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Voltage droop due to series resistor

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***Abstract*—The paper simply describes advantages and issues related to parallel connection of more DC/DC converters. It also describes one droop method called Voltage droop due to series resistor. Article contains analysis of this method by computer simulations conducted in OrCAD and its PSpice module.**

***Keywords*—DC/DC converter, switch-mode power supply, current-sharing, droop methods, series resistor**

I. Introduction

The switch-mode power supplies (SMPS) are very popular recently because of their higher effectivity, lower cost, smaller size and lower weight compared with 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 step-down (buck) converter. This type of converter is also used for analyze in this article.

The use of one DC/DC converter can 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 is mostly problematic and some special arrangements are necessary. The load of every converter needs to be equal to each other. In other words, level of their output currents needs to be equal or very similar. It is the basic principle and requirement for proper functioning. 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 required amount of output power. There have been proposed several so called *current-sharing methods* because of that. These methods can be differentiate and divided in to two groups. The first group is *droop methods* and the second one is *active current-sharing methods*. This article is aimed on analysis of one particular droop method. It is one of the simplest droop methods called *voltage droop due to series resistor* [1], [6].

II. Voltage Droop Due to Series Resistor

This method is one of the simplest. As in other droop methods, there is no need of interconnections between control circuits of each converter. The output current of each converter is adjusted by additional resistor connected in series with load. Block diagram of this method is shown at the next figure [1], [3].

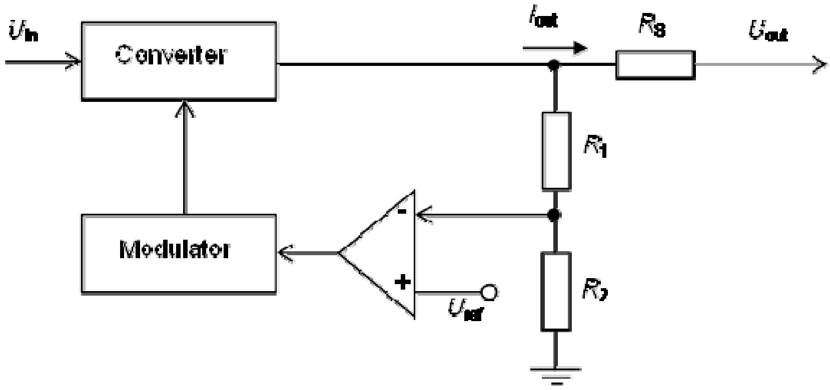

Fig. 1 Block diagram of voltage droop due to series resistor

Resistor *Rs* in block diagram represents mentioned series resistor. A value of this resistor is usually about tens to hundreds of *m*Ω. The value of the resistor is needed to be set manually according to own measurements. It is one of the disadvantages along with power dissipation in the resistor. Once is resistor appropriately adjusted, this method can ensure proper current-sharing and stable functioning of parallel connected converters. The main advantage of this method is its simplicity [1], [3], [6].

III. Verification using Computer Simulations

Proposal of this method is only theoretical. There is need of verification at least by computer simulations. It will give us some view how this method works. For design and simulation of the whole system was used OrCAD with PSpice module. Two DC/DC converters connected in parallel are shown at the figure below.

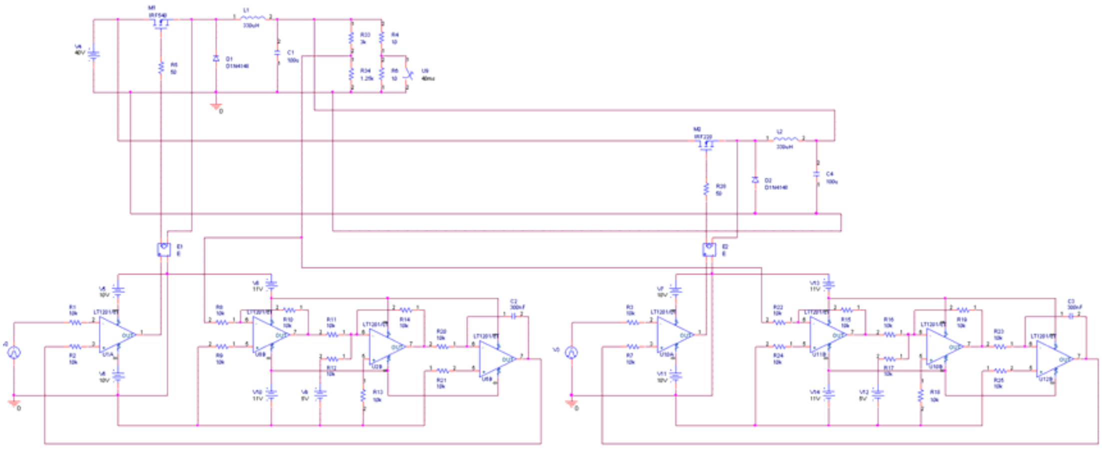

Fig. 2. Scheme of parallel connected DC/DC converters with *I* controllers and without series resistor

Each of the converters is controlled by identical I controller, but every converter has different switching transistor. A reason of that is simulating difference between converters. Simulation models are ideal and identical (transistors of the same type), but in reality there is never two totally identical transistors or other components. The first transistor is model of IRF540 and the second one is model of IRF220.

