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Adaptive Dead Time Compensation for Continuous Cross-Period Single Phase-Shift Control of Dual Active Bridge Converters

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Introduction

Power level testing of hybrid and electrical vehicle drivetrain components are inevitable during development. The Modular Hybrid Drive System (MHDS) Laboratory at the Budapest University of Technology and Economics was built to serve such needs in the automotive industry. A galvanically isolated 360kW DC/DC converter was needed. As a cost-effective solution. the DAB topology with a 400Hz laminated steel core transformer was chosen. Due to the low switching frequency and the transient response requirements, a novel control strategy had to be researched. This paper is focusing on the dead time effects in such applications and an adaptive compensation method is introduced.

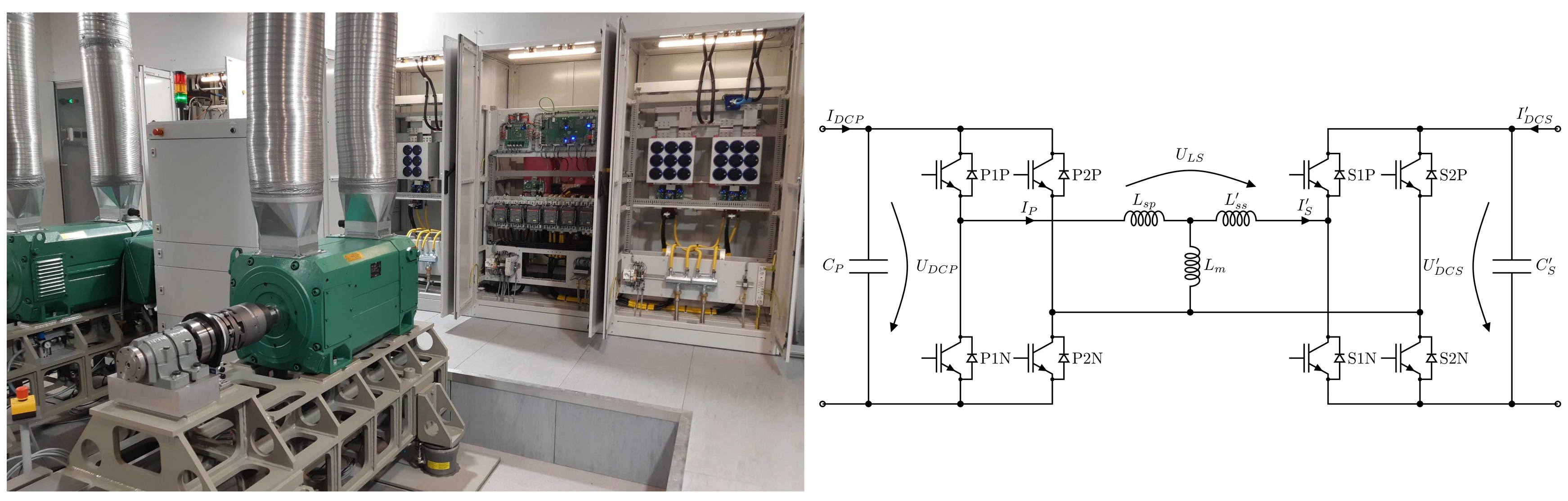


Fig. 1. The 360 kW DAB converter in the MHDS laboratory and its power circuit diagram.

