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Current-sharing influences in parallel buck DC/DC converters

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***Abstract* — The paper examines the influence of unequal inductance on current-sharing properties in parallel connected buck DC/DC converters. The article is also exploring the influence of different DC/DC converters connected together in parallel system on current-sharing capabilities. The mentioned influences are examined with the help of PC simulations.**

***Keywords* — current-sharing, DC/DC converter, inductance, PC simulations**

I. Introduction

The switch-mode power supplies (SMPS) are recently very popular because of their high effectivity, lower cost, smaller size and lower weight compared to conventional linear power supplies. The essential and vital part of every SMPS is DC/DC converter. The mostly used DC/DC converter in SMPS is buck (step-down) converter. This type of converter is also used for analyze in this article [3], [4].

The use of one DC/DC converter can easily reach its limits, when high power output is needed. A parallel interconnection of more converters can be appropriate and promising solution. However, more converters connected in parallel are mostly problematic and some special arrangements are necessary. The load of every converter needs to be equal to each other. In other words, the level of their output currents needs to be equal or very similar. It is the basic principle and a requirement for proper functioning. This property and at the same time basic requirement is well known as **current-sharing**, thus converters need to have the same share on the overall amount of output current. When this is not satisfied, one of the converters may be very dominant and subsequently excessively stressed. Consequently, it leads to faults and the whole system is not functional and does not deliver the required amount of output power [1], [2], [5], [6].

In further chapters are verifications conducted by PC simulations of how unequal inductances negatively influence the current-sharing. Another verification concerns use of two different converters in one system. For all the simulations are used OrCAD and its PSpice module.

II. Influence of unequal inductance

A. *Same inductances ($L_1=100\mu H$; $L_2=100\mu H$)*

Because of the possibility to evaluate the influence of unequal inductances, there is a need to have results from system with same inductances. Therefore the first step is to simulate parallel connected converters, but with same inductance value $L_1=L_2=100\mu H$. For both converters were used LM2576 switching regulators, specifically their PSpice models. Also, both converters have same capacitors $C_3=C_4=1mF$ and they are supplied from one power supply U=40V.

Scheme of the system from OrCAD is in the Fig. 1.

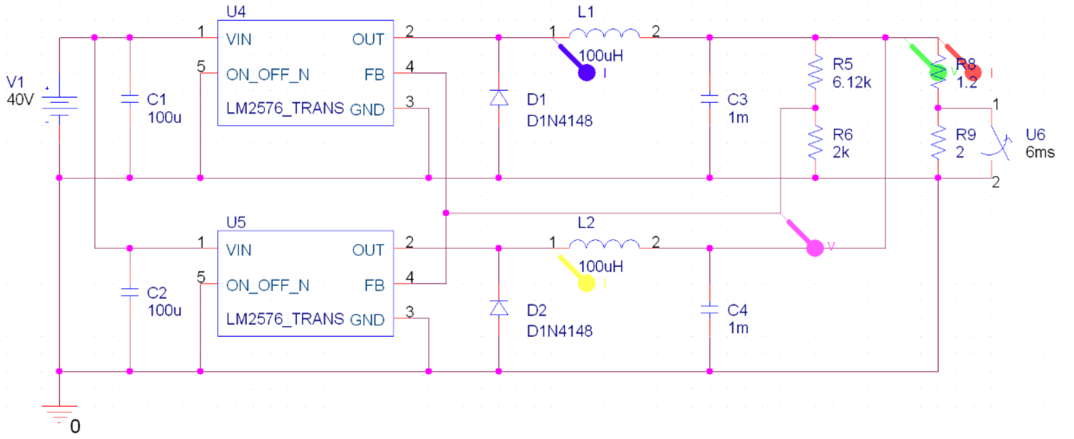

Fig. 1 Scheme of the parallel connected DC/DC converters with the same inductance value (L_1=100µH; L_2=100µH)

The output resistive load is variable. In time of 6ms resistivity increases from 1,2Ω to 3,2Ω. Consequently, output currents will differ according to variation in load. The simulation results of the system are in the Fig. 2 and Fig. 3.

