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An Educational Simulator for Switched-Mode Power Converter

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Abstract

We have developed an educational simulator for switched-mode power converter (AESOP) that has new algorithm and user-friendly interface. This algorithm is so fast and stable that students can always get the simulation results in a very short time. Moreover, the time step is automatically optimized so that students do not have to set and care for it, and no other simulation parameter setting are needed except for an error tolerance parameter. These features of this simulator will play a vital role to enhance motivation of students and to continue studies for this field.

1. Introduction

Much more electrical energy has been needed due to vast increase of communication and information equipments such as computers and mobile phone and so on in IT society. Thus, switched-mode power converter (SMPC) that is used to convert voltage in those equipments must satisfy all demands of high efficiency, high power factor, low noise, small size from viewpoints of energy and environmental issue. Many kinds of circuit topologies and semiconductor devices for switched-mode power converter have been proposed and investigated to cope with abovementioned problem. However, the abrupt decrease in supply voltage and increase in supply current in microprocessor make the problem of high power efficiency difficult.

Therefore, an education associated with power electronics in universities and colleges becomes much more important. However, it has been said that few students enter power electronics engineering in universities and colleges. We should show them the impact and importance of power conversion technology using Information technology. Especially, simulation software could attract more students by bridging between the actual cases and the abstract concept taught in classroom. It can show how modeling can help understanding problems and help solving them. However, no existing simulator satisfies all requirements for educational and practical simulator such as accuracy, speed, stability and easiness. Therefore, we developed an educational simulator for switched-mode power converter (AESOP) that has new algorithm and user-friendly interface to satisfy educational needs.

In this paper, we describe the state-of-the-art of educational simulator in SMPC and the features of an educational simulator for switched-mode power converter.

2. Contents of power electronics

Power electronics is the application of electronic circuits to energy conversion[1]. Thanks to power electronics, the electricity needed to run the things which are used everyday is processed, filtered, and delivered with maximum efficiency, smallest size and minimal weight. This technology encompasses the use of electronic components, the application of circuit theory and design techniques, and the development of analytical tools toward efficient electronic conversion, control, and conditioning of electric power. The main areas of power electronics research include:

[1] Electronic devices (like diodes and transistors)
[2] Control and regulation
[3] Topologies for various converter circuits
[4] Magnetic components (transformers and inductors)
[5] Electronic circuit packaging and manufacturing
[6] Control of electrical motors.

We mainly focus on areas of [2] and [3], and have developed the educational simulator for SMPC that will be used in classroom in university. Figure 1 shows the block diagram of power supply system. Recently, the supply voltage for microprocessor chips that are widely used for IT equipment, decreased up to 1.7 [V], and the supply current increased up to more than 40 [A]. This means it becomes difficult to attain high power conversion efficiency. Moreover, those chips becomes much more sensitive to external noise. This external noise mainly comes from conventional SMPC. Therefore, aiming at reducing switching losses and EMI of power converters, a new circuit topology such as soft switching techniques is needed so that high efficiency, small size, low weight can be achieved.

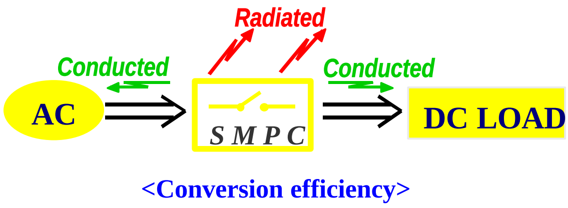

Fig.1 Block diagram of power supply

3. State-of-the-art of educational simulator in SMPC

So far, there are used some simulator for SMPC education as SPICE, SABER and so on. However, no existing simulation simulator satisfies all requirements for educational and practical simulator such as accuracy, speed, stability and easiness. Some simulators such as SPICE and SABER have problems of simulation speed and convergence stability. Other simulators may have problems of accuracy and easiness. Some of fast simulator which employ an averaged device model of switch, do not determine an on-off transient time exactly, or are difficult to set parameters including a time step.

