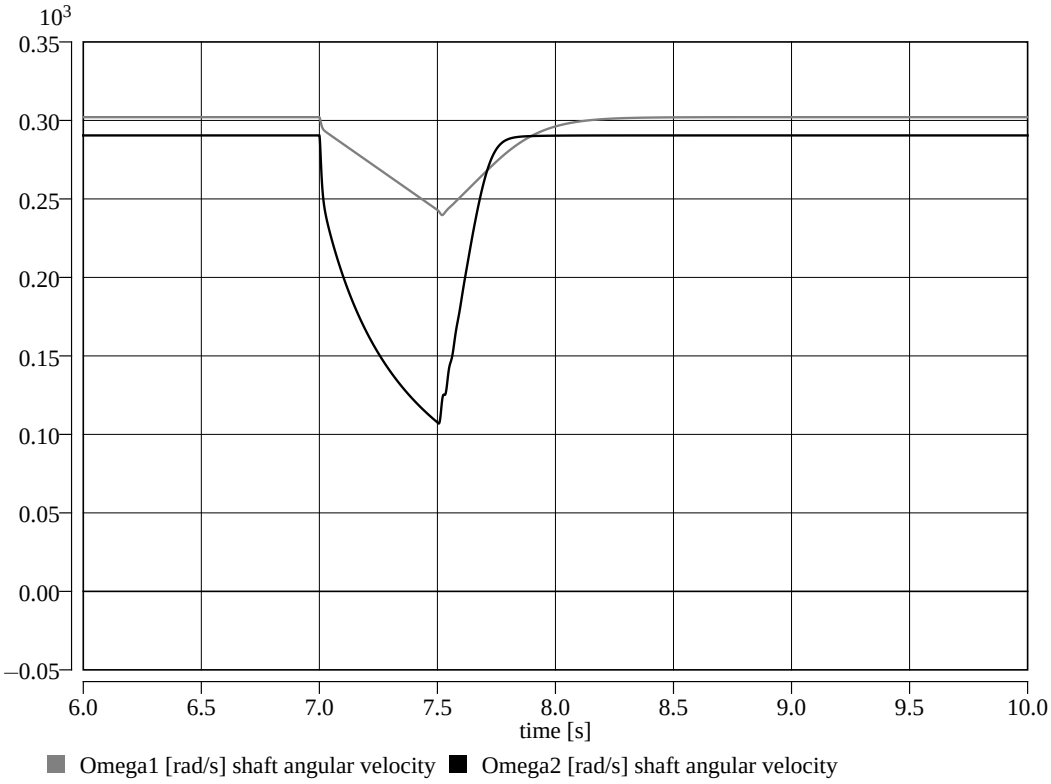

10^3
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
–0.05
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
time [s]
Omega1 [rad/s] shaft angular velocity
Omega2 [rad/s] shaft angular velocity

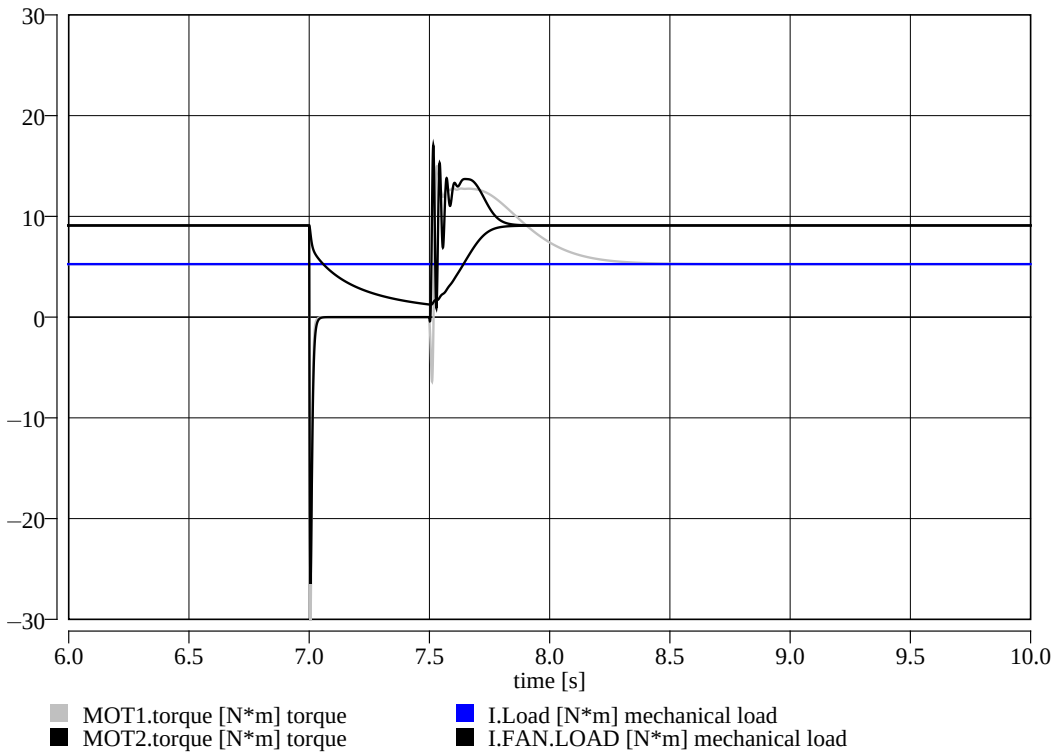

20
15
10
5
0
–5
–10
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
time [s]
MOT1.torque [N*m] torque
MOT2.torque [N*m] torque
I.Load [N*m] mechanical load
I.FAN.LOAD [N*m] mechanical load

