MODELING OF THE OPTIMAL TRAJECTORY CONTROL SYSTEM OF RESONANT DC/DC CONVERTERS OPERATING ABOVE RESONANT FREQUENCY

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The paper presents behavioral modeling of the control system of resonant DC/DC converters, operated above resonant frequency under "optimal trajectory control" technique. This method predicts the fastest response possible with minimum energy surge in the resonant tank. In this paper the investigations are extended and the specific variant of the series DC/DC converter controls system operated above resonant frequency is proposed.

Simulation and experimental results from the investigation of the converter are shown.

Keywords: resonant DC/DC converters, behavioral modeling, optimal trajectory control.

1. INTRODUCTION

The several control methods of series resonant DC/DC converters are widely discussed and compared in resent years [1-7]. Due to the presence of resonant circuit with its fast transient response, the control of resonant converters is considerably more complex than PWM converters [1].

The advantages of the optimal trajectory control method over the existing methods are reduced stress on the reactive and power semiconductor switching elements of the circuit and faster response in case of large variations of circuit operating conditions without affecting the global stability of the system [1], [8]. This method predicts the fastest response possible with minimum energy surge in the resonant tank.

In this paper the investigations are extended and the specific variant of the series resonant DC/DC converter controls system operated above resonant frequency is proposed. The control system is described using Analog Behavioral Modeling (ABM) [9].

2. BEHAVIORAL MODELING OF THE OPTIMAL TRAJECTORY CONTROL SYSTEM

The control system is described using Analog Behavioral Modeling (ABM). Fig.1 shows the simulation resonant DC/DC converter. The transistor individual control circuits are introduced [10].

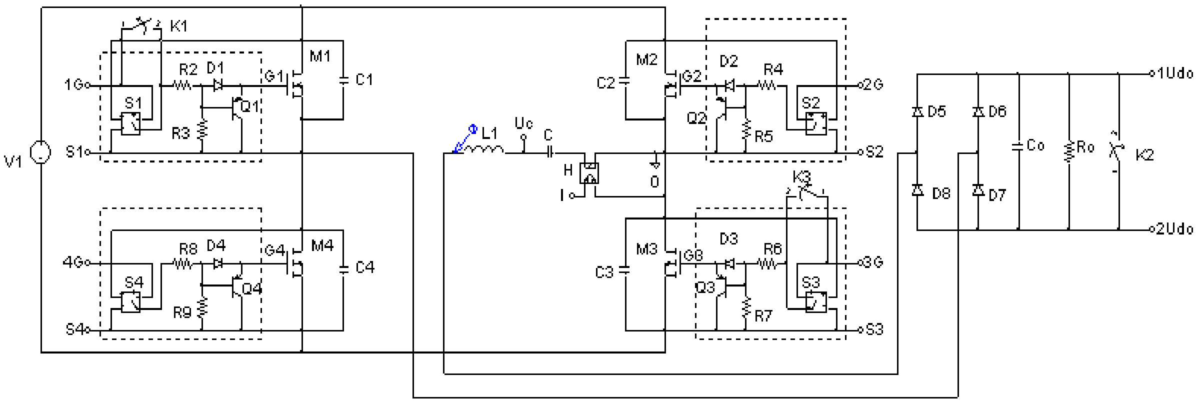

Fig.1. The simulation full-bridge resonant DC/DC converter

The proposed control system (CS) is shown in fig. 2 and in fig. 3 – the waveforms, which explain the system operation.

