

## ANALYSIS OF THE USE OF SELECTED SIMULATION PROGRAMS IN THE EXAMINATION OF POWER ELECTRONICS CONVERTERS

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**Abstract:** Along with the development of power electronics technologies, the importance of converter systems grows in the widely understood economy.

Simulation programs enable to broaden the didactic offer for technical schools and universities and increase the self-education opportunities. The use of computer simulations often helps to understand difficult phenomena occurring in the operation of converter systems. Information obtained during simulation tests enable the verification of the knowledge gained by pupils, students and engineers in real model laboratories.

The article presents the application of the selected simulation programs in broadening the knowledge of converter systems.

**Keywords:** Simulation Program, MATLAB-Simulink, Tcad, Electronics Workbench.

### Introduction

In education and researches, as demonstrated by practice, the best didactic results are achieved through the use of virtual laboratory devices. Exercises on real objects are often uncomfortable, sometimes dangerous, and in special cases impossible [1]:

- Long time to carry out the experiment (often exceeding hours of classes);
- Risk of damaging or destroying a real object, and consequently – the limited possibility of its examination;
- High costs;
- Safety of exercising persons;
- Classes usually take place in subgroups of several persons – it very much impedes the allocation of individual tasks for each person.

The presented limitations of classical laboratories can be compensated by the use of mathematical models in computer simulations. The virtual form of classes does not preclude the use of classes in the real laboratory in the curriculum, but it enables a much broader understanding of the material, as well as allows for the extension of the teaching methodology in the extramural study system.

Virtual laboratory positions allow the determination of the basic characteristics of the examined systems in two methods:

- In „normal” method, by changing the selected parameter and recording the values of tested objects for

each simulation with later designation of required characteristics;

- Program method, in which measurements and designation of basic characteristics are performed automatically.

The use of simulation programs is particularly desirable in the widely understood electrotechnics. The results obtained in simulation programs in other technical fields (such as mechanics) are not as satisfactory as those obtained during electrical system simulations. This is primarily connected with the fact that all phenomena, elements, circuits, systems and electrical machines can be described by mathematical models.

It should also be emphasized that the use of mathematical computer models during laboratory exercises on real objects is one of the examples of the so-called augmented reality [2]. Simulation programs along with CBT (Computer Based Training) computer simulators [3] significantly broaden the didactic base.

The field of electrical engineering that deals with the transformation of electrical power with the use of semiconductor power elements is called power electronics, and systems that transform electrical energy containing these components (valves, connectors) are called converter systems. Problems related to the designing of converter systems in the last 10-15 years have taken on a new meaning. This is connected with the today's achievements, particularly in the area of new computer technologies based on high-speed processors, memories, solid state drives (SSD) and advanced

software (e.g. CAD packages). Modern computers help to solve practically all engineering problems: tasks, analysis, and synthesis of calculations and construction of both individual elements and complex systems.

The converter system consists of several components [2]:

- DC or AC power sources;

- Converter systems with connectors and passive elements (capacitors, coils and resistors);

- Load in the form of an electrical system or electric machine;

- Converter control system.

Figure 1 presents the block diagram of the converter system.

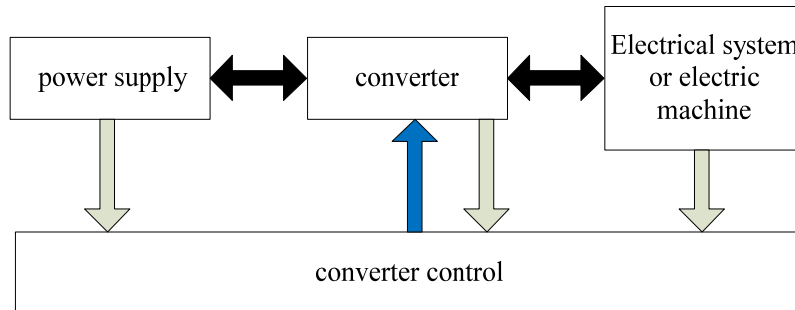


Fig.1. The block diagram of the converter system.

