A MULTIFUNCTIONAL CONVERTER FOR THE INVESTIGATIONS AND TRAINING IN THE FIELD OF THE ELECTRIC ENERGY CONVERTERS

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The converters of the DC-AC or PWM direct-current power are more widely used devices for the automated electric drives control, as well as for the different technological processes control. In principle they are multi-parametric systems, because of the electromagnetic processes in them are due to the interaction of the many factors. The multi-parametrication determines the significant difficulties by analyzing, optimizing and practical research of them, too. From this point of view with the purpose of an intensification of the lecturers', students' and graduate students' research and development work from particular necessity is the creating a multifunctional converter experimental configuration as a base module for the investigations and training in the field of the electric energy converters. In this paper the results from the electric converter design and research are presented that depending on the switching devices control algorithm can be realized the following functions: a full-bridge transistor inverter for the DC load control; a full-bridge transistor resonant inverter and the PWM inverter. An experimental model for the lecturers', students' and graduate students' development and training are proposed.

1. INTRODUCTION

The converters of the DC-AC or PWM direct-current power are more widely used devices for the automated electric drives control, as well as for the different technological processes control. In principle they are multi-parametric systems, because of the electromagnetic processes in them are due to the interaction of the many factors. The multi-parametrication determines the significant difficulties by analyzing, optimizing and practical research of them, too. From this point of view with the purpose of an intensification of the lecturers', students' and graduate students' research and development work from particular necessity is the creating a multifunctional converter experimental configuration as a base module for the investigations and training in the field of the electric energy converters. [1].

1. BASE CIRCUIT CONFIGURATION DESCRIPTION
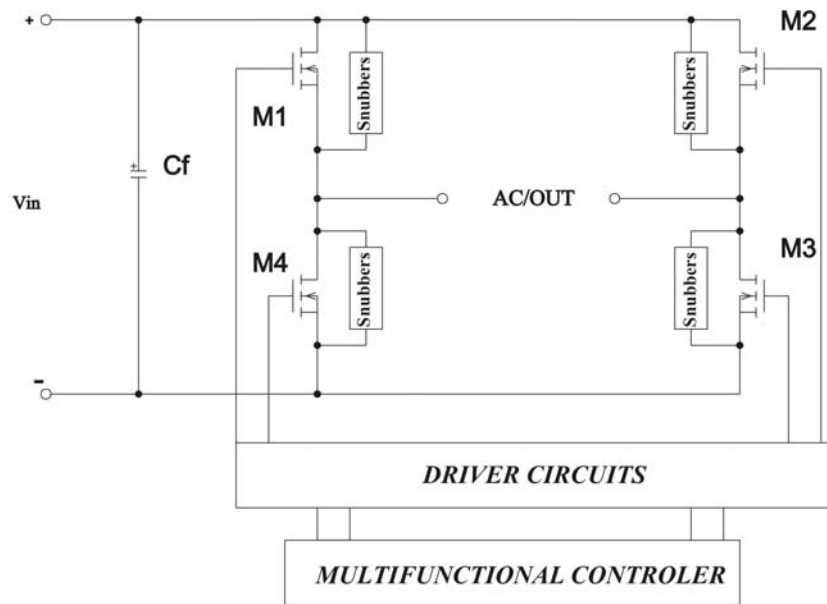Fig.1 shows the block diagram of the proposed devices.

Fig.1 Base circuit configuration

MOSFET and IGBT transistors like switching devices are expected to use, in order that the students and graduate students can be investigate the two elements operation modes in the real converters and make a valuation of the switching devices power losses and all system efficiency depend on the transistors operation mode.

The converter consists from DC source voltage V_{in}, the transistor full-bridge inverter, driver circuits and the multifunctional controller. The full-bridge inverter configuration allows the different loads in the bridge diagonal to be switched like: a DC motor, a series resonant link or AC loads require sinusoidal voltage.

The driver circuits ensure the necessary transistors gate pulses. The multifunctional controller forms the control pulses for the power circuit different modes. Those are pulsewidth modulating signals (PWM) by giving low modulation, dephased at 180° and etc.

2. THE POWER CIRCUIT OPERATION MODES
2.1 The generation of the sinusoidal voltage for the AC loads control

By means of the PWM control the sinusoidal voltage generation from the inverter is realized. By varying of the transistor turn-on time is achieved the rectangular asymmetrical bipolar voltage pulses, which source the AC RL load [2].

