TUTORIAL 6 : START UP OF AN INDUCTION MOTOR

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1 Introduction

This tutorial shows you how to simulate the no-load start up as well as the rated motor operating point of an induction motor. The figure 1.1 shows the example we are going to study. The initial condition is a machine at standstill, the currents nil, the circuit breaker is then switched on to start the motor.

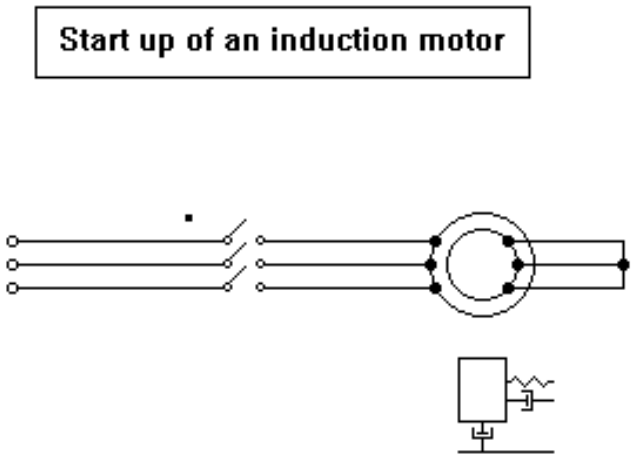

Figure 1.1: *studied example*

2 Construction of the circuit

2.1 Construction of the power part

All submenu commands you have to select are represented in **Bold** in one line. Make sure you are in the **Edit** mode. Select the following submenus and place the elements on the editing grid as shown in figure 2.1.1.

Elements	**Elements 3ph**	**Voltage Supply**	
Elements	**Elements 3ph**	**Circuit Breaker**	
Elements	**Machines**	**Induction**	**3ph Wound Rotor**
Elements	**Machines**	**Mechanical Mass**	

