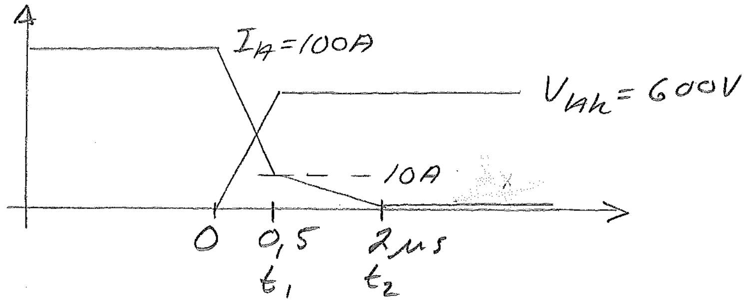
BWW Uppg 8.1



GTO-tyristor med RCD charge-discharge snubber

$f_{sw} = 1kHz$

i) Man måste räkna på två olika intervall

$0 < t < 0,5\mu s$: $p(t) = v(t)\cdot i(t) = \frac{V_{AK}}{\Delta t_1}\cdot t\left(I_{AK_1} - \frac{\Delta I_{AK_1}}{\Delta t_1}\cdot t\right)$

$0,5 < t < 2\mu s$: $p(t) = v(t)\cdot i(t) = V_{AK}\left(I_{AK_2} - \frac{\Delta I_{AK_2}}{\Delta t_2}(t - t_1)\right)$

$$E_{off} = \int_0^{2\mu s} v(t)\cdot i(t)\,dt =$$

$$= \int_0^{0,5\mu s} \frac{600}{0,5\cdot 10^{-6}}\cdot t\left(100 - \frac{90}{0,5\cdot 10^{-6}}\cdot t\right)dt +$$

$$+ \int_0^{1,5\mu s} 600\left(10 - \frac{10}{1,5\cdot 10^{-6}}t\right)dt =$$

$$= \int_0^{0,5\mu s} 1200\cdot 10^6 t\,(100 - 180\cdot 10^6 t)\,dt + \int_0^{1,5\mu s} 6000 - 4\cdot 10^9 t\,dt =$$

$$= \int_0^{0,5\mu} (120\cdot 10^9 t - 216\cdot 10^{15} t^2)\,dt + \int_0^{1,5\mu} 6000 - 4\cdot 10^9 t\,dt =$$

$$= \left[60\cdot 10^9 t^2 - 72\cdot 10^{15} t^3\right]_0^{0,5\mu} + \left[6000t - 2\cdot 10^9 t^2\right]_0^{1,5\mu} =$$

$$= 6\cdot 10^{-3} + 4,5\cdot 10^{-3} = 10,5\,mJ$$

$$P_{off} = E_{off}\cdot f_{sw} = 10,5\cdot 10^{-3}\cdot 1\cdot 10^3 = 10,5\,W$$

$$\frac{P_{tail}}{P_{off}} = \frac{4,5}{10,5} = 42,9\%$$

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ii) $i_{Cs} = I_{out} - i_A = I_{out} - \left(I_{A0} - \frac{\Delta i_1}{t_1} \cdot t\right) = I_{out} - I_{A0} + \frac{\Delta i_1}{t_1} t$

$$i_{Cs} = C_s \frac{dv_c}{dt} \Rightarrow v_{Cs}(t_1) - v_{Cs}(0) = \frac{1}{C_s} \int_0^{t_1} i_{Cs}(t)\,dt =$$

$$= \frac{1}{C_s} \int_0^{t_1} \left(I_{out} - I_{A0} + \frac{\Delta i_1}{t_1} \cdot t\right) dt = \left\{ I_{out} = I_{A0},\ v_{Cs}(t_1) - v_{Cs}(0) = V_{dc} \right\} =$$

$$= \frac{1}{C_s} \int \frac{\Delta i_1}{t_1} t\, dt = V_{dc}$$

(1) $$V_{dc} = \frac{1}{C_s} \left[\frac{\Delta i_1}{2t_1} \cdot t^2 \right]_0^{t_1} = \frac{1}{C_s} \frac{\Delta i_1}{2} \cdot t_1$$