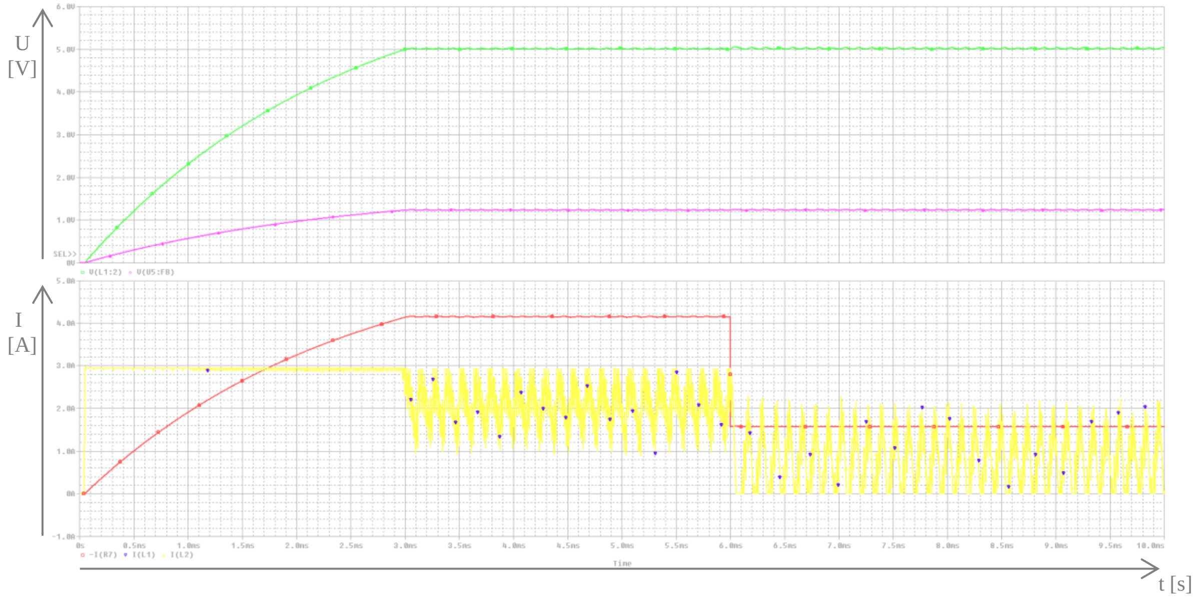

Fig. 2 Simulation results of the parallel DC/DC converters with the same inductance value (L_1=100µH; L_2=100µH)

Fig. 3 Detailed simulation results of the parallel DC/DC converters with the same inductors(L_1=100µH; L_2=100µH)

From the Fig. 2 and Fig. 3 can be clearly seen that currents are quite equal. For R_z=1,2Ω is average of both currents 2A and for R_z=3,2Ω it is 1A. Output voltage is regulated to 5V.

B. *Unequal inductances (L_1=100µH; L_2=200µH)*

Scheme stays the same in this case, only inductance value in the second converter is 100µH higher.

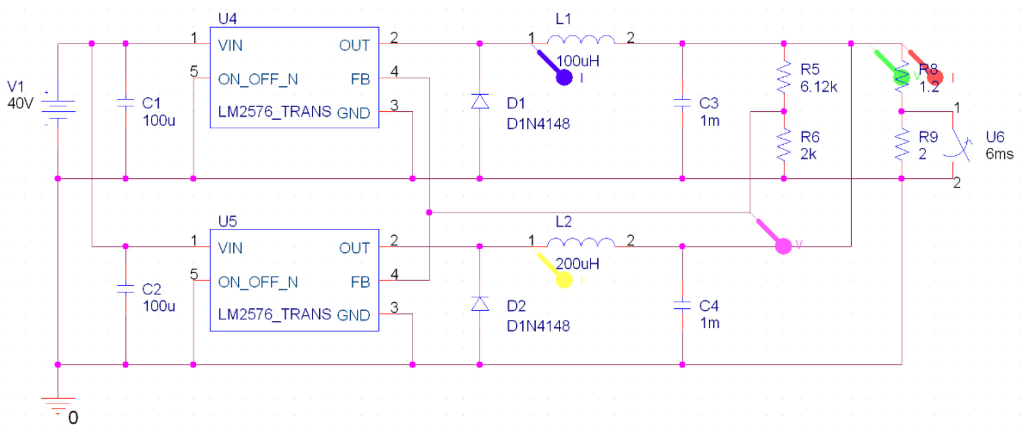

Fig. 4 Scheme of the parallel connected DC/DC converters with the unequal inductance values (L_1=100µH; L_2=200µH)