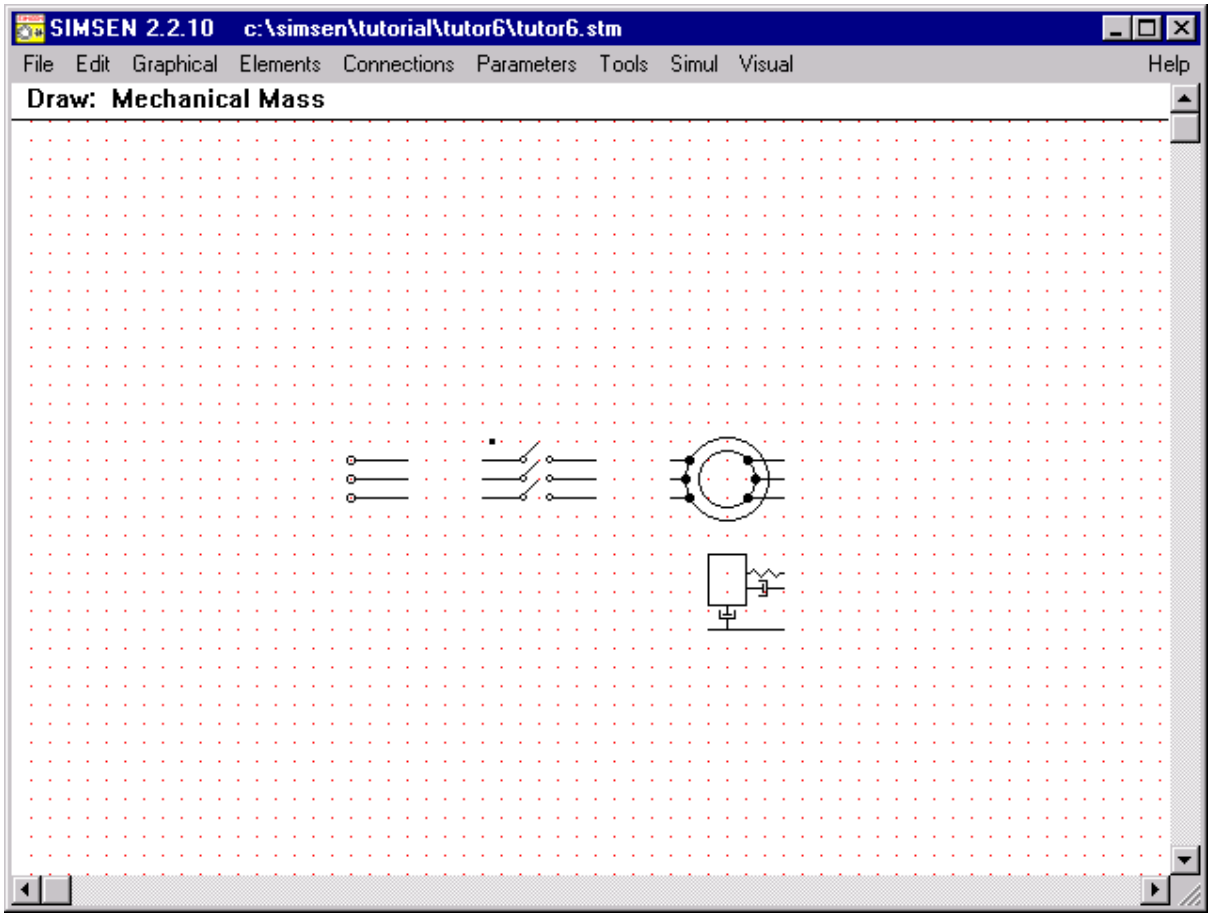

Figure 2.1.1: *Selecting and placing elements on the editing grid*

2.2 Electrical connections (wires and crossings)

You have placed your elements on the editing grid. Now you have to connect them, according to the desired topology. Select the submenu:

Connections Wire

Wire the elements as shown in figure 2.2.1.