The average value of this voltage represents a subharmonic of the high frequency AC voltage and by low near the sinusoidal is changed. In consequence of the load inductance the upper harmonic content in the load current is significant smaller than in the inverter output voltage (fig.2). The load voltage U_T and current I_T shapes are shown in this curve. In the used inverter control modification, sine function is putted in the table format containing 256 eight-bit words. The method for the sine programming is shown in fig.3. The value of the function "sine" is rounded off

nearest higher or smaller binary number that is ensured an improvement of the sine approximation.
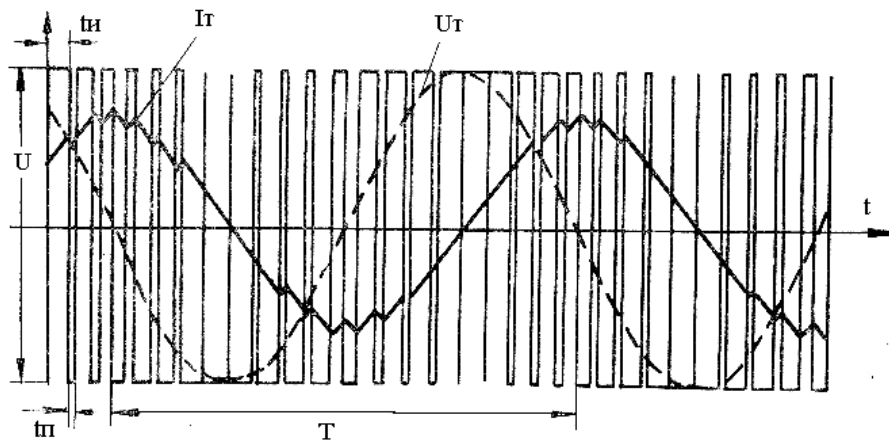

Fig.2

The each discrete value, which in the memory cell with addresses 00 - FF are recorded, can be evaluated through the equation:

- for the positive half wave for addresses – X from $0_{10} \div 127_{10}$

$$(+)Y = 128.sin[(x + 1).c] + 127 \qquad\qquad x = 0 \div 127 \qquad (1)$$

- for the negative half wave for addresses $x = 128 \div 255$ (2)

$$(-)Y = 127 - 127.sin[(x - 127).c] \qquad\qquad x = 128 \div 255 \qquad (3)$$

- in these equations the constant – c is equal to

$$c = \frac{\pi}{128}. \qquad\qquad (4)$$

In fig.3 the dates in the graphical type are shown. Hear X-axis plotting memory cell addresses and Y-axis plotting the sine dates recording in the corresponding memory cell. The value of the each one discrete determines the control pulses duty cycle for the corresponding transistors pair.
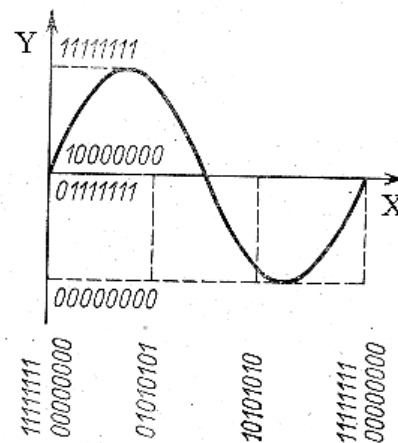

Fig.3

2. 2. DC motor pulse control

The reversible transistor circuit for the DC motor control is realized through the full-bridge circuit shown in fig.4. The circuit control is symmetrical. In this circuit the transistors from the opposed bridge arm VT1, VT3 and VT2, VT4 with identical

signals are switched [3].

The rectangular pulses with alternating polarity are fed to the motor armature. Fig. 5 shows the voltage Ua and current Ia shapes in the motor armature by duty cycle D > 0.5 and fig.6 shows the motor mechanical characteristic for variable duty cycle D. The control voltage is equal to zero for D = 0.5 (Uy = 0), and mechanical characteristics crosses the beginning of the axis.

The static characteristics by symmetrical reversible circuit can be evaluated from the equations:
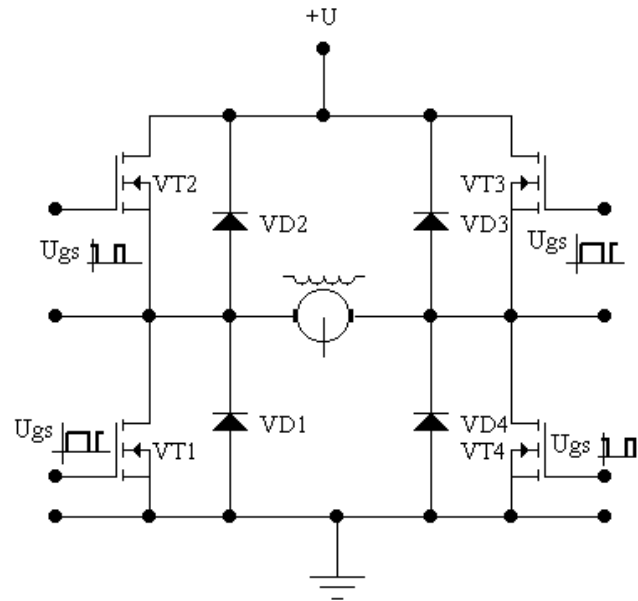

