

Jahrestagung ILEAG e.V.

Auslegung und Entwicklung einer Reluktanzmaschine in Sternschaltung (SRS)

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05.12.2016

Zwickau

Wissen für Morgen



Agenda



DLR Institute of Transportation Systems



E-Mobility



SRS Concept





Quelle: efw-Suhl



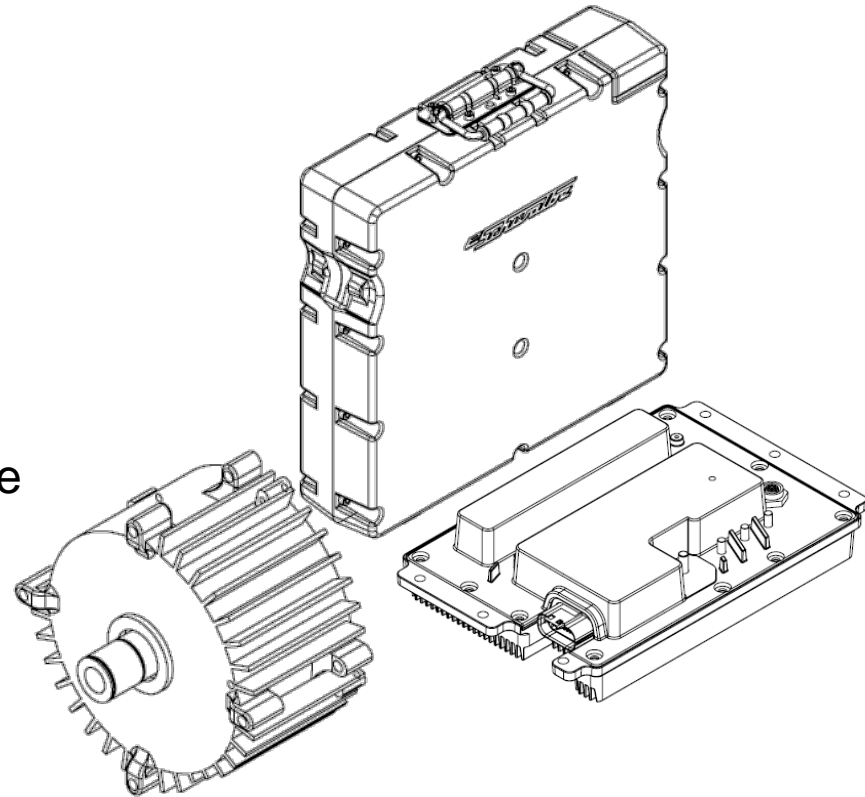


<http://www.myschwalbe.com/>



SRS

- Maximales Drehmoment: 40 Nm
- Maximale Leistung: 7,5kW
- Maximale Drehzahl: 1700/Min
- Der Bauraum ist wie folgt festgelegt:
Außendurchmesser Stator: 180mm; Länge Stator: 75mm
- Die Motoren werden an einer Zwischenkreisspannung von 48V betrieben.
- Der Umrichter liefert einen maximalen Phasenstrom von 240A.