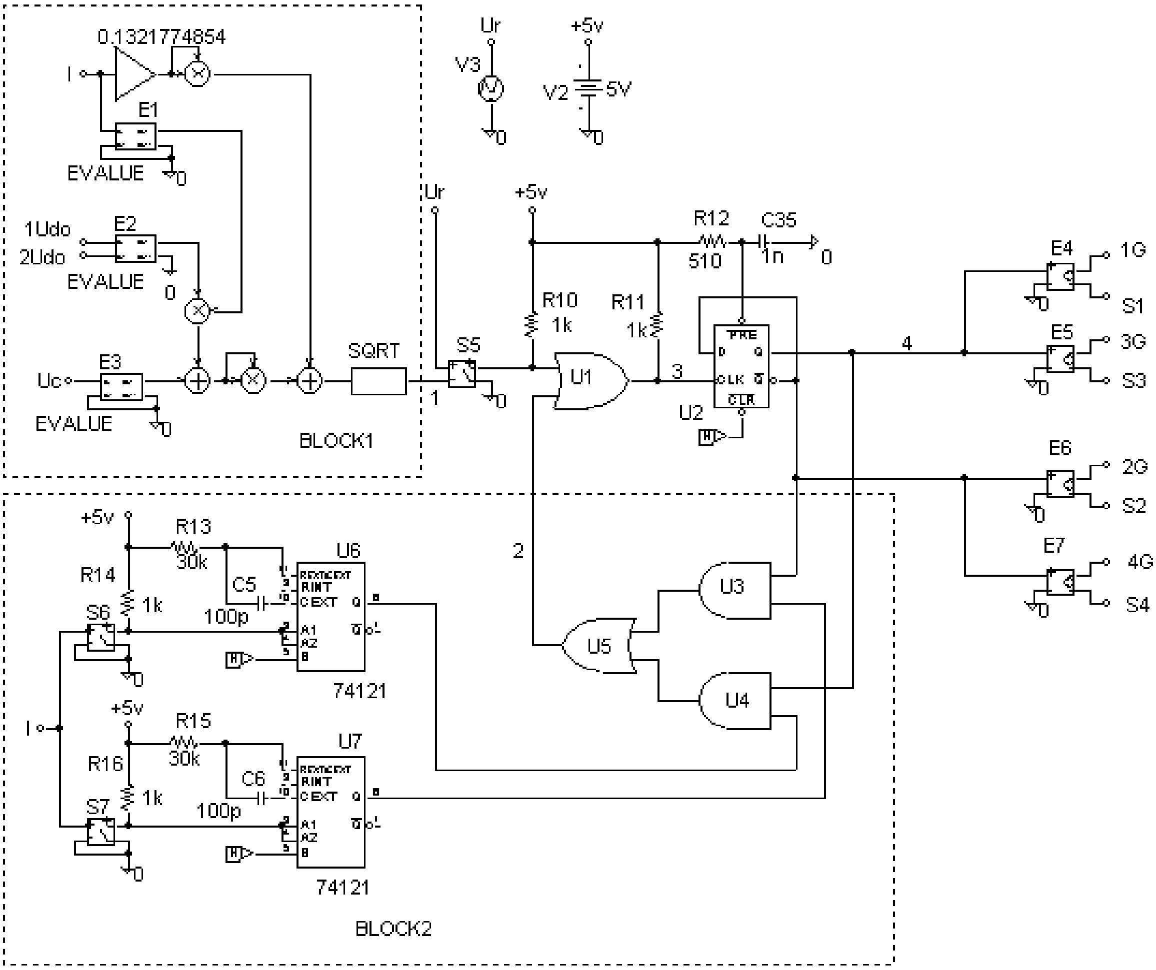

Fig. 2. Converter control system behavioral modeling

From the instantaneous values of i, u_C, U_0 and U_d, the control circuits computes the variable D [11] at every instant as given by BLOCK1, where

(1) $$D = \sqrt{i'^2 + \left[u'_C + signi'\left(1 + U'_0\right)\right]^2} \ .$$

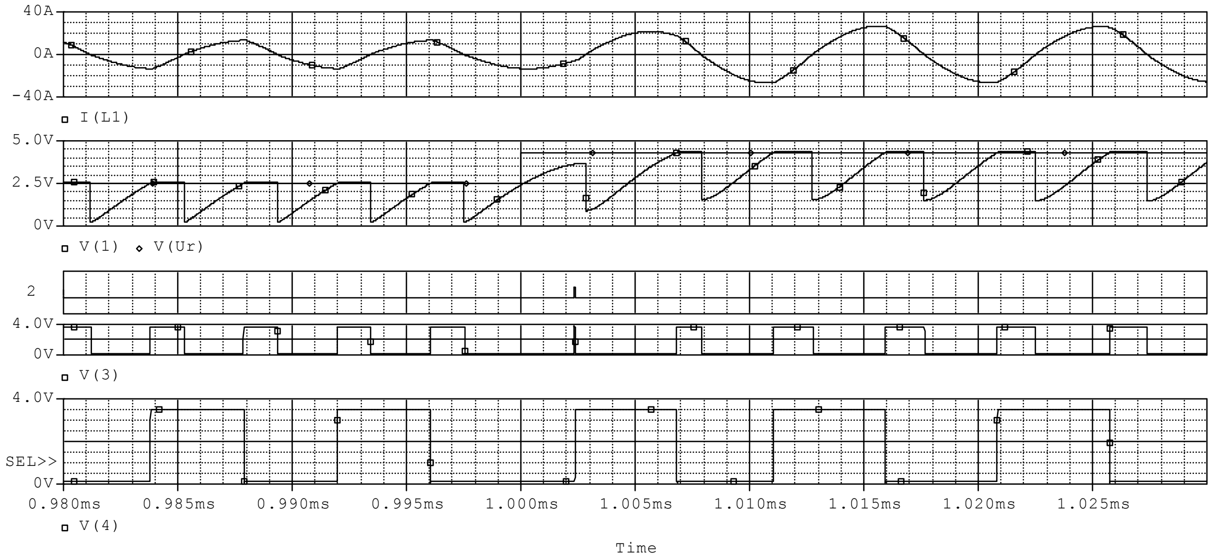

Fig. 3. Control system main waveforms

The dependent current control voltage source (CCVS) H senses the current trough the resonant tank. The signals for voltages U_0 and u_C are fed to the dependent voltage sources of EVALUE type (E2 and E3). The output of E1 (EVALUE) is the logical signal whose state (+1 or –1) is determined by the $signi'$. The dependent voltage source E1 realizes function:

(2) SGN (V(%IN+, %IN-))

in the EXPRESSION field of the EVALUE element.