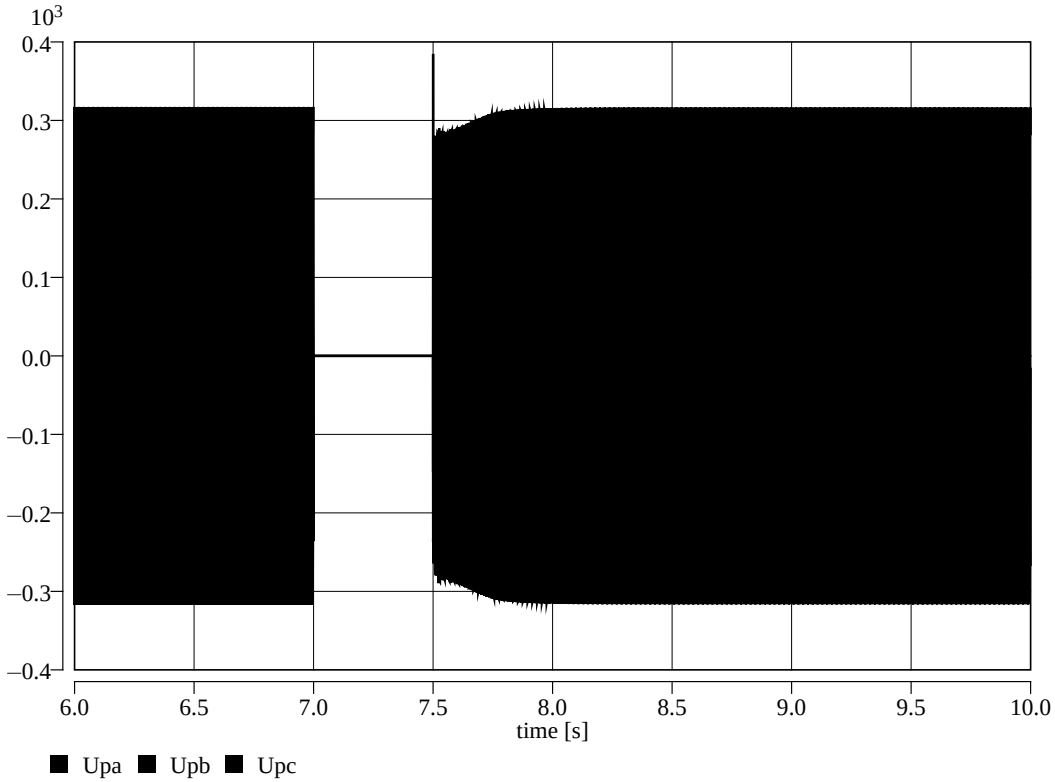

10^3
0.4
0.3
0.2
0.1
0.0
–0.1
–0.2
–0.3
–0.4
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
time [s]
Upa Upb Upc

