TRANSITION PROCESSES IN A DC/DC CONVERTER FOR BATTERY CHARGING

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A DC/DC converter for battery charging is investigated in respect to maximum components voltages and currents. Using PSPICE simulations, the influence of the snubber components R_{sn} and C_{sn} on the voltage and current stresses is analyzed for the given converter scheme and application. Practical equations for dimensioning the values of R_{sn} and C_{sn} are obtained. The operating parameters and efficiency of the converter are improved by optimising the filter components R_f and C_f. Conclusions are derived for proper design of R_{sn}, C_{sn}, R_f, and C_f.

Keywords: DC/DC Converter for battery charging; voltage and current stresses

1. INTRODUCTION

In [1] a DC/DC converter for battery charging is proposed (Fig.1) with ability to operate under high difference between the input and output voltages. But this feature leads to high pulse currents through the switches.

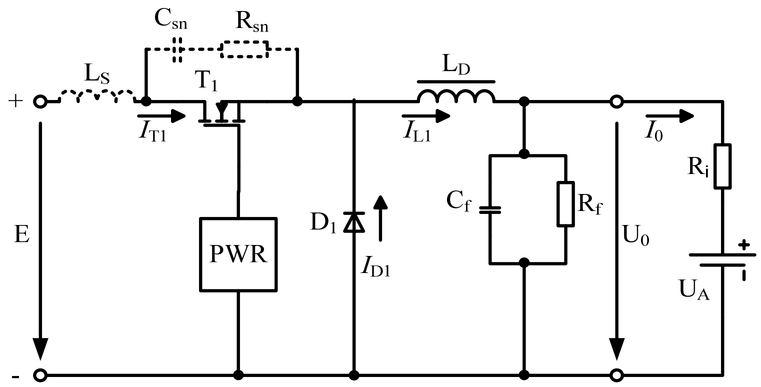


Fig.1. Investigated DC/DC converter for battery charging.

The aim of the paper is the investigation of the current and voltage stresses of the switches of the investigated DC/DC converter for battery charging (Fig.1), which occur during the transition processes of the converter, as well as the methods for decreasing their amplitudes. The transition processes of the converter occur when the load is turned on and off, when the switch is turned on and off or under emergency – failure in a component of the converter. Additional components are advisable to increase the reliability of the converter in case of failure.

For battery charging converters a low active losses are typical feature. Anyhow this fact creates conditions for heavy resonant processes by the parasitic components, causing high voltage and current stresses on the converter components.

One of the major tasks to be solved in switching mode power converters is decreasing the voltage and current stresses of the switches, caused by the parasitic components of the scheme. In Fig.2 typical voltage and current waveforms across the switch of the investigated scheme (Fig.1) are shown.

