Herbert WIDLOK*, Michał WIDLOK*

CONCURRENT SIMULATIONS IN EDUCATION PROCESS FOR POWER ELECTRONICS

SUMMARY

Article presents new idea of incorporating Concurrent Simulations into Education Process for Power Electronics. Advanced laboratory tools like PCI data acquisition cards allows simultaneous registration of many signals with high accuracy and resolution in the practically unlimited amount of time. Modern concept and method of such concurrent research are described. The ability to implement these research during the student laboratory exercise is also presented. Design of the laboratory model is shown with the experimental and simulation research.

Keywords: *Concurrent simulations, simultaneous registration measuring data, computer simulation research, education process*

SYMULACJE WSPÓŁBIEŻNE W PROCESIE NAUCZANIA ENERGOELEKTRONIKI

W pracy przedstawiono zagadnienia wykorzystania nowej koncepcji badań współbieżnych w procesie nauczania energoelektroniki. Rozwój techniki cyfrowej pozwala zastosować karty pomiarowe pozwalające na równoczesną rejestrację wielu sygnałów równocześnie z dużą dokładnością i rozdzielczością w praktycznie nieograniczonym horyzoncie czasowym. Szeroko omówiono koncepcję i metodykę ww. badań oraz wskazano na możliwości zaimplementowania takich badań podczas studenckich ćwiczeń laboratoryjnych. Przedstawiono projekt stanowiska laboratoryjnego oraz wybrane rezultaty badań eksperymentalnych i symulacyjnych.

Słowa kluczowe: *badania porównawcze, współbieżna rejestracja danych pomiarowych, symulacja komputerowa, proces edukacyjny*

1. INTRODUCTION

The following paper presents new method of concurrent simulation, used for verification of compatibility between the real measurements and computer simulation results, and for teaching of power electronics. A special laboratory model have been designed and constructed in the institute of power electronics and it is constantly used during the laboratory research. This paper refer to the past publication [1] presented by author about concurrent simulation in the educational process. Conceptually the presented method using concurrent computer simulation and real measurements of the same object.

It is known that computer simulation base on the mathematical models. Therefore it is very hard to precisely model or simulate parasitic elements or other electrical interferences always presented in the environment. Experience shows that concurrent laboratory measurements is the best method to learn and understand electronics. This method can improve efficiency of learning process and clearly shows the advantages and flaws of computer simulation and real measurements.

Modern laboratory equipment (like acquisition cards or digital oscilloscopes) enables to watch and log a lot of high resolution data points during almost unlimited amount of time. The recorded data can be then verified using very advanced mathematical methods in programs like Matlab. During the analysis and verification all known mathematical and statistical methods of signal processing can be used.

2. CONCEPTION OF CONCURRENT INVESTIGATION

The laboratory model used during the educational process should meet given demands, while the most important are:

- time of the computer simulation, real measurements and data verification should be short;
- the results should be presented very clearly and easily to understand;
- digital acquisition card needs a special and efficient software that works with realtime operation system (like RT-Linux or QNX);
- object control signals and even object parameters should be easily changed during the measurements.

This demands can be meet by most of modern PC computers with high quality graphics and acquisition cards. The conception of concurrent investigation is presented on Figure 1.

The equipment used the laboratory research consists of:

- the Measured Object is a power-electronics circuit with large number of sensors and with the special mechanical construction that clearly shows most important elements to the students;
- digital acquisition card with large number of configurable analogue inputs PC computer that records data form the card and provides environment for verification of the simulation and real data.

