PC Target Simulation for Direct External Signals Commands of Single Phase Inverter

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Abstract: - An electronic system cud be realized after obtained results from simulations. When adapting commands signals for inverters is important to use complete Matlab-Simulink schema what include real value for inverter load. Use Matlab-Simulink and real-time Workshop is an direct and alternative solution for design an application with real-time hardware. The board dedicate target is connected through classical PCI interface with an PC and direct command an single phase inverter made by IGBT electronic devices.

Key-Words: - inverter, Simulink, real-time, PWM signals.

1 Introduction

The simulation of some complex processes such as PWM (Pulse Width Modulation) inverter control, offers one datum's set. These values are saved in "Workspace of MATLAB". With one created program, it is possible to do analysis. It can be analyze the load current and the voltage load. The results expressed by values obtained after simulation are the base of improving the necessary "soft" to control the real electronic inverter with an board what is connected through classical PCI (Peripheral Component Interconnect) interface with an PC.

Use Matlab-Simulink and Real-Time Workshop is an direct and alternative solution for design an application with real-time hardware. After creating an PWM model in an Simulink schema (Fig.2.) an electronic interface is used. The Real-Time Workshop cud be use to transform the model to C code for assembling or for an executable independent application. Simulink External Mode enables communication between Simulink and a PWM model executing on a real-time. External mode performs real-time parameter tuning and data viewing using Simulink with scope or data workspace. An Very High Level Language (VHLL) is an optimal solution for most applications lake these described.

Few applications include uninterruptible power supplies, electrically driven vehicles and system that mach ac loads to alternative energy sources that produce dc (such as photovoltaic arrays).

2 Inverter with direct external PWM signals from PC

The electronic board is made for transferring analog signals for the gates of IGBT (Insulated Gate Bipolar Transistor) power electronics devices (IGBT1,…, IGBT4) what are in the classical bridge single phase inverter topology. The electronic PCI board contains two Digital/Analog converters for command in the same time, one of the diagonals (AB in Fig.1.) of the bridge inverter (IGBT1 - IGBT3 and respectively IGBT2 - IGBT 4).

The harmonic canceled PWM technique is applied in the three-level inverters. A full-bridge voltage source inverter contain four IGBT (Insulated Gate Bipolar Transistor) switches and one dc source (Fig.1.). The three states of an output waveform can be obtained by Simulink-Matlab bloc for work in real-time. The output waveform is chopped N times per quarter. Each switch is, therefore, switched N times per cycle to generate such waveform. Let N be the number of switching angles per quarter-cycle. The output waveform is assumed to be odd quarter-wave symmetry, whose amplitude equals V_{DC}.

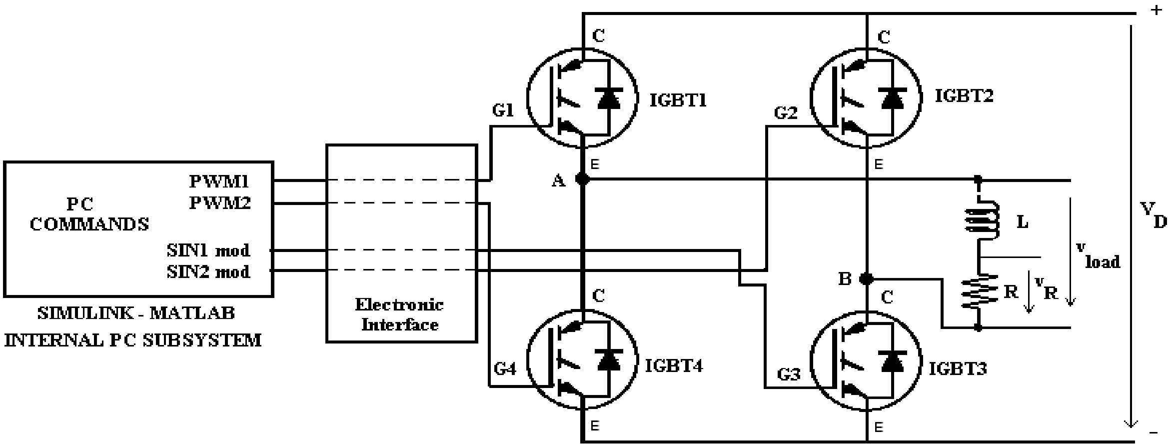

Fig.1. IGBT Single Phase Inverter with direct external PWM signals from PC.