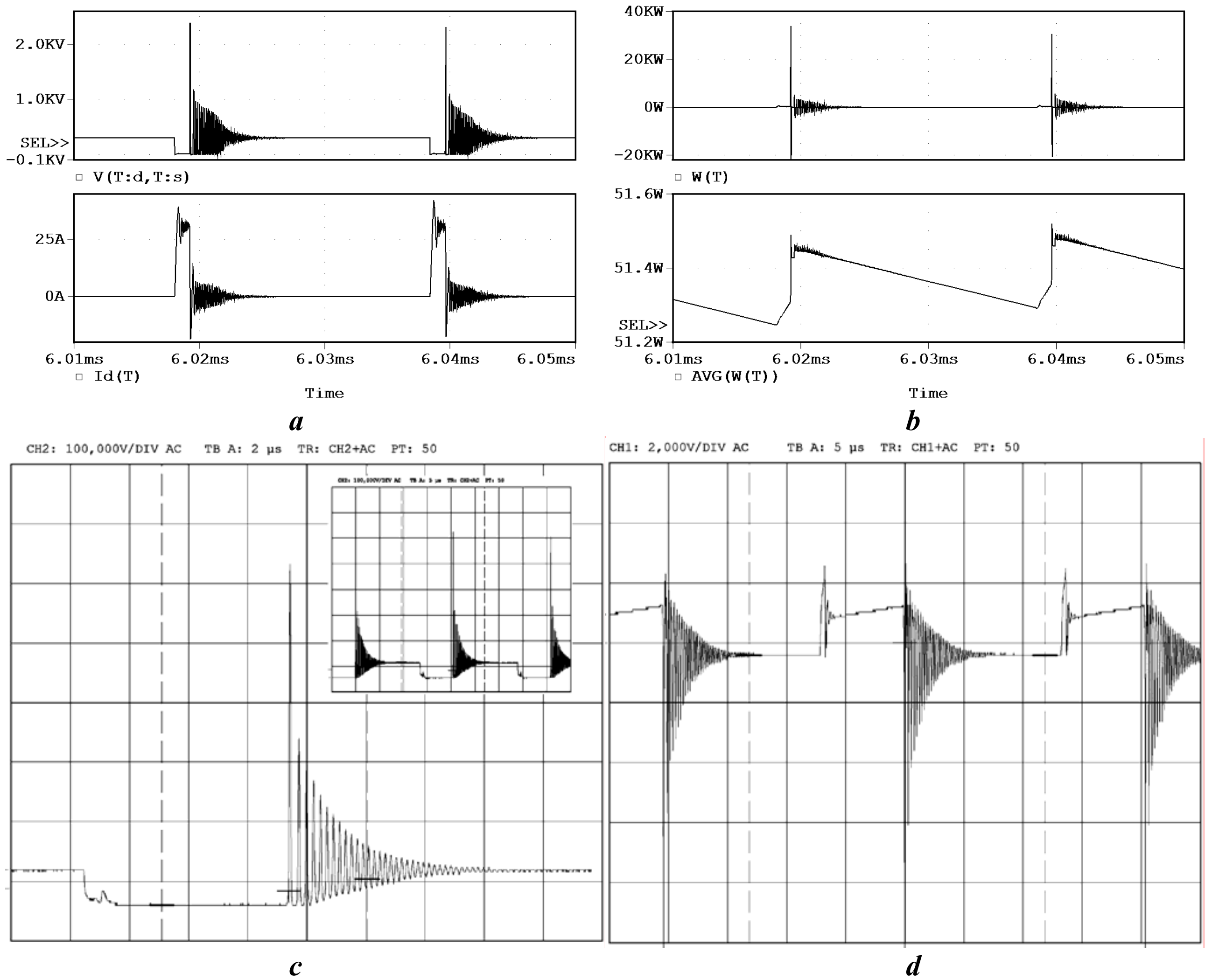


Fig.2. Waveforms at turn on and turn off of the switch transistor, parasitic elements considered:
Simulations: 2a – voltage and current of the transistor, 2b- switching and average transistor losses.
Experiments: 2c- voltage accros the transistor, 2d- current through the transistor.

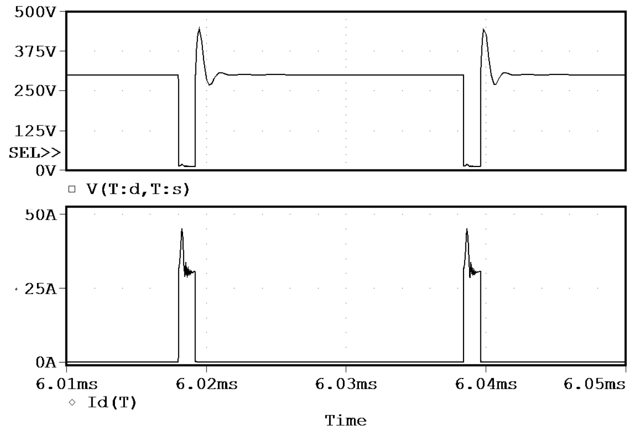
2. INVESTIGATION OF THE IMPACT OF PARALLEL SNUBBERS

It is clear that as a result of the parasitic inductance of the wires and the output capacity of the transistor, voltage peaks at turn off of the transistor are approximately 5 times bigger than the supply voltage – fig.2a. It is obvious that when the transistor is turned off a series resonant circuit is formed with frequency much higher than the frequency of the control circuit, which leads to significantly prolonged turn off time of the transistor. Consequently the switching and average losses are increased – Fig.2b.