CCP-SPS control

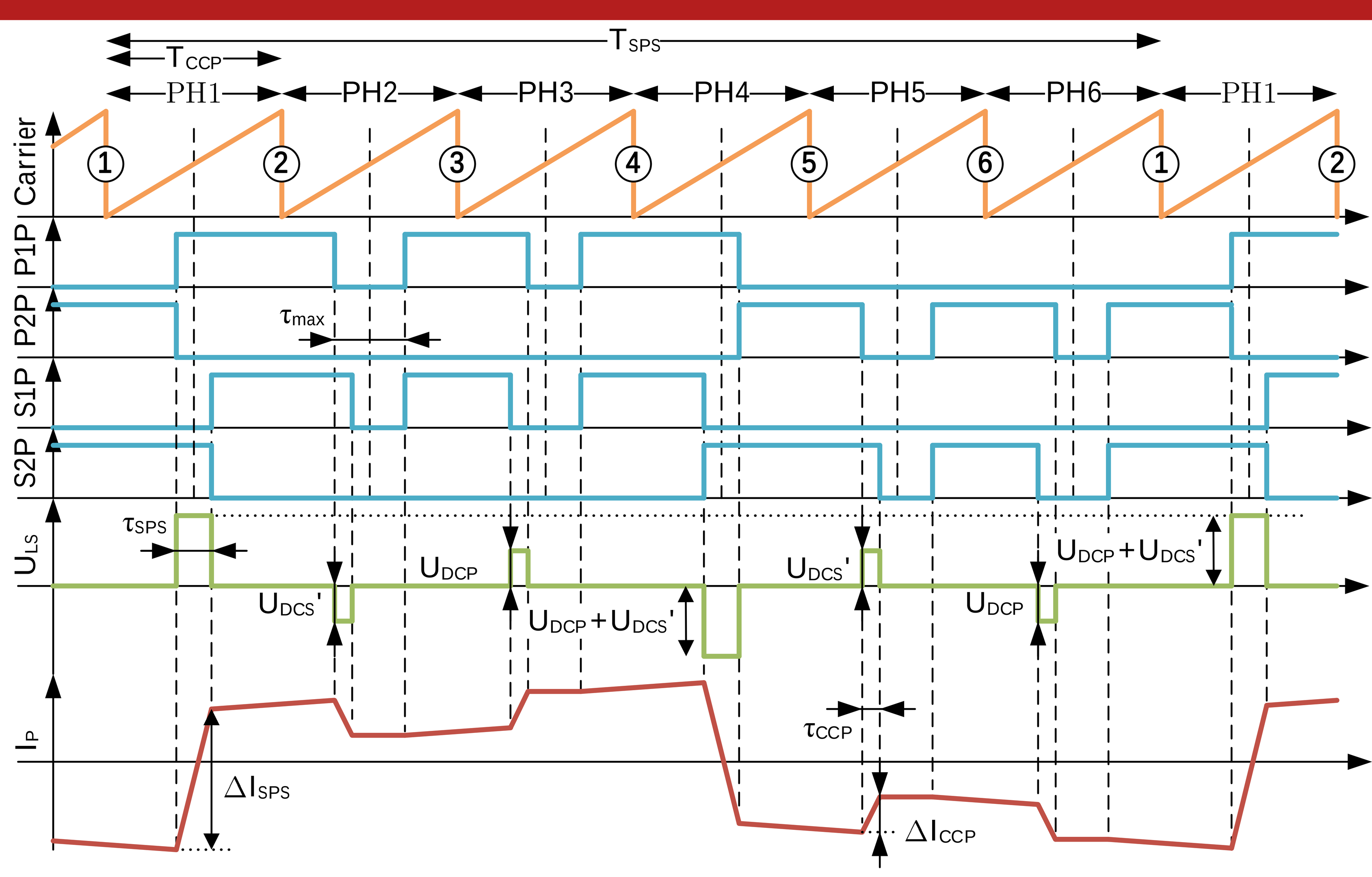


Fig. 2. Resulting waveforms of the CCP-SPS control , illustrating possible in-period current modifications.