$$C_s = \frac{\Delta i_1}{2 \cdot V_{dc}} \cdot t_1 = \frac{90}{2 \cdot 600} \cdot 0{,}5 \cdot 10^{-6} = \underline{\underline{37{,}5\,nF}}$$

$$E_{off_1} = \int_0^{t_1} \underbrace{\frac{1}{C_s} \frac{\Delta i_1}{2t_1} \cdot t^2}_{(1) \Rightarrow v_{Cs}(t)} \cdot \underbrace{\left(I_{A0} - \frac{\Delta i}{t_1} \cdot t\right)}_{i_A(t)} dt =$$

$$= \frac{\Delta i_1}{C_s} \int_0^{t_1} \left(\frac{I_{A0}}{2t_1} \cdot t^2 - \frac{\Delta i}{2t_1^2} \cdot t^3 \right) dt = \frac{\Delta i_1}{C_s} \left[\frac{I_{A0}}{6t_1} \cdot t^3 - \frac{\Delta i_1}{8t_1^2} t^4 \right]_0^{t_1} =$$

$$= \frac{\Delta i_1}{C_s} \left(\frac{I_{A0}}{6} t_1^2 - \frac{\Delta i_1}{8} t_1^2 \right) =$$

$$= \frac{90}{37{,}5\,nF} \left(\frac{100}{6} \cdot 0{,}5\,\mu s^2 - \frac{90}{8} \cdot 0{,}5\,\mu s^2 \right) = 3{,}25\,mJ$$

$P_{off_1} = 3{,}25\,mJ \cdot f_{sw} = 3{,}25\,W$

$P_{off,tail}$ är samma som innan $\Rightarrow$

$P_{off,tot} = 3{,}25 + 4{,}5 = \underline{\underline{7{,}75\,W}}$

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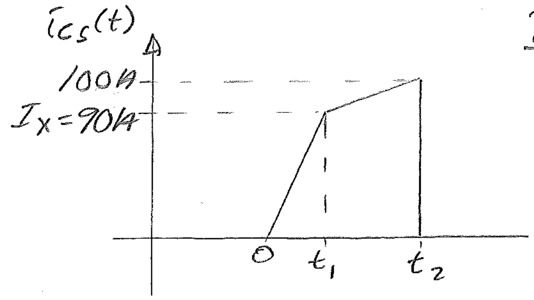

iii)

$$U_{c_s}(t_2)-U_{c_s}(0)=\frac{1}{C_s}\int_0^{t_2} i_{c_s}(t)\,dt=$$

$$=\frac{1}{C_s}\int_0^{t_1}\frac{\Delta i_1}{t_1}\cdot t\,dt+\frac{1}{C_s}\int_{t_1}^{t_2} I_x+\frac{\Delta i_2}{t_2-t_1}\cdot t\,dt=$$

$$=\frac{1}{C_s}\left(\left[\frac{\Delta i_1}{2t_1}\cdot t^2\right]_0^{t_1}+\left[I_x\cdot t+\frac{\Delta i_2}{2(t_2-t_1)}\cdot t^2\right]_{t_1}^{t_2}\right)=$$

$$=\frac{1}{C_s}\left(\frac{\Delta i_1}{2}t_1+I_x(t_2-t_1)+\frac{\Delta i_2}{2}(t_2-t_1)\right)=V_{dc}$$

$$C_s=\frac{1}{600}\left(\frac{90}{2}\cdot 0{,}5\cdot 10^{-6}+90\cdot 1{,}5\cdot 10^{-6}+\frac{10}{2}\cdot 1{,}5\cdot 10^{-6}\right)=275\,nF$$

$$E_{off}=\int_0^{t_1} U_{c_s}\cdot i_{c_s}\,dt+\int_{t_1} U_{c_s}\cdot i_{c_s}\,dt=$$