With the addition of few extra elements to limit the increase rate of the transistor voltage and current, the influence of the previously mentioned parasitic reactive elements can be dramatically decreased.

One way to decrease the voltage peaks is adding a passive compensating circuit parallel to the transistor (C_{sn} and R_{sn}), shown with dashed line in Fig.1.

Calculating the value of R_{sn} is e relatively easy, when the frequency of the parasitic resonance processes is known. At known parasitic inductance L_S the value of the capacitor is calculated C_{sn}. Resistance R_{sn} is most often chosen equal or close to the value of the characteristic resistance of the formed resonance circuit – L_S-C_{sn}.



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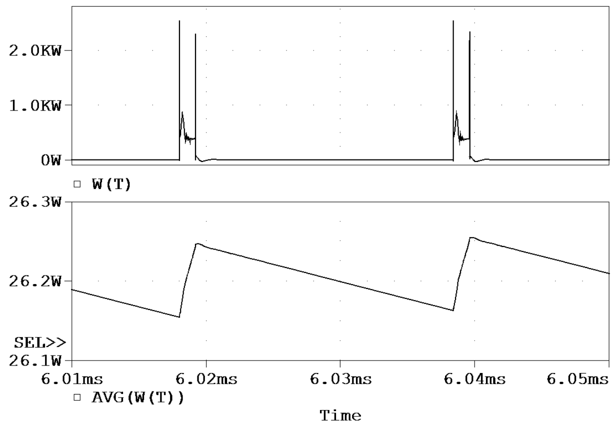

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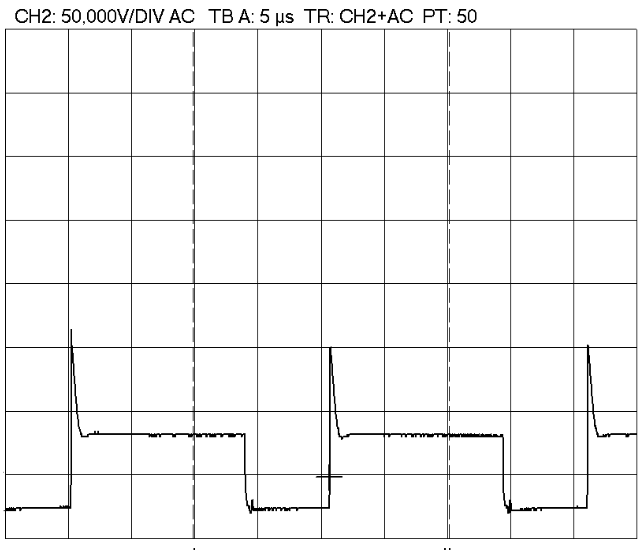

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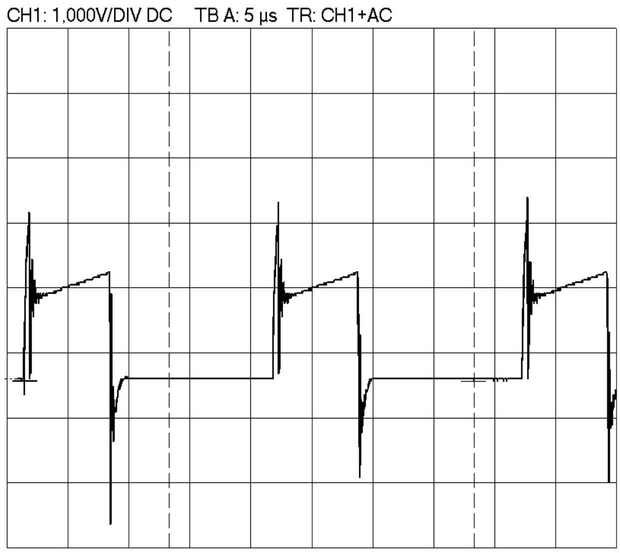