Therefore, we developed an educational simulator for switched-mode power converter which has new algorithm[2][3] and user-friendly interface. This algorithm is so fast and stable that we can always get the simulation results in a very short time. Moreover the time step is automatically optimized so that we do not have to set and care for it, and no other simulation parameter setting are needed except for an error tolerance parameter. As the result, although, the conventional simulators take long simulation time or may fail to simulate such as switching surge, harmonic noise, AESOP can simulate those characteristics in a remarkably short time. These features of this simulator will play a vital role to enhance motivation of students and to continue studies for this field.

4. Features of Simulator <AESOP>

This simulator has the following good features.

[1] Running on a personal computer environment

It runs fully on a personal computer. The platform OS is Windows98 which is the most popular 32bit OS for the personal computer in the world.

[2] Fast algorithm

The algorithm of this simulator is originally developed and completely optimized for the switching power converters. As SMPC has two kinds of time constants in the circuit that values are quite different, it is difficult to converge in a short time. So, Automatic optimization of time step by using eigen value can be executed. Therefore the simulation speed is remarkably high and it can run on a personal computer.

[3] Object-oriented design

This simulator AESOP is designed by object-oriented programming. It is improved and expanded continuously by feedback from users.

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5. Major functions of simulator: AESOP

[1] Transient response analysis

It is particularly suitable for transient response analysis. It simulates all kinds of transient response such as startup transient response, step transient response and so on.

[2] Waveform analysis

It has a powerful scope window that displays various waveforms of simulation results. It feels like an oscilloscope used in real experiments.

[3] Steady-state analysis

Steady-state analysis is so difficult that most simulators take a lot of simulation time, or even fail the simulation. It has original algorithms for the steady-state analysis so that it finishes the steady-state analysis in very short time.

[4] Sweep analysis

Sweep analysis is the steady-state analysis where a circuit parameter changes. A typical one is load characteristics, where the steady-state output is obtained with some load change. It can do the sweep analysis where any one of parameters is swept.

[5] Control analysis

It also simulates a controlled circuit. AESOP has a variety of devices related to control method, such as a PWM control, a switching frequency control, a peak current control and so on.

[6] AC input analysis and three phase input analysis

It can simulate not only converters with DC input, but also converters with AC input, including converters with three phase AC input.

[7] Harmonics analysis

In order to do a harmonics analysis, it calculates frequency spectrum of waveform by FFT (Fast Fourier Transform). At the same time it calculates an input power, a power factor of input line current, a total distortion ratio and so on, which are important for the harmonics analysis.

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6. Examples of course material (Switching surge due to parasitic elements)

We take Current-mode resonant converter as an example of exercise for students. Figure 2 and 3 shows the basic circuit topology and its high-frequency equivalent circuit model, respectively. Undesirable switching surge is caused by parasitic elements such as depletion capacitance in diode, leakage inductance in transformer, parasitic resistance and inductance in smoothing capacitor, and minority charge on diode and

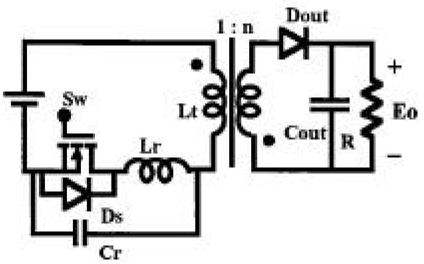

Fig.2 Current-mode resonant converter

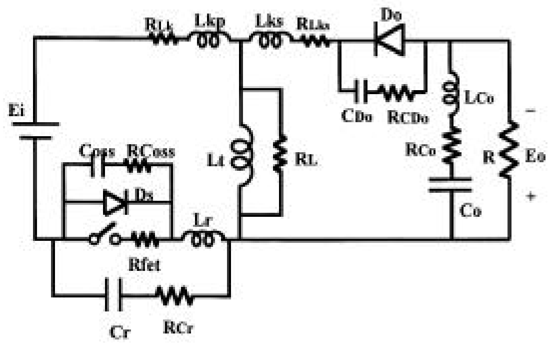

Fig.3 High-frequency equivalent circuit.