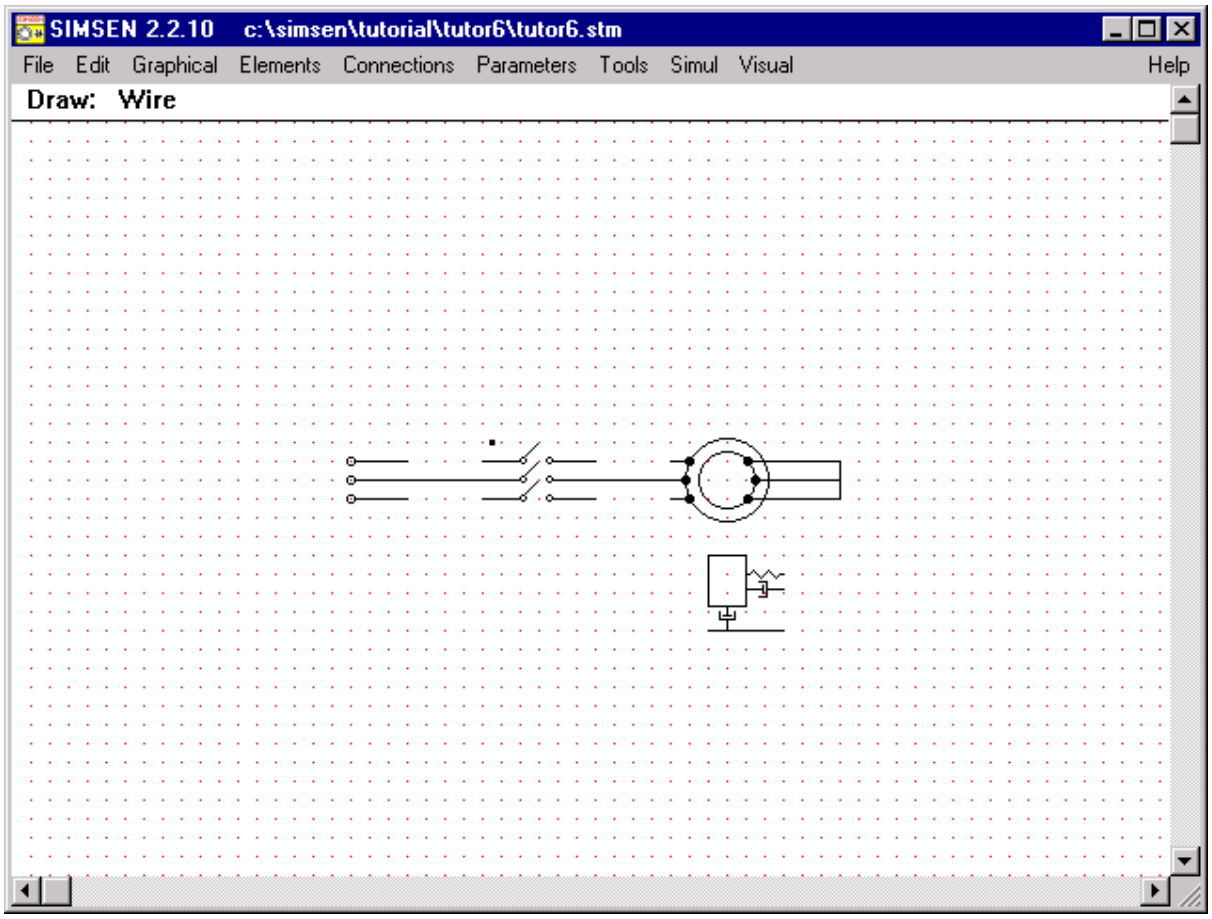

Figure 2.2.1: *Wiring the elements*

Note that even if you are connecting three–phase elements, you don't have to connect the three terminals (but you can if you want). The interface connects automatically the two missing phases when switching to **Simul** mode.

Warning: Be careful to connect the stator terminals of the induction machine to the network supply, and not the rotor terminals.

Now add the crossing points to specify the electrical connections between wires. Select the submenu:

Connections Crossing

Place the crossing as shown in figure 2.2.2.

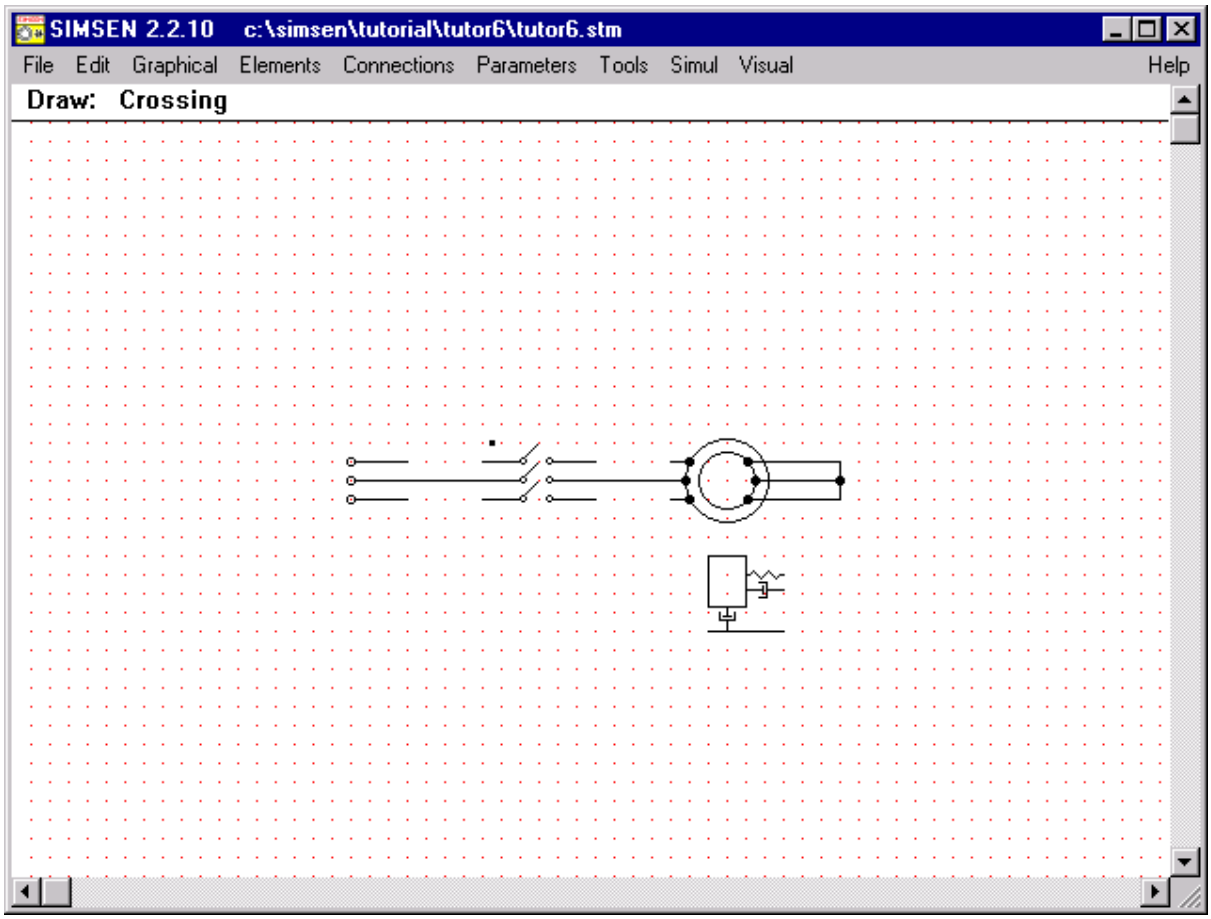

Figure 2.2.2: *Adding crossings*

2.3 Parameters of the power part

Before adding the regulation part it is useful to specify the parameters of the power part. To recognize the elements, the figure 2.3.1 shows you the power part element's names.

