1 Buck Converter with RCD Snubber

Figure 1 shows the circuit diagram of a Buck-Converter which is used to supply the D.C. clutch drive of an electrical fork lifter. The output current is additionally smoothed by the ripple filter choke L_G .

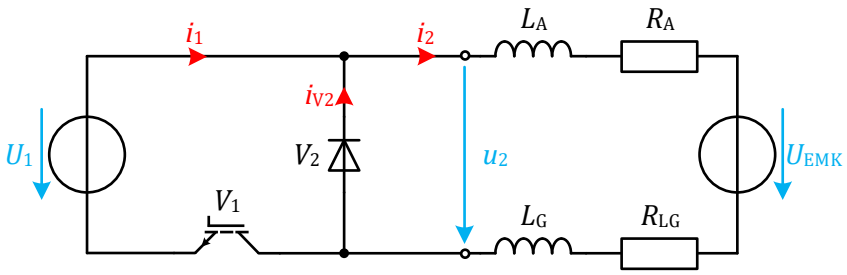

Figure 1: Buck-Converter

The following values are known:

- Input voltage: $U_1 = 120$ V
- Induced counter voltage: $U_{EMK} = 60$ V
- Armature inductance: $L_A = 500$ µH
- Ripple filter choke: $L_G = 1.5$ mH
- Load resistance $(R_L = R_A + R_{LG})$: $R_L = 0.5\ \Omega$
- Switching period: $T_S = 0.5$ ms
- Time constant of the ohmic-inductive load: $\tau_L = (L_A + L_G)/R_L$

1. Calculate the turn-on-time T_e when the output current becomes discontinuous $(i_2(0) = i_2(T_S))$ and sketch the temporal current and voltage waveforms of u_2,i_1,i_2 and i_{V2}. How much do the temporal waveforms change if the turn-on-time is reduced to the half of the calculated value?

2. Sketch the proportion of U_{EMK}/U_1 for a variable T_e/T_S when the Buck-Converter operates in boundary conduction mode and

   a) $\tau_L = 0.2 \cdot T_S$

   b) with negligible R_L

3. How much are the mean value of the output current I_2 and the ripple of the output current Δi_2 if the Buck-Converter operates in steady state with $T_e = 0.35$ ms?

The RCD snubber circuit around the switching transistor V_1 prevents the invalid high voltages that appear due to the parasitic leakage inductances L_{S1}...L_{S4} of the wiring and voltage source.

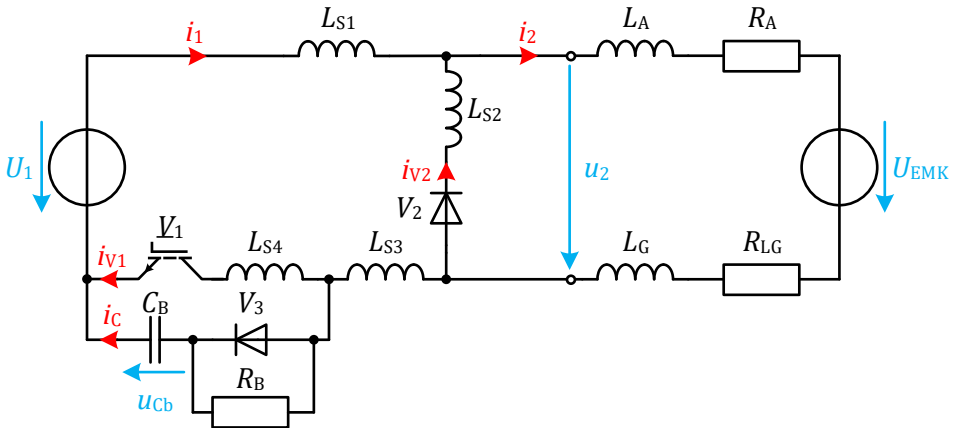

Figure 2: Buck-Converter with RCD-Snubber and leakage inductances

The following values are also known:

- Leakage inductances: $L_{S1} = 2\ \mu H$
  $L_{S2} = L_{S3} = L_{S4} = 100\ nH$

4. Calculate the temporal voltage waveforms of the capacitor voltage u_{Cb} and the transistor voltage u_{CE} right after the turn-off event and with the following assumptions:
   a) The output current is constant during the turn-off process $I_2 = 50$ A
   b) The transistor current i_{V1} decreases within the turn-off time $t_f = 1\ \mu s$ until it reaches zero.
   c) The RCD snubber circuit has ideal components.
5. Compute the capacitance of C_B for the given specification of $u_{CE} \leq 2 \cdot U_1$.
6. Calculate the power loss P_V of the resistor R_B if the Buck-Converter operates in periodically switching mode. Determine the maximum valid value of the switching frequency for a specified loss of $P_V \leq 50$ W on the condition that the whole energy, stored in the capacitor C_B, is transformed to heat in the resistor R_B.