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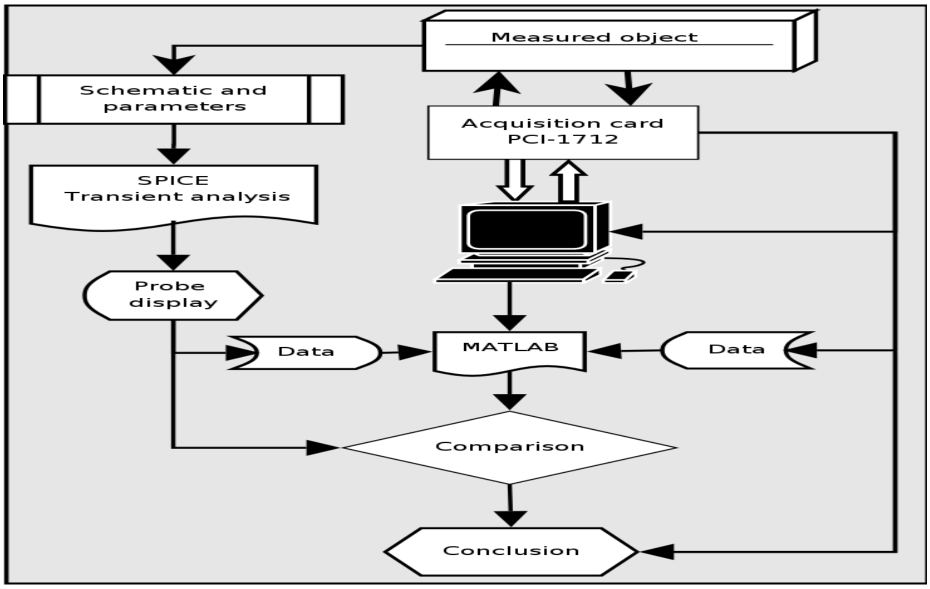

Fig. 1. The idea of concurrent simulation

2.1. Computer simulation of the object

Before the simulation, it is necessary to create detailed schematic of the measured object and to measure all of its parameters. The parameters for used models of power switches and other important elements are also needed. This part is usually quite hard and time consuming. Schematic of the laboratory object is given on Figure 2.

The object consist of:

- 3-pulse rectifier AC-DC,
- switched DC-DC converter (with single IGBT transistor),
- regulated RL load and output filter (with capacitor Co and free-wheeling diode Do).

Control system is made of:

- PI voltage regulator with limits (op. Amp LM324),
- hysteresis current regulator realized with digital elements, with regulated hysteresis loop (by potentiometer R12).

Simulation results can be compared with real measured data directly on the computer screen. It is very easy to visually differences between the results even with complicated waveforms. Real measurements depends on large number of parasitic effects, electro-magnetic interferences and other variables that are almost impossible to simulate.

Differences between the data can checked by computing standard deviation, mean values and so on.