### Simulation programs in the examination of converter systems

With mathematical description (mathematical model), the examination of the characteristics of the converter system can be performed with the use of analytical methods or computer simulation. Analytical methods have significant limitations. They allow a full-scale study of systems that are described by first and second degree differential equations. Systems that are described by third and fourth differential equations are subjected to analytical solution, but the influence of system's parameters should be examined by numerical methods. Systems of higher degrees are only tested by numerical methods. Numerical methods are based on the use of computer simulation.

In the early historical stages of computer simulation, programs were created in machine language (1100101 ...). The next step was the assembler language. Later, "higher level" programming languages (Algol, BASIC, Fortran, Pascal, C++ and others) appeared. The programming technology used in those years required quite a lot of time to create the models.

Since the 1970s, many of utility simulation packages have been created. They primarily automated the presentation stage of a mathematical model in a computer.

### MATLAB-Simulink

Among the simulation programs, the leading position is occupied by MATLAB-Simulink from Math Work.

The first version of MATLAB package was developed more than 20 years ago. Development and improvement of this package was carried out simultaneously with the development of the means of computer technology. The MATLAB package name is derived from the phrase Matrix Laboratory and it is primarily focused on data

processing (matrices and vectors). Therefore, despite the relatively high growth of changes in the generation of computer technology, MATLAB-Simulink was able to absorb everything that was the most precious from each generation.

As a result, MATLAB-Simulink has the richest number of library functions. The problem during the work with the use of this program is connected with the difficulty to quickly find these elements that are needed to solve the determined task. Simulink package is an attachment to the MATLAB package. During the simulation with the use of Simulink, the principle of the visual programming is applied. According to this principle, the user creates a model of the device and performs calculations on the screen (from standard block libraries). In this case, unlike in classical methods of simulation, the user does not need to know the programming language in advanced level.

Simulink is an independent MATLAB tool and the user does not need to know the MATLAB itself and its other attachments. On the other hand, the access to MATLAB function and other its tool remains open and they can be used in Simulink (S-function).

MATLAB-Simulink package has found use in education and various fields of science and technology [4]:

- Automation;
- Electrical engineering;
- Mechanics;
- Railway industry;
- Aviation;
- Robotics;
- Measurements;
- Thermal calculations;
- Medicine;
- Acoustics and music.

When modeling simulation systems in the electrical engineering, it is possible to take advantage of ready-made blocks of dynamic models for electrical machines, passive and active components of electrical circuits,

elements of semiconductor connectors, various measuring elements for analysis of circuits and many others. Figure 2 shows the topology of vector control system for induction motor implemented in Matlab-Simulink

program. Furthermore, it presents the results of simulation for this system. Figure 3 presents the results of the system's simulation from Figure 2.

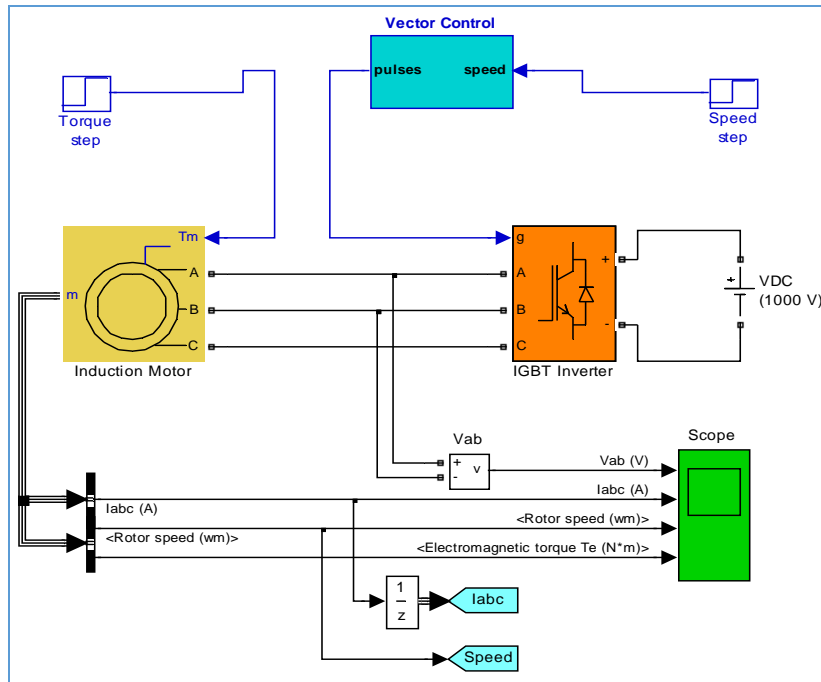


Fig. 2. Vector Control of a Induction Motor implemented in Matlab-Simulink.

