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CALCULATION OF THE PARAMETERS ON OUTPUT CURRENT IN FULL–BRIDGE SERIAL RESONANT POWER CONVERTER

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1. Introduction

In converters in applications of induction heating there is an equivalent resistance of the resonant circuit and the resonant and dumping are different. Also in these converters, the voltage waveforms are pulse and the current has a dumped sinusoidal form. In such cases is required the phase angle and maximum value on the output current of the converter be calculated in respect to the dumping frequency.

2. Calculated of the Output Current of the Serial Resonant Bridge Converter

Calculation of the current in wide band around the resonant frequency based on calculate the value of the phase angle and maximal value on current in this wide band.

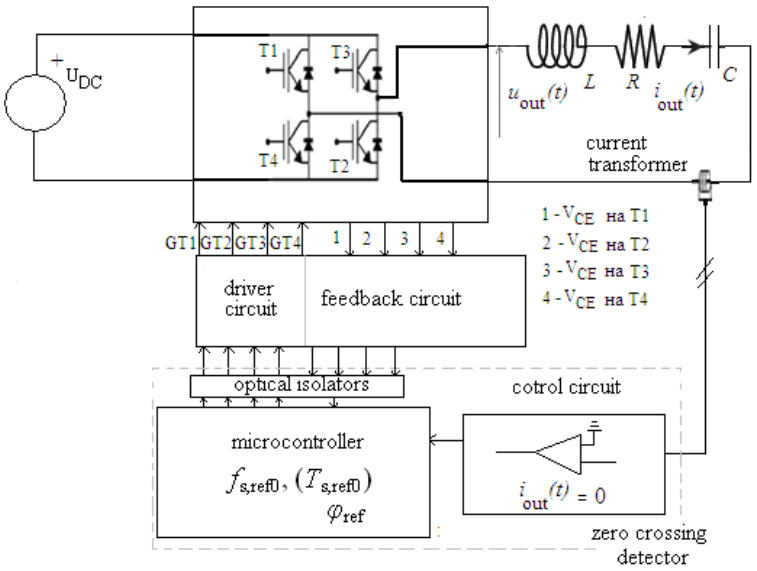


Fig. 1 Block diagram of the full-bridge series-resonant converter.

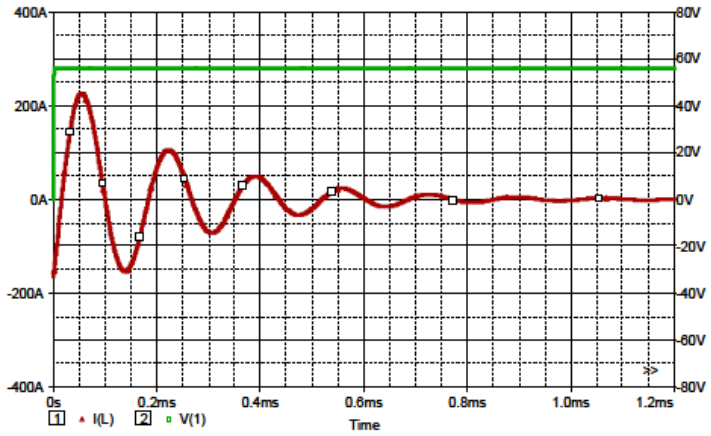


Fig. 3. Current waveform in the series-resonant circuit when excited by a Heaviside step voltage with amplitude UDC = 60 V. Parameters' values are R = 0.24 Ω, L = 26.5 μH and C = 26.6 μF with initial values iL(0+) = –165 A and uC(0+) = –163 V.

In this paper for full-bridge serial resonant converter supplay with square voltage, dependence on phase angle from damping and resonant circle frequency is derived as:

$$\varphi = \operatorname{arctg}\left(\frac{\sin(\pi \frac{\omega_d}{\omega_s})}{e^{+\frac{\pi}{2Q}\frac{\omega_0}{\omega_s}} + \cos(\pi \frac{\omega_d}{\omega_s})} \right) \qquad (2)$$

$$i(t) = \frac{2U_{DC}}{L\left[\omega_d - \left[\alpha \sin(\frac{\pi}{x}) - \omega_d \cos(\frac{\pi}{x})\right] e^{-\frac{\pi}{2Qx}}\right]} e^{-\alpha t} * \sin\left[\omega_d t - \operatorname{arctg}\left(\frac{\sin(\frac{\pi}{x})}{e^{+\frac{\pi}{2Q}\frac{1}{x}} + \cos(\frac{\pi}{x})} \right)\right] \qquad (16)$$

In (16) the of the output current of the serial bridge converter is calculation in relation to the deviation of the switching of damping frequency in a wide band around the resonant frequency.