The effects of dead time

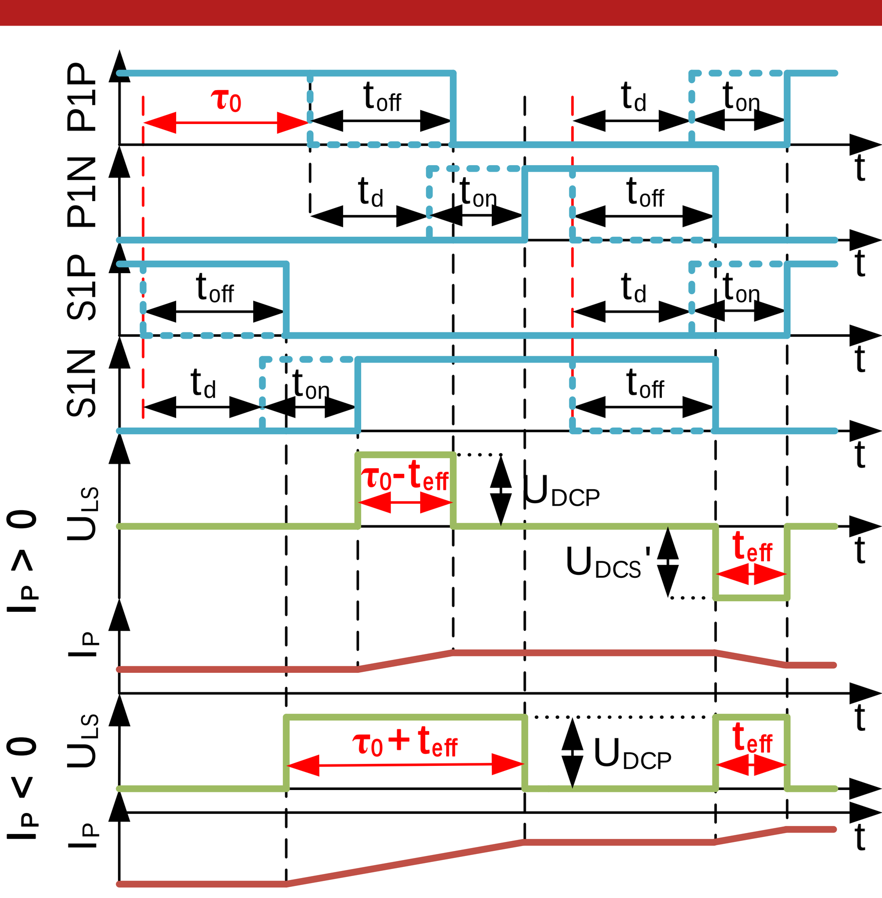


Fig 3. Increasing current in PH2 and PH3

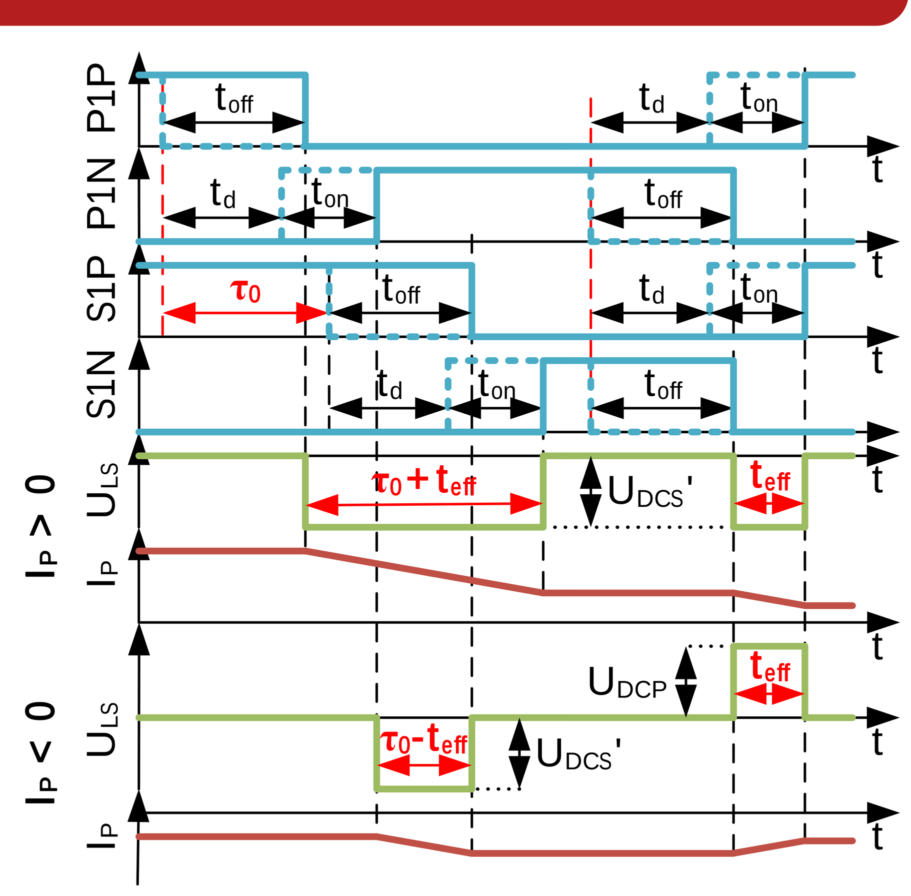


Fig 4. Decreasing current in PH2 and PH3

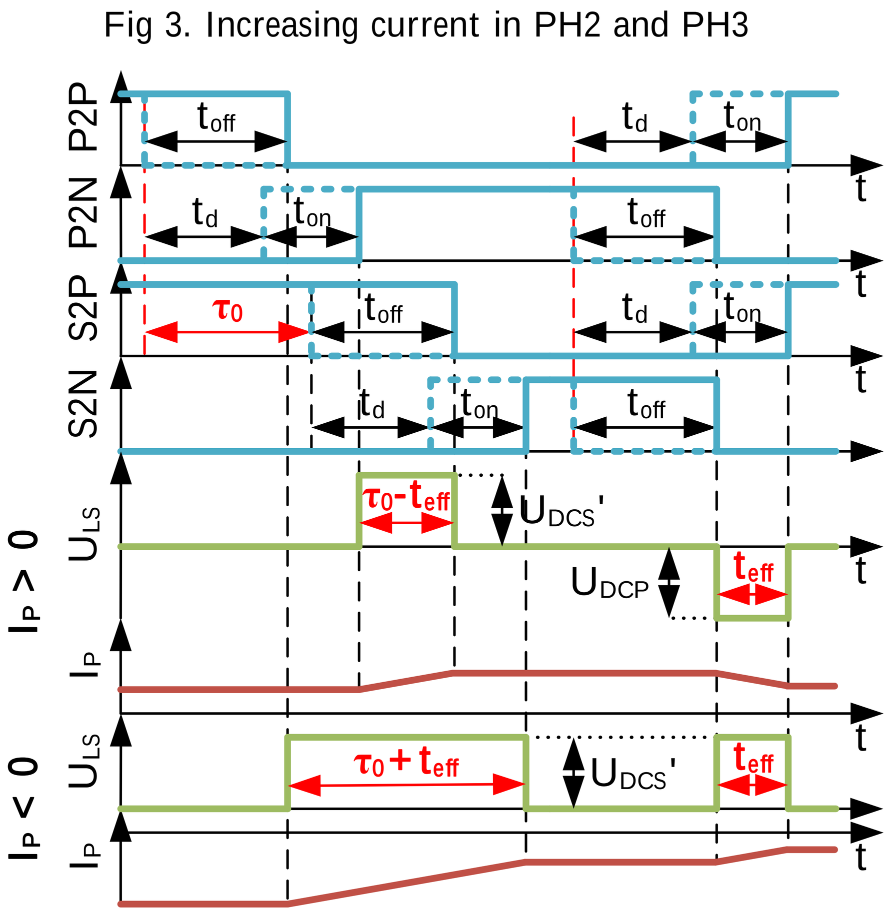


Fig 5. Increasing current in PH5 and PH6