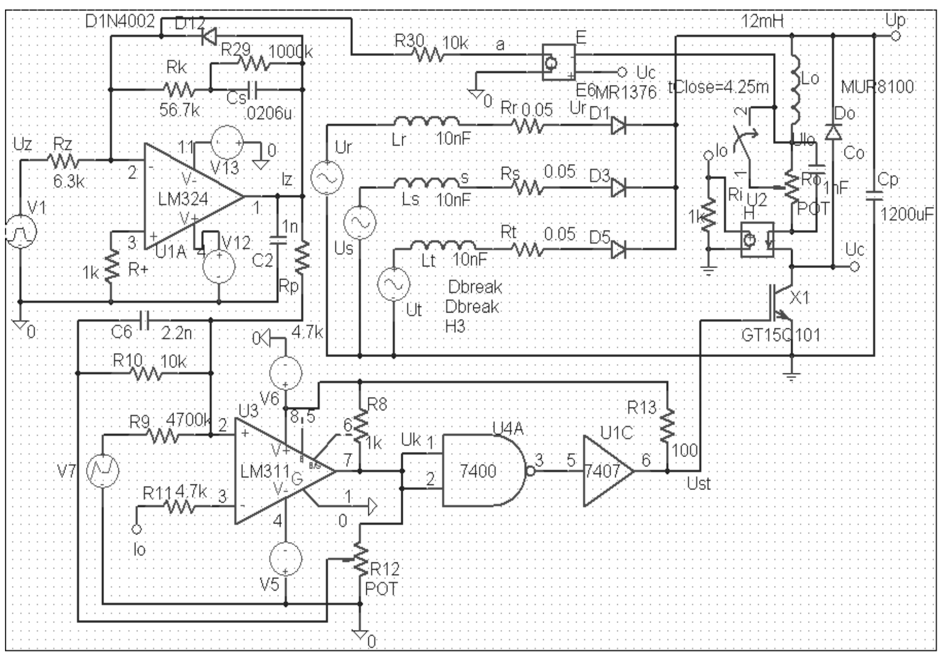

Fig. 2. Schematic of laboratory model

During the laboratory students can change control signals, disturbances, and even schematic of the object. Simulation parameters, like type of analysis are also free to change. One of the goals of the presented method is to create a "feel" how parasitic compotes and other interferences affect the results. Other thing is that students can critically compare their simulation results with the "original" measured data that is very important for gaining experience.

2.2. Measurements of the real object

One of the most critical piece of equipment for the measurements of the real object is the digital acquisition card installed in the PC computer. During the investigation an Advantech PCI-1712 multifunction card have been used. Block diagram of the card is presented on Figure 3.

Figure 3 Most important features of the card are:

- PCI bus,
- 16-single-ended or 8-differential analog input channels,
- single 12-bit A/D converter, sampling frequency up to 600 kS/s,
- programmable input multiplexer and amplifier,
- advanced trigger logic,
- 1 kS FIFO memory.

The card has it's own PCI interface (PCI9054) on board that can handle interrupts and DMA transfers needed for high speed data acquisition. A/D converter is connected with internal card bus through FIFO memory. With this configuration much less load is put on PC processor, because the card just generates an interrupt when the FIFO is nearly full, and then PC initiates DMA transfer. Without FIFO PC would have to pull the card for availability of next data point all the time. Programmable input multi-plexer and amplifier can match channel sensitivity to the given signal and further reduce the PC load. Windows drivers provided with the card does not meet the requirements for high frequency sampling and long data buffers. It is not clear if the limits are related to the drivers itself or to the Windows OS that definitely can't be used as reliable, high speed, real-time environment.

To overcome the problems new drivers was written for the Linux OS. To meet real time requirements RTAI environment have been used with the Adeos kernel patch. The drivers were written in the Comedi package that is an open-source framework and application interface for the data acquisition cards. Using such package let the designer change the hardware without changing his/her dedicated software, if the low-level drivers are provided. Theoretically PCI-1712 comes with Linux drivers made for Comedi, however it was impossible to made them work. Finally authors decided to write theirs own low-level drivers under Comedi. The work was very hard mostly because the documentation that comes with the card is not complete. Emails sent to company with questions about the not working Linux drivers and then about the card documentation gives no useful reply.

The written drivers still does not support all the features possible with the card's hardware but it is possible to make usable measurements with them.

The measurements have been done with the dedicated program that reads configuration form the file (channels sensitivity, order, buffers length, and so on) and then saves the data points in the file. The data can then be red by Matlab or other program, where the analysis and processing is done.