The received value of D (v (1) in fig.2) is compared with control signal Ur.

The voltage controlled switches S6, S7, one-shot multivibrators 74121 and logical elements U3, U4, U5 ensure soft switching condition $\theta_Q < \pi$ and $I' > I'_{min}$. (BLOCK2).

The shaped pulses are fed to the flip-flop trigger U2. The pulse distributor U2 forms two channels of the control pulses, dephased at 180^0. The dependent voltage control voltage sources (VCVS) E4÷E7, provide the required power, amplitudes and galvanic separation of the control signals.

As noted in [1,9], the maximum rate at which the tank energy can change in half a cycle is limited. Thus the system takes more than a half-cycle to reach the target trajectory. Fig. 4 shows the PSpice simulation results of the system response to large changes in control input. In fig.4a, when control input decrease, the tank energy is reduced by a series of successive diode conductions.

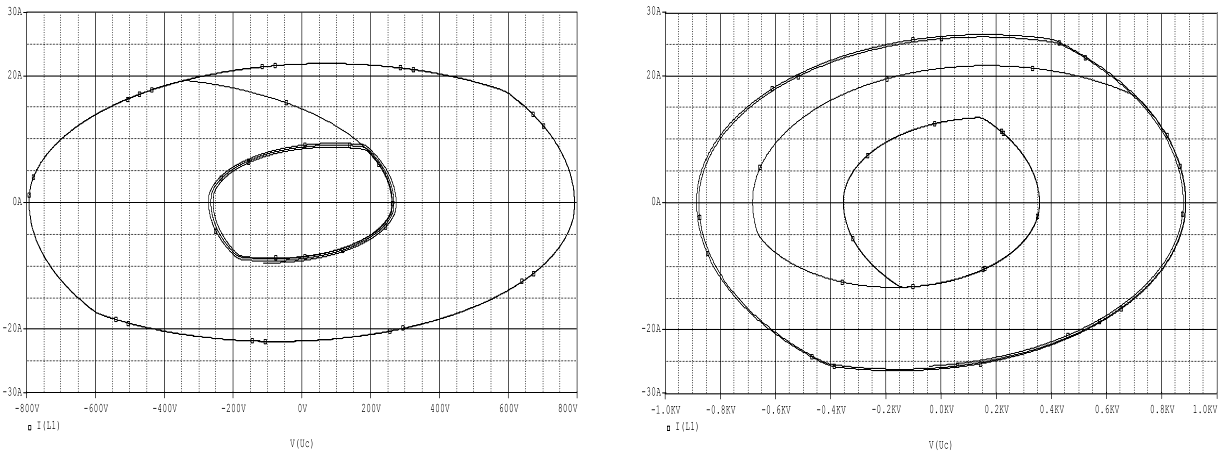

Fig.4. Response of optimal trajectory control for

a) Control decrease $R_{D1}=4.3 \rightarrow R_{D2}=2.5$ ($t = 1980 \div 2030\mu s$)

b) Control increase $R_{D1} = 2.5 \rightarrow R_{D2}= 4.3$ ($t = 980 \div 1030\mu s$)

Likewise in fig.4b, when control input increase, the tank energy is built up a series of successive transistor conductions. Thus by utilizing the desired diode trajectory itself as the control low, the new steady state can be reached. In both cases, the system reaches the new equilibrium trajectory in the minimum possible time limited only by the intrinsic properties of the resonant converter.

Fig.5a shows PSpice simulation results of the system response at converter start-up. The performance of the method under short-circuit is also remarkable as shown in fig.5b. Within a short time, the system abruptly reaches another equilibrium trajectory at energy level only slightly greater than the earlier one. Thus optimal trajectory control fully exploits the potential of a converter to respond quickly to the demands of control and load.