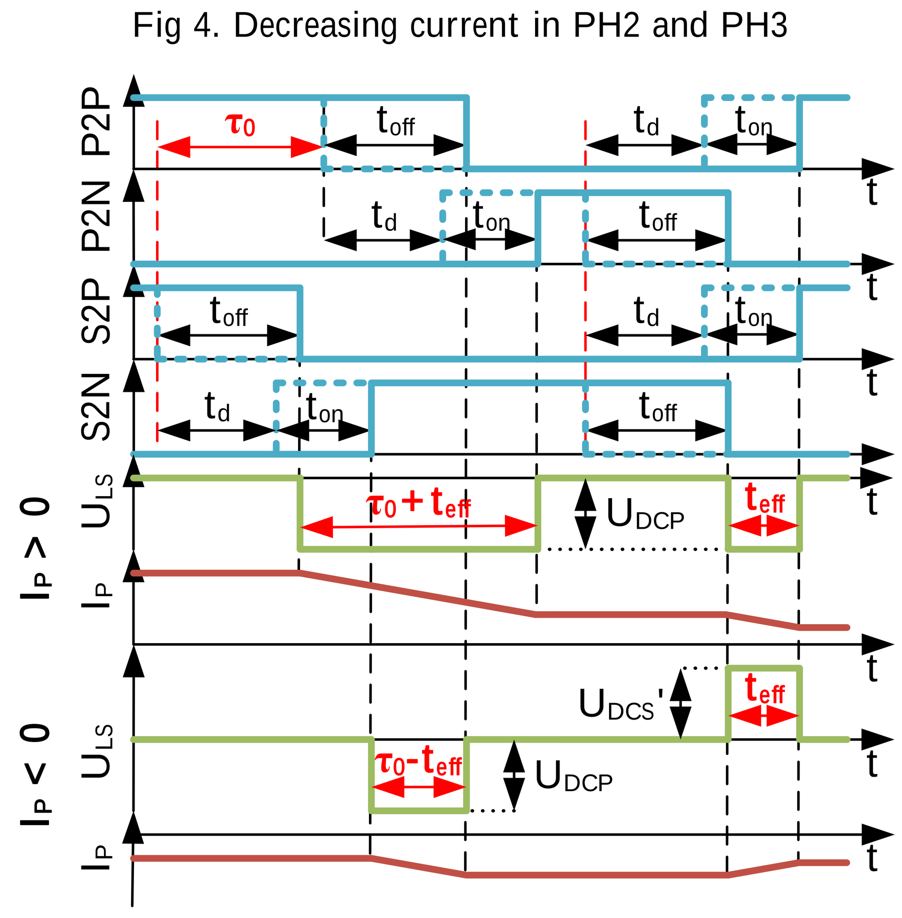


Fig 6. Decreasing current in PH5 and PH6

Adaptive control

The transformer current is sampled before and after the switching action. In the next PWM cycle the previously required and measured current change is