Simulation and Animation of Power Electronics in Modern Education

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Abstract: - The computer simulation and animation often enrich modern education in the field of power electronics and electrical drive systems. These modern tools can bring great benefit for fuller understanding of special effects and characteristics of power electronic circuit. Animation during the simulation opens up a new area for the power electronics design engineer. During the animation, can be seen the level of the node-voltages, the level of the branch currents or current path in the circuit. This paper brings some practical results of research devoted to the strong and weak features of education by PC.

Key-Words: - Simulation, Animation, Education, Power Electronics, Caspoc, Buck-Boost

1 Introduction

Teaching and understanding Power Electronics and Electrical Drives can be done with the use of books and the blackboard. This is well-tried technique to show the main characteristics of power electronic circuit and operation. But teaching by blackboard usually brings a lot of time to draw the basic waveforms of converter operation on paper while keeping the state of the converter in mind. Simulation made a change here, because it gave us the possibility to use a computer for drawing while keeping our attention to the operation of the converter. Simulation enabled us to study the behavior for different parameters and conditions. Still the user has to keep the converter in mind and he has to make an interpretation of simulation results. During simulation the converter operation is presented as a cartoon that is possible to change according to grade of education or quality of students. These possibilities of simulation are not possible with only books, blackboard or measuring on the physical model of converter, because even a real operating converter does not show so many operating details as during animation. Next benefits are high speed and ability to change parameters (value elements) of model converter to understand their effect on quality of circuit.

Contemporary simulation programs derive benefits from powerful of computers. It is possible to do all simulation of mechatronics systems with electric machines, electronic converter and drives. Standard demands for a simulation package are:

- fast simulation;
- detail models of semiconductors switches, inductors, transformer, machines;
- user friendly interface with schematic editor;
- easy visualization of simulation results;
- link with mathematical processing;
- and link with modeling language (C/C++).

Typical power electronics system analyses consist of many aspects and are multidisciplinary. These are, for example, parameters of magnetic actuators, parameters of semiconductors switches, electrical machine parameters, thermal effects, different control issues, packaging and parasitic effects. Well known simulation packages are Spice and MATLAB-Simulink. Other typical programs for modeling mechatronics system are Vissim and Dynast. Software for simulation and analyses of electronics circuit are for example: SPICE, MicroCAP, Saber and Electronics Workbench. Special simulation packages for Power Electronics and electrical drives are CASPOC, Krean, ATOSEC, PSIM and Simplorer.

In view of my good previous practical experience with CASPOC this paper is directed towards the simulation software CASPOC.

CASPOC makes it possible to create your own models and perform simulations and animations of DC converters, DC/AC converters, AC/DC converters, controlled rectifiers, DC converters with control, Induction Machines with inverters, Brushless DC machines, etc. In animation you can actually see the converter switching, see how integrators in controllers build up charge and how a motor start to rotate.

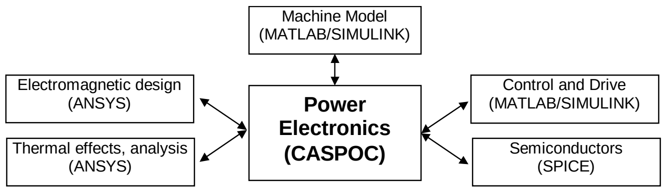

Fig. 1 Integrated simulation

Designers of applications of power electronics have to direct on one or more of these aspects. The power electronics simulator is central and the interaction (data) exchange with different analysis and design tools is hereby necessary. Standard is the interface between power electronics simulator (e.g. CASPOC) and the software package MATLAB/ Simulink. MATLAB/ Simulink is a very strong tool for control (Control toolbox) and for creating system models of electric machines and drives (Power System Blockset). Drive and control system can be implemented in CASPOC and coupled to MATLAB/Simulink. Another example is the data exchange with ANSYS, for solving electromagnetic, thermal and mechanical resonance effects. Fr example for the thermal effects, the electrical characteristics of the device depend on its temperature distribution, at the same time the generated heat depends on the power loss. ANSYS can be used for analysis of the electromagnetic field, parameters of electrical machines and etc. Design of electrical machines can be done in program TESLA. The simplified block diagram of integrated simulation can be seen in Fig. 1.

Animation slows down the simulation. A simulation should be as fast as possible. Therefore the user should have the ability to turn the animation on or off.

2 Visualization and Simulation Results

Visualization of the simulation is most important in power electronics. Animation can be very helpful to understand and verify the principle of the converter. Very often it is necessary to show the current-path. Students, for example, can see the current-paths in rectifiers (Fig. 2) or three-phase inverter (Fig. 3). During animation, it becomes clear to the user how the converter is behaving.

