DEVELOPMENT OF POWER-ELECTRONICS SIMULATION SOFTWARE

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ABSTRACT

This study presents simulation software on power electronics. For this purpose, VisSim™ simulator is used and models of single and three-phase rectifiers, PWM choppers and inverters, AC choppers, SMPS networks, are developed and their performance waveforms are obtained. Conventional and brushless dc motor simulations are added to the package together with some load characteristics. It is believed that, this package would be a useful tool for teaching of power electronics and performance predictions of electrical drive systems.

I. INTRODUCTION

There are various published works to analyze power electronic devices and networks, which cover the V, I, dV/dt, dI/dt, turn-on and turn-off characteristics of semiconductors and give accurate information about power electronic network behaviours. These studies mainly use languages like SPICE, (Simulation Program with Integrated Circuit Emphasis) ACSL (Advanced Continuous simulation) and SABER. These programs are useful in detailed design studies, where time domain analysis is necessary for predicting the detailed circuit performances. [1][2][3]

There is another approach in which semiconductor is represented as ideal switch which is either on or off. The simulation of the power electronic (PE) networks is managed by forming blocks representing mathematical functions. Matlab backed SIMULINK is the most frequently used of them [4][5]. VisSim™ is in this group. Although there have been quite a number of successful papers on simulating electrical machines, power systems and power electronic networks by using the software mentioned above, surprisingly the VisSim™ had little attention. This study presents an attempt to develop a software package to simulate various power electronic networks in VisSim™ environment [6]. The ultimate objective is to develop a power electronics toolbox, which should be compatible with VisSim™ electrical machine and power systems toolbox, thus enabling a complete system solution.

Since the governing equations and functions can easily be represented with blocks in VisSim™ and the simulation method is simple and versatile, it is adapted as simulation environment in our study.

The general trend in electrical engineering is similar to other disciplines that, more system approach and more involvement with communication systems and use of information technologies will be imminent. Additionally, education devices, tools and teaching environments are changing. Supplementary software for teaching is becoming an ordinary practice. It is also expected that, this simulation software would fulfil some of the needs of the education circles. Thus, additional objective of this study is to develop software, which covers the undergraduate level power electronic topics, by emphasizing the system approach.

It is known that the application of power electronics is spreading. There are numerous motor control methods; various power system applications and number of power supply configurations. In most of these applications, power-conditioning methods are employed by wave shaping techniques. It is believed that, the software adapting semiconductor elements as a single switch and presenting the wave tailoring methods would be necessary. In addition to the power-electronic network simulations, models of various electric machines and loads should be inserted.

With the aid of MS Visual Basic program, a menu has been prepared to classify the power electronic networks. This menu is displayed on the screen; thus users can easily select the type of the PE system.

There is another advantage of having dynamic simulation software that the real time control can be achieved by using the simulation package through the interface hardware without any low-level language [8]. It is believed that, this subject is not in the scope of this paper. Thus, it is not discussed here.

In the second section of this paper, simulation of the fundamental power-electronic circuits will be presented together with PWM methods. Generally single switch models are used, enabling large signal analysis. For detailed studies, switch turn-on and turn-off

characteristics are also modelled covering small signal analysis. In the third section, the number of SMPS circuit simulations and, their input and output waveforms will be described and shown. The fourth section is devoted to electric motor and drive simulations.

II. EXPERIMENTAL

A. *Fundamental Power electronic Circuits Rectifier*

The VisSim™ blocks are formed to compute the dynamic behaviour of single and three phase rectifiers. The load consists of L, R, and E serially connected, which is similar to that of DC machines. For controlled rectifier, firing angle of each thyristor is defined by comparing a ramp function and a step function. In Figure 1, a VisSim™ simulation model of a single-phase controlled rectifier is presented. The instantaneous current and voltage waveforms are shown.