Simulation results of the scheme in the Fig. 4 are in the Fig. 5 and Fig. 6.

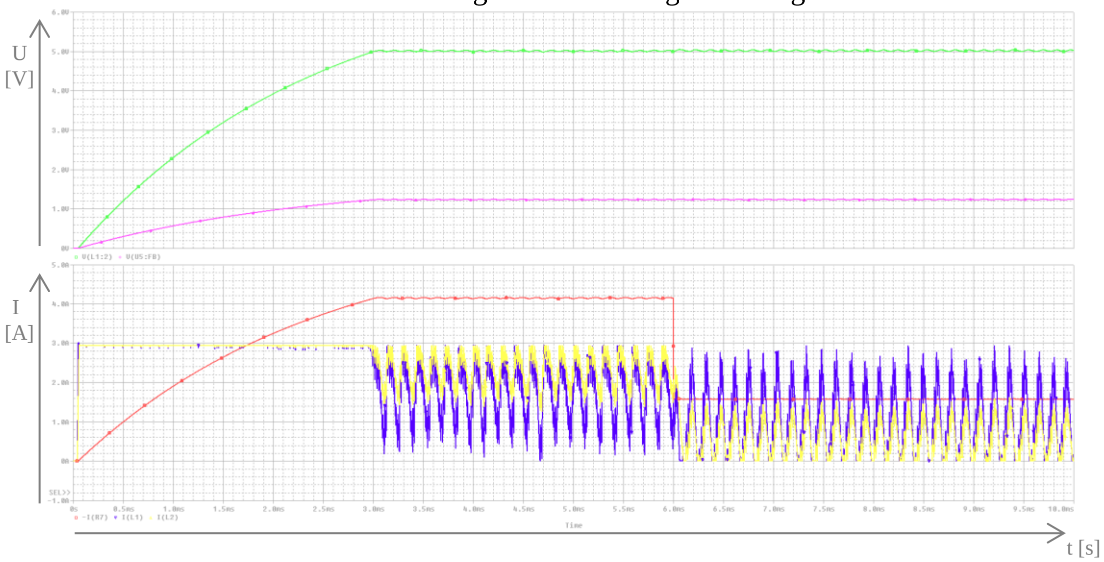

Fig. 5 Simulation results of the parallel DC/DC converters with the unequal inductance values (L_1=100µH; L_2=200µH)

