Issues on Simulations of Inverter Power Supply

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***Abstract* – The modern supply for non-industrial equipment, unlike the industrial power supply installations, must have specific parameters (voltage and frequency). Some modern devices, as the converter – inverter system with static commutation elements, can be used in order to obtain these parameters. The role of the converter in this system is to convert the alternative current of the industrial supplying device to a continuous current; with the help of the inverter the voltage is converted back to alternative voltage.**

This paper presents the alternative – continuous current conversion bridge (the converter), the continuous – alternative conversion bridge (the inverter) having different switching elements and the PWM command signal generation methods of the semiconductor elements by using the "Matlab–Simulink" graphical environment. The system, converter-inverter, has been simulated for a specific parameters R, L, C. These parameters have been obtained after a designing calculation for a universal load. The simulations presented use the static switching device as optimal for a proper behaviour of the inverter in the case of the given charge.

***Keywords:* power supply, inverter, simulation.**

I. INTRODUCTION

The paper presents a simulation in the "Matlab–Simulink" graphical environment, for an installation power source. This power source contains a converter circuit, an inverter and a command circuit for the inverter with static switching elements.

For example, the heating adjustment inside the electromagnetic induction heating installation is achieved especially according to the electromagnetic field penetration depth. As it can be seen in the penetration depth equation, the frequency adjustment changes the penetration depth and also the layer of the product, which is being heated. The industrial supply voltage of low, medium and high voltage is of 50 Hz frequencies. The heating system using different methods to adjust the voltage according to the needs of the technological process: rotating and static converter and ferromagnetic frequency multipliers. The development of power electronics, based on static switching elements more stable and well-performing, lead to lower economical costs and higher efficiency of the AC/DC and DC/AC conversion installations. Therefore, the industrial power voltage will be changed into a continuous voltage, and then it will be converted back to an alternative signal, with the help of the inverter, according to the parameters required by the technological process.

II. NUMERICAL MODELLING OF THE INVERTER

Numerical modelling is performed in Matlab, which is a high performance set of programs dedicated to numerical calculations and graphical representations used in the field of science and engineering. It contains numerical analysis, signal processing and graphical representation, in an environment easy to learn and to use, based on natural programming. After a long time development, today Matlab is a standard in the academic life and research fields of the problems related to the signals processing, systems identification, statistic control, experimental date processing, etc.

For the analysis of an electric circuit of an inductor, they have simplified the original circuit to an induction R – L serial one. This simplified circuit was adapted to a condenser C, which can be connected serial or parallel. Depending on the connection of the condenser with the serial R – L elements, it is obtained a series or parallel resonant circuit.

The situation shown in figure 1 is easy to obtain in the Matlab–Simulink graphical environment; you must have the minimum level of knowledge about the object-oriented programming and about the phenomenon you want to simulate.

Matlab program offers the user a set of pre-defined blocks that can be used to construct the new phenomenon. The pre-defined blocks have standard functional parameters, but they can be modified depending on the application. The modification of these parameters can be done using a special window, by double-clicking on the block image.

Figure 2 and 3 is showing the Simulink scheme for simulating a converter circuit, which has the target to convert and filter 220 V(rms) alternative voltage. The converter contains 4 semiconductor diodes connected in a bridge so that the alternative voltage conversion is possible. Then this converted double-alternated voltage is filtered by a L-C filter in order to obtain the signal of continuous voltage.

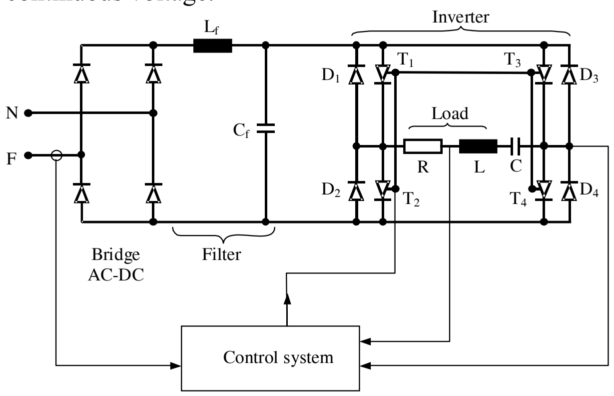

Figure 1. Electric scheme of an installation that needs converted parameter.