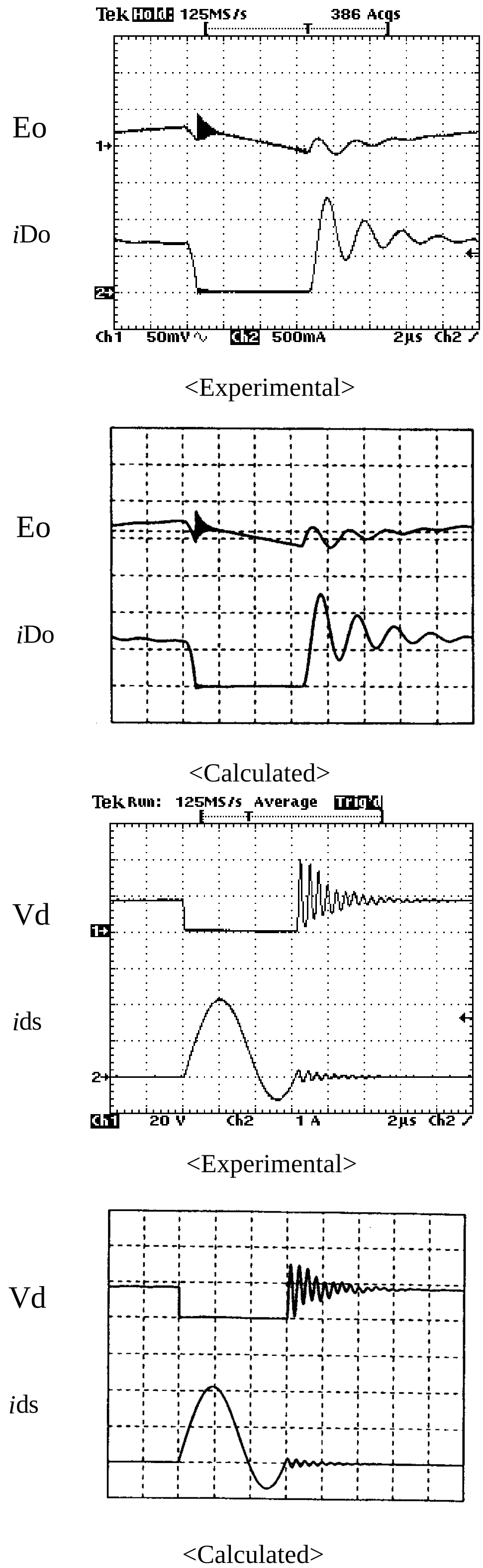

Fig.4 Waveforms for current-mode resonant converter. (Eo:50mV/div., *i*Do:0.5A/div., Vd:20V/div., *i*ds:1A/div.)

semiconductor switch, and so on. This high-frequency equivalent circuit modeling is quite important, by which simulation is executed. Students must understand parasitic elements in each device before simulation. Simulation and experimental results are compared in Fig.4. This figure shows waveforms of output noise voltage Eo, MOSFET voltage Vds, MOSFET current *i*ds and diode current *i*Do. This converter operates at switching frequency of 50kHz. Both experimental and calculated waveforms are all in good agreement. Figure 5 demonstrates Simulation result of AESOP. In this figure, there are three kinds of windows such as Scope window that shows waveforms just as oscilloscope, State window that shows the sequences of states in one switching period, and Control window by which we can change voltage range, current range and time range. Figure 6 shows the frequency domain waveform of output voltage surge.

7. Conclusion

We have developed an educational simulator for switched-mode power converter (AESOP) that has new algorithm and user-friendly interface. This algorithm is so fast and stable that students can always get the simulation results in a very short time. This simulator is effective to switching surge analysis, too.

Our future work is to show the educational effectiveness in class room at university.