Because of odd quarter-wave symmetry, the dc component and the even harmonics are equal to zero. From [1] with same adapted electrical magnitude, the Fourier series of the three-level PWM as follows:

$$v_{PWM}(\omega t) = \sum_{n=1}^{\infty} V_n \sin(n\omega t) \qquad (1)$$

where

$$V_n = \frac{4}{\pi}\frac{V_{DC}}{n}\left[\sum_{k=1}^{N}(-1)^{k+1}\cos(n\alpha_k)\right] \qquad (2)$$

α_k is the switching angles

$$\alpha_1 < \alpha_2 < \alpha_3 < ... < \alpha_N < \frac{\pi}{2}$$

Vdc is the magnitude of dc source and "n" is the harmonic order.

$$V_1 = \frac{4}{\pi}\frac{V_{DC}}{1}\left[\sum_{k=1}^{N}(-1)^{k+1}\cos(1 * \alpha_k)\right] \qquad (3)$$

$$V_3 = \frac{4}{\pi}\frac{V_{DC}}{3}\left[\sum_{k=1}^{N}(-1)^{k+1}\cos(3 * \alpha_k)\right] \qquad (4)$$

…

$$V_N = \frac{4}{\pi}\frac{V_{DC}}{N}\left[\sum_{k=1}^{N}(-1)^{k+1}\cos(N * \alpha_k)\right] \qquad (5)$$

The cosine terms of α_N are negative with even N and positive with odd N.

Applying the Newton's method to solve PWM switching angles, the nonlinear equation system waveforms can be written as follows:

$$\left[\sum_{k=1}^{N}(-1)^{k+1}\cos(N * \alpha_k)\right] = \frac{\pi}{4}\frac{V_1}{V_{DC}} = \frac{\pi}{4} * M \qquad (6)$$

$$\left[\sum_{k=1}^{N}(-1)^{k+1}\cos(3 * \alpha_k)\right] = \frac{\pi}{4} * \frac{3V_3}{V_{DC}} \qquad (7)$$

…

$$\left[\sum_{k=1}^{N}(-1)^{k+1}\cos(N * \alpha_k)\right] = \frac{\pi}{4} * \frac{NV_N}{V_{DC}} \qquad (8)$$

According to the above nonlinear system, N-1 surplus harmonic can be cancelled from the output $v_{PWM}(\omega t)$ waveform by setting equations to zero and calculated these α_k values from computer.

An classical solution adopted by an Simulink-Matlab schema use a fundamental V_1 sinusoidal function with "f_{sin}" frequency and an triangular function with "f_t" frequency, cording with condition:

$$f_{triangular} = 2Nf_{sin} \qquad (9)$$

Value of the "N" is the number of pulses in an half cycle and the triangular function must change his polarity after each semi-cycle.

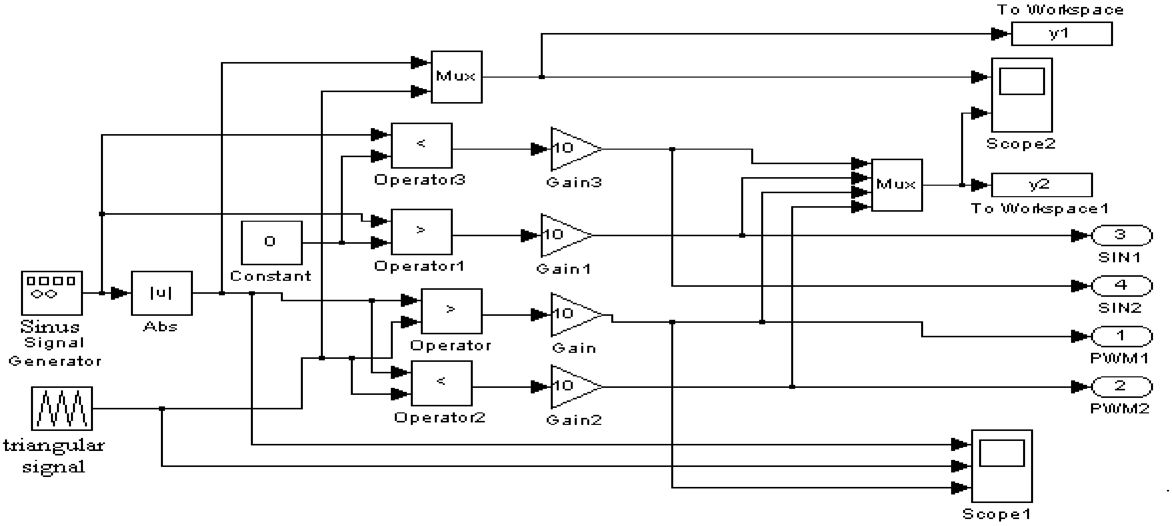

Fig.2. PWM generator for outside PC with Simulink real-time mode.