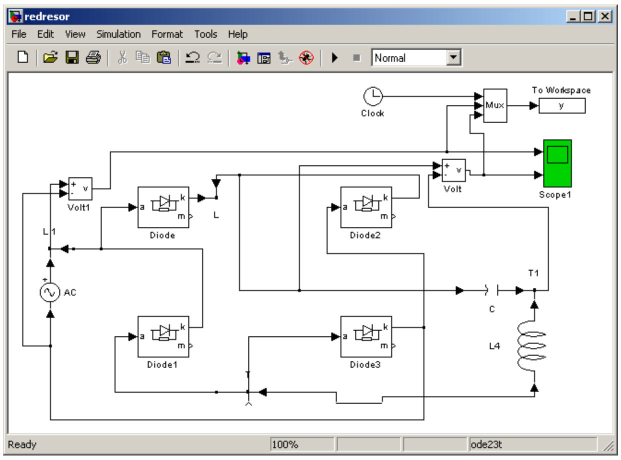

Figure 2. Simulink scheme for an alternative voltage conversion.

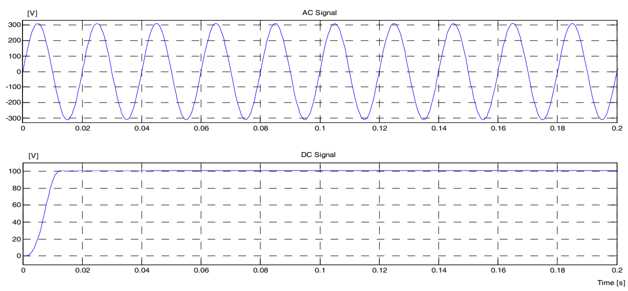

Figure 3. The sinusoidal signal and the converted and filtered signal in Simulink-Matlab.

An inverter can be designed in the Matlab-Simulink graphical environment as described below: the static switches will be taken out from the storage location and placed in a bridge; the charge, which can be an inductor of an induction electro-thermal device, will be placed between the arms of the bridge; in our system the charge is more simple, it is a RLC series resonant circuit.

R, L, C circuit parameters were obtained after a design calculation in the case of an inductor for an induction heating technological process, for which the inputs are: heating temperature, working frequency imposed for the inductor and the material processing time. Knowing the frequency imposed for the power supply of the inductor and the values of R, L, C series parameters, a Simulink scheme can be implemented in the Matlab program for simulating the functioning of a real inductor power supply circuit. The inverter is developed with commanded static commutation elements. Depending on the imposed technological frequency there are different types of static commutation elements that can be used: GTO thyristors, IGBT transistors, MOSFET transistors.

Figure 4 shows the numerical modelling scheme for an inverter circuit with MOSFET switching elements, in the Matlab-Simulink graphical program.

In order to be sure that the charge current is alternative, the positive alternation is obtained by activating the MOSFET and MOSFET-3 elements. The negative alternation is obtained by activating the MOSFET-1 and MOSFET-2 elements. As far as possible the charge voltage should not randomly vary, between two impulses, due to the self induced voltage from the coil; therefore a by-pass is needed when the charge voltage approaches the level of 0 volts. The performing switching elements contain a diode placed anti-parallel with the static commutation element. This diode creates the necessary by-pass, as shown in figure 1.

A correct command for a bridge inverter with R L C charge must take into account the power stored inside the coil and must find a proper by-pass way for the voltage discharge. One of the well performing commands is the width modulation (PWM) command for switching elements. The charge voltage is composed of the PWM impulses and the current has a sinusoidal form, according to the modulation and to the number of PWM impulses.

The PWM command with sinusoidal modulation is used to remove the superior harmonics up to a given level. The greater is the number of pulses in a given period of time, the more harmonics can be removed.

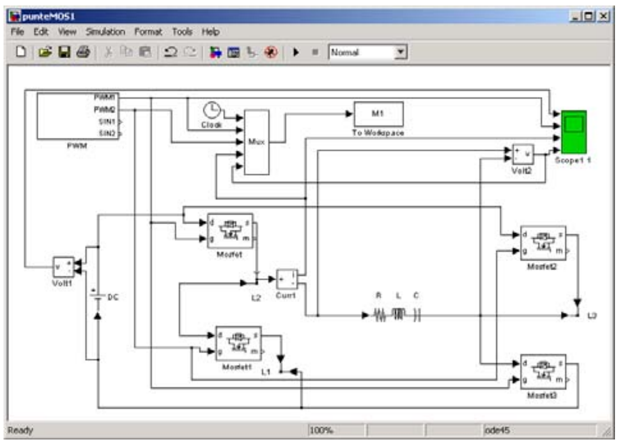

Figure 4. Bridge inverter with MOSFET switching elements.

The closing and opening impulses depend on the fundamental harmonic value that is obtained at the inverter output. This one must remove the harmonics smaller than 2N. The maximum number of N impulses, obtained in a half-period, is limited by the maximal frequency of the switches functional process; the higher is the increase of the commutation losses the higher is the frequency of the switches.

The Simulink scheme for PWM command signal generation using sinusoidal modulation is presented in figure 5. Figure 6 shows the modulation of the two signals in order to obtain the PWM signal. The number of impulses applied to static commutation elements is changing when the triangular signal frequency is modified.