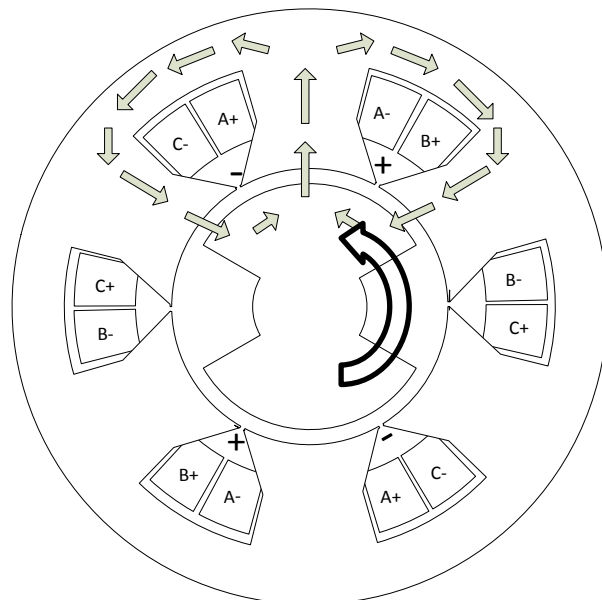
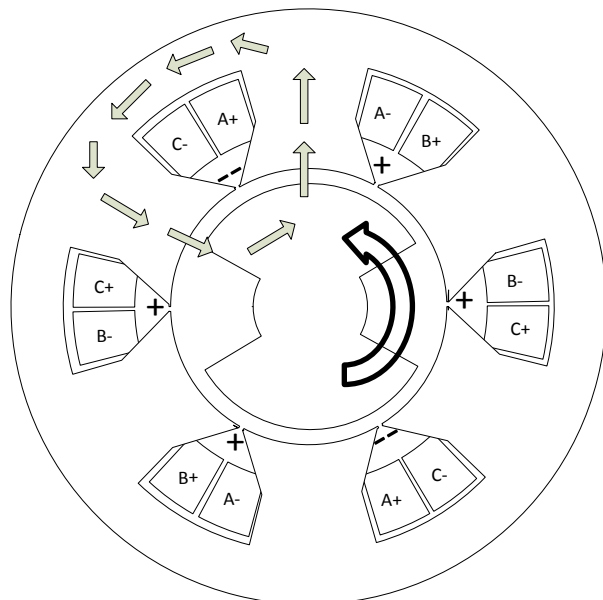
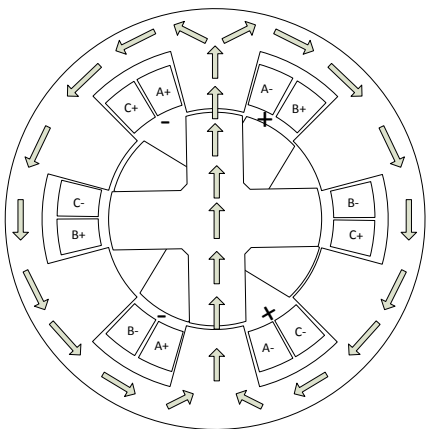


Operating data: Operating point 3 @ 20.0°C winding and magnet temperature, sinussoidal currents, wye connection

Designation	Formula char.	Value	Unit
Peak torque	T_3	5.6	Nm
Max. speed @ peak torque	n_3	1.700.0	rpm
Shaft power	P_{mech3}	997.3	W
Efficiency	η_3	87.4	%
Total losses	P_{Tot3}	142.8	W
Ohmic losses	P_{Cu3}	7.4	W
Iron losses	P_{Fe3}	131.8	W
Magnet losses	P_{Mag3}	3.6	W
RMS value of the phase currents	I_{Ph3}	20.4	A
Phase advance angle	γ_3	0.0	el. deg.
DC link voltage	U_{DC3}	48.0	V

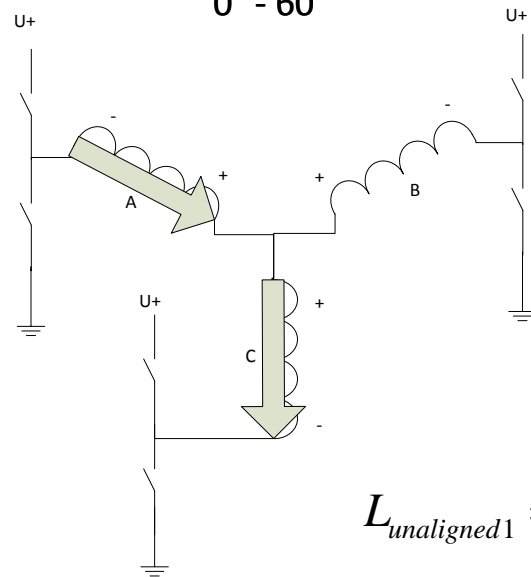
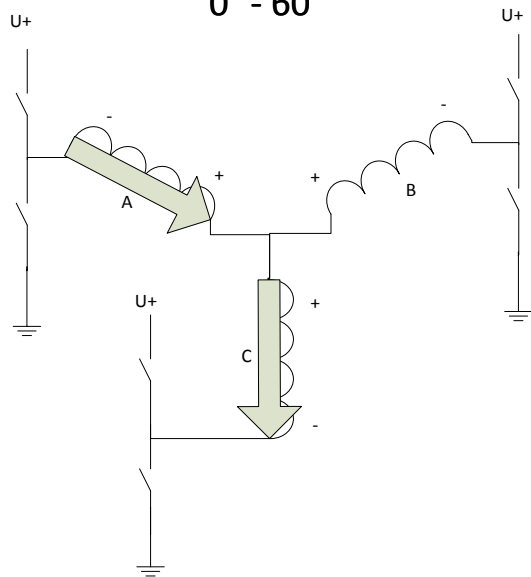