Simulations were performed firstly for converters without series resistor, thus for system without application of any method. The simulation results are showed at the picture bellow.

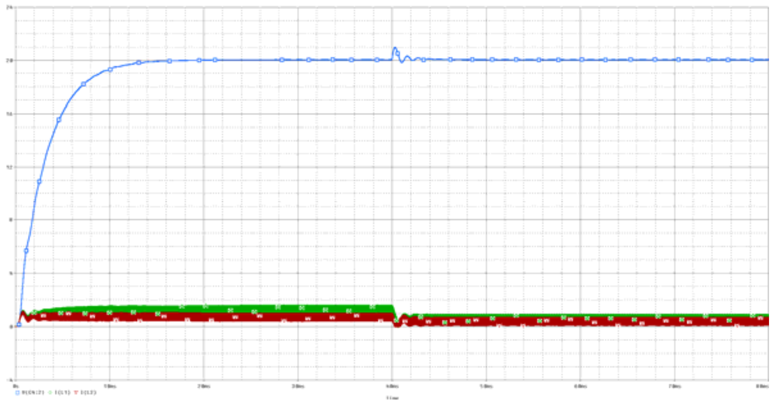
Fig. 3. Simulation results for parallel DC/DC converters without using series resistor

The blue curve represents output voltage, red and green curves are currents through individual converters. Value of the load is 5Ω for first 40ms of simulation. The load resistivity is increased to 10Ω for other 40ms. As can be seen, the *I* controller maintains output voltage at 20V, since duty cycle *D* is set to 0,5. However currents through individual converters differ to each other. This difference is larger for higher load (approximately two times higher for lower electrical resistivity) and smaller for lower load (higher ohmic value of load). At the figures bellow are showed details of current curves for both loads.

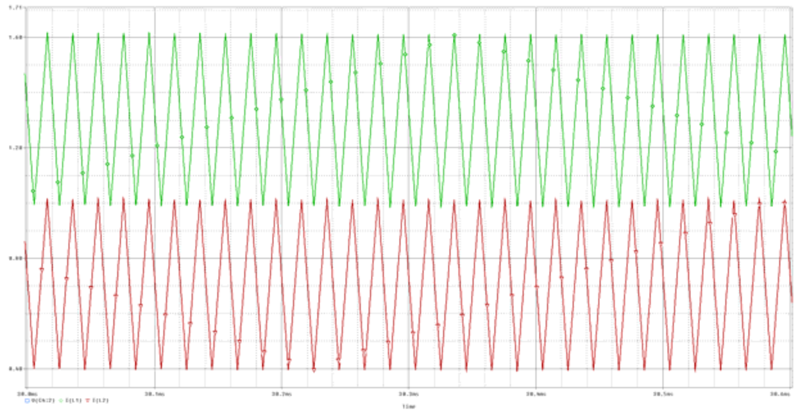
Fig. 4. Detail of current curves for 5Ω output load without series resistor

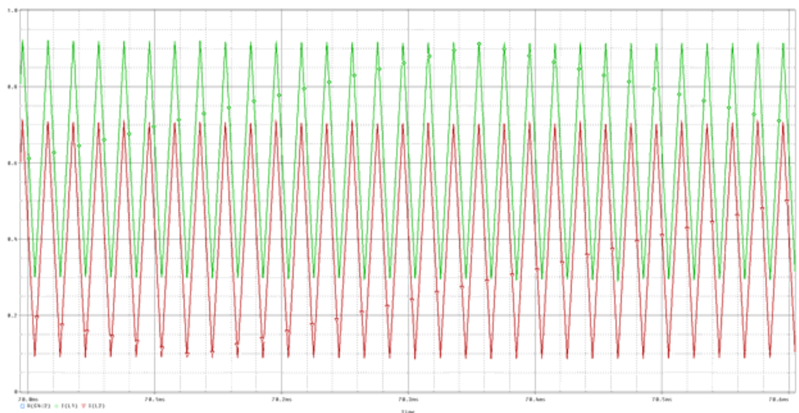
Fig. 5. Detail of current curves for 10Ω output load without series resistor

The converter with higher current uses IRF540 as switching converter, thus the series resistor needs to be connected in this converter for ensuring droop. The scheme of parallel connected DC/DC converters with series resistor connected in converter with IRF540 is showed at the next figure.