compared. The difference is fed into an integrator as an error signal. The output of the integrator is used to change the phase-shift.

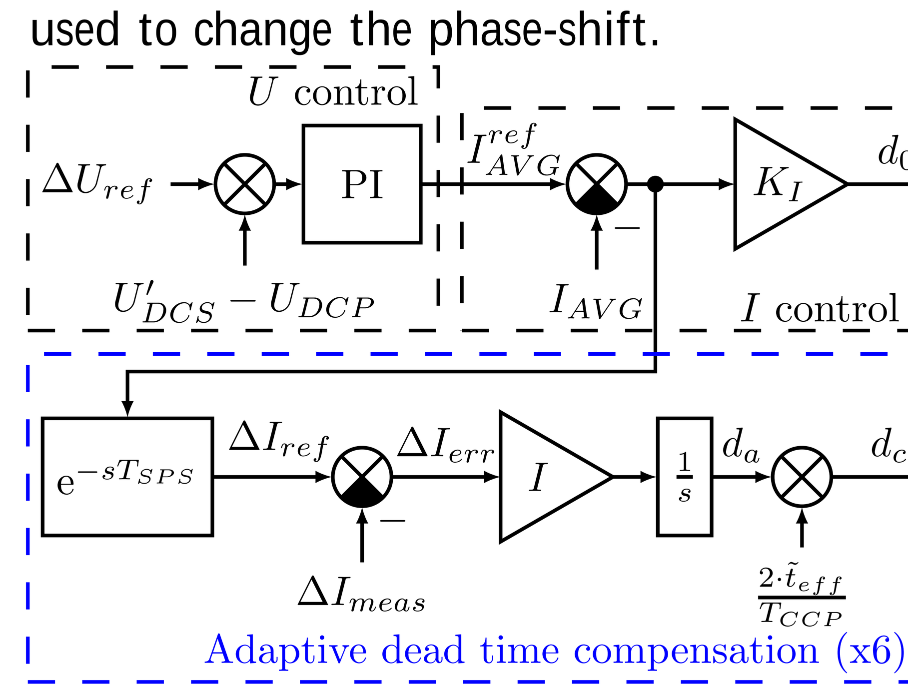


Fig. 7. The control diagram of the CCP-SPS algorithm with adaptive dead time compensation.