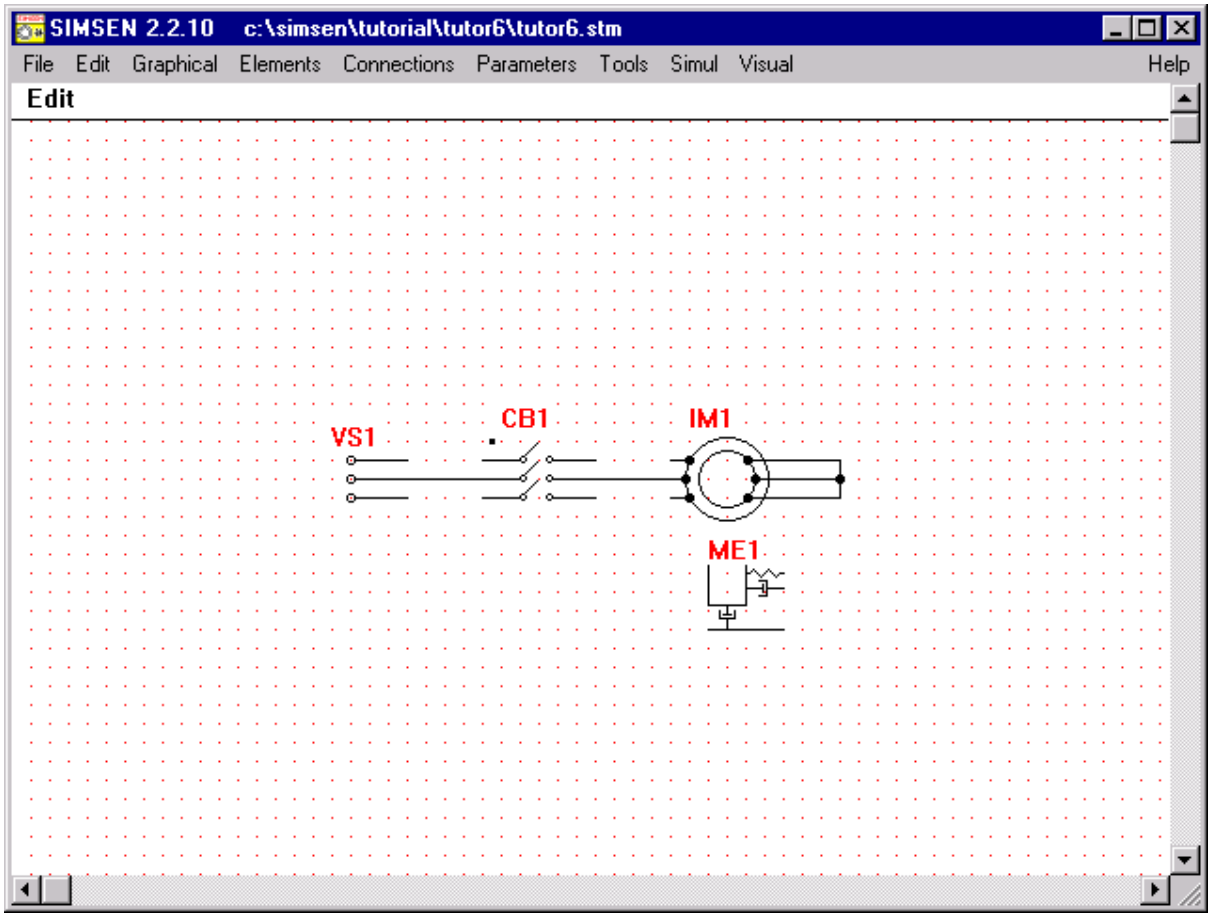

Figure 2.3.1: *Power part element's names*

When introducing the parameters for each element you can call the related help file by clicking on the corresponding command on the bottom right of the window. Thus you can benefit from more information about the current element. Select the submenu:

Parameters Elements

Directly click on the element you want to parameterize. Thus you can open the related window for each element. The next pages will show you, with **bold characters**, the parameters you have to introduce for each element of the power part.