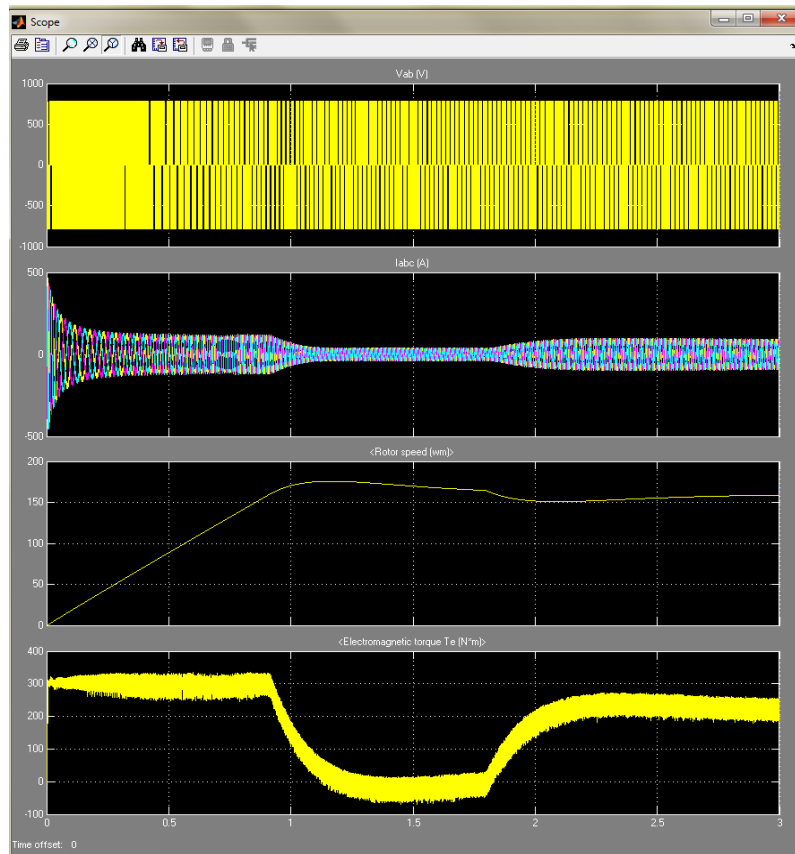


Fig. 3. The Results of the system's simulation from Fig. 2.

## TCAD 7

TCad simulation program was created at the University of Technology in Gdańsk at the Department of Power Electronics and Electrical Machines under the supervision of Dr Eng. Krzysztof Iwan. Copyright belongs to the Faculty of Electronics and Automation of the University of Technology in Gdańsk.

The TCad package is designed for analysis of converter systems, including drive systems. Works lasted since 1985, when the version 3.0 was developed. The improved version TCad 7.0 enables the work with the program in Windows XP, Vista, 7, as well as 8 and 10 – both in 32 and 64 bit variants. Furthermore, the program is successfully used in the WINE runtime environment on Linux systems. In particular, the compatibility of TCad 7 has been tested against WINE 1.4 in Ubuntu 12.04 LTS and 16.04 LTS (with WINE 1.6).

When creating a topological model of a converter system, it is necessary, as in a practical system, to divide it into structural parts: primary and secondary. The program has a rich library of ready-made components, from which any topology of the system can be implemented.

At the Maritime Academy in Szczecin, the TCad 7 program is successfully used in the Laboratory of Electrical Machines and Drives. Students develop the models of power converters on the classes. Moreover, they take advantage of the program for testing electrical machines.

The TCad 7 package includes TCad Graf program, which is a graphical post-processor. It is used to create presentations from the waveforms obtained in the simulation process. It enables the observation of waveforms contained in different files, as well as the comparison of simulations for the same scheme – before and after changing system's parameters (for easier analysis of the obtained results).