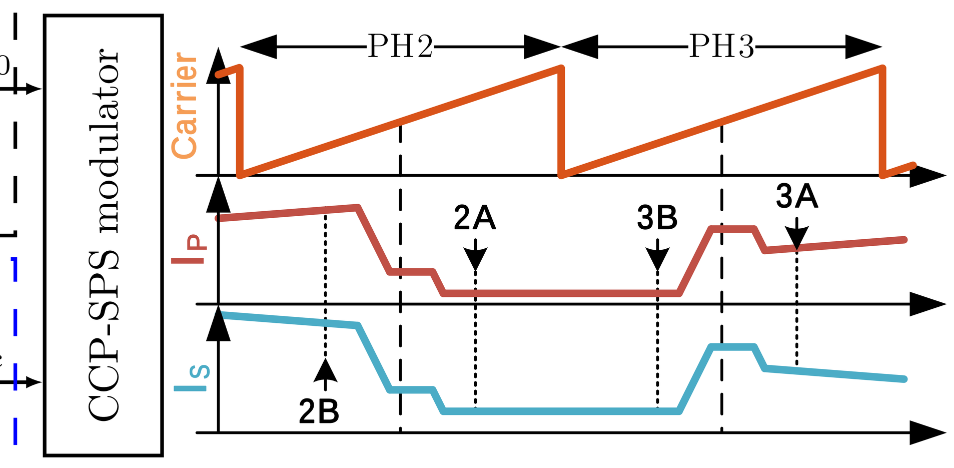
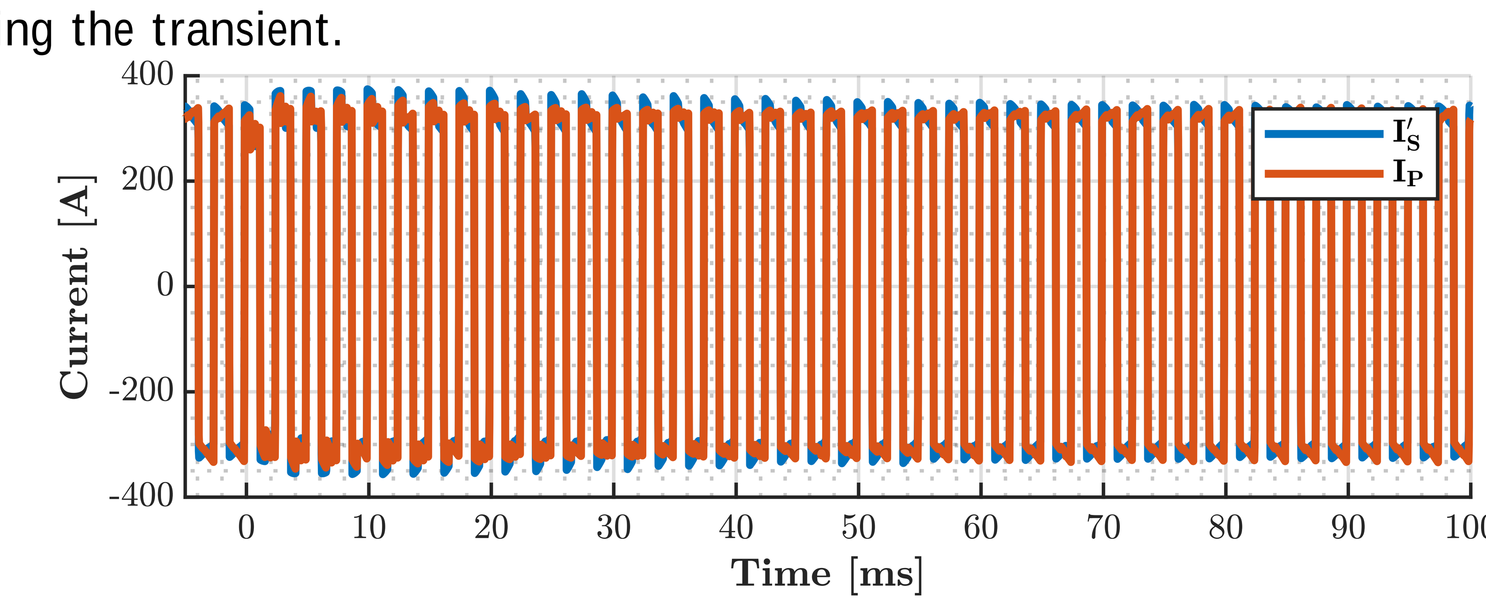


Fig. 8. The transformer current sampling points for the adaptive controller, in the PH2 and PH3 phases before (2B, 3B) and after (2A, 3A) the switching action.