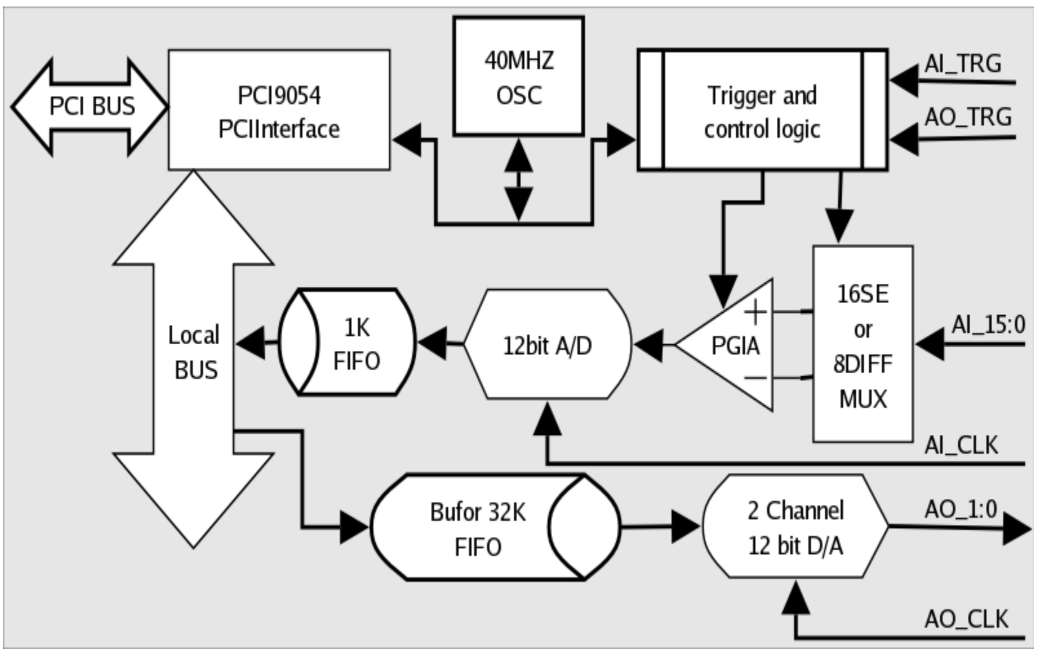

Fig. 3. Block diagram of data acquisition card

3. EXAMPLE OF CONCURRENT INVESTIGATION

The investigation have been done on the laboratory model designed to control DC motors or other loads. The schematic is shown on Figure 2.

According to the conception presented on Figure 1, the theoretical analysis and initial laboratory measurements were made first. All of the object parameters were identified and simulation parameters for the computer program were estimated. Models for all elements used in the real circuit were chosen from the libraries provided by the manufacturers for the simulation package. All this work was necessary to create simulation schematic and the script.

Eight characteristic variables with names corresponding to Figure 2 are presented on the following figures.

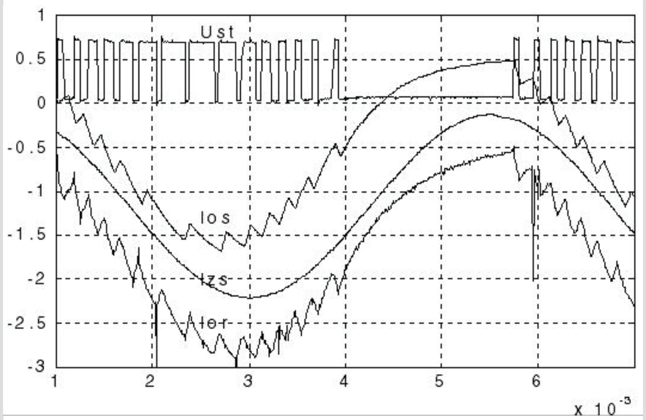

Fig. 4. Transient waveforms of the real (Ior) and simulated (Ios) load current and control voltage Ust

Figure 4 shows the real (Ior) and simulated (Ios) load current and control voltage Ust. The input signal was a 200 Hz sinusoidal waveform Izs. To make interpretation more easy control signal (Izs) was placed inside the Ior and Ios, that were moved for +/–1 A.

Otherwise Ior and Ios would overlap. As we can see both waveforms are almost identical.

The currents precisely following the control signal, while the high frequency ripple is constant and it depends only on the preset current regulator hysteresis loop. Working frequency Fp and duty cycle D depends widely on the load of the DC-DC converter. For maximum load Dmax = 0.88 while Fp = 2.35 kHz.

Minimum load reduces Dmin to 0.03 and Fp to 519 Hz. In theory the maximum working frequency is when D = 0.5, what is confirmed by the simulation and real measurements. The work frequency is then Fp = 5.34 kHz.

Next picture (Fig. 5) shows transient waveforms of the drainsource voltage on the IGBT transistor Uc and the voltage on the load inductance Ulo.