2.3.1 Voltage Supply 3ph **VS1**

```
- GENERAL DATA :

Name    = VS1
Comment =
Writing = SI

- RATED VALUES :

Sn       [VA] =  0.00000000000E+0000
Un        [V] =  0.00000000000E+0000
Fn       [Hz] =  0.00000000000E+0000

- PARAMETERS :

Ulrms     [V] =  4.00000000000E+0003
Fs       [Hz] =  6.00000000000E+0001
Ths     [deg] =  0.00000000000E+0000

- INITIAL CONDITIONS :

Ia        [A] =  0.00000000000E+0000
Ib        [A] =  0.00000000000E+0000
Ic        [A] =  0.00000000000E+0000

- SPECIFIED OPERATING POINT :

Pc        [W] =  0.00000000000E+0000
Qc      [Var] =  0.00000000000E+0000

- CALCULATED VALUES :

Ulrms     [V] =  0.00000000000E+0000
Ilrms     [A] =  0.00000000000E+0000
P         [W] =  0.00000000000E+0000
Q       [Var] =  0.00000000000E+0000
```

Explanation:

Each element of the system must have a different name. The rated values Sn, Un, Fn are used in two cases: either the user will use the Load-Flow program Inisim and the frequency is required or the user wishes to get output results in per unit ('Writing = PU') and the three rated values are required. As 'Writing' is by default set to SI (International System), you can omit the input of rated values. The initial conditions are the values that will be used to start the next simulation. The current explanation is valid for all the elements of the power part.

2.3.2 Circuit Breaker 3ph **CB1**

```
- GENERAL DATA :

Name     = CB1
Comment =
Writing = SI

- RATED VALUES :

Sn       [VA] =  0.00000000000E+0000
Un        [V] =  0.00000000000E+0000
Fn       [Hz] =  0.00000000000E+0000

- PARAMETERS :

Ron     [Ohm] =  0.00000000000E+0000
Roff    [Ohm] =  1.00000000000E+0008
dT      [sec] =  1.00000000000E-0004

- INITIAL CONDITIONS :

Ia         [A] =  0.00000000000E+0000
Ib         [A] =  0.00000000000E+0000
Ic         [A] =  0.00000000000E+0000

- STATE OF PHASES :

a          [1] =  0.00000000000E+0000
b          [1] =  0.00000000000E+0000
c          [1] =  0.00000000000E+0000

- CALCULATED VALUES :

Ilrms      [A] =  0.00000000000E+0000
Ulrms1     [V] =  0.00000000000E+0000
P1         [W] =  0.00000000000E+0000
Q1       [Var] =  0.00000000000E+0000
Ulrms2     [V] =  0.00000000000E+0000
P2         [W] =  0.00000000000E+0000
Q2       [Var] =  0.00000000000E+0000
```

Explanation:

The phases of the circuit breaker are switched off (a=b=c=0). They will be switched on after some milliseconds to supply the motor. This order will be given from a disturbance defined in the main file (see section 2.4).

2.3.3 Induction Machine WR 3ph **IM1**

```
- GENERAL DATA :

Name     = IM1
Comment =
Writing = pu

- MECHANICAL SYSTEM :

ME1 1.000

- RATED VALUES :

Sn       [VA] =  1.00000000000E+0006
Un        [V] =  4.00000000000E+0003
Fn       [Hz] =  6.00000000000E+0001
u         [1] =  1.00000000000E+0000
Pp        [1] =  2.00000000000E+0000
Connect   [-] =  Yy

- PARAMETERS :

rs      [p.u] =  1.00000000000E-0002
xss     [p.u] =  1.00000000000E-0001
xhs     [p.u] =  4.00000000000E+0000
xsr'    [p.u] =  1.00000000000E-0001
rr'     [p.u] =  1.00000000000E-0002

- INITIAL CONDITIONS :

Ila1      [A] =  0.00000000000E+0000
Ilb1      [A] =  0.00000000000E+0000
Ilc1      [A] =  0.00000000000E+0000
Ip        [A] =  0.00000000000E+0000
Ila2      [A] =  0.00000000000E+0000
Ilb2      [A] =  0.00000000000E+0000
Ilc2      [A] =  0.00000000000E+0000
Is        [A] =  0.00000000000E+0000
Thm     [deg] =  0.00000000000E+0000
N       [rpm] =  0.00000000000E+0000

- SPECIFIED OPERATING POINT :

P1c       [W] =  0.00000000000E+0000

- CALCULATED VALUES :

Ulrms1    [V] =  0.00000000000E+0000
Ilrms1    [A] =  0.00000000000E+0000
P1        [W] =  0.00000000000E+0000
Q1      [Var] =  0.00000000000E+0000
Ulrms2    [V] =  0.00000000000E+0000
Ilrms2    [A] =  0.00000000000E+0000
P2        [W] =  0.00000000000E+0000
Q2      [Var] =  0.00000000000E+0000
```