The conventional way of generating PWM signals for inverter commands (Fig.2.) is to use the sinus triangle intercept. A sine wave is obtained in the "sinus signal generator" and after an bloc "abs" is obtained only the half positive sine wave. A triangle wave is obtained from an repeating sequence bloc from Simulink-Matlab. After few maximal or minimal operators and same amplifier blocs are obtained 4 signals adapted for 4 IGBT gates.

3 Internal PC Simulation

A high-frequency power electronic bridge converter simulink schema is shown in Fig.3.

When $v_{load} = V_{DC}$ ($V_{DC} = 310V$ in this application) IGBT1 and IGBT3 are on, and when $v_{load} = 0$, IGBT2 and IGBT3 are on.

When $v_{load} = -V_{DC}$, IGBT4 and IGBT2 are on, and when $v_{load} = 0$, IGBT1 and IGBT2 are on.

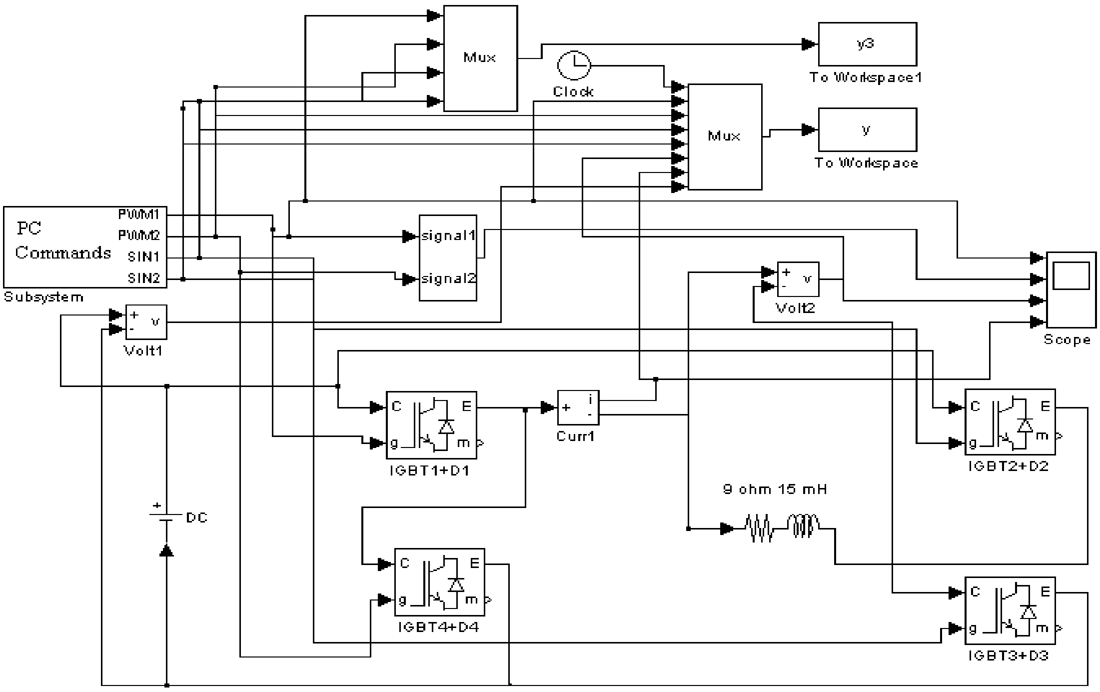

Fig.3. Bridge IGBT inverter Simulink schema with gates signals commands

This switching sequence shows that when $v_{load} \geq 0$, IGBT3 can remain on for a half cycle and v_{load} can be created by switching IGBT1 and IGBT4. Similarly, when $v_{load} \leq 0$, IGBT2 can remain on for a half cycle while IGBT1 and IGBT4 alternate.