HIL simulation results

The proposed algorithm was tested in a HIL simulation environment. A MATLAB Simulink model of the main circuit was running on a Zybo Zynq-7000 ARM/FPGA SoC development board in real-time. The adaptive compensation algorithm implemented in C language and compiled to a TMS320F28075 based DSP card. The simulated switch-off delay was changed from 3 µs to 40 ns while the converter was running. The voltage, current and internal control variable waveforms were collected during the transient.



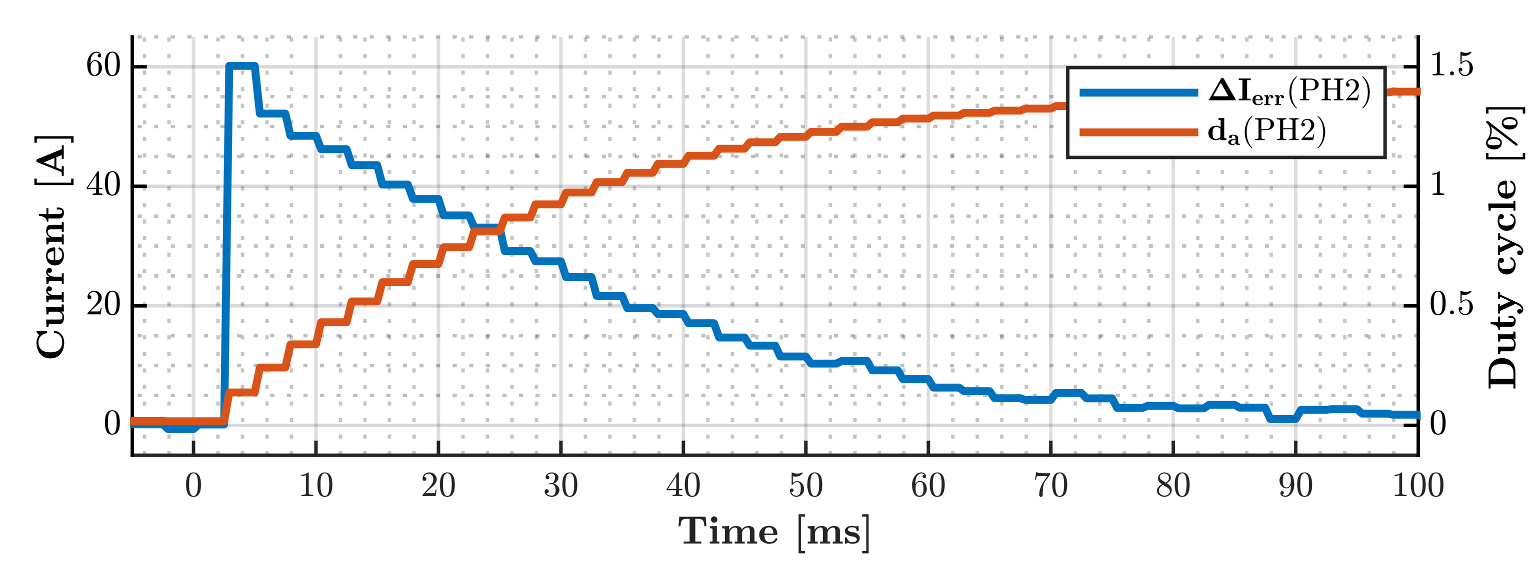


Fig. 8. The transformer currents and the adaptive controller variables when t_{off} is changed from 3 µs to 40 ns.