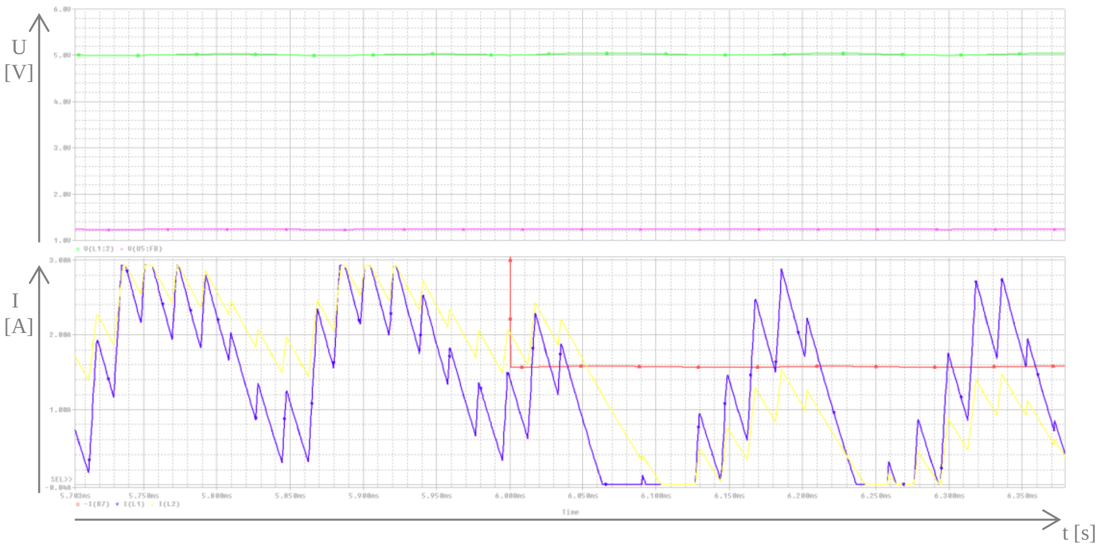

Fig. 6 Detailed simulation results of the parallel DC/DC converters with the unequal inductors (L_1=100µH; L_2=200µH)

As can be seen in the Fig. 5 and Fig. 6 converters are not sharing currents equally any more. According to output load, the difference between the two currents is from 0,5A to 0,7A.

C. Unequal inductances (L_1=100µH; L_2=300µH)

Scheme stays the same again, only inductance in the second converter is 300µH.

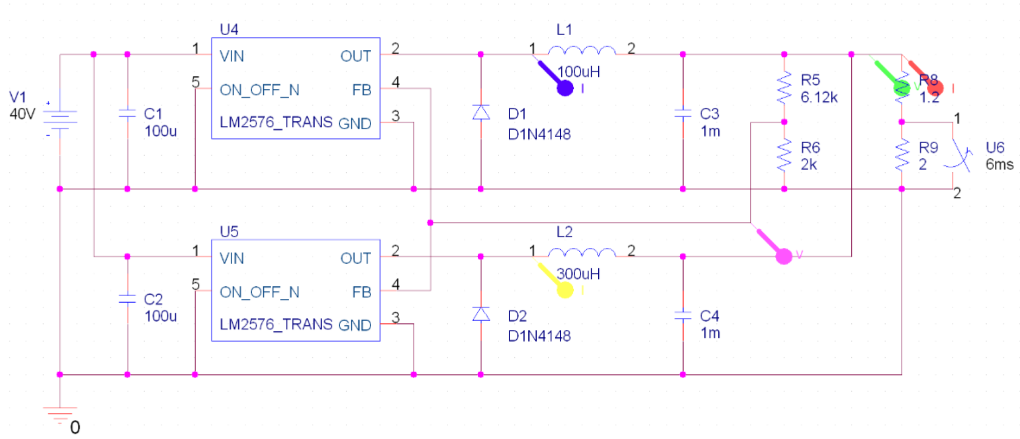

Fig. 7 Scheme of the parallel connected DC/DC converters with the unequal inductance values (L_1=100µH; L_2=300µH)

Simulation results of the scheme shown in the Fig. 7 are in the Fig. 8 and Fig. 9.