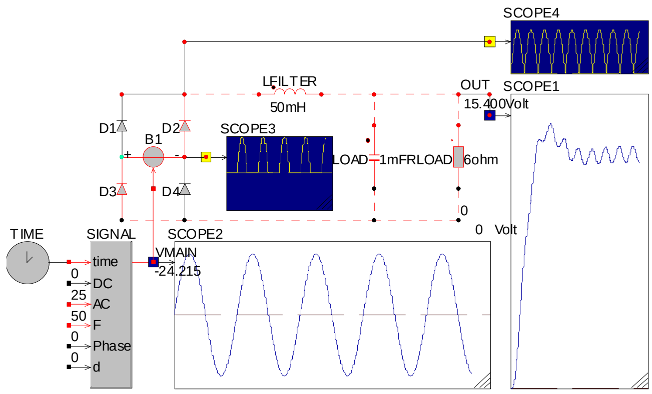

Fig. 2 Diode rectifier- current-paths

Animation is not only a very strong tool for teaching; it is very ready at hand for checking the behavior, or searching for failure modes. During animation, failure modes are possible to be detected. Even those failure modes, the user was not aware of. During failure

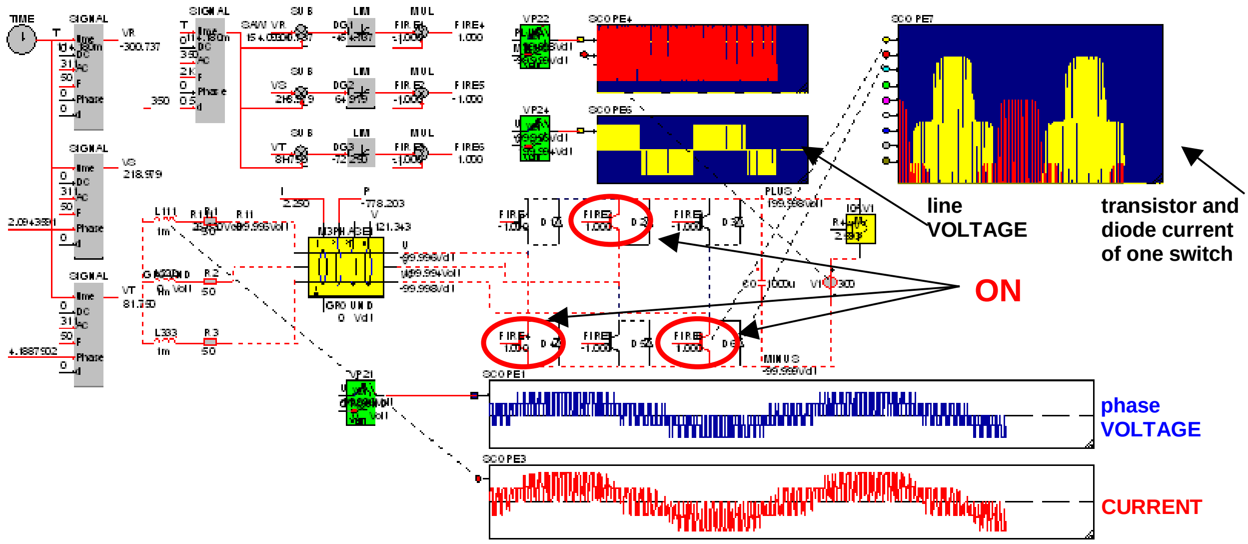

Fig. 3 Three phase inverter - current-paths, actual voltage and current, switch status

analysis without animation it requires a lot of time to check each component. With animation, each failure is directly displayed, for example a switch is opened or closed at a wrong interval. Or some voltage levels are too high.

To visualize the values of voltage and current, two different levels are required. Also the control signals can vary in value from the voltage and current level. Typical control signals can range between 0 and 1 (ON), where the on-status of a control signal is clearly signaled by a red color and the off-status is signaled by a black color (Fig. 3).

3 Different Examples of Visualizing

A. Brushless DC machine with 6-pulse control

In Fig. 4 a Brushless DC machine with 6-pulse control and IGBT inverter is displayed. The block BLDCM models the brushless machine, where on the left side the block is connected to the inverter and on the right side, the mechanical load is connected.

At the bottom the parameters for the brushless machine are defined, being the back-emf constant K and the inertia of the rotor. Other parameters for the machine are fixed inside the block, so the example runs also under the, in nodes limited, freeware version of CASPOC. At the top of the BLDCM block the angle of the rotor is exported, which is required for a simple control of the IGBT's. The node A indicates the angle of the rotor in radians and is connected to the left side of the block GATECTRL, which fires the IGBT's as function of the angle A.

