17. Simulation tools

Felix Jenni; Paul Scherrer Institute; CH-5232 Villigen PSI; Switzerland; felix.jenni@psi.ch

1. Why Simulations

Simulation is a very important means in the field of power electronics. There are a number of reasons for this fact, as there are:
- Saving of development time
- Saving of costs ('burnt power circuits tend to be expensive')
- Better understanding of the function
- Testing and finding of critical states and regions of operation
- Fast optimisation of system and control

Today it is difficult to imagine the task of power electronics development without help of a simulation!

2. Principle of simulation in the past and today

The key-operation of all simulation is the solution of differential / integral equations. That can be done with analogue or digital computers:

a) Analogue computers

Simulation tools are quite old. It is more than 50 years that analogue computers were built in numbers for various simulation purposes. Essentially, they were based on the functions: addition, subtraction and integration. That allowed the simulation of linear physical systems that could be described with linear integral equations. Multiplication, division and other nonlinear operations came later as addenda.

The 'program' of a simple linear equation on an analogue computer looked as follows:

$$y = \int (a - b)dt$$
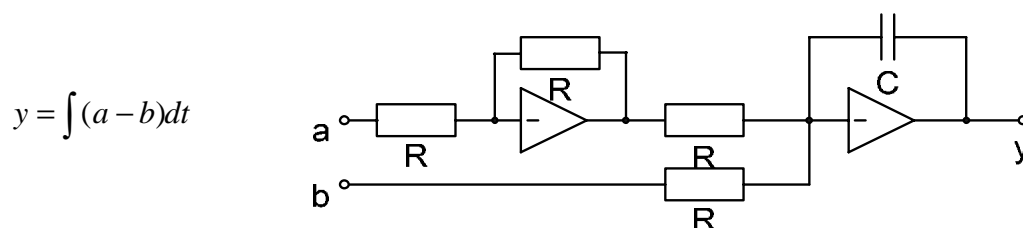
(The operational amplifier being ideal, i.e. no drift, and RC= 1)

The result of the integration on an analog computer is mathematically correct. Depending on the time-constants of the integration, a time-scaling of the equation was sometimes necessary. Given by the maximal output voltage of the amplifiers the amplitudes of the signals had to be scaled too. It is obvious that in the end a rescaling of the output 'result' was needed too. Time scaling and rescaling caused problems for beginners!
While analogue computers where widely used in the past, most of them vanished after 1980.
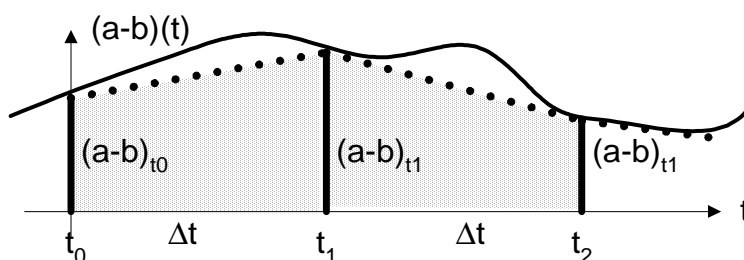
b) Digital computer

On a digital computer the integration can be represented by a simple summation according to:

$$y = \sum_i (a-b)_{ti} \Delta t$$
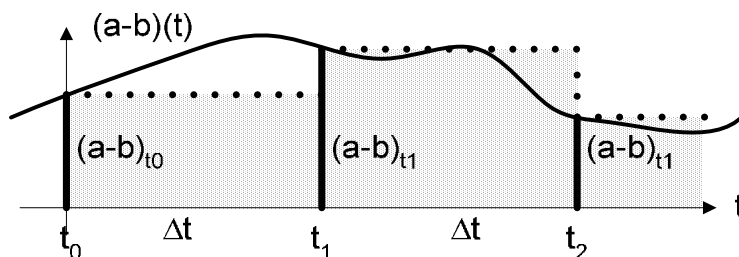
An improved integration looks as follows:

$$y = \sum_i \{(a-b)_{ti} + (a-b)_{ti+1}\} \frac{\Delta t}{2}$$

Besides the two shown fixed step solver (Δt = constant), solvers exist, which adapt the time step to the function that has to be integrated. They are very useful for systems that contain switching actions.

Over all, a large number of integration methods ('solvers') exist. All of them have advantages and disadvantages. But in general, all of them compute a time discrete summation only as an approximation of the integral. Therefore, the integration-algorithm is very important for the result of a simulation. An inappropriate algorithm can lead to long simulation times and / or wrong results.

In spite of the problems of a correct integration simulations on digital computers have a number of advantages:

- Easy implementation of nonlinear functions (multiplication, division, complex functions …)
- Comfortable input and output of model and data
- No drift and offset problems
- Translation of a graphically entered model into a mathematical description for the simulation by the computer → this has brought an extreme comfort in the last years.
- Some tools provide an automatic linearization of nonlinear systems
- No time and amplitude scaling necessary
- …..

F. Jenni   05.05.2004

3. Simulation tools

The best available simulation tool is the tool you are used to!
(Provided, that it can solve the task.)