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0° - 60°

0° - 60°



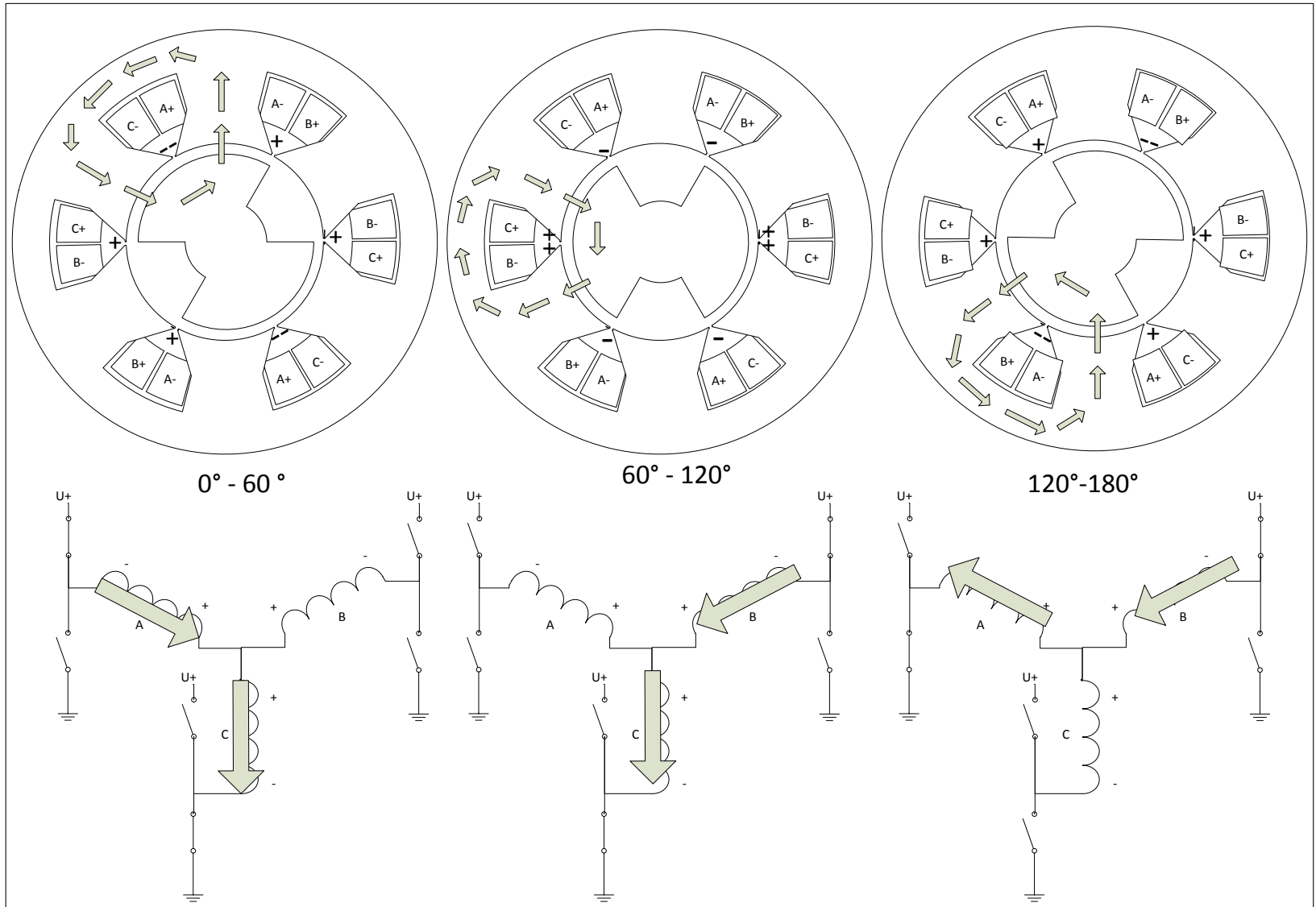
$$L_{aligned} = \frac{N^2}{R_{mSRS}} = \frac{4N_z^2}{R_{mSRS}}$$