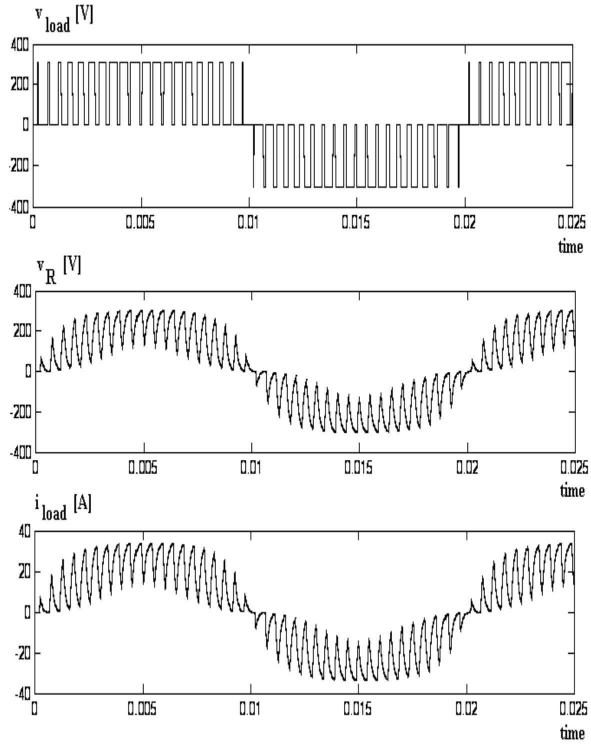

Fig.4. Waves for load when $R = 9\Omega$ and L=1mH.

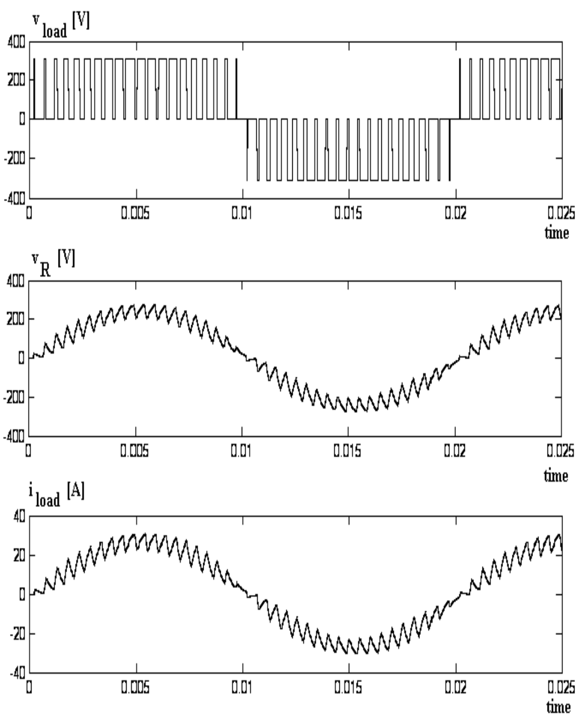

Fig.5. Waves for load when $R = 9\Omega$ and L=3mH

In this application IGBT1 and IGBT4 are switching at the high frequency of the carrier $f_{triangle}$, while IGBT2 and IGBT3 unfold the modulated carrier by switching at the much lower sinus frequency f_{sin}.

The harmonic distorsion is moved to higher frequencies, making filtering easier. Figures 4,5,6, shows the different L filtering for $R = 9\Omega$ in the load of the bridge inverter.

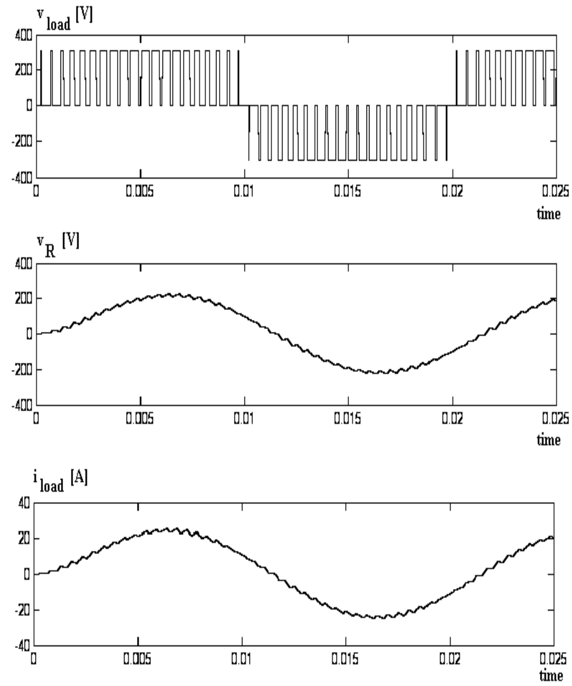

Fig.6. Waves for load when $R = 9\Omega$ and L=15mH

The spectrum of the load current can be limited most easily in the case of high frequency PWM voltage waveforms.

4 Conclusion

The results expressed by values obtained after simulation are the base of improving the necessary "soft" with real-time hardware for direct interface the PC with external Bridge Single Phase Inverter. The application is made by an internal PC board, and offers PWM analog signals for an electronic interface, used for inverter.

References:

[1] A. Kelemen, M. Imecs, *Vector control of AC Drives*, Ed. G.J. Retter, United Kingdom,1987.

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[3] O. Neamtu, *Power electronic converters for supply ac motors*, Ed. University of Oradea, 2002.