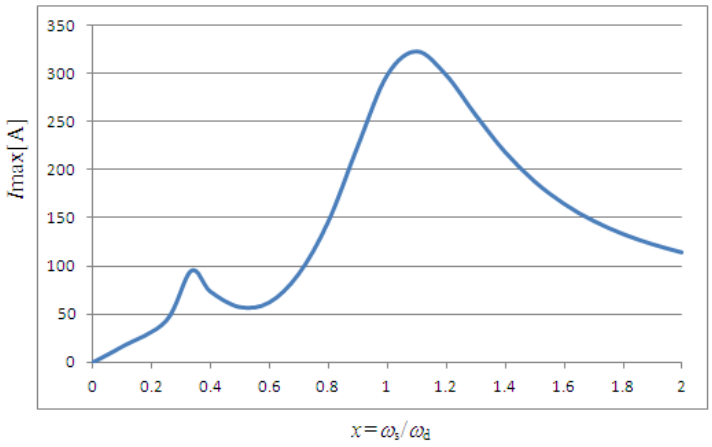


Fig. 5. Graph of the maximum output current of the converter I_{max} obtained with the exact equation.

3. Experimental results

A check of the theoretically derived equations in the preceding chapters is made using the full-bridge IGBT converter who operates in mode on the induction heating furnace with nominal output power converter from 15 kW and resonant frequency 5.994 kHz. In the Fig. 6 is shown control module on this converter.

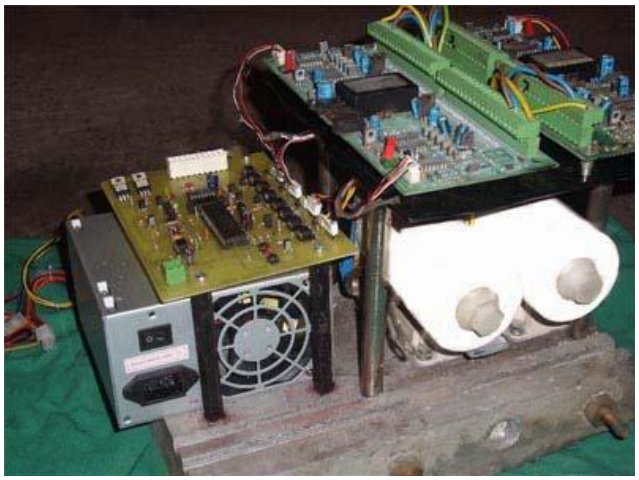
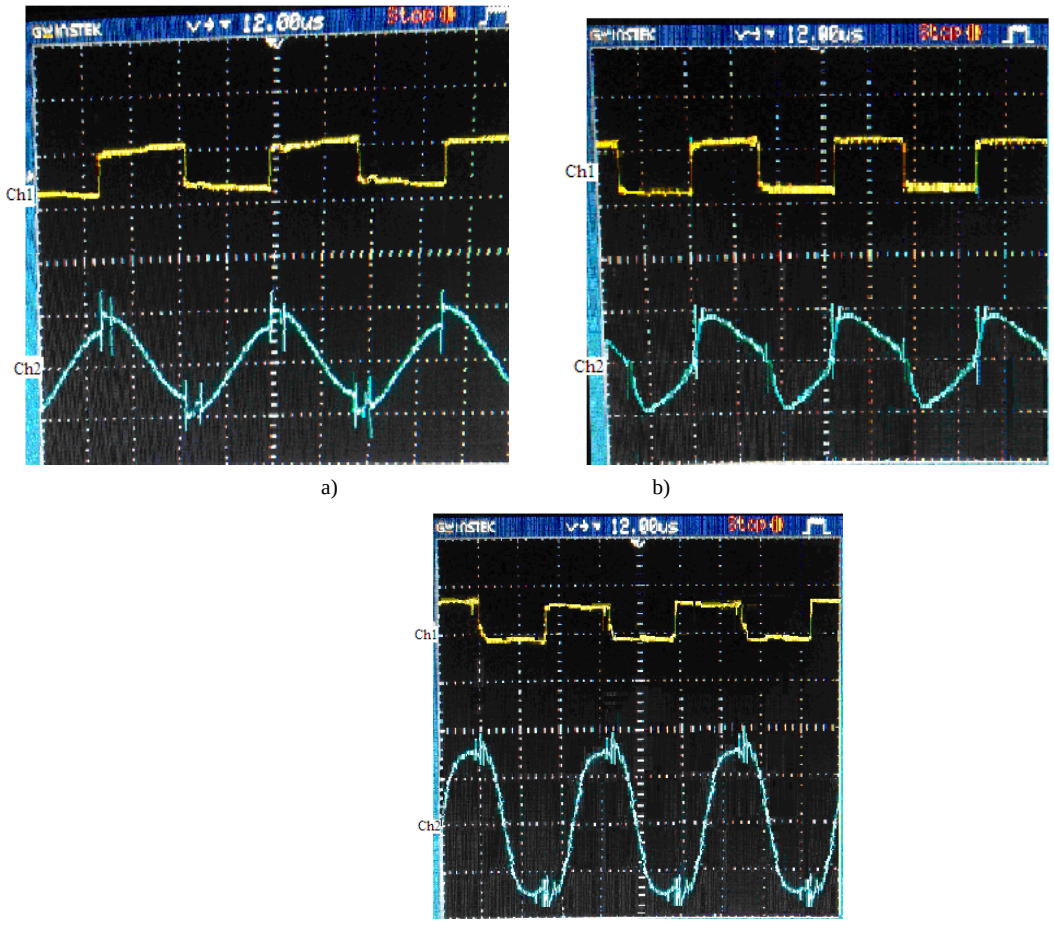
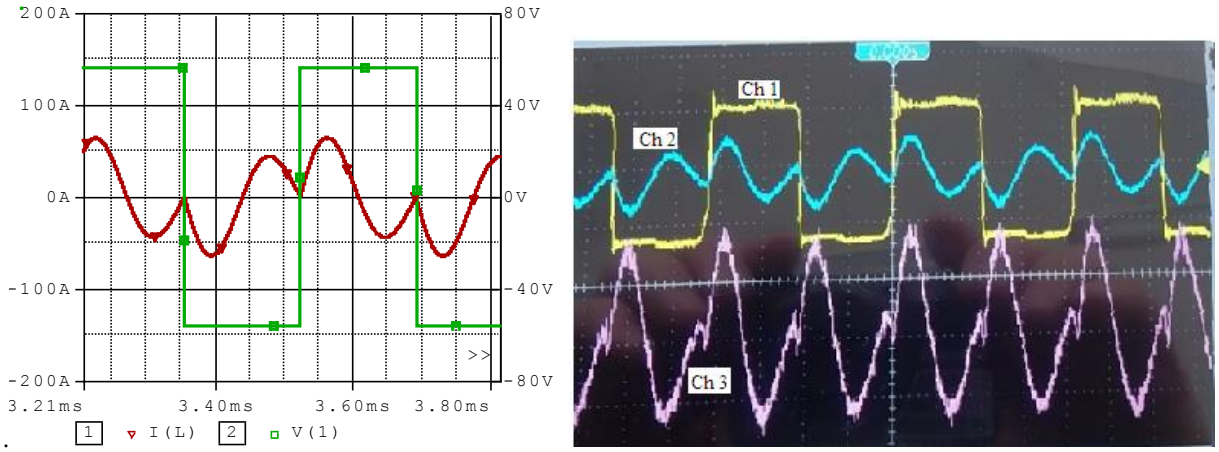