B. *SMPS DC Chopper*

This is the model of a step down PWM chopper supplying a dc motor. Duty cycle is defined by comparing a high frequency sawtooth wave with a control dc signal as seen in Figure 2. This model is versatile that, dc output is easily adjusted by changing the control step signal. Pure inductive or resistive loads or the combination of two load elements can easily be taken into account by fixing other elements to zero in the load module. It is believed that, this kind of illustrative representation of actual networks may also contribute to the teaching of power electronics.

C. *Simulation of PWM Methods in Inverter*

In Figure 4. the VisSim model of a single phase PWM bridge inverter is presented. Although only single step modulation and sinusoidal pulse width modulation methods are presented here, other PWM methods could be covered in the same manner. As it is seen, for single step modulation, a triangle wave is compared with a dc control signal and quasi-square output waves are formed. For the sinusoidal PWM, as it is in the actual case, a sine wave is compared with high frequency triangle waves. Running the simulation programme for different cases can easily show the effect of PWM type and load's time constant on the inverter output voltage and current waveforms.

D. *Simulation of AC Chopper*

Similar to the method described above the simulation of a single-phase ac chopper is realized by synthesizing the function blocks defined by VisSim™ mother program. The firing instants are set similarly. The load block consists of the serial connection of L and R. This model is particularly useful for developing the performance curves of static reactive power compensation schemes. It would be interesting to detect that, for pure inductive load, any firing instant earlier than $\pi/2$ would cause the omitting of the firing of the incoming thyristor as it is described in textbooks. In Figure 5. the VisSim model of the single-phase ac chopper is shown.

E. *Switched Mode Power Supplies*

The non-isolated and isolated switched mode power supplies are simulated in the following order. The step down dc/dc converter, step up dc/dc converter, buck boost dc/dc converter, forward converter, flyback converter, push pull converter, half and full bridge converters. With the prepared menu in MS Visual Basic program, each type is called and, the equivalent circuit is seen on the screen [7]. In order to analyse each network; VisSim™ model of each type is solved for the required data. On the same screen, input and output waveforms of each SMPS can be seen. In Figure 6 and Figure 7. the VisSim™ model of buck boost and flyback converters is presented together with the input and output waveforms. Since the simulation principle is the same, other SMPS types are not presented in this paper.

F. *Simulations of Drive Systems*

Since a drive system consists of a power electronic supply, electrical machine and a control unit, it is necessary to simulate each part of the system. The simulation of power electronic part is presented above. The control and machine parts are considered together for conventional drive systems such as dc and induction motor drives. For rather unconventional motors like switched reluctance and brushless dc motors, power electronic circuits should be included into the motor mathematical models.

III. CONCLUSION

Software for simulating the power electronic circuits has been developed by using VisSim™ simulator. The VisSim™ models have been presented through MS Visual Basic menu, under three titles. The fundamental power electronic circuits title covers rectifiers, inverters, ac and dc choppers, and PWM methods. Switched mode power supplies heading covers buck, boost, buck-boost, forward, flyback, pushpull, half and full bridge configurations. It seems that, this software will be a useful as supplementary material for university power electronic courses as well as industry-based further education programs.

This software will also be used for sophisticated motion control purposes; in that case, the DSP codes could be generated directly by using VisSim models. [8]

For detailed power-electronic design, the advanced simulation version, which covers the dynamic switching characteristics of semiconductors could be used.

