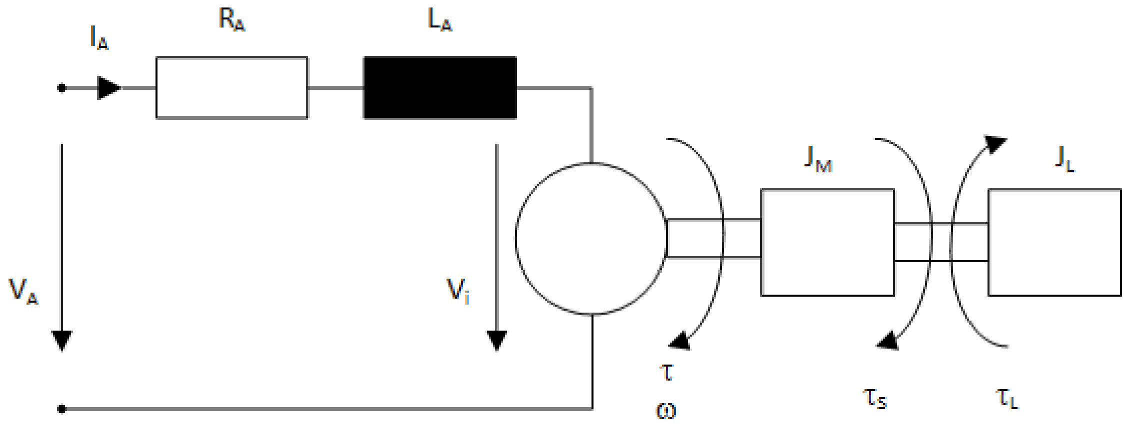
The kinetic energy of rotating masses is converted to electric energy using an electric machine and subsequently dissipated in the internal resistance and the external braking resistance to heat.

DC-Machine with Permanentmagnet Excitation



Farady's Law: $V_i = k\Phi \cdot \omega$

Lorentz' Law: $\tau = k\Phi \cdot I_A$

These two basic equations get implemented in the „electro-mechanical converter".

Kirchhoff's voltage law: $V_A = R_A \cdot I_A + L_A \cdot \frac{dI_A}{dt} + V_i$

Equation of Motion: $\tau - \tau_L = (J_r + J_L) \cdot \frac{d\omega}{dt}$

Parameter sets:

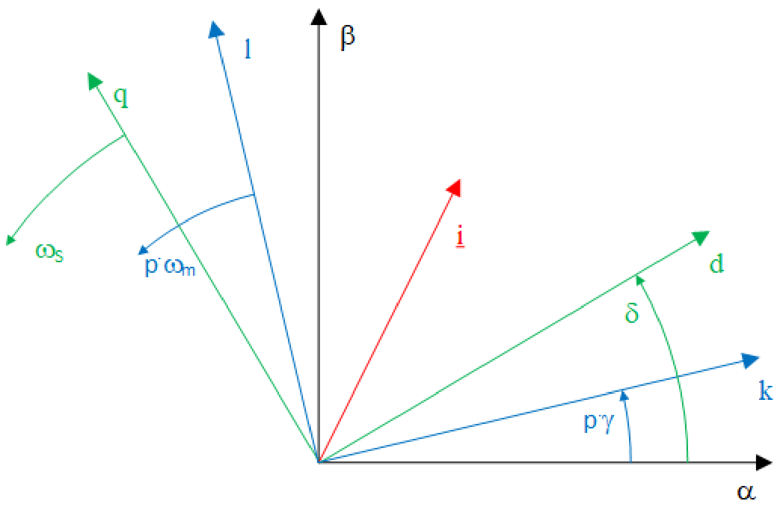
			Unite 48V	Unite XL
Nominal armature voltage	V_{ANom}	V	48	480
Nominal armature current	I_{ANom}	A	20	10
Armature resistance @ 20°C	R_{ARef}	Ω	0,23184	2,625
Nominal armature temperature	T_{ANom}	°C	95	95
Armature inductance	L_A	mH	0,6	6,5
Induced voltage at nom. speed	V_{iNom}	V	42	446
Nominal shaft speed	ω_{Nom}	rpm	3150	1500
No-load speed	ω_0	rpm	3600	1614
Machine constant	$k\phi$	Wb	0,127322243	2,839511426
Nominal torque	τ_{Nom}	Nm	2,546444851	28,39511426
Rotor's moment of inertia	J_r	kg.m²	0,0012	0,012
Stator's moment of inertia	J_s		4 x J_r	4 x J_r

$$R_A(95°) = R_A(20°) \cdot \frac{235° + 95°}{235° + 20°}$$

$$V_{iNom} = V_{ANom} - R_{A95°} \cdot I_{ANom} = k\phi \cdot \omega_{Nom}$$

$$V_{ANom} = k\phi \cdot \omega_0 \rightarrow \omega_0 = \omega_{Nom} \cdot \frac{V_{ANom}}{V_{iNom}}$$