Fig.4

$$\frac{\omega}{\omega_0} = 2D - 1 - \frac{Icp}{I_K} \qquad (5)$$

$$\frac{\omega}{\omega_0} = 2D - 1 - \frac{M_c}{M_k} \qquad (6)$$

In them the following common symbols are used: ω – motor shaft actual speed; ω_0 – ideal no load speed; I_{cp} – average current through the motor armature; I_{κ} – short circuit current; M_c – static resisting torque; M_{κ} – short circuit torque.
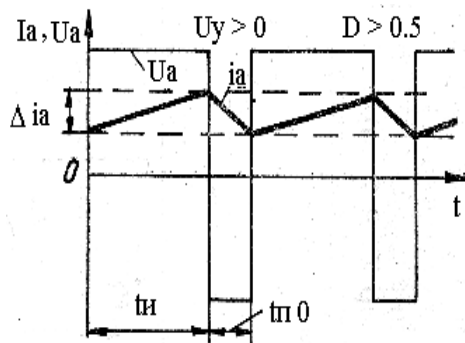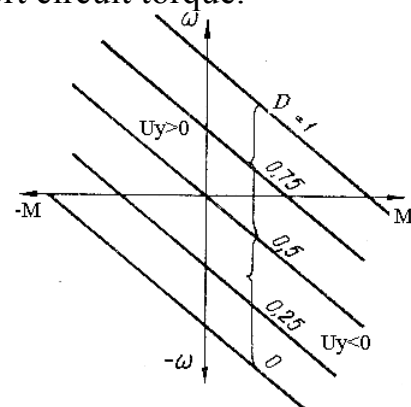

Fig.5

Fig.6

2.3 Transistor resonant inverter

The inverter operates in continuous current mode as $\omega_S > \omega_0$. In this mode the zero voltage transistors turn on is realized. Fig.8 shows the waveforms, which explain the circuit processes.

The following common symbols are used:

I_{C0}, U_{C0} – initial values of the resonant link current and voltage across series capacitor C.
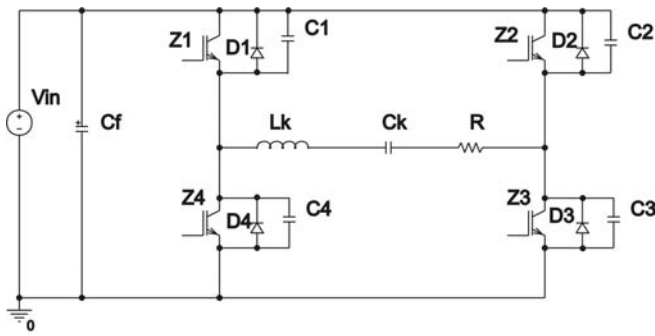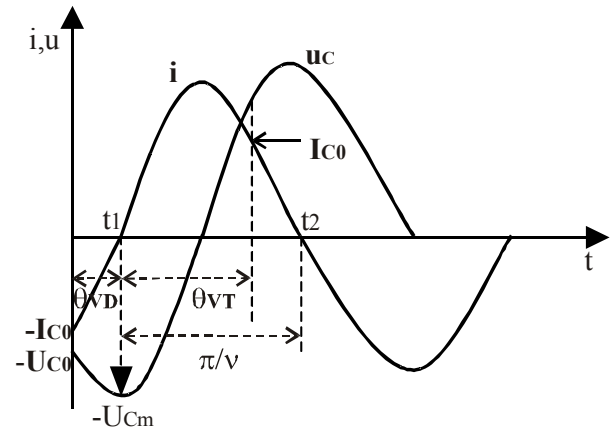
Fig.7 Full-bridge resonant inverter

Fig.8 Current through the series resonant link and voltage across series capacitor

The inverter operation above resonant frequency is characterized with that the transistor turn on from each inverter arm always by zero voltage (ZVS) and diode completely restored switching property from other arm is realized. This reduces commutation loses and increases inverter efficiency [4].