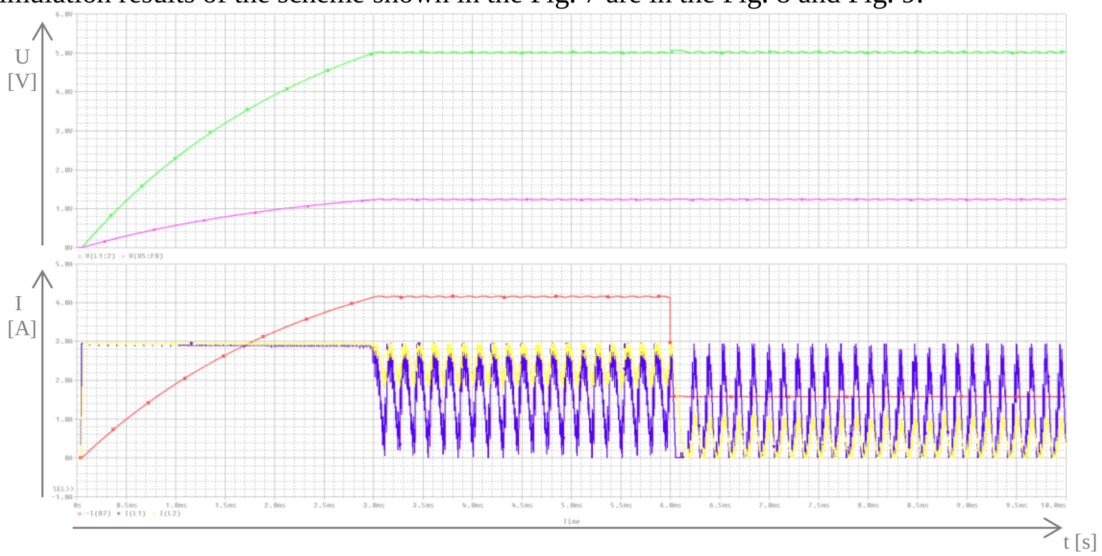

Fig. 8 Simulation results of the parallel DC/DC converters with the unequal inductance values (L_1=100µH; L_2=300µH)

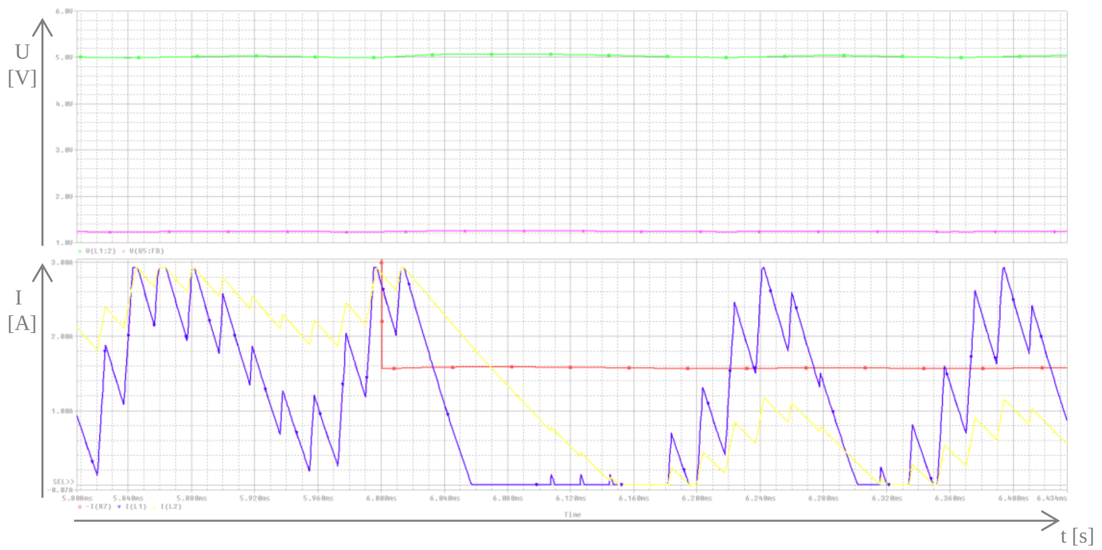

Fig. 9 Detailed simulation results of the parallel DC/DC converters with the unequal inductors (L_1=100µH; L_2=300µH)

As can be seen in the Fig. 8 and Fig. 9, output currents vary even more. According to output load, the difference between the two currents is approximately 1A.

III. INFLUENCE OF DIFFERENT CONVERTERS

In this case inductances are the same, but converters themselves are different. One converter is the same LM2576 as the one, which was used for investigating inductance influence. The second one uses regulation from LM2576, but it has own switching transistor and auxiliary circuits. The whole topology is shown in the Fig. 10.

