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Increase in current stresses of the boost converter due to border collision bifurcation

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Abstract: Border collision bifurcation in a DC-DC boost converter is under investigation. Mathematical model of the converter is proposed and exact simulation is carried out. The simulation algorithm is based on Runge-Kutta fourth-order method. Bifurcation diagram of the inductor current versus input voltage is simulated. By decrease of the input voltage, the converter undergoes Neimark-Sacker bifurcation and border collision bifurcation. As a consequence of border collision bifurcation the peak value of the inductor current jumps to a considerably higher value. The same phenomena is reproduced experimentally. The inductor currents before and after border collision bifurcation obtained by the simulation and by the measurement qualitatively match. The increase of inductor current my cause the failure or shortening of the service life of the converter switches. By proper change of the converter parameters border collision bifurcation can be avoided. In order to avoid border collision bifurcation the converter load capacitance and feedback proportional gain are adjusted. In both cases the simulation results and the measurement qualitatively match.

Keywords: border collision bifurcation, boost converter, current stresses, Neimark-Sacker bifurcation

1. Introduction

A DC-DC boost converter is a time-varying nonlinear circuit of a second order or a higher. As such, it is prone to various bifurcations [1-4]. Border collision bifurcation [2-4] can be especially undesirable. It can cause large increase of the converter currents and thus lead to converter failure. Thorough researches on this topic has not yet done. In this article simulation and measurement of increase of the converter currents due to border collision bifurcation are presented. Avoidance of bifurcation by changing the converter parameters is also shown.

2. Results and Discussion

A DC-DC boost converter, Fig. 1 is under consideration. Bifurcation diagram of inductor current versus input voltage is shown in Fig.2. At input voltage E = 12 V the converter operates in period-one steady-state determined by the PWM-clock frequency. By decrease of input voltage to E = 11,4 V the converter undergoes the first Neimark-Sacker bifurcation (NS). By further decrease of input voltage the converter undergoes series of Neimark-Sacker bifurcations [1]. At input voltage E = 9,4 V the converter undergoes the first border collision bifurcation (BCB). This lead to the significant increase of inductor current, Fig. 3 and Fig. 4 and consequently increase of switch currents.

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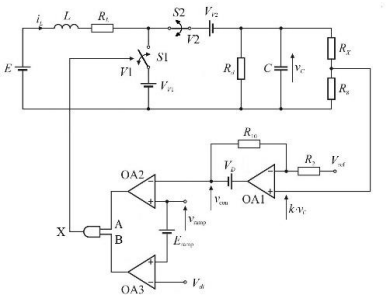

Fig. 1. Schematic circuit diagram of the boost converter

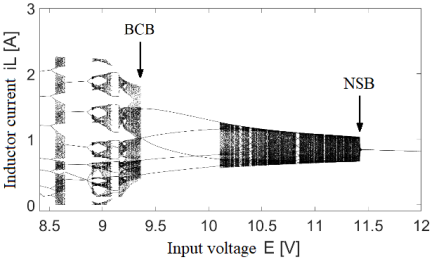

Fig. 2. Bifurcation diagram obtained by decrease of the input voltage

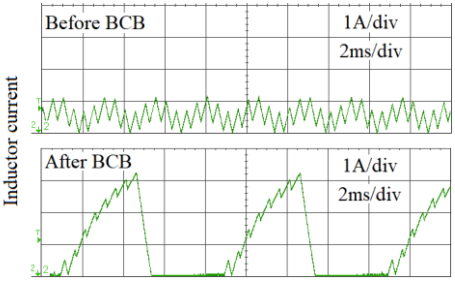

Fig. 3. Inductor current obtained by measurement.
Up – Inductor current before the bifurcation.
Down – Inductor current after the bifurcation.

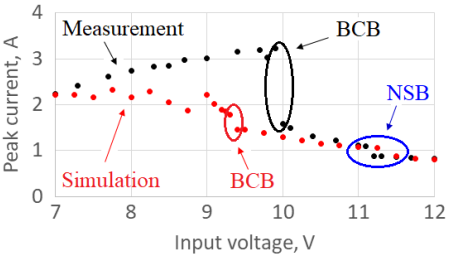

Fig. 4. Peak inductor current versus input voltage obtained by simulation and measurement.

By change of the converter load capacitance and feedback proportional gain an area of period-one steady-state can be broaden and the border collision bifurcation can be avoided.

3. Concluding Remarks

Undesirable large increase of the boost converter current caused by border collision bifurcation is presented. Simulation results corresponds to measurement results. Avoidance of bifurcation by changing the converter parameters is also shown.

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