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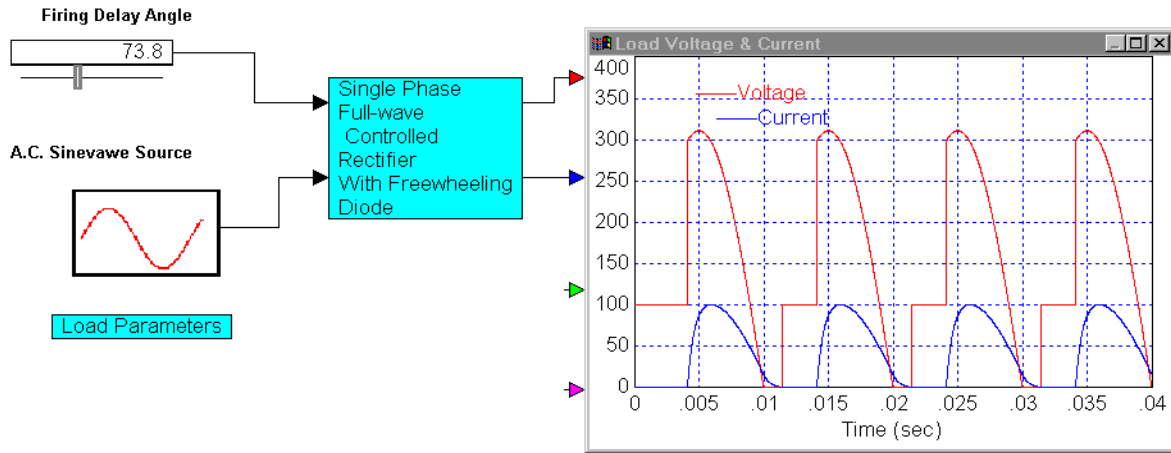
Figure 1. Single Phase Controlled Rectifier.
