Exercise 10: 6-Pulse Bridge Circuit

For the assembly of a converter supplied DC drive train the following devices will be used:

Three-phase transformer:

Rated power:	$S_{\mathrm{Tr}} = 180\ \mathrm{kVA}$	Equivalent resistance per phase:	$R = 8\ \mathrm{m\Omega}$
Nominal secondary line voltage:	$U_{\mathrm{LN}} = 400\ \mathrm{V}$	Equivalent inductance per phase:	$L = 0.1\ \mathrm{mH}$

DC motor:

Nominal power:	$P_{\mathrm{N}} = 160\ \mathrm{kW}$	Resistance of armature circuit:	$R_{\mathrm{A}} = 25\ \mathrm{m\Omega}$
Nominal voltage:	$U_{\mathrm{AN}} = 440\ \mathrm{V}$	Inductance of armature circuit:	$L_{\mathrm{A}} = 2\ \mathrm{mH}$
Nominal current:	$I_{\mathrm{AN}} = 390\ \mathrm{A}$		

Smoothing inductor:

Inductance:	$L_{\mathrm{Dr}} = 4\ \mathrm{mH}$	Resistance:	$R_{\mathrm{Dr}} = 5\ \mathrm{m\Omega}$

Thyristors:

Threshold voltage:	$U_{\mathrm{T0}} = 1\ \mathrm{V}$	Equivalent resistance:	$r_{\mathrm{T}} = 1.5\ \mathrm{m\Omega}$
Recovery time:	$t_{\mathrm{q}} = 200\ \mu\mathrm{s}$		

1. Which converter topology is suitable for this application and why?
2. Draw the equivalent circuit diagram for this arrangement and write the formula to calculate $U_{\mathrm{d}\alpha}$. Determine the firing angle α_{N} for nominal operation.
3. Which control angle α_3 has to be set if the line voltage has dropped by 5% and the DC motor shall still be supplied with nominal voltage and current? How many percent P_{U} does the maximum available converter voltage U_{di0} lie above the required voltage?
4. Determine the maximal stress of the thyristors at nominal operation in case of ideal smoothed motor current with regard to
   - periodic peak blocking voltage U_{TRR}.
   - the arithmetic average current $I_{\mathrm{T(AV)}}$ and the root mean square current $I_{\mathrm{T(RMS)}}$.
   - power losses P_{T}.
   - the current slope di/dt.
5. Calculate the efficiency η_{A} of the complete drive train (neglect the excitation losses) and the efficiency η_{SR} of the converter at nominal operation.
6. For the analysis of the commutation, I_{d} and L_{k} are assumed to be constant. Draw the equivalent circuit diagram of the commutation loop when V_3 (phase 3) commutates to V_1 (phase 1). Calculate the overlap time at nominal operation. The commutation resistances (R_{k}) can be neglected.

7. Use the results from problem 6 and the auxiliary sheet below to draw the waveform of the output voltage and the voltage at the switch V_1. Draw the overlap time and the protection time as well.
8. Determine the maximum control angle α for the worst case condition if the protection time is twice as high as the recovery time at $U_{\mathrm{LN}} = 400\ \mathrm{V} \pm 10\%$.

Auxiliary diagram for problem 7