It is necessary to mention about the very rich "help" (description of the program and examples of simulation), which gives the opportunity to use the program without special preparation [2]. It is also important that the price of the application is more than 10 times lower than the price of MATLAB.

The following figure 4 presents the topology of the single-phase hysteresis inverter implemented in TCad 7.0, as well as the results of the simulation for this system (Fig. 5).

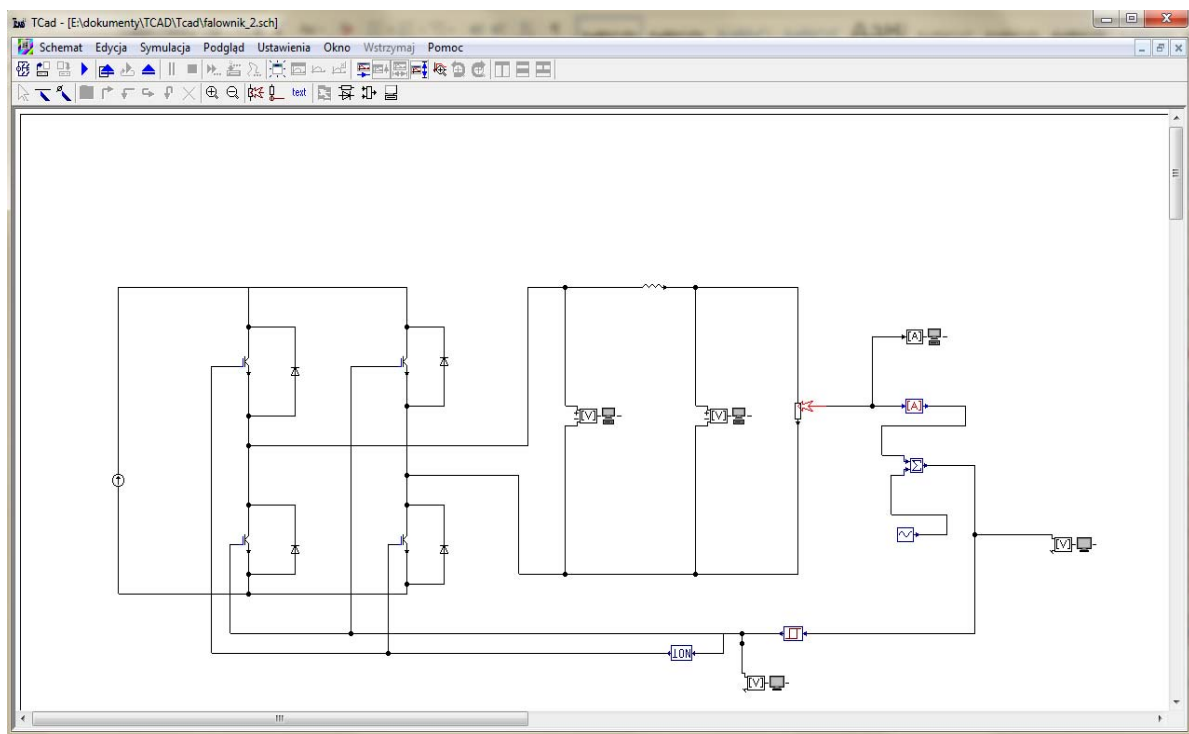


Fig. 4. System of the single-phase DC/AC converter implemented in TCad 7.0.