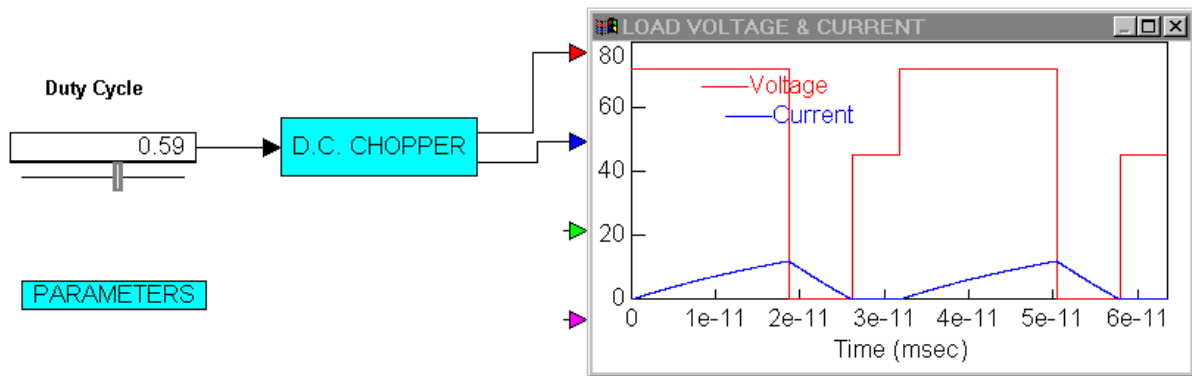
Figure 2. DC Chopper.
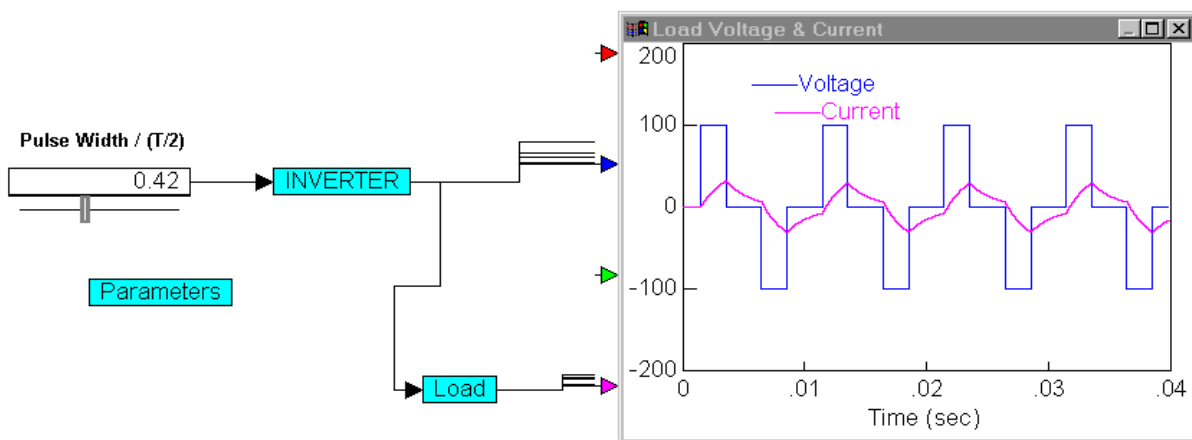
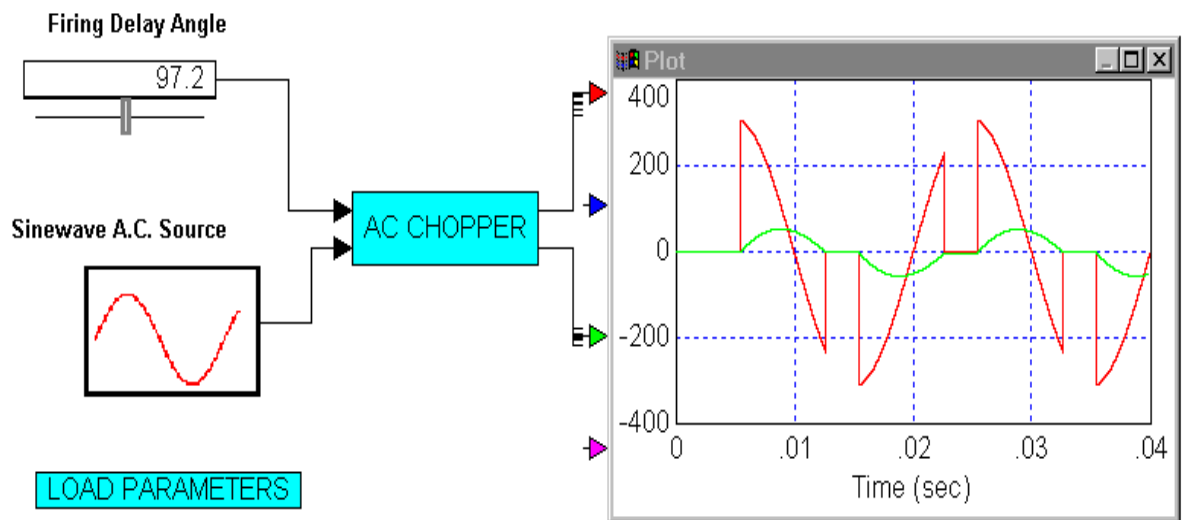