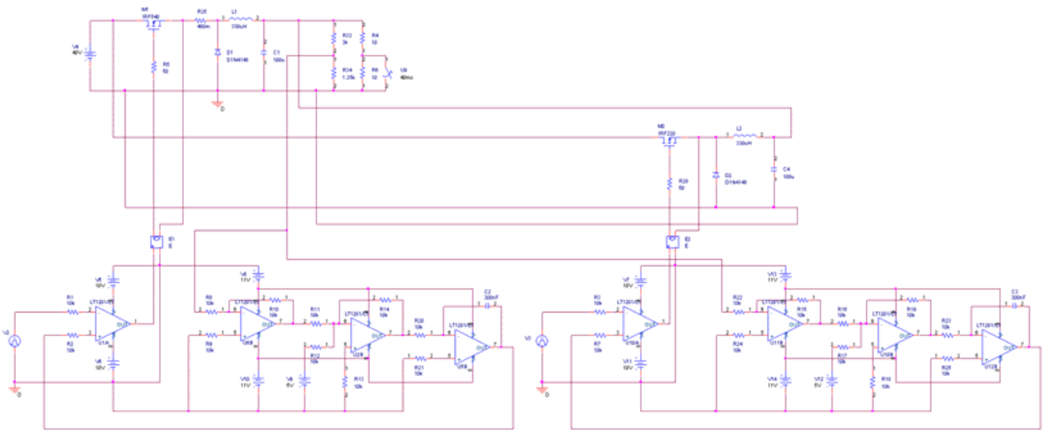

Fig. 6. Scheme of parallel connected DC/DC converters with *I* controllers and with series resistor

The series resistor is set to 480mΩ. This value was determined by more successive simulations. Final simulation results for circuit with this resistor value are showed at the figures bellow (also details of current curves for both output loads).