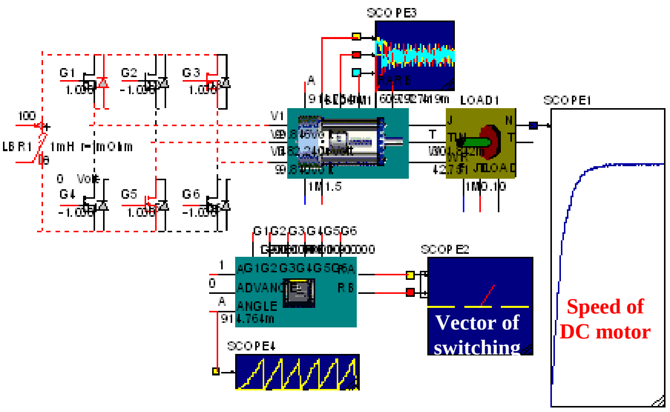

Fig. 4 Brushless DC machine with 6-pulse control

B. Example DC shunt machine with crane

In Fig. 5 the animation of a DC shunt machine with crane is shown. The DC shunt machine is controlled by a controlled voltage source, which is regulated by a library-block 'Crane Control'. Also a controlled rectifier could have been used here. The library-block modeling the crane includes an object-block, which models the visualization of the crane. Depending on the angle of the axis of the DC shunt machine, the load is lifted by the crane.

Other practical and interesting simulation can be found [1, 2, 3, 4 and 8]. For example: in [8] the simulation of a modern solution of hybrid car system configuration is presented, where the variable speed-voltage system of hybrid cars is simulated.

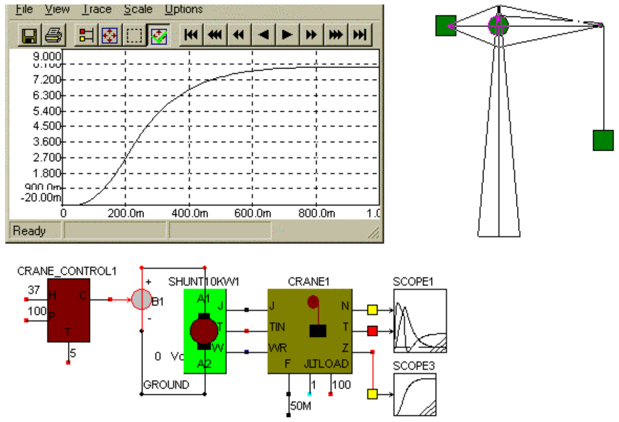

Fig. 5 DC shunt machine with crane

C. Example of capacitor effect for harmonics spectrum of generator current

Current harmonics of an un-direct electronic converter with capacitor between diode rectifier and inverter create extra losses inject into a generator. Harmonics of different current waves are expressed analytically with harmonics (k·6±1), where k=1,2,3,… . Results of capacitor effect eventuality C for harmonics current spectrum are shown in Fig. 6. Bigger capacitor results in higher harmonics distortion and the worse current spectrum of generator.

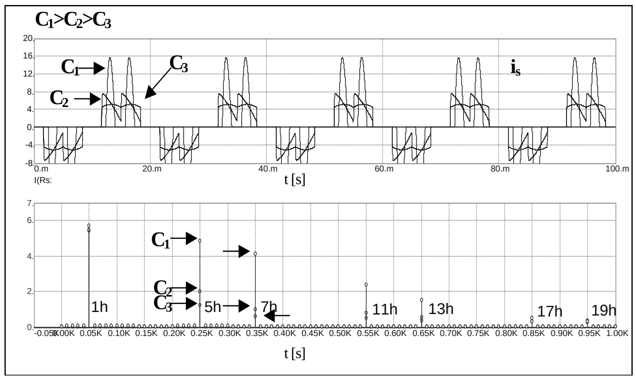

Fig. 6 Capacitor effect for harmonics spectrum of current

This simulation was done in MicroCAP that makes it possible to do a Spice simulation with high accuracy but very slowly and without animation. And so it is usually used special software (CASPOC or Simporer) for simulation in the power electronics.

D. Visualization and animation with software "iPES"

The last example of visualization and animation in the Power electronics that will be shown in this paper is the special education product "iPES" (Interactive Power Electronics Seminar by Prof. Johann Kolar [2, 6 and 10]). These are educational modules dedicated to basic power electronic circuits. The module includes DC/DC converters, basic diode and thyristor converter systems, AC/DC inverter, space vector modulation and basic signal theory. The modules can be downloaded from (www.ipes.ethz.ch) and used for personal purposes. For example: the fundamental problem about understanding the space vector of a six switch PWM rectifier from program iPES is shown in Fig. 7 [10].