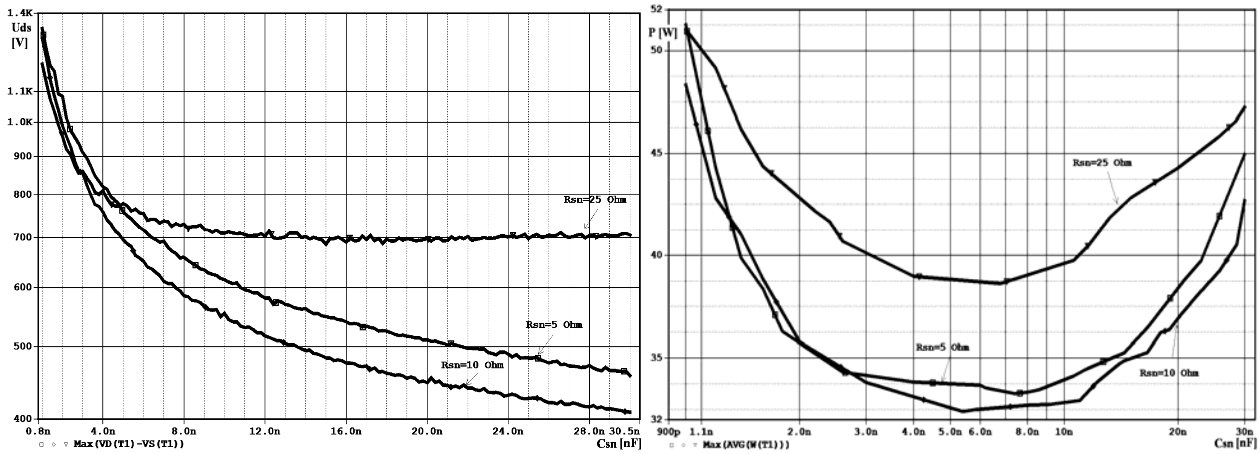
d

Fig. 3 Waveforms at turn on and turn off of the switch transistor with snubbers R_{sn}-C_{sn}:
Simulations: 3a – voltage and current of the transistor, 3b- switching and average transistor losses.
Experiments: 3c- voltage across the transistor, 3d- current through the transistor.

In figure 3 are shown corresponding waveforms with the additional compensating circuit (snubbers).

One can see that the voltage peaks are not higher that 50% of the supply voltage. Also the turn off time is decreased and parasitic resonance process is not detected. As a result the switching losses are significantly decreased which leads to decreasing the average losses in the transistor.

In figure 4 are shown the waveforms of voltage across the transistor vs. capacitance of C_{sn} at different values of R_{sn} – fig.4a and the average losses in the transistor – fig.4b.