References

[1] http://www.pels.org/

[2] Masatoshi NAKAHARA, “ A fast computer algorithm for switching converters” , IEEE Trans. on PE, Vol.12, No.1, pp.180-186, Jan. 1997.

[3] Masatoshi NAKAHARA and Toru HIGASHI, “ A Fast and stable simulation algorithm with self-optimization of time step for switching power converters” , Record of IEEE PESC’ 98, pp.1105-1110, May. 1998.

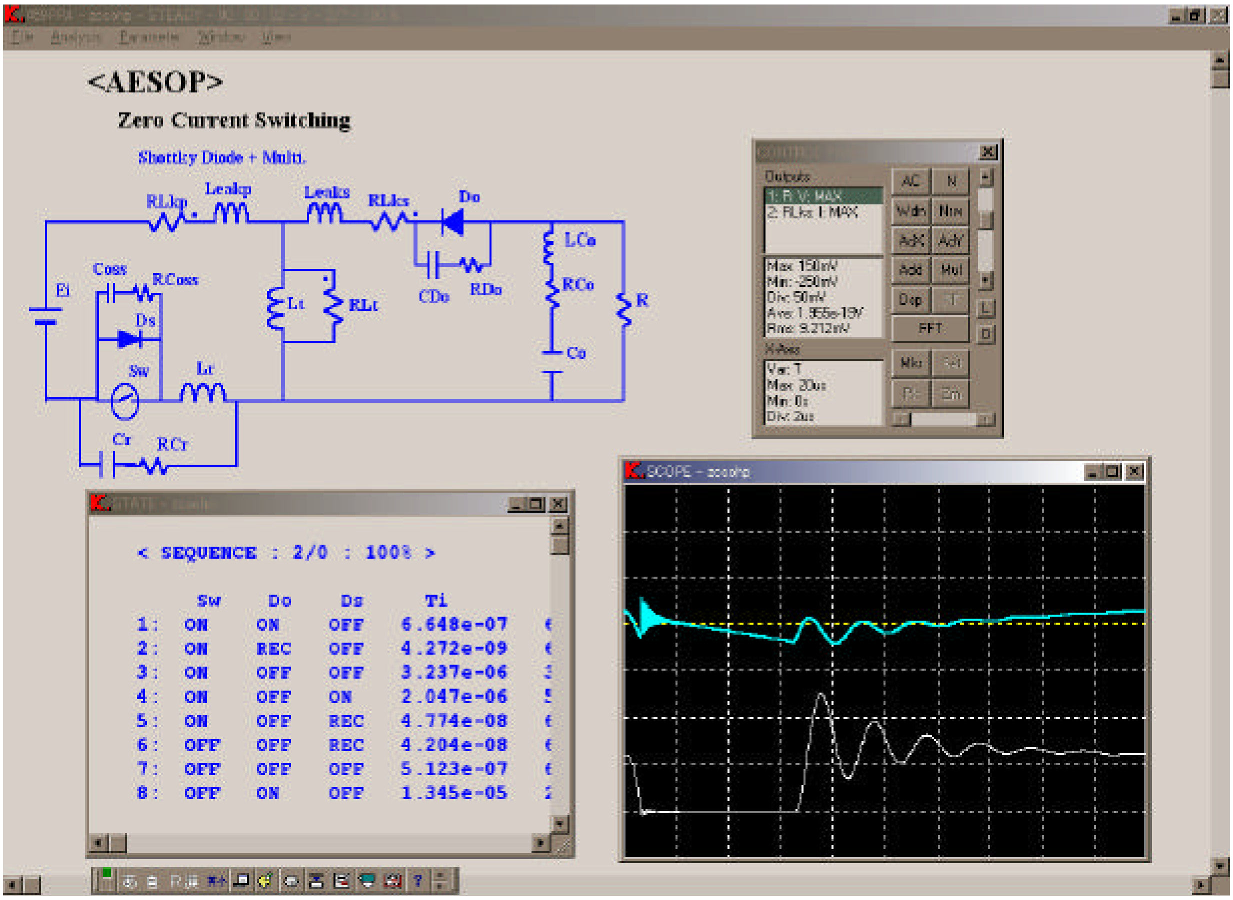

Fig.5 Simulation results (Scope window: Time domain).