Synchronous Machine with Permanentmagnet Excitation



Stator fixed frame $\alpha + j\beta$

Rotor fixed frame $k + jl$

Field fixed frame $d + jq$

For synchronous machines the field fixed frame and the rotor fixed frame are the same.

γ is the mechanical angle of the rotor φ_m (with respect to the stator).

For this machine Clarke and Park transform for voltages and currents are implemented in the corresponding electro-mechanical converter:

$$\begin{bmatrix} cos(p\cdot\varphi_m) & -sin(p\cdot\varphi_m) \\ sin(p\cdot\varphi_m) & cos(p\cdot\varphi_m) \end{bmatrix}\cdot\begin{bmatrix} i_d \\ i_q \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{2}{3}\cdot\begin{bmatrix} cos\left(0\cdot\frac{2\pi}{3}\right) & cos\left(1\cdot\frac{2\pi}{3}\right) & cos\left(2\cdot\frac{2\pi}{3}\right) \\ sin\left(0\cdot\frac{2\pi}{3}\right) & sin\left(1\cdot\frac{2\pi}{3}\right) & sin\left(2\cdot\frac{2\pi}{3}\right) \end{bmatrix}\cdot\begin{bmatrix} i_u \\ i_v \\ i_w \end{bmatrix}$$

The zero components fulfills the following equation:

$$i_0 = \frac{1}{3}\cdot(i_u + i_v + i_w)$$

$$v_0 = L_0\cdot\frac{di_0}{dt}$$

Set of Equations:

Due to magnetic saliency and the permanent magnets acting in one foxed direction with respect to the rotor the equations have to be implemented in the rotor fixed frame:

$$v_d = R_S\cdot i_d + L_d\cdot\frac{di_d}{dt} - p\cdot\omega_m\cdot L_q\cdot i_q$$

$$v_q = R_S\cdot i_q + L_q\cdot\frac{di_q}{dt} + p\cdot\omega_m\cdot L_d\cdot i_d + p\cdot\omega_m\cdot\psi_{PM}$$

$$\tau = \frac{3}{2}\cdot p\cdot\left[\psi_{PM} + \left(L_d - L_q\right)\cdot i_d\right]\cdot i_q$$

$$\tau - \tau_L = (J_r + J_L)\cdot\frac{d\omega}{dt}$$

Parameter sets:

			S1FT7102	S1FT7105
Nominal RMS stator voltage per phase	V_{sNom}	V	$400/\sqrt{3}$	$400/\sqrt{3}$
Nominal RMS stator current per phase	I_{ANom}	A	8	15
Stator resistance @ 20°C	R_{sRef}	Ω	0,6	0,15
Nominal stator winding temperature	T_{sNom}	°C	95	95
d-axis inductance	L_d	mH	12,5	4,2
q-axis inductance	L_q	mH	12,5	4,2
zero component inductance	L_0	mH	1,25	0,42
Open circuit RMS voltage at nom. speed	V_{sOC}	V	183,8571932	199,7631931
Nominal shaft speed	ω_{Nom}	rpm	1500	2000
Number of pole pairs	p		5	5
Nominal stator frequency	f_s	Hz	125	166,6666667
Rotor's moment of inertia	J_r	kg.m²	0,009	0,018
Stator's moment of inertia	J_s		4 x J_r	4 x J_r

The machines have $m = 3$ stator phases, the windings are star-connected.

Stator frequency is strictly related to mechanical shaft speed:

$$2\pi \cdot f_s = p \cdot \omega_m$$

Flux linkage space phasor of stator due to permanent magnets can be calculated from open circuit voltage at nominal speed:

$$\sqrt{2} \cdot V_{sOC} = \psi_{PM} \cdot 2\pi \cdot f_s$$