a *b*

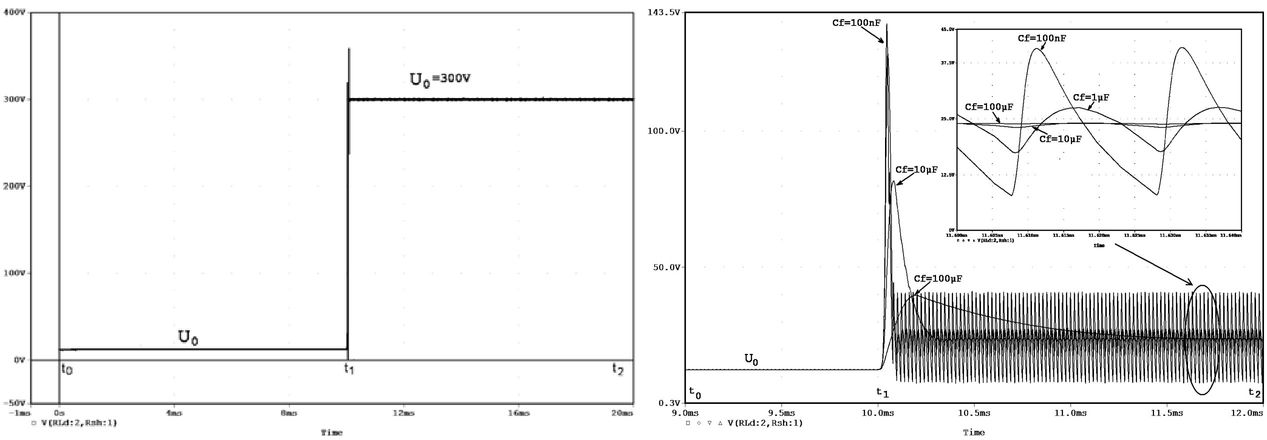
Fig.4. Maximum voltage and dissipated power of the transistor as a function of the capacitor.

From the graphs above it is clear that by using appropriate value of R_{sn} and C_{sn}, over-voltage across the transistor U_{DS} can be limited to values less than 500V, which is the maximum voltage of most frequently used switching transistors.

It should be mentioned that the value of the capacitor is not random. There is an optimal range of values for which the dissipated power is minimal.

3. Investigation of the Impact of Output Filter Components

For investigating the processes occurring in the DC/DC converter, the scheme is analyzed and in the conditions of turning on and off of the battery. In fig.5a are shown the waveforms without the components R_f and C_f (filter components). The time intervals are as follows: $t_0 \div t_1$ – working mode, $t_1 \div t_2$ – no load. It is obvious that during turn off interval of the battery (no load), the output voltage U_{out} is equal to the supply voltage E=300V. Decreasing that voltage to human-safe values can be achieved with additional elements R_f and C_f. In fig.5b are shown waveforms at different values of the capacitance C_f.

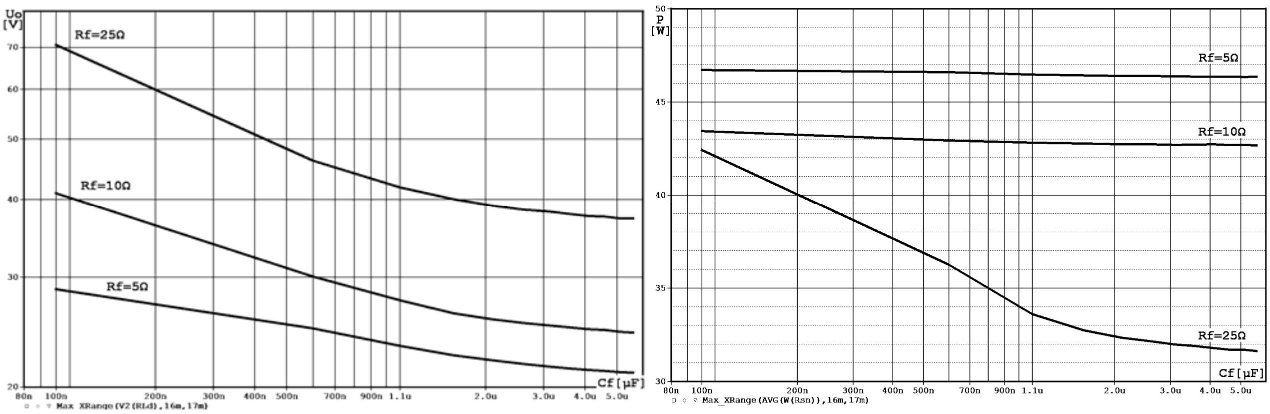


a *b*

Fig.5. Waveforms at load commutation. Fig.5a – waveforms without R_f-C_f. Fig.5b – waveforms at different values of C_f.