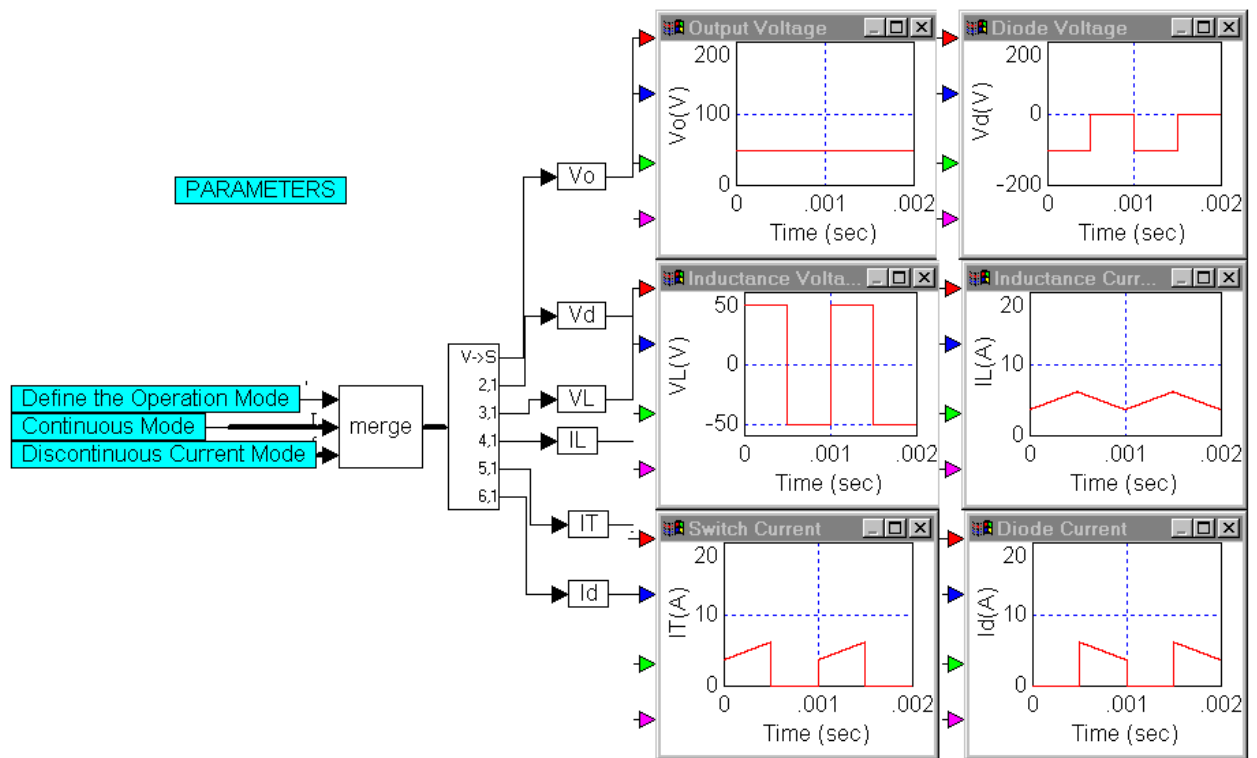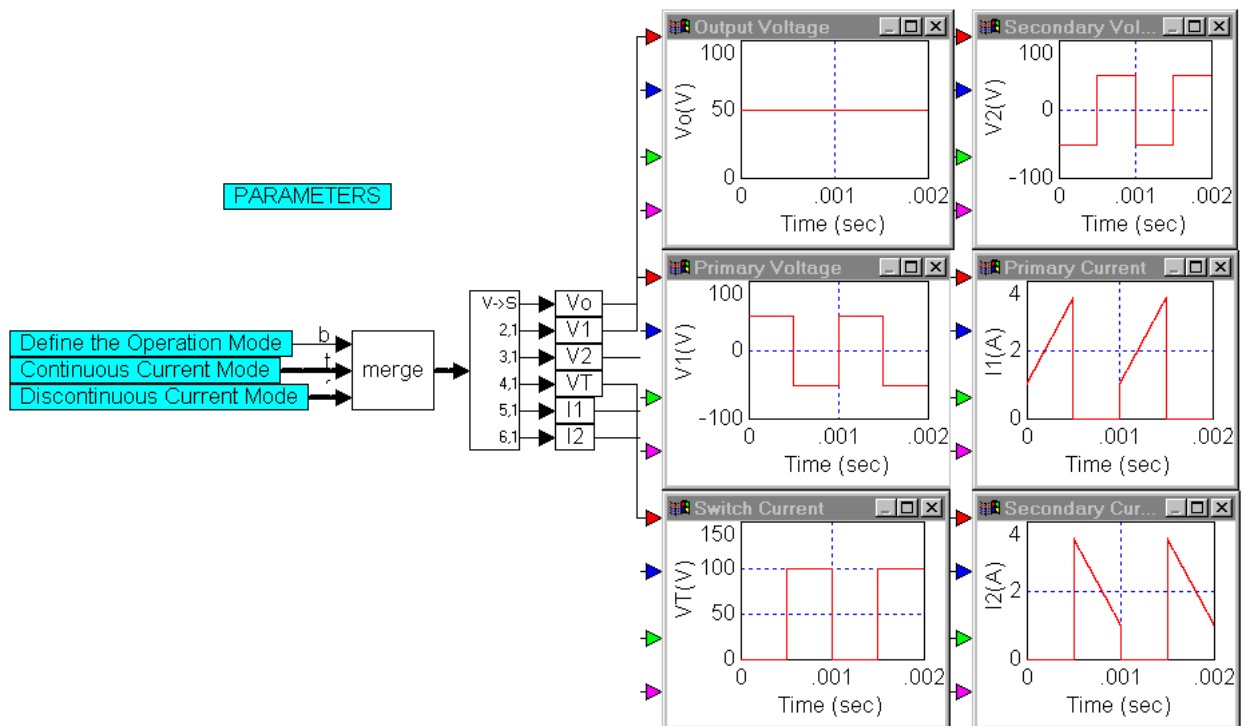Figure 3. Single Phase Inverter