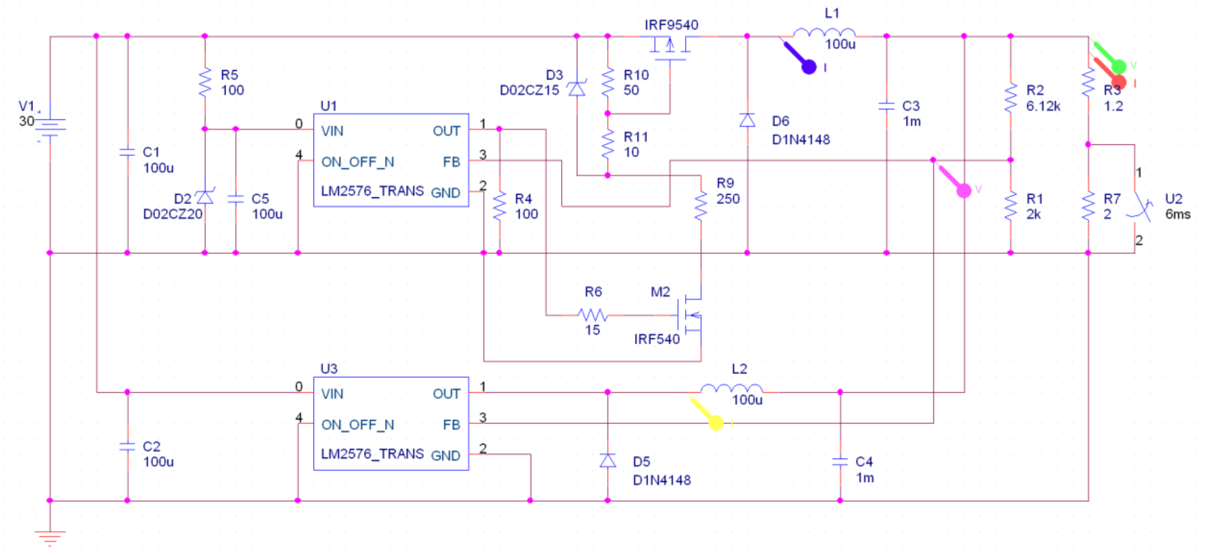

Fig. 10 Scheme of the two different parallel connected DC/DC converters

In the circuit are used Zener diodes for stabilization of input voltage for LM2576 and for control voltage of LM9540 switching transistor. Transistor LM9540 is MOSFET with P channel and it serves as the main switching element. Input voltage is set to 30V because the auxiliary circuits are balanced for this value. Output characteristics are in the Fig. 11 and Fig. 12.