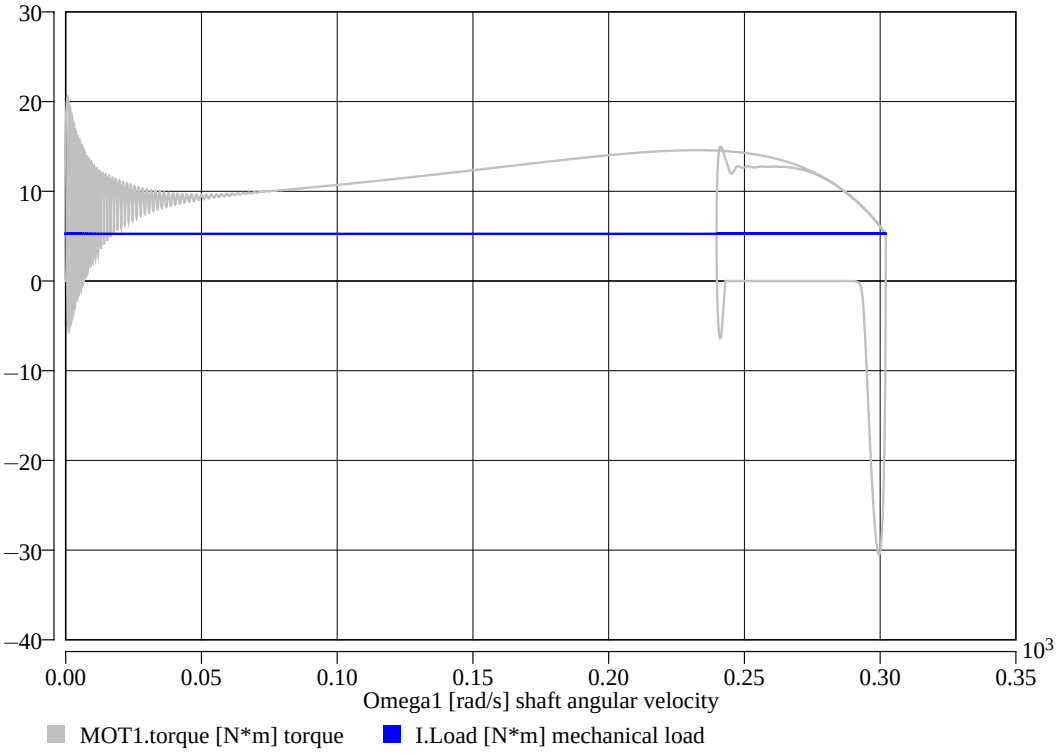

I.MOT1.Las [A] stator current
30
20
10
0
–10
–20
–30
I.MOT2.Las [A] stator current
30
20
10
0
–10
–20
–30
6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0
time [s]

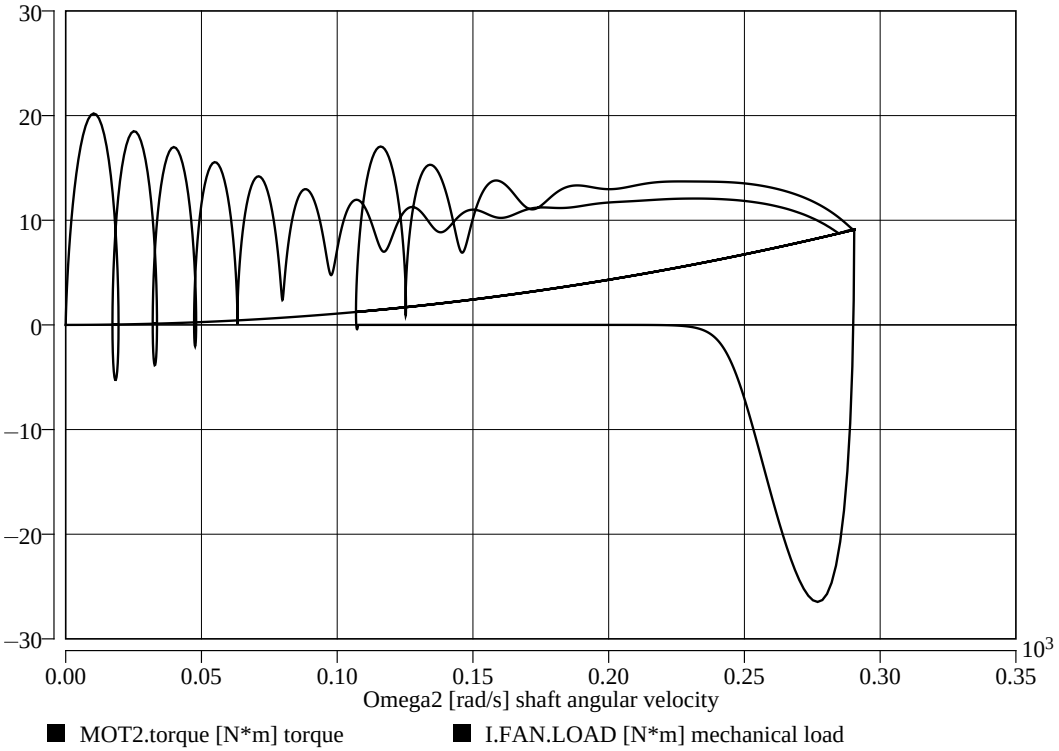

30
20
10
0
–10
–20
–30
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
time [s]
I.MOT1.Lar [A] rotor current
I.MOT2.Lar [A] rotor current


10^3
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
–0.05
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
time [s]
Omega1 [rad/s] shaft angular velocity
Omega2 [rad/s] shaft angular velocity


30
20
10
0
–10
–20
–30
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
time [s]
MOT1.torque [N*m] torque
MOT2.torque [N*m] torque
I.Load [N*m] mechanical load
I.FAN.LOAD [N*m] mechanical load


10^3
0.4
0.3
0.2
0.1
0.0
–0.1
–0.2
–0.3
–0.4
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
time [s]
Upa
Upb
Upc


30
20
10
0
−10
−20
−30
−40
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
10^3
Omega1 [rad/s] shaft angular velocity
MOT1.torque [N*m] torque
I.Load [N*m] mechanical load


30
20
10
0
−10
−20
−30
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
10^3
Omega2 [rad/s] shaft angular velocity
MOT2.torque [N*m] torque
I.FAN.LOAD [N*m] mechanical load