Explanation:
The results will be saved in per unit (Writing = **pu**). 100% (coefficient **1.000**) of the electromagnetic torque will be transferred to the mechanical mass **ME1**.

2.3.4 Mechanical Mass **ME1**

```
- GENERAL DATA :

Name     = ME1
Comment =
Writing = SI

- MECHANICAL MASS CONNECTED :


- RATED VALUES :

Pn         [W] =  0.00000000000E+0000
Nn       [rpm] =  0.00000000000E+0000

- INERTIA PARAMETERS :

J       [kgm2] =  5.00000000000E+0001
Ae   [Nms/rad] =  0.00000000000E+0000
NAe      [rpm] =  0.00000000000E+0000
Tmin      [Nm] =  0.00000000000E+0000
Tfr       [Nm] =  0.00000000000E+0000
kpext      [1] =  0.00000000000E+0000
Text      [Nm] =  0.00000000000E+0000

- COUPLING PARAMETERS :

K     [Nm/rad] =  0.00000000000E+0000
Ai   [Nms/rad] =  0.00000000000E+0000
r          [1] =  0.00000000000E+0000
Tcoupl    [Nm] =  0.00000000000E+0000
state      [1] =  0.00000000000E+0000

- INITIAL CONDITIONS :

N        [rpm] =  0.00000000000E+0000
Thm      [deg] =  0.00000000000E+0000
```

2.4 Simulation parameters

Select the following submenu command:

Parameters Simulation

Fill the main file as follows:

```
- COMMENT :


- SIMULATION PARAMETERS :

Time min                          [sec] =   0.0000000000000
Time max                          [sec] =   5.0000000000000
Integration step                  [sec] =   0.0002000000000
Precision for immediate events      [%] =   1.0000000000000
Precision for simultaneous events   [%] =   1.0000000000000
Integration process                 [-] = RK45
Write in output files every         [1] = 5
Initial conditions from           [E/M] = E
Disturbances activated            [Y/N] = YES

- CONSTANT DATA :


- PARAMETERS :


- INITIAL CONDITIONS :


- DISTURBANCES :

0.05:CB1.abc=1
```

Explanation:

Simulation of the circuit behavior during **5s** with an integration step of **200us**. To reduce the results size, save only each **5**th calculated point. A disturbance is defined: the three phases of the circuit breaker **CB1** will be switched on (**a = b = c = 1**) at the time **0.05s**. Note that the disturbances are activated (Disturbances [Y/N] = **YES**).

3 First Simulation

Click the **Simul** menu to go enter simulation mode. Then, click the **Sim** menu and answer **Yes** to the next question. The simulation starts. When the simulation is terminated, the simulation window looks as shown in figure 3.1.