There are a number of powerful simulation tools available. All of them have advantages and disadvantages. They can be grouped into three parts; according to the way the system to be simulated is 'entered into the computer':

Mathematical input
In this case an exact mathematical description of the circuit to be simulated is entered into the machine. This can be done with various programming languages as there are Basic, Fortran,….., or the very practical Matlab. (Matlab with the toolbox 'Simulink' has an additional feature: the possibility to enter the mathematical description in graphic form.)

Input in Matlab:
```
% Calculated data
udc_in  =   udc0;
uout_0  =   m0*udc_in
iout0   =   uout_0/Rm
```

Netlist input
This form of an input was used for example by former versions of Spice. The physical elements of a circuit, i.e. resistors, capacitors, active elements were entered on the keyboard as a description list. This form of entering a circuit can still be used in Spice. But, it is no longer necessary. Nowadays, the circuit can be entered into the computer graphically.

Example:
```
R_R1          N2 N1   10
C_C4          N5 N6   1u
D_D1          N6 N1 D1N4007 100
+SIN 0 326.6 50 0 0 240
V_V12          N14 0
+SIN 0 326.6 50 0 0 0
R_RD          N16 N15   20m
D_D4           0 N6 D1N4007 100
```

Graphical input
This group contains the tools with the most comfortable form of entering the system into the machine. Most of today's simulation packages for power electronic provide graphic input. In the following only such tools (beside Matlab-Simulink) will be discussed.

3.1 What can be expected from a good tool?
Some properties of a good tool are:
- Comfortable, intuitive input of the circuit
- Correct models for the elements (as simple as possible but, as good as necessary)
- Correct error messages
- Robust execution of the simulation
- Sophisticated integration algorithm
  (various algorithms to be chosen for the type of model)

- Good output of the simulation results (formats which can be exported to other programs)
- Support from the manufacturer
- Portability of models from one program version to following ones
- …..

3.2 Critical tasks and other critical points

Difficult for digital simulation tools are:
- fast events like switching actions
- differentiation

Some tools do have electrical elements which are not good enough modeled (some had even been wrong….). To find 'bad' elements in a simulation can be very time consuming.

3.3. A selection of simulation tools

There are a number of simulation tools available. All of them have advantages and disadvantages (one of the latter being often the costs). The following selection of tools provides graphical input.

a) PSpice

PSpice exists for a long time on the market. It started as a simulation tool for low power electronic circuits. A large library with PSpice models for various electronic components exists. Further models can be added. Today it can simulate analog and digital circuits with a lot of features. The representation of numerical blocks and controllers is difficult.

Availability, costs:
Industry from 7500 €
Universities from 3000€
Student licenses / demo version available (reduced model sizes)

Information:
www.logmatic.ch ; www.orcad.com ; www.orcadpcp.com

b) Matlab / Simulink / SimPowerSystems / PLECS

Matlab is a mathematical tool that is established for a long time. Toolboxes for various applications exist. One of them is Simulink, a graphic tool for the entering of functions. Simulink itself can be expanded with another toolbox: SimPowerSystem. This toolbox is designed for the simulation of electrical power systems including power electronics. The elements of the various toolboxes can be combined.

Availability, costs (Matlab, Simulink and SimPowerSystem):
Industry from 8400 €
Universities from 2100€
Demo version / Student licenses available for a small amount (reduced model sizes)

Information:
www.mathworks.ch ; www.mathworks.com

An additional toolbox for the simulation of power electronics is PLECS.
This is a fast and reliable power toolbox for matlab.
www.plexim.com

F. Jenni   05.05.2004

c) PSIM

PSIM is one of the tools that had been developed specifically for power electronics. Therefore, it is optimized for the tasks arising in this field. This results in fast simulation runs. PSIM offers some add-ons, one of them being an interface to Matlab / Simulink. With that interface the full mathematical power of Matlab is accessible.

Availability, costs :
Industry from 1700 €
Universities from 280€
Demo version / Student licenses available for a small amount (reduced model sizes)

Information:
www.powersimtech.com ; www.powersys.fr

d) Simplorer

Basically Simplorer consists of four modeling languages:
- VHDL-AMS for analog-mixed-signal-design
- Circuit Simulator for the simulation of power electronic circuits
- Block diagram simulator for the simulation of controllers and similar tasks
- State machine simulator for event driven systems
These features enable the engineer to choose the language most appropriate to the task.
Simplorer can be interfaced to a number of other Simulation tools.

Student version available (reduced model sizes)
Prices and Conditions are unknown to the author.

Information:
www.ansoft.com

e) CASPOC

This tool is designed for the simulation of power electronics and electrical drives. It provides a large library of blocks for both topics. Further, code in Pascal and C can be included.

A freeware version of CASPOC is available.
Prices and Conditions are unknown to the author.

Information:
www.integratedsoft.com

f) Saber

Saber is a tool that has been developed for a wide range of applications, including power electronics. Saber can handle analogue, digital, mixed and event driven devices. It can be linked to digital simulations to handle models written in Verilog or VHDL.

Prices and Conditions are unknown to the author.

Information:
www.avanticorp.com