$$=\int_0^{0{,}5\mu s}\underbrace{\frac{1}{C_s}\frac{\Delta i_1}{2t_1}\cdot t^2}_{U_{cs}}\cdot\underbrace{\left(I_{A0}-\frac{\Delta i_1}{t_1}\cdot t\right)}_{i_A}dt+$$

$$+\int_{0{,}5\mu s}^{2\mu s}\underbrace{\frac{1}{C_s}\left(\frac{\Delta i_1}{2}t_1+I_x\cdot t+\frac{\Delta i_2}{2\Delta t_2}\cdot t^2\right)}_{U_{cs}}\cdot\underbrace{\left((I_{A0}-\Delta i_1)-\frac{\Delta i_2}{\Delta t_2}\cdot t\right)}_{i_A}dt=$$

$$=\int_0^{0{,}5\mu}\frac{1}{C_s}\frac{\Delta i}{2t_1}t^2 I_{A0}-\frac{1}{C_s}\frac{\Delta i_1^2}{2t_1^2}\cdot t^3\,dt+$$

$$+\int_{0{,}5}^{2}\frac{1}{C_s}\left(\frac{\Delta i_1}{2}t_1(I_{A0}-\Delta i_1)-\frac{\Delta i_1\Delta i_2}{2\Delta t_2}\cdot t_1\cdot t+I_x t(I_{A0}-\Delta i_1)-I_x\frac{\Delta i_2}{\Delta t_2}t^2\right.$$

$$\left.+\frac{\Delta i_2}{2\Delta t_2}(I_{A0}-\Delta i_1)t^2-\frac{\Delta i_2^2}{2\Delta t_2^2}\cdot t^3\right)dt=$$

$$= \frac{1}{C_s}\left[\frac{\Delta i_1}{2t_1} I_{A0} \frac{t^3}{3} - \frac{\Delta i_1^2}{2t_1^2}\cdot\frac{t^4}{4}\right]_0^{0,5\mu s} +$$

$$+ \frac{1}{C_s}\left[\frac{\Delta i_1}{2} t_1 (I_{A0}-\Delta i_1) t - \frac{\Delta i_1 \Delta i_2}{2\Delta t_2}\cdot t_1 \frac{t^2}{2} + I_X (I_{A0}-\Delta i_1)\frac{t^2}{2} - I_X \frac{\Delta i_2}{\Delta t_2}\frac{t^3}{3} + \right.$$

$$\left. + \frac{\Delta i_2}{2\Delta t_2}(I_{A0}-\Delta i_1)\frac{t^3}{3} - \frac{\Delta i_2^2}{2\Delta t_2^2}\frac{t^4}{4}\right]_{0,5}^{2\mu s} =$$

$$= \frac{1}{275nF}\left(\frac{90\cdot 100}{2\cdot 0,5\mu s}\cdot\frac{0,5\mu s^3}{3} - \frac{90^2}{2\cdot 0,5\mu s^2}\cdot\frac{0,5\mu s^4}{4}\right) +$$

$$+ \frac{1}{275nF}\left(\frac{90\cdot 0,5\mu s}{2}(100-90)\cdot 1,5\mu s - \frac{90\cdot 10}{2\cdot 1,5\mu}\cdot 0,5\mu \frac{1,5\mu^2}{2} + \right.$$

$$+ 90(100-90)\frac{1,5\mu^2}{2} - 90\frac{10}{1,5\mu}\cdot\frac{1,5\mu^3}{3} + \frac{10}{2\cdot 1,5\mu}(100-90)\frac{1,5\mu^3}{3} -$$

$$\left. - \frac{10^2}{2\cdot 1,5\mu^2}\cdot\frac{1,5\mu^4}{4}\right) = 2,318\,mJ$$

$$\Rightarrow P_{off} = E_{off}\cdot f_{sw} = 2,318\cdot 10^{-3}\cdot 1000 = \underline{\underline{2,32\,W}}$$