$$L_{unaligned 2} = 0$$

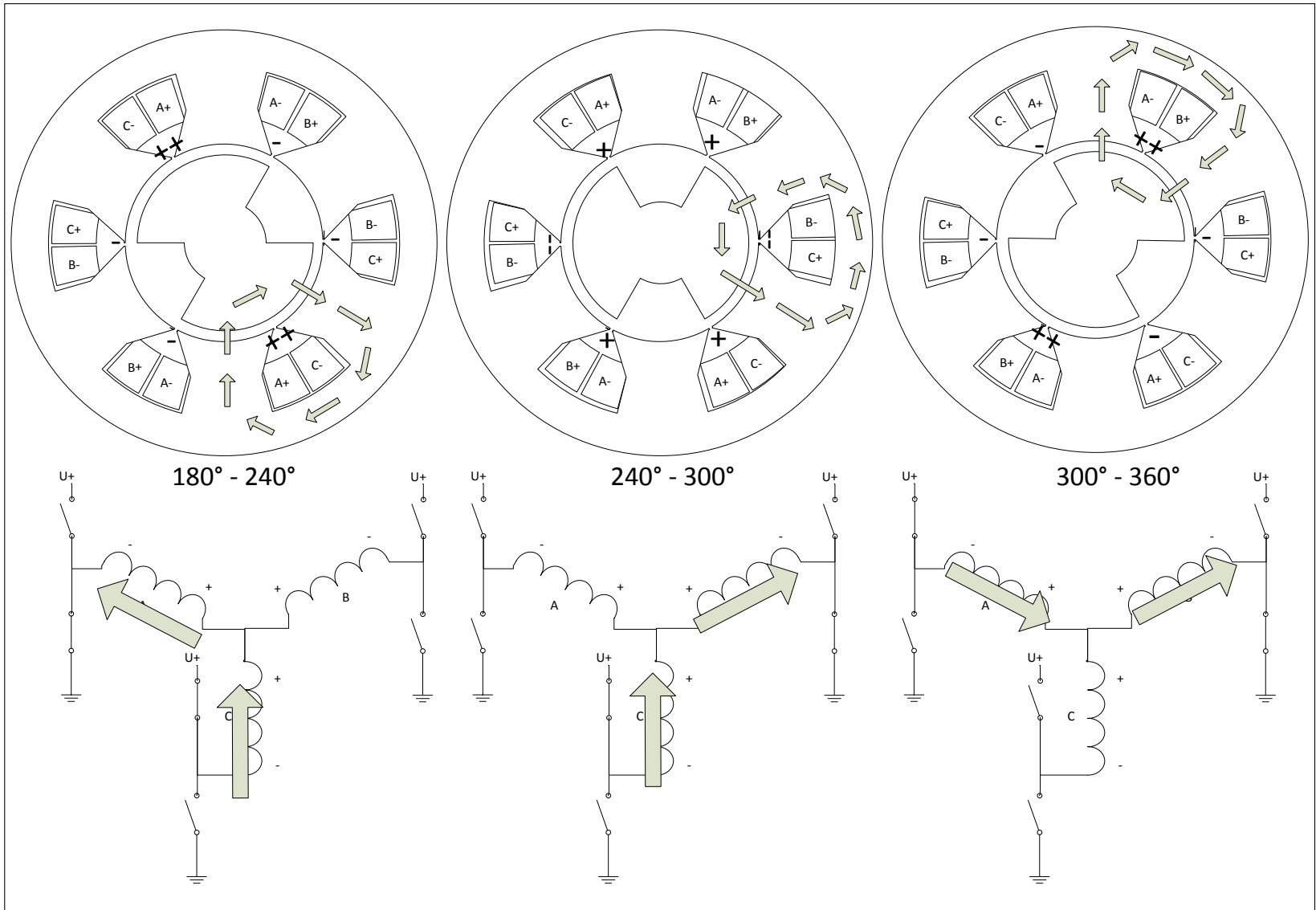
$$L_{unaligned 1} = \frac{N_z^2}{R_{mSRS}}$$