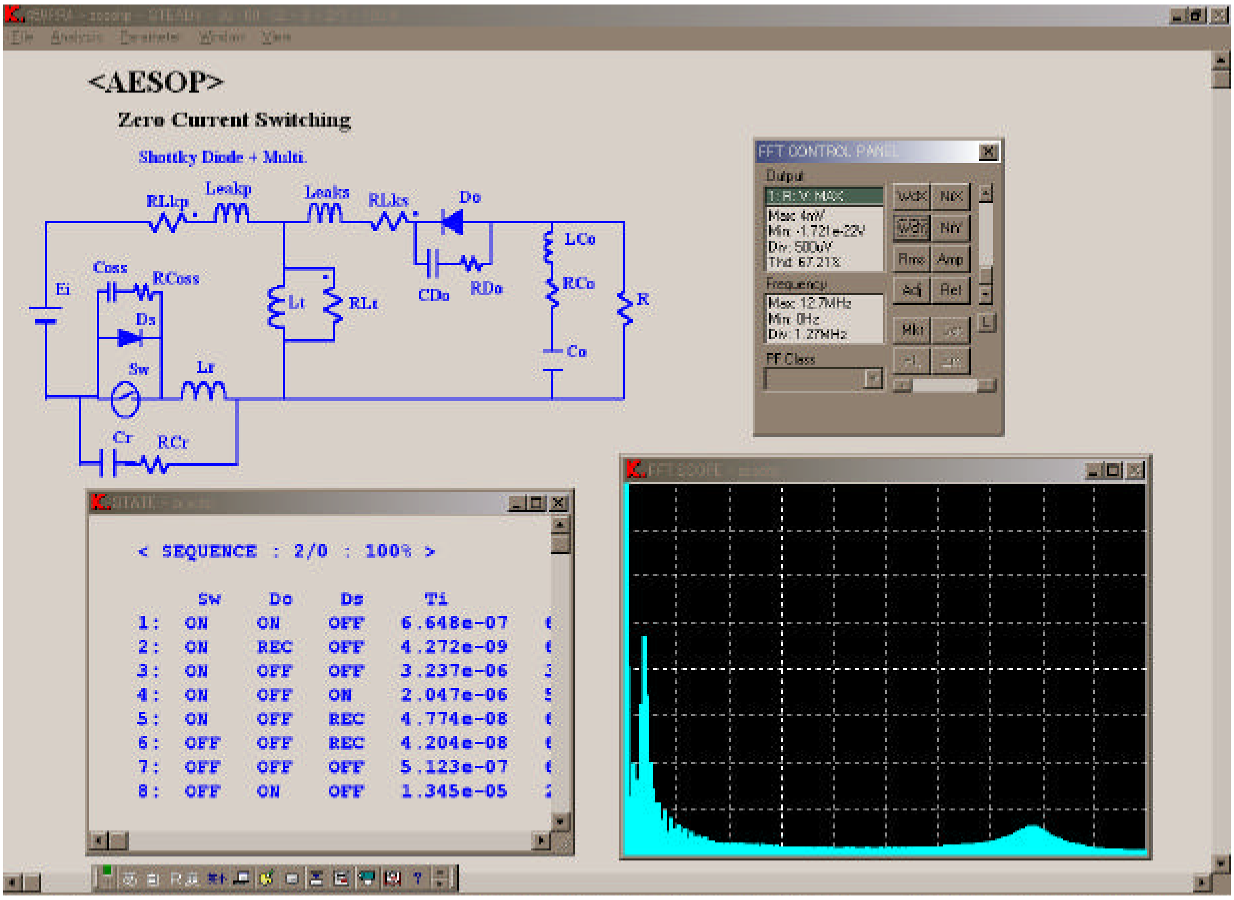

Fig.6 Simulation results (Scope window: Frequency domain).