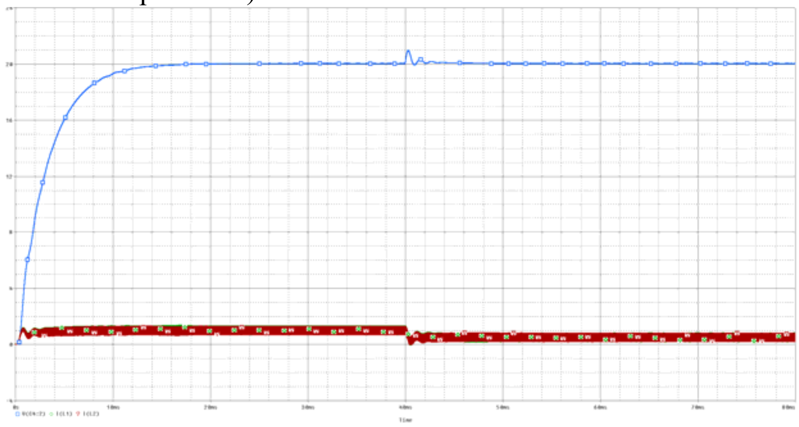

Fig. 7. Simulation results for parallel DC/DC converters with series resistor

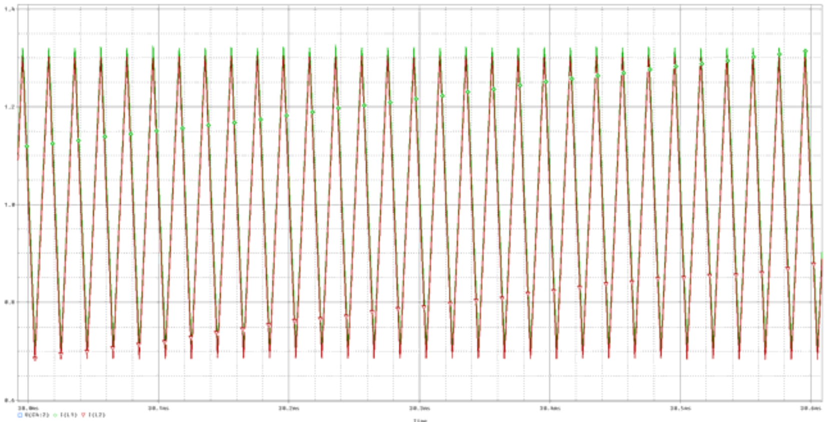

Fig. 8. Detail of current curves for 5Ω output load with series resistor

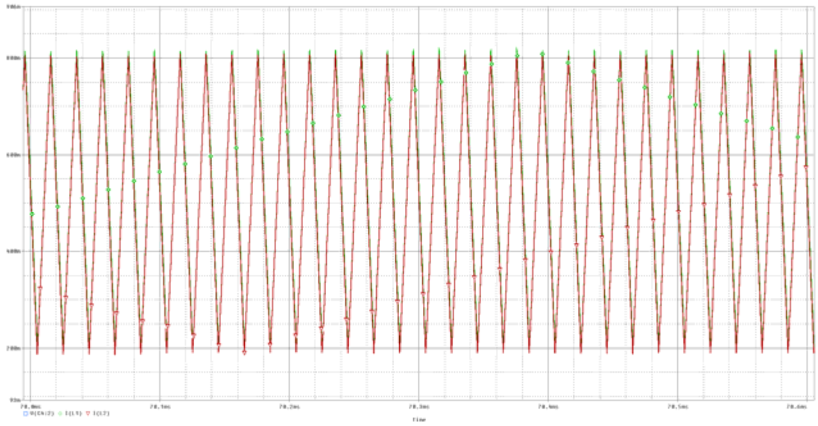

Fig. 9. Detail of current curves for 10Ω output load with series resistor

As can be seen at the figures above, droop method using series resistor has proved as functional at least according to computer simulations conducted by OrCAD program and its PSpice simulation environment. Difference in currents of both converters is almost completely eliminated. Actually, the difference is at the level which may be acceptable and functionality of parallel converters should be ensured.

IV. CONCLUSION

The article deals with issue of parallel co-working of more DC/DC converters. One of the simplest droop methods is analyzed with help of computer simulations. The main finding is the proving of functionality of using the series resistor in the parallel connection. If proper adjusted, this resistor can provide proper current-sharing, so it can be used in simple systems, where requirements on the control are not that high. The main future effort should be aimed at analyzing of all the known methods. These analyses can give us the good overview, which is important for proposing and conducting the most convenient solution.

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REFERENCES

[1] LUO, Shiguo - YE, Zhihong - LIN, Ray-Lee - LEE, C. Fred, “A Classification and Evaluation of Parallel Methods for Power Supply Modules,” IEEE, 2002. ISBN 0-7803-5421-4.

[2] BATARSEH, Issa - SIRI, Kasemsan - LEE, Henry, “Investigation of the Output Droop Characteristics of Parallel-Connected DC-DC Converters,” IEEE, 2002. ISBN 0-7803-1859-5.

[3] JAMERSON, Cliff - MULLETT, Chuck, “Parallel Supplies via Various Droop Methods,” HFPC, 1994.

[4] SIRI, Kasemsan - LEE, C.Q. - WU, Tsai-Fu, “Current Distribution Control for Parallel Connected Converters,” IEEE, 2002. ISSN 0018-9251.

[5] SABATE, J. - VLALKAVIC, V. et al., “Modeling and Design of Parallel-Model Power Supply,” VPEC Final Project Report, 1992.

[6] WU, Renhua et al., “Load-Current-Sharing Control for Parallel Operation of DC-DC Converters,” IEEE, 2002. ISBN 0-7803-1243-0.

[7] Guzan M., Špaldonová D., Hodulíková A., Tomčíková I., Gladyr A.: Boundary Surface and Load Plane of the Ternary Memory, In: Electromechanical and energy saving systems. Vol. 15, no. 3 (2011), p. 163-167. - ISSN 2072–2052

[8] Bereš M., Perduľak J., Kováč D.: Autonomous mobile robot with obstacles prediction In: SSIEE 2014 : proceeding of scientific and student's works in the field of Industrial Electrical Engineering : volume 3. - Košice : TU, 2014 S. 166-169. - ISBN 978-80-553-1711-4

[9] Kováčová I., Kováč D., Vince T.: Elektromagnetická kompatibilita - 1. vyd - Košice : TU, - 2009. - 137 s. - ISBN 978-80-553-0150-1.

[10] Bučko,R., Kováč,D., Konokh,I.: Embedded systém and speech recognition, Electromechanical and energy saving systems: Quarterly research and production journal Vol. 2011, No. 3 (2011), pp. 168-172, ISSN 2072-2052.
[11] Dziak,J. : Linear circuit simulation using MATLAB and modeling of nonlinear elements, In: SCYR 2014 Proceeding from Comference: 20.5.2014: Herľany, S. 70 - 71, Košice : Technická univerzita v Košiciach, 2014 /978-80-553-1714-4/.
[12] Jacko P., Kováč D.,: Converters and time conversion measurement of STM32F446RE microcontroller , In: Electromechanical and energy systems. Modeling and optimatization methods. - Kremenchuk : Kremenchuk Mykhailo Ostrohradskyi National University, 2017 P. 154-155. - ISSN 2079-5106.