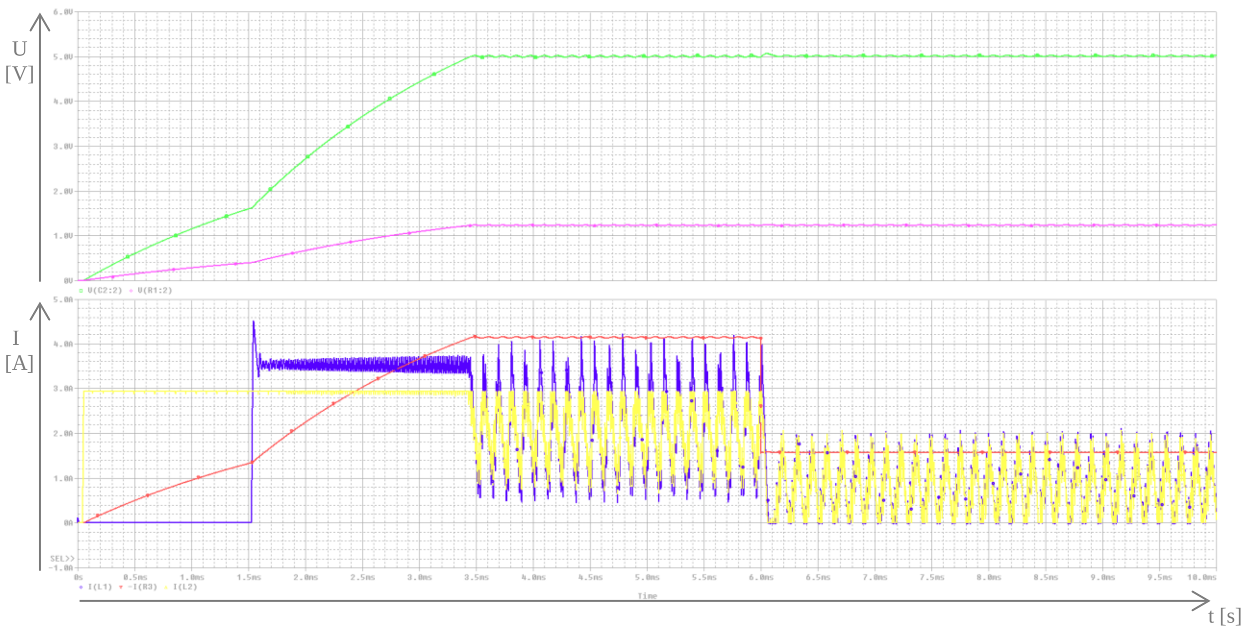

Fig. 11 Simulation results of the two different parallel connected DC/DC converters

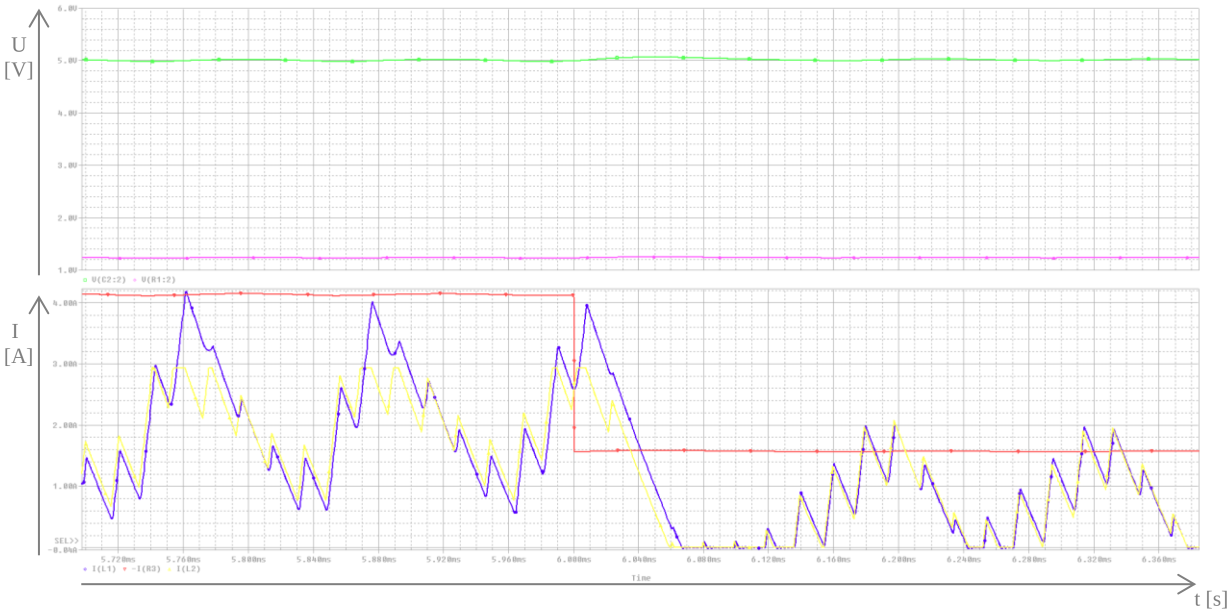

Fig. 12 Detailed simulation results of the two different parallel connected DC/DC converters

As can be seen in the Fig. 11 and Fig. 12, in case of two different converters, currents are also different, though not so much as if the inductors are unequal. The difference between them is reaching 0,5A in high load (1,2Ω) while in lower load (3,2Ω) the difference is minimal.

IV. Conclusion

Simulation results provide us the best view how the unequal inductors and different converters negatively influence current-sharing properties. These two factors are the main requirements for properly functioning parallel connected converters. So theoretically, when these are ensured to be the same, the parallel system can be working properly. However, in practice these requirements are hardly possible to reach, because real electronic components are not always completely the same. Therefore, some current protection or regulation needs to be implemented. In that case good current-sharing can be achieved even though the differences in inductances or in converters themselves.

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