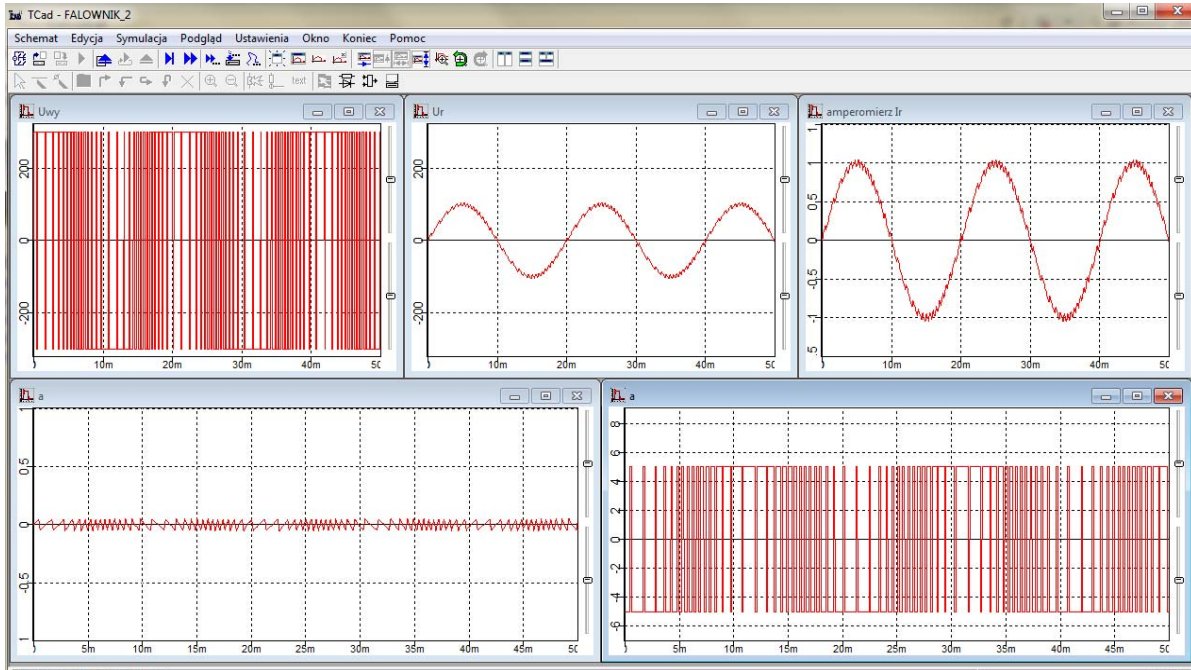


Fig. 5. The Results of the system’s simulation from Fig.2.

**Electronics Workbench**

Electronics Workbench (EWB) simulation system is characterized by a simple and easy-to-understand user interface. In general, EWB can be applied at the level of technical secondary school and at the level of engineering universities. There are four basic versions: student, educational, hobby and professional. When working with EWB, the user feels like in a real measurement laboratory. EWB enables the simulation of the real workplace. It is equipped with measuring instruments that allow the analysis of electrical circuits in real time.

EWB is primarily used for the examination of digital and analog systems. EWB is one of the most far-reaching realizations of „visualization” for the world of electrical signals processing [6].

In this program the user can implement autonomous converter systems with the use of ready-made libraries of elements. The program is not perfect. The library of electrical parts and elements is rich, but measuring devices are available only individually.

The figure 6 presents EWB program’s libraries of elements.

Figure 7 show the AC/DC converter implemented in EWB program.