Fig. 6. The control module with IGBT drivers and IGBTransistors.



Ch1=100V/div, Ch2=300A/div, time=50μS

Fig. 7. Wave form the output converter voltage and current a) with a frequency smaller, b) at the resonant frequency and c) at a higher frequency than the resonance.



a.) b)

f_s = 0,5 f_0 = 2 979 Hz, Ch1=50V/div, Ch2=100A/div, Ch3= 2000W/div, time=80μS

Fig. 8. Wave form on the output voltage and current of switching frequency f_s = 0,5 f_0 = 2 979 Hz, obtained with: a) simulation in PSpice and b) with an experiment.

In Fig 8 on the chanel 1 is given wave form on the output voltage, chanel 2 is wave form on the output current and chanel 3 is output converter active power.

4. Analysis of the results

From Fig. 5 we can see that the maximum value of the output current of the converter I_{max} according to the exact equation (15) is highest value for x = 1.1. Also and here for the values on x < 0.6 the maximum value of the output current has significant oscillations and for x > 1.1 this current decline with lower slope.

From Fig. 5 and Fig. 7b can see that for f_s/ f_0 = 1, obtained is maximum current abound 300 A with exact equation (15), as and with experimantal results. For switching frequency above resonance f_s/ f_0 = 1.1, the current has a greater value around 320 A.

Also from Fig.8 can see that for the frequency f_s = 0,5 f_0 = 2 979 Hz maximal current value is around 60 A and it is the same current value of the graph of Fig. 5 obtained by the

equation (15).

5. Conclusion

In this paper for full-bridge converter with serial resonant circuit, analytical are derived exact general equations for dependencies of the maximum voltage of the capacitor and the maximum value of the output current. This equations giving dependences on this parameters from the deviation on the switching from damping frequency in wide bands around resonant frequency. Derived expressions can be used for controlling of the full-bridge serial resonant converter. The results of the experimental testing are close to the values of the parameters obtained by the derived equations.. From these general equations can be obtained the equations for the case when $\omega_s \approx \omega_d \approx \omega_0$.