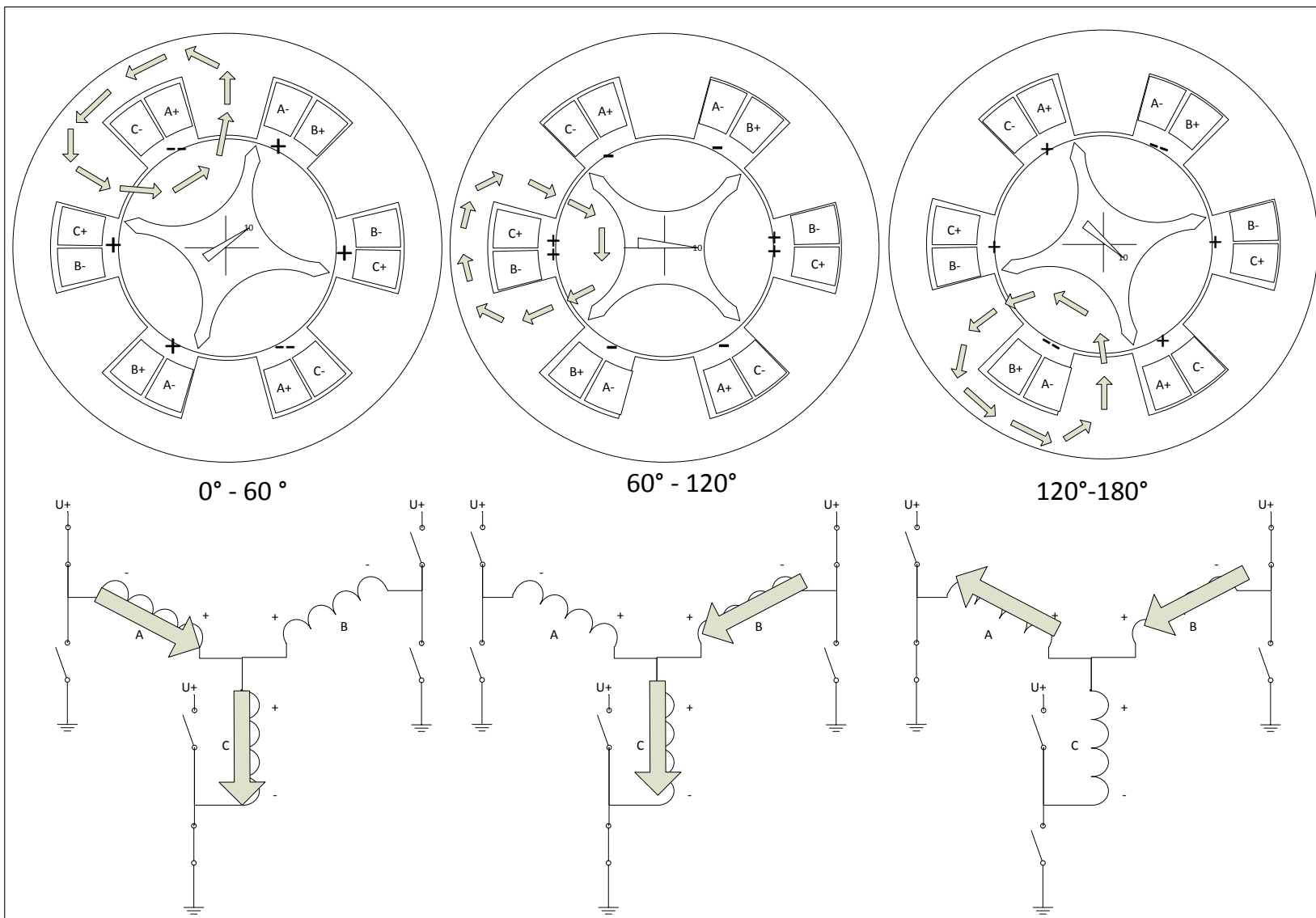
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	S/R	SRS 6/2	SRS 6/4
M	$M_{SR}(\varphi, I) \approx \frac{l_{air} B_{max}^2 r_{ls} l_s N_N}{12 \mu_0 \mu_r}$	$M_{SRS}(\varphi, I) \approx \frac{l_{air} B_{max}^2 C_{mSRS}^2 r_{ls} l_s N_N}{8 \mu_0 \mu_r}$	$M_{SRS}(\varphi, I) \approx \frac{l_{air} B_{max}^2 C_{mSRS}^2 r_{ls} l_s N_N}{8 \mu_0 \mu_r}$
Omega	$\varpi_{mSR} = \frac{U_{ZK}}{B_{max} C_m r_{ls} l_s c_{wSR} N_Z}$	$\varpi_{mSRS} = \frac{8}{3} \frac{\pi U_{ZK}}{B_{max} A_{Core} c_{wSRS} N_Z N_N}$	$\varpi_{mSR} = \frac{4}{3} \frac{U_{ZK}}{B_{max} r_{ls} l_s c_{wSRS} N_Z}$
P	$P_{max} = \frac{l_{air} B_{max} N_N}{12 \mu_0 \mu_r} \frac{U_{ZK}}{c_{wSR} N_Z}$	$P_{max} = \frac{l_{air} B_{max} C_{mSRS} N_N}{6 \mu_0 \mu_r} \frac{U_{ZK}}{c_{wSRS} N_Z}$	$P_{max} = \frac{l_{air} B_{max} N_N}{6 \mu_0 \mu_r} \frac{U_{ZK}}{c_{wSRS} N_Z}$
Pcore	$P_{Fe} = m_{Fe} k_{1,5T} \left(\frac{1}{50Hz} \frac{\varpi_m}{2\pi} N_P \right)^{1,6} \left(\frac{B_{max}}{1,5T} \right)^2$	$P_{Fe} = m_{Fe} k_{1,5T} \left(\frac{1}{50Hz} \frac{\varpi_m}{2\pi} N_P \right)^{1,6} \left(\frac{B_{max}}{1,5T} \right)^2$	$P_{Fe} = m_{Fe} k_{1,5T} \left(\frac{1}{50Hz} \frac{\varpi_m}{2\pi} N_P \right)^{1,6} \left(\frac{B_{max}}{1,5T} \right)^2$