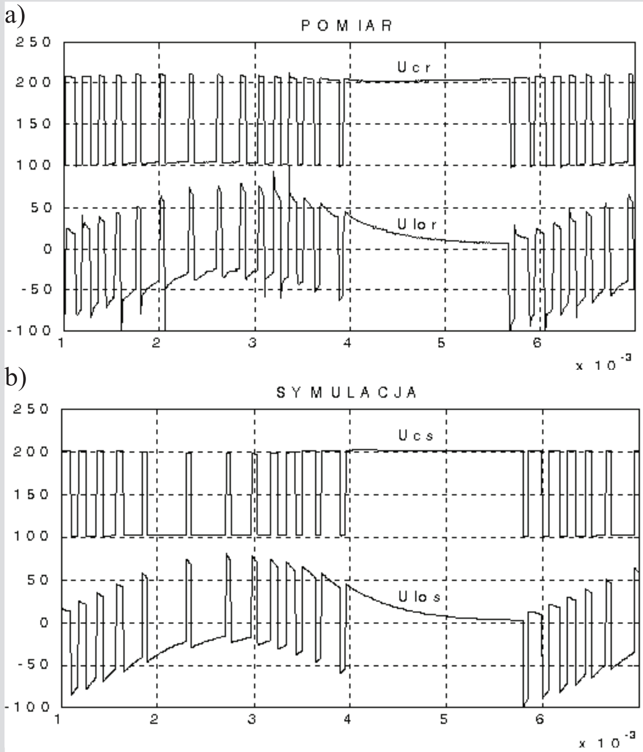

Fig. 5. Transient waveforms of the drainsource voltage on the IGBT transistor Uc and the voltage on the load inductance Ulo

4. SUMMARY

Presented method of concurrent investigation:

– improve of teaching process,
– ensure better understanding of difficult electronics problems,
– create laboratory training more interesting.

Additionally when using modern data acquisition card (preferably with PCI bus) with software designed by authors the method also enables to:

– almost unlimited time of data logging (software is also very effective because of RT-Linux operation system used),
– concurrent measurement of many signals with high accuracy and resolution,
– generate control and even disturbance signals,
– data acquisition on 16 channels with 400 kHz sampling rate.

During a few months of using the laboratory model and software have been improved.

Results presented in chapter 4 clearly shows that the concept and method is correct.

References

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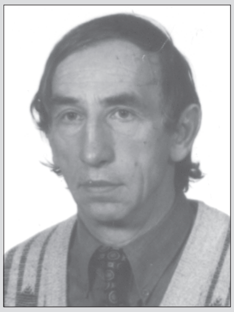

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Herbert Widlok was born in Bielsko, Poland in November 1940. He received The M.S.E.E, and Ph.D. degrees in 1968 and 1977, respectively both from University of Mining and Metallurgy, Faculty of Electrical and Automation, Cracow, Poland. Since 1970 he has been engaged in research development and teaching in Power Electronics and electrical drivers in Institute of Drive Automation of AGH University of Science and Technology.

In 1991 he submitted his thesis "Metallurgical Multi-Motor Drivers as an Object of Micro-computer-Based Control" then he was granted the scientific title assistant professor.

He is currently interesting in microprocessor-based control systems especially in metallurgical rolling mills drives. His teaching activities are computer simulations and the application of concurrent simulation method for learning power electronics.

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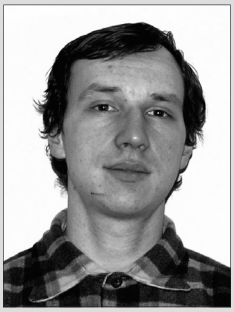

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Was born in 1979 in Kraków, Poland. He received M.Sc. degree in electrical engineering from the AGH University of Science and Technology in Kraków on the subject "Testing and analysis of high speed interfaces with specially designed ICSP programming device" in 2003. Concurrently he is on the third year of Ph.D. Studies on AGH University of Science and Technology. He also works for R&D Marine Technology Center designing military underwater systems. His research directions are power electronics and micro-controller control systems.

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