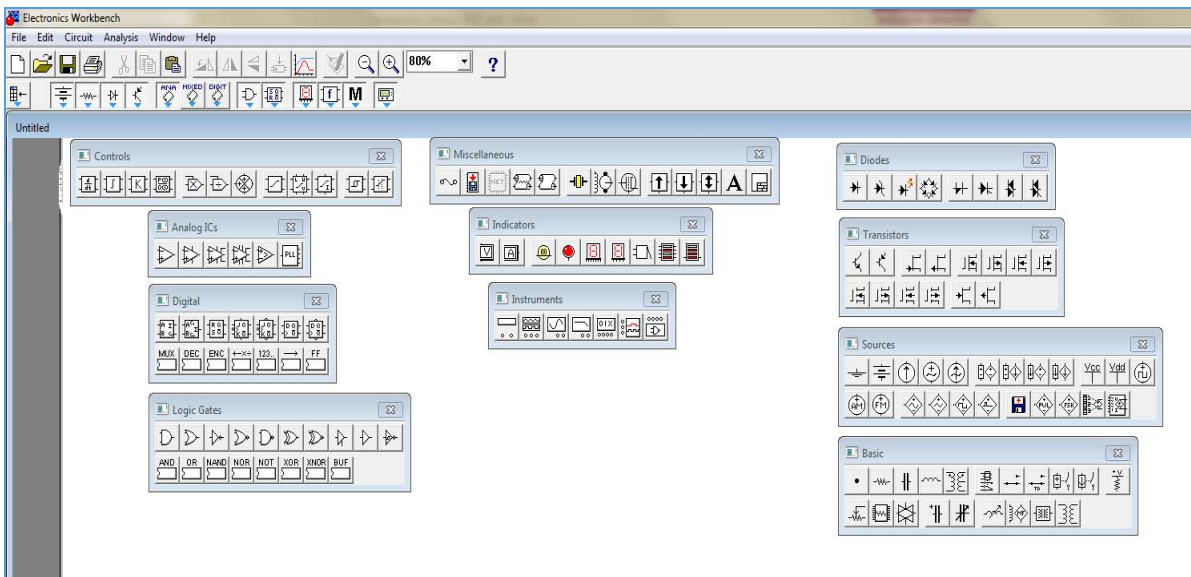


Fig. 6. EWB program’s libraries of elements.

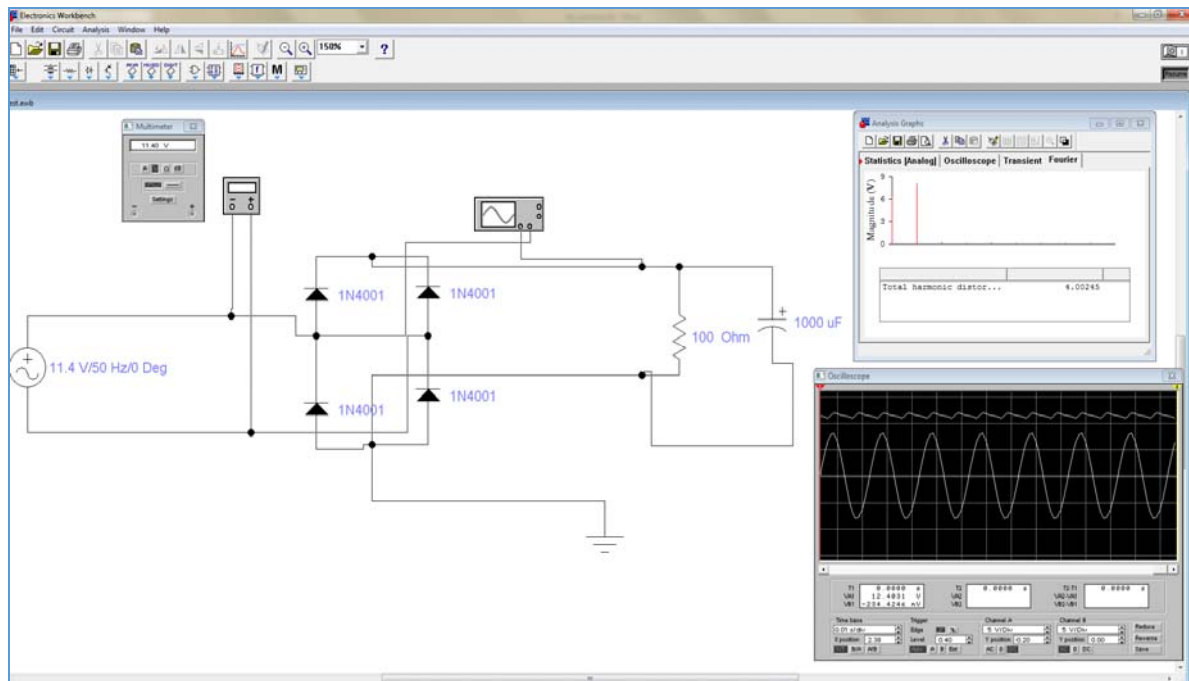


Fig. 7. AC/DC converter implemented in EWB program.

## Conclusions

The initially used analytical methods for the examination of converter systems quickly proved to be insufficient. Continuous development of computer technologies has enabled the use of computer simulations for expanding the didactic and scientific base – especially in the field of electrical engineering.

The simulation programs presented in this article show the possibilities of supporting the didactic process based

not only on classical educational technologies. The use of computer simulations enables, apart from working in teams, the independent work, which can be performed by practicing persons with different levels of knowledge. Difficult issues connected with the examination of converter systems can be solved by practicing persons from scratch. The author's didactic practice confirms the effectiveness of the use of the discussed simulation programs in the didactic process.

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