The control system is self-oscillating [5], [6]. The operation of the control system (CS) is synchronized with the current **i** in the resonant circuit. The simulation results from OrCad PSpice analysis [7] are shown in fig.9, which explain the system operation. The control algorithm is following: the information for the current through the resonant link by means of sensor is fed to input synchronized device. The shaped pulses give information about the resonant current zero crossing.

These pulses start the sawtooth voltage generator (SVG) fig. 9. The voltage increasing time is equal to the transistors turn on time t_{VT}. After comparison of the two signals, the comparator output shaped pulses are used to zeroing SVG and at the same time are fed to the two channels of the control pulses, dephased at 180^0.

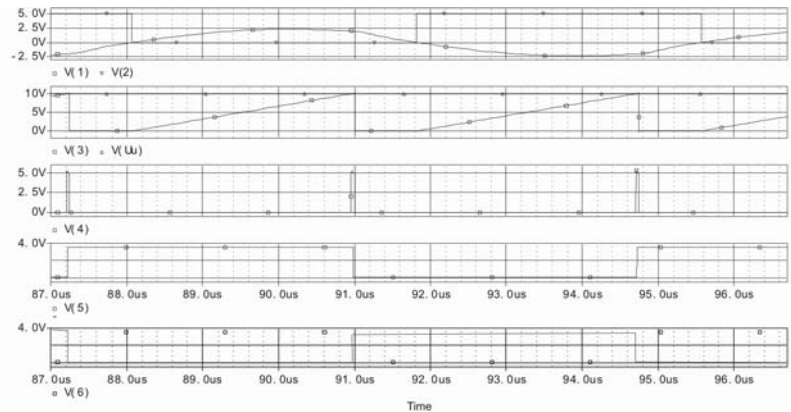Fig.9. Control system main waveforms

The transistor resonant inverter have been designed by following input evidence: $P = 250W$; $f = 100kHz$; $U_d = 30V$. $\omega' = 1,15$ is chosen. The resonant circuit elements values are: $C = 350nF$, $L = 9.6\mu H$ and $R = 1.47\Omega$. The following quantities values are received: $k = 2.87$; $\nu = 1.16$; $\alpha = 0,84$; $\theta_{VD} = 0,64rad$; $\theta_{VT} = 2.06rad$; $K_U = 1,28$; $K_\theta = 1,49$; $U_{C0} = 59V$; $U_{Cm} = 84V$; $I_{L0} = 14,5A$; $I_{VTav} = 5,02A$; $I_{VDav} = 0.87A$; $\theta_m = 1,43rad$; $I_{VTmax} = 18A$; I_d

MOSFET transistors, type IRF9540N have been used. During the simulation snubbers value is 1nF. Fig. 10 shows the OrCad PSpice computer simulation results, which confirm these from the analysis - U_{Cm} = 83.3V, I_{VTmax} =17.7A.
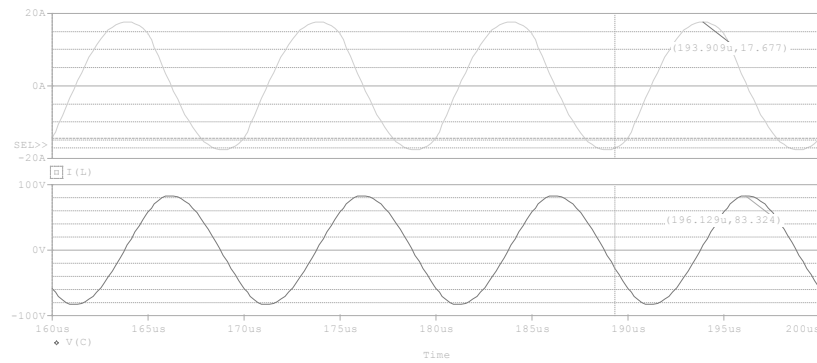

Fig.10 Resonant link current and voltage across series capacitor

The research of the proposed converter is on the basis of the scientific project via R&DS № I - 571/ 06.08.04 with the TU-Sofia, branch Plovdiv on a subject " A multifunctional converter research as a base module for the investigations and training in the field of the electric energy converters".

3. CONCLUSIONS

In this paper are presented the results from the converter design and investigation, which depends on switching devises control algorithm, can be performs the functions of: sinusoidal voltage converter; full-bridge transistor circuit for DC motor control; full-bridge transistor resonant circuit. The three circuit configuration algorithms are described. The purpose of the made investigations is taken off performances and the formulation of conclusions about the investigation circuits applicability for the control of the DC motors, asynchronous motors, as well as the resonant inverters. By means of properly programs the transient and established modes in the shown circuits are modeled. An experimental model for the lecturers', students' and graduate students' development and training are proposed.

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