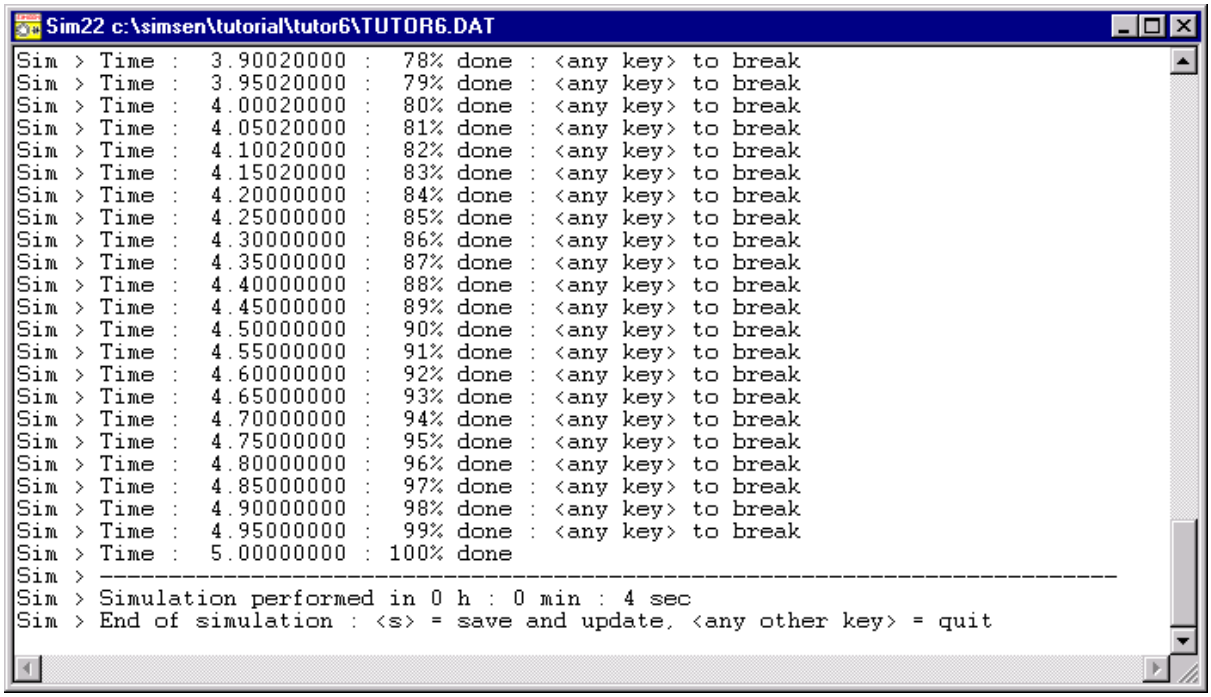

Figure 3.1: *End of the simulation*

Please wait until you can read the last simulation message
'End of simulation: <s> = save and update, <any other key> = quit'.

After the simulation, save the last calculated point by **pressing the <s> key**, to use it as initial condition for the next simulation.
The window will close automatically.