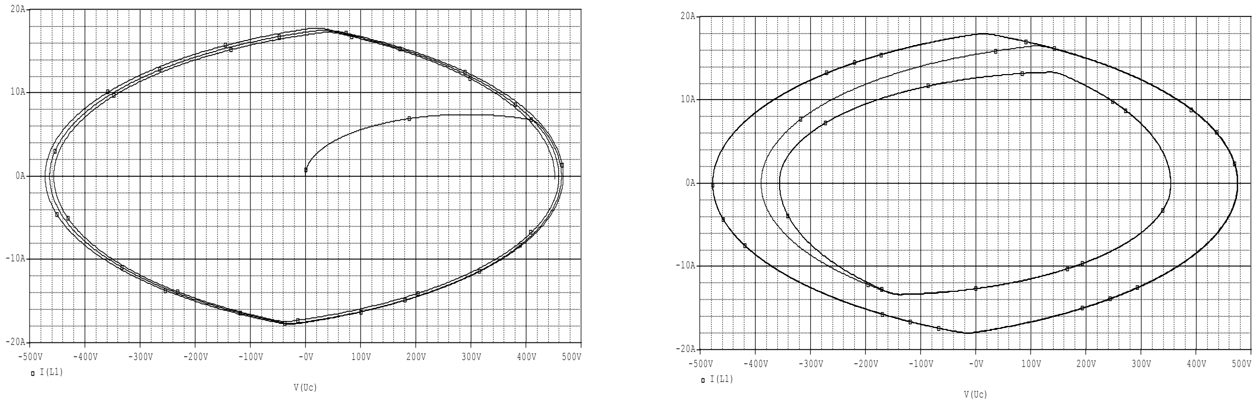

Fig.5. Transient under

a) Converter start-up $R_D = 2.5$ ($t = 0 \div 30\mu s$)

b) Load short circuit $R_D = 2.5$ ($t = 2980 \div 3030\mu s$)

3. EXPERIMENTAL RESULTS

The computer simulation and experimental results of the resonant DC/DC converter are given by the following conditions: power supply U_I=300V; switching frequency f=125kHz; output power P=3kW; and resonant link elements L= 72.577μH and C= 46.157nF. During the experiment snubbers' value is 1nF.

Fig. 6 sows response of optimal trajectory control in the case for control increase.

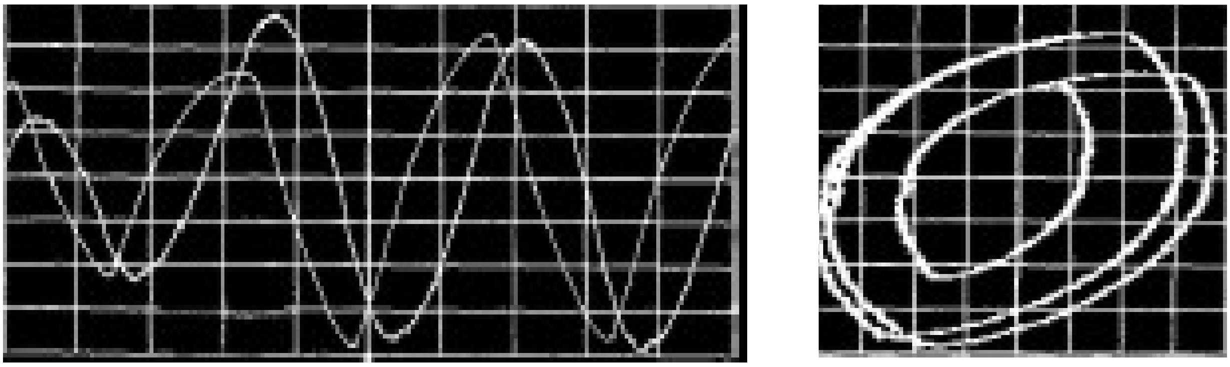

Fig.6. Response of optimal trajectory control for control increase

a) Resonant current i_{L1} (5A/div) and capacitor voltage u_C (200V/div)

b). State plane -x: u_C (200V/div) and y: i_{L1} (5A/div).

A very good agreement between simulation (fig.4b) and experimental results (fig.6) can be seen.

4. CONCLUSIONS

In the paper are presented the PSpice simulation results of the system response to large changes in control input. Showing different cases: when control input decrease, the tank energy is reduced by a series of successive diode conductions, likewise when control input increase the tank energy is built up a series of successive transistor conductions. Thus by utilizing the desired diode trajectory itself as the control low, the new steady state can be reached. In both cases, the system reaches the new equilibrium trajectory in the minimum possible time limited only by the intrinsic properties of the resonant converter.

PSpice simulation results of the system response at converter start-up are shown too. The performance of the method under short-circuit is also remarkable. Within a short time, the system abruptly reaches another equilibrium trajectory at energy level only slightly greater than the earlier one. Thus optimal trajectory control fully exploits the potential of a converter to respond quickly to the demands of control and load. A very good agreement between simulation and experimental results can be seen.

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The paper is reviewed by Prof. Ph.D. Stefan E. Tabakov.