The inverter is simulated for the basic working frequency of f = 2500 [Hz]. The inverter is numerically modelled for static switches MOSFET, and for 3 different frequency values of the modulating wave (1000 Hz, 5000Hz and 10000 Hz frequency) (thus it removes the harmonics up to level 1 and 12). The following figures 7, 8, and 9 present the output signals of the simulated inverter.

In this figures we present the active power P and reactive power Q associated with a periodic voltage-current pair that can contain harmonics. P and Q are calculated by averaging the V I product with a running average window over one cycle of the fundamental frequency, so that the powers are evaluated at fundamental frequency.

$$P = \frac{1}{T}\int_{(t-T)}^{t}\left(V(\omega t)\times I(\omega t)\right)dt \qquad (1)$$

$$Q = \frac{1}{T}\int_{(t-T)}^{t}\left(V(\omega t)\times I(\omega t - \pi/2)\right)dt \qquad (2)$$

where:

$$T = \frac{1}{f}$$

V - Voltage on load;
I - Current on load;

Also in figure 7, 8 and 9 is presented the Total Harmonic Distortion (THD) of a periodic distorted signal. The signal is measured for current. The THD is defined as the root mean square (RMS) value of the total harmonics of the signal, divided by the RMS value of its fundamental signal.

In this case for current the THD is:

$$(THD) = \frac{I_H}{I_f} \qquad (3)$$

where:

$$I_H = \sqrt{I_2^2 + I_3^2 + I_4^2 + ... + I_n^2}$$

I_n - RMS value of the harmonic n;
I_f - RMS value of the fundamental current.

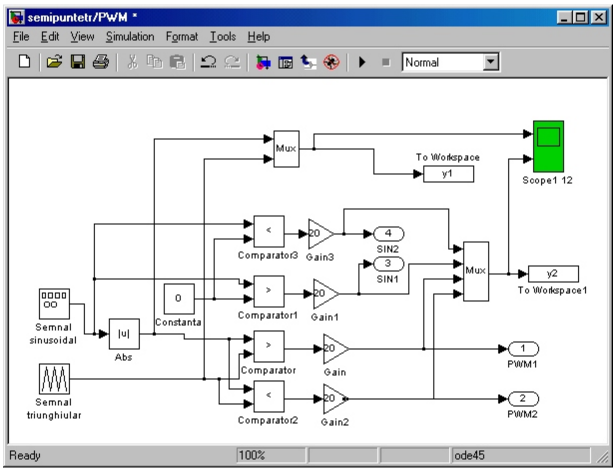

Figure 5. Simulink scheme of the PWM signals generator with sinusoidal modulations.

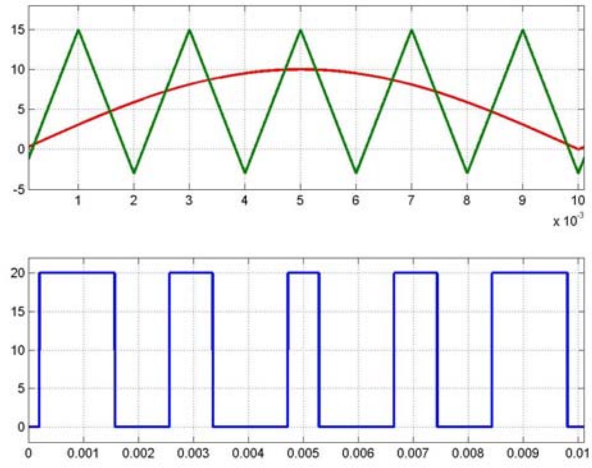

Figure 6. PWM signal with sinusoidal modulation.

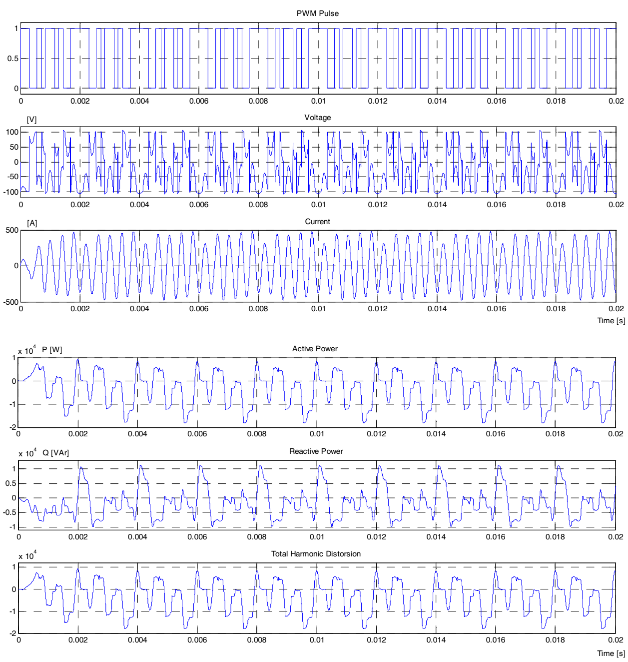

Figure 7. Output signals of the inverter with MOSFET switching elements, for a 2500 Hz resonant frequency and 1000 Hz modulation signal frequency.