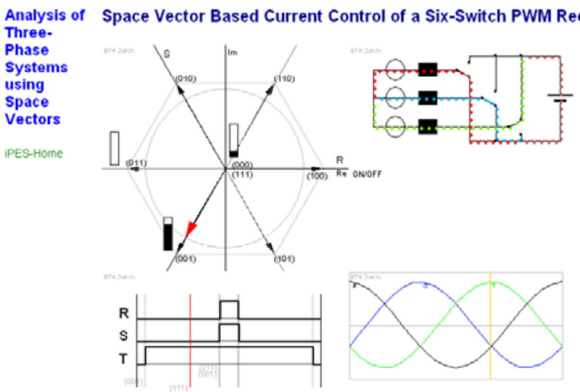

Fig. 7 Space Vector of six- switch PWM Rectifier

Here it is possible to drag the red voltage space vector on the left side with the mouse in the complex plane. The three bars show the distribution of the relative on times of the according space vectors of the rectifier input voltages.

4 Practical Considerations in Education

Animation during simulation opens up a new area for teaching and designing circuit of power electronics converters. The main disadvantage of simulation is: everything looks easy to do.

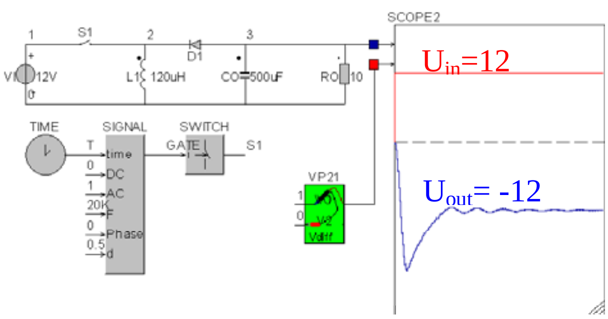

Fig. 8 Simulation of Buck-Boost converter in Caspoc

It is necessary to say that simulation cannot give any practical knowledge about the design of a converter and the set up of converters. In Fig. 8 the results of a simulation of a buck-boost converter are shown. This converter is designed to stabilize the output voltage of a solar system (from 0 to 22 V) to 14 V for battery charging. This converter has a variable duty cycle and feed-back control of voltage.

But the real output characteristics of the converter are different from our simulation. Real waveforms of the input and output voltages of the same buck-boost converter with the same component values are shown in Fig. 9. The output voltage of converter has a ripple in line with theory, but there are other voltage peaks that are created due to the construction of the converter.

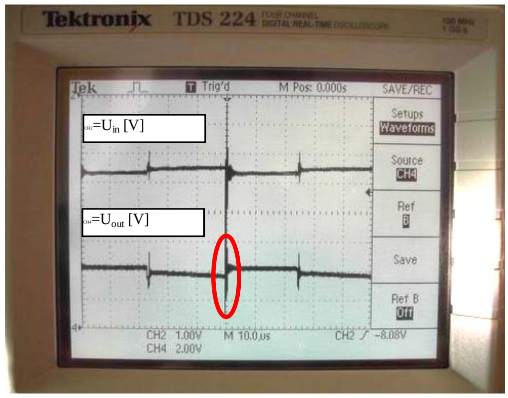

Fig. 9 Real waveforms of Buck-Boost converter

Our converter is set up only with a low ESR capacitor and the connection between the switch, inductor and diode is done by wires (not like one point). Also it is required to use a combination of ceramic, ESR and polypropylene capacitors. Fig. 10 shows the results of a power electronics design without taking care of reducing the parasitic components. For education the influences of the parasitic components can be studied and shown on the oscilloscope.

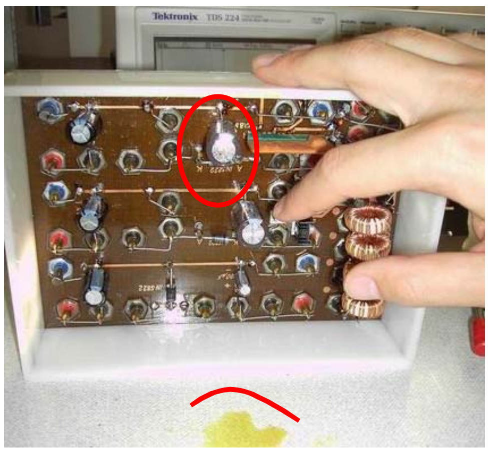

Fig. 10 Construction of a Buck-Boost converter

5 Conclusion

Power electronic and drive systems are getting more complex today and simulation with animation can help to a better understanding of the system and the working principles of mechatronic systems or converters.

Displaying a current-path gives insight in the behavior of the circuit and can reveal failure modes. Animation can be a practical tool for modern education methods and for designing power electronics and electrical drives.

For power electronic circuits the value of nodal voltages and branch currents can be visualized during the simulation and the conducting semiconductors can be identified. For electrical drives, the moving or rotating objects can be visualized.

Simulation and animation are modern tools of education but it is necessary to remember that also a practical evaluation is important. During the practical building of a converter parasitic components can be studied. Practical skills and design rules must be shown in laboratory.

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