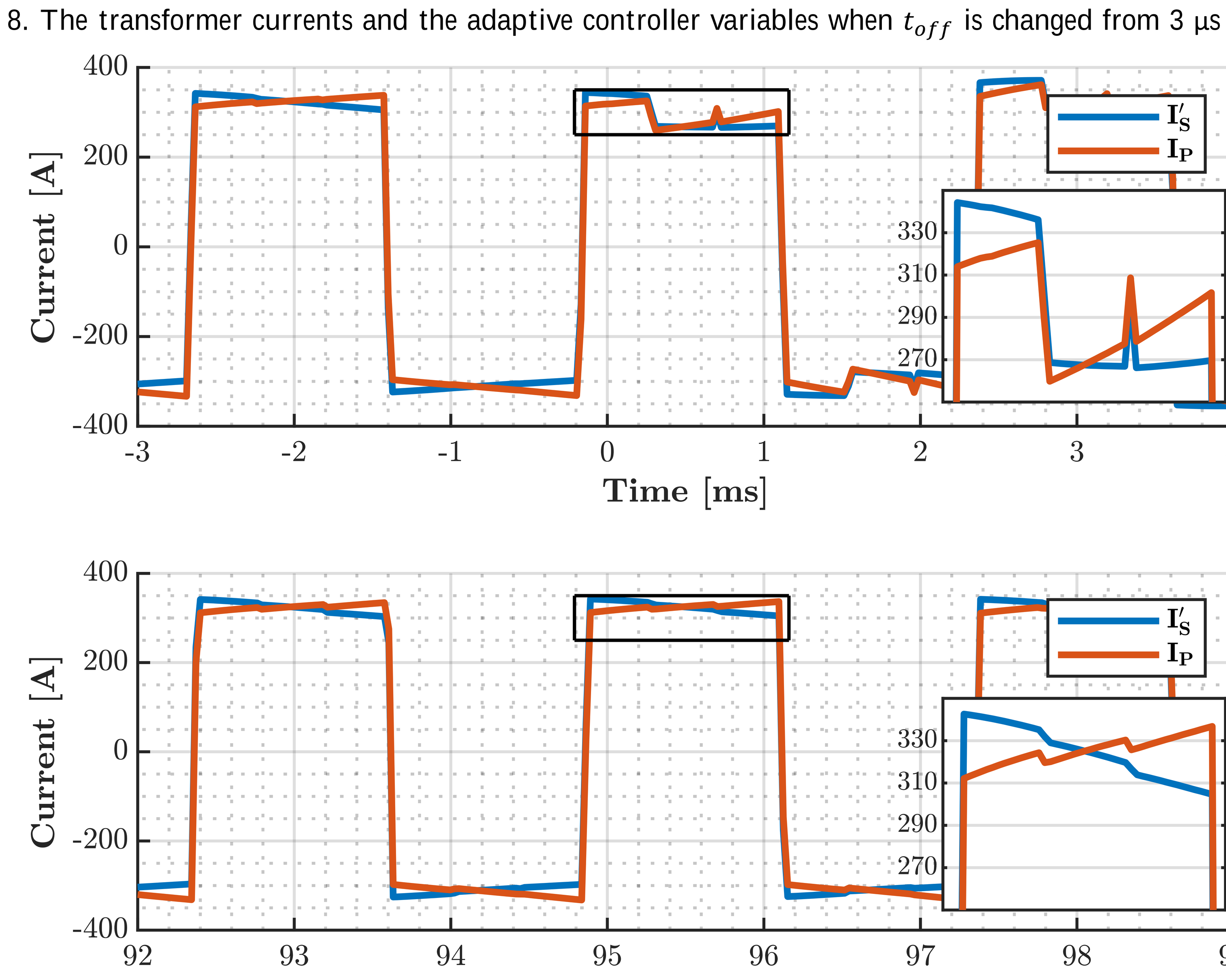


Fig. 9. The transformer currents at the beginning (top) and at the end (bottom) of the transient.

Acknowledgements

This work was performed in the frame of FIEK 16-1-2016-0007 project, implemented with the support provided from the National Research, Development and Innovation Fund of Hungary, financed under the FIEK 16 funding scheme.

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