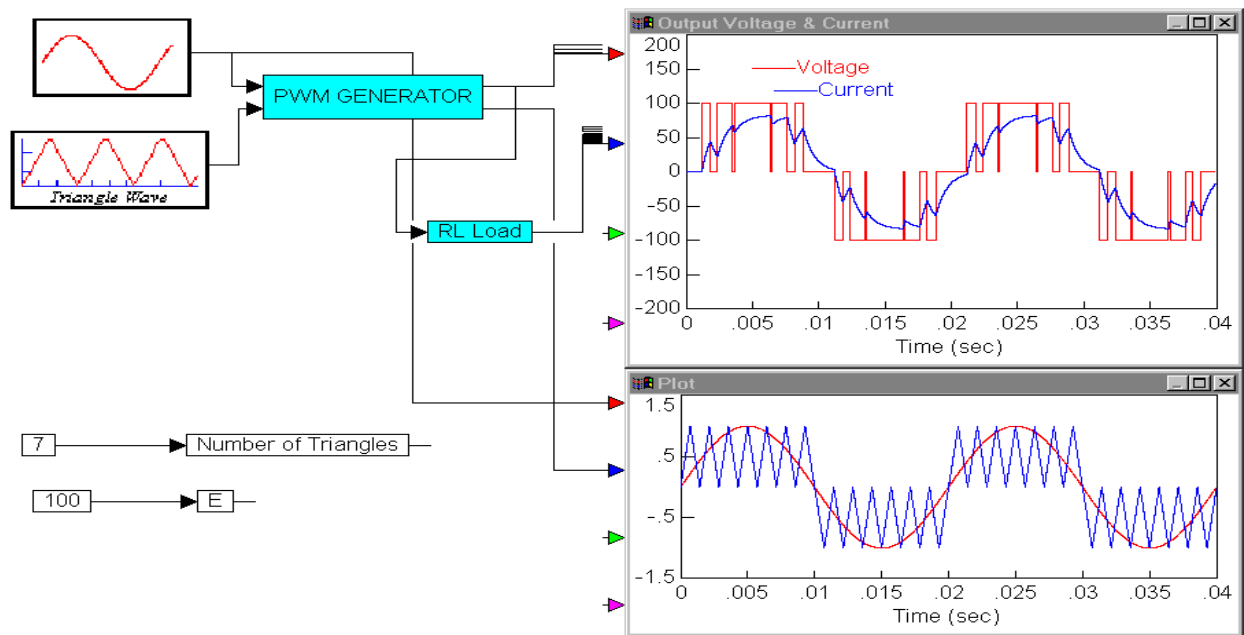
Figure 4. SinePWM.

Figure 5. AC Chopper

Figure 6. Buck Boost dc/dc Converter

Figure 7. Flayback Converter