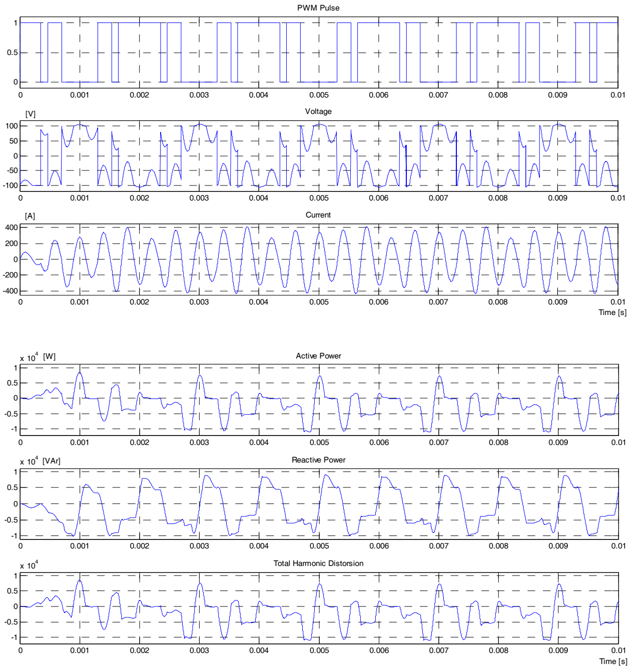

Figure 8. Output signals of the inverter with MOSFET switching elements, for a 2500 Hz resonant frequency and 5000 Hz modulation signal frequency.

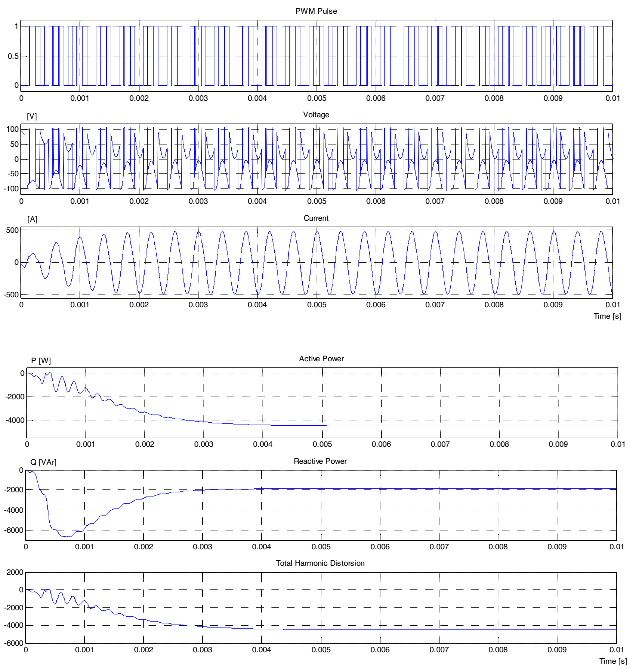

Figure 9. Output signals of the inverter with MOSFET switching elements, for a 2500 Hz resonant frequency and 10000 Hz modulation signal frequency.

III. CONCLUSIONS

The results confirm the idea that more and more harmonics are removed when the modulation signal frequency is increased. In the same time, the charge current will have an almost perfect sinusoidal shape. Although, while this frequency and the switching frequency are growing, the amplitude of the charge current is lower. This process is important in the case of the inverter with GTO commutation elements (it is able to support great currents but low switching frequency). As a conclusion, the MOSFET commutation elements have a good behaviour at high commutation frequencies, despite the fact that there are important losses when the commutation frequency grows higher. The IGBT elements have a good behaviour too even if their commutation time intervals are a little bit longer than the MOSFETs'. Although, when the commutation frequency grows, the charge voltage peaks do not appear anymore. The only one effect is that the voltage charge and current are diminished.

PWM command technique is more advantageous when dealing with power adjustment or when we want to remove some harmonics. These important advantages explain why this type of command is often used, in spite of the fact that it requires a more complicated command device and quick semi-conductor devices (the costs are bigger). The technical progresses of the command (specialized integrated circuits) and power semi-conductor devices make this technique more and more attractive.

The computerized simulation of the inverter circuits helps us to prevent the disturbing voltages and currents, the power supply network errors, to reduce the number of early failures, to discover new optimal low cost solutions for any application etc.

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