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Tabelle 1: Drehmoment und Leistung verschiedener Motorauslegungen

Bezeichnung	r_{ls} (m)	c_w	N_Z	N_N	C_m	A_{Core} [m ²]	ϖ_m [1/Min]	M_{max} [Nm]	P_{max} [kW]
PMSM 18/16	0,05	12	3	18	0,9	0,00118	1768	40,0	7,4
S/R 18/15	0,05	6	4	18	1	0,00065	4244	12,9	5,7
SRS 18/6	0,05	12	4	18	0,9	0,00118	3144	15,7	5,2
SRS 18/12	0,05	12	4	18	1	0,00065	2829	19,3	5,7
S/R 42/35	0,053	14	4	42	1	0,00030	1716	31,8	3,3
SRS 27/18	0,053	18	4	27	1	0,00046	1780	30,7	5,7
SRS 30/10	0,053	20	4	30	0,9	0,00075	1780	27,3	5,1
SRS 36/10	0,053	24	4	36	0,9	0,00062	1483	33,2	5,2
SRS 36/20	0,053	24	4	36	1	0,00035	1335	40,9	5,7



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Bezeichnung	r_{ls} (m)	c_w	N_Z	N_N	C_m	A_{Core} [m ²]	ω_m [1/Min]	M_{max} [Nm]	P_{max} [kW]
PMSM 18/16	0,05	12	3	18	0,9	0,00118	1768	40,0	7,4
SRS 36/20 @320A	0,053	24	3	36	1	0,00035	1780	40,9	7,6



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Tabelle 3: Erhöhung der gravimetrischen und volumetrischen Leistungsdichte

Bezeichnung	l_s bzw. l_{s_opt} [m]	A_{Core} [m ²]	ϖ_m [1/Min]	M_{max} [Nm]	P_{max} [kW]	P_{core} [W]	$\frac{P_{core}}{P_{max}}$ [%]	f_{core} [Hz]	$\frac{l_s}{l_{s_opt}}$ [%]
PMSM 18/16	0,075	0,00118	1768	40,0	7,4	79	1,1%	38	100,0%
S/R 42/35	0,075	0,00028	2425	30,0	7,6	271	3,6%	180	100,0%
SRS 36/12	0,075	0,00059	2096	33,2	7,3	99	1,4%	67	100,0%
SRS 36/24	0,075	0,00033	1886	38,7	7,6	142	1,9%	120	100,0%
PMSM 18/16 (l_{s_opt})	0,009	0,00014	15031	4,7	7,4	286	3,9%	319	850,0%
S/R 42/35 (l_{s_opt})	0,063	0,00023	2910	25,0	7,6	302	4,0%	216	120,0%
SRS 36/12 (l_{s_opt})	0,013	0,00010	12575	5,5	7,3	291	4,0%	400	600,0%
SRS 36/24 (l_{s_opt})	0,021	0,00009	6791	10,8	7,6	305	4,0%	432	360,0%



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Kontakt

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