From the waveforms above, one can see that for low values of C_f during the switching process a voltage peak of U_{out} occurs, with value bellow 50V at $R_f = 10\Omega$. The pulsations of the output voltage are high at values of C_f, less than 1µF.

For more precise calculation of the values of C_f and R_f the practical diagrams are derived, shown in Fig.6.



a ***b***

Fig.6. Output voltage U_{out} and losses in R_f as a function of the value of C_f at different values of R_f. fig.6a – maximum output voltage, fig.6b – losses in R_f.

From the diagrams above it is clear that minimum losses are at C_f > 1µF and $R_f = 10 \div 25\Omega$ (for the investigated values of R_f and C_f). Besides this the output voltage increases at values of $R_f > 10\ \Omega$. From experiments and simulations the following formulas are derived:

$$R_f = (20 \div 50)\ R_{out}, \qquad C_f = (20 \div 40) / f.\ R_{out},$$

where $R_{out} = U_{out}/I_{out}$ is the equivalent load of the circuit;
f is the converter operating frequency.

In Fig.7 the total losses of the switch are shown for the two time intervals: operating mode – the switch is ON, and no closed switch mode.

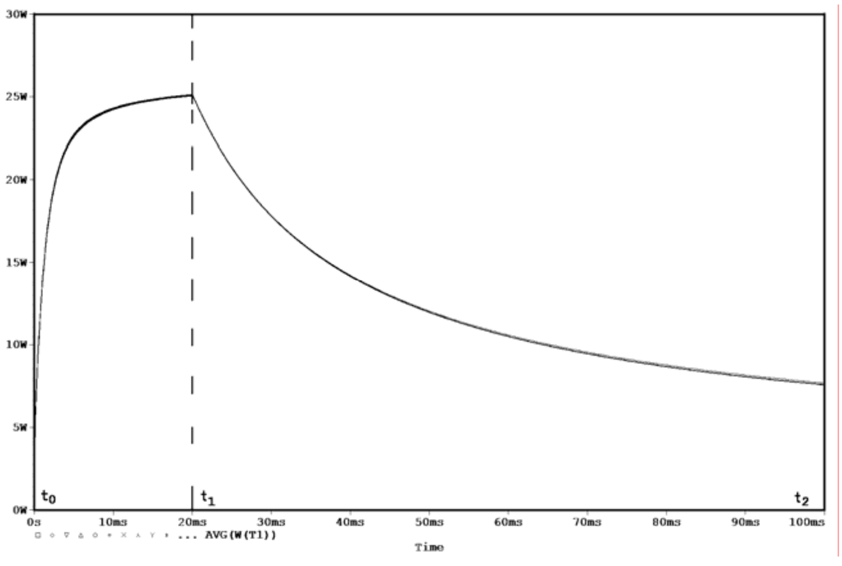


Fig.7. Power losses of the transistor.

4. CONCLUSIONS

1. The impact of the snubber components R_{sn} and C_{sn} on the voltage and current stresses is investigated for the considered converter scheme and application. Practical advices for choosing the values of R_{sn} and C_{sn} are derived ($R_{sn} \cong \sqrt{L_{sn} / C_{sn}}$).
2. The graphical dependence of the peak voltage and switch losses on R_{sn} and C_{sn} are obtained giving the recommendation for their optimal values.
3. The influence of the filter components R_f and C_f on the operating parameters and efficiency of the converter is investigated and conclusions are derived as well as equations for their dimensioning: R_f=(20÷50) R_{out}, C_f=(20÷40) / *f*. R_{out}.

5. ACKNOWLEDGMENT

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6. REFERENCES

[1] Yudov D., Dimitrov A., Valchev V., "*Step Down Converter Working With Opposite Electromotive Voltage*", BFU conference, Drqnovo, 29-30 April, 2006.

[2] Philip C. Todd '*Snubber Circuits: Theory , Design and Application'*.

[3] Yudov D., Valchev V., '*Power Electronics*', Textbook for the Technical University of Varna, 2006.