4 First Results

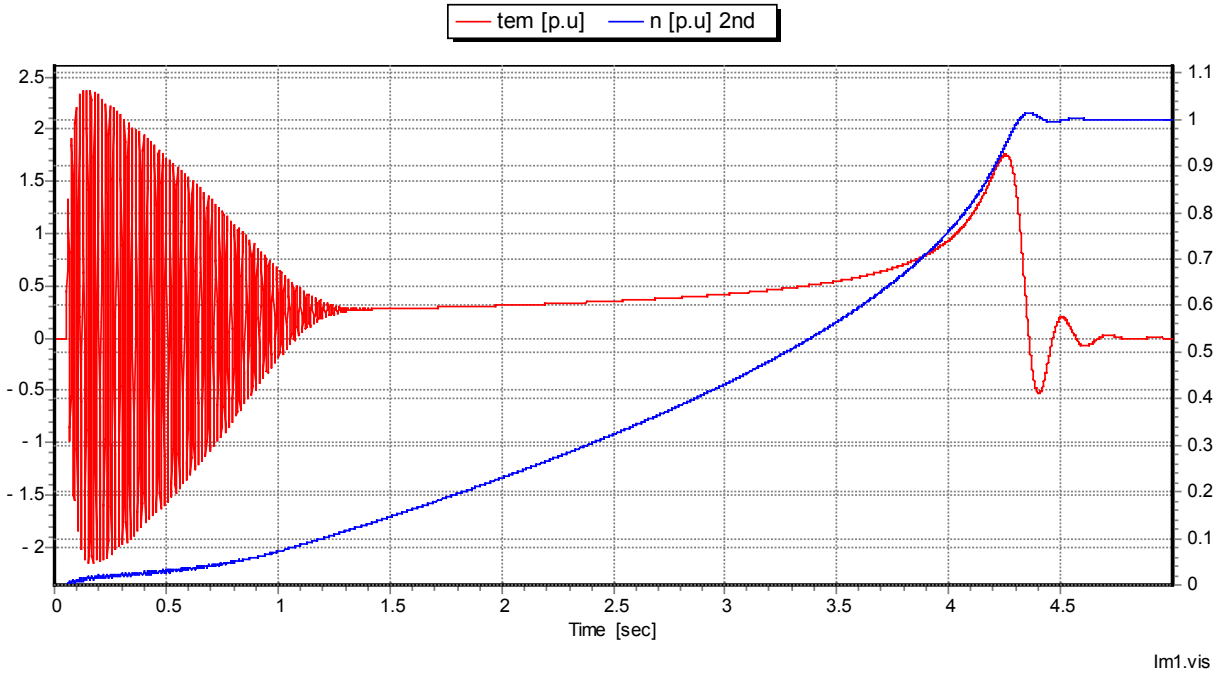

Figure 4.1: *Air-gap torque and speed of the machine*

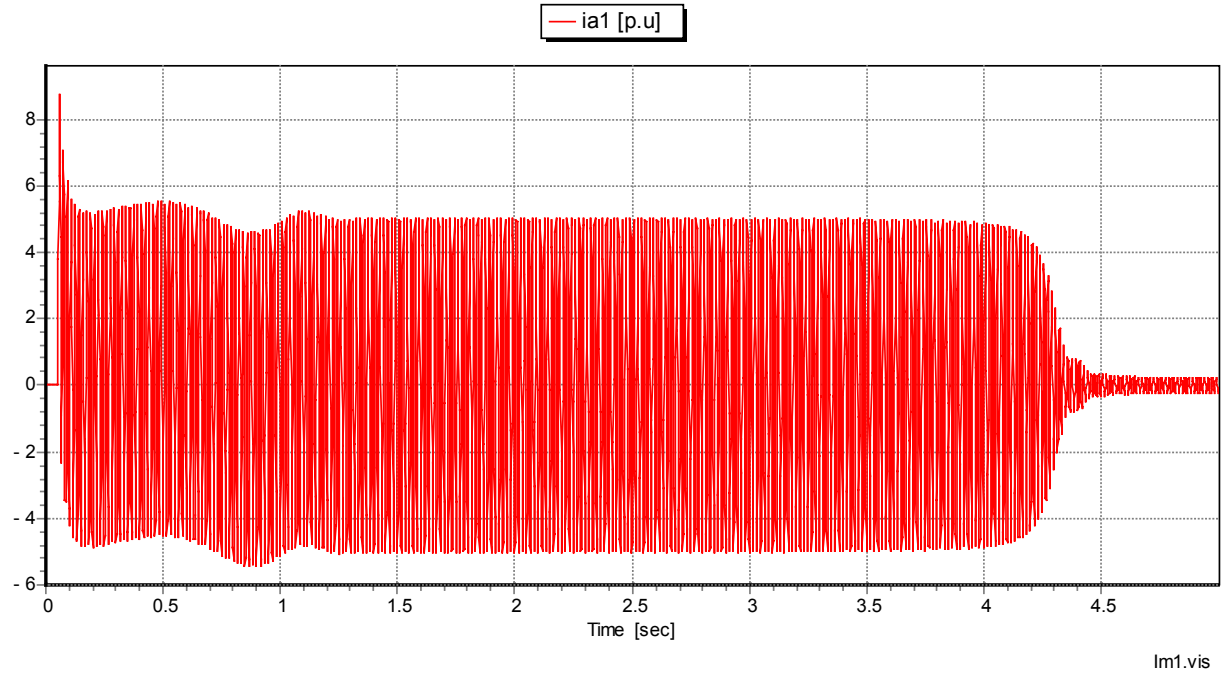

Figure 4.2: *Stator current in the phase a*

5 Rated motor operating point of the induction motor

After returning in the Editor Mode, change some parameters to load the motor.

5.1 Parameters

5.1.1 Mechanical Mass **ME1**

```
- GENERAL DATA :

Name    = ME1
Comment =
Writing = SI

- MECHANICAL MASS CONNECTED :


- RATED VALUES :

Pn         [W] =  0.00000000000E+0000
Nn       [rpm] =  0.00000000000E+0000

- INERTIA PARAMETERS :

J       [kgm2] =  5.00000000000E+0001
Ae   [Nms/rad] =  0.00000000000E+0000
NAe      [rpm] =  0.00000000000E+0000
Tmin      [Nm] =  0.00000000000E+0000
Tfr       [Nm] =  0.00000000000E+0000
kpext      [1] =  0.00000000000E+0000
Text      [Nm] = -5.30000000000E+0003

- COUPLING PARAMETERS :

K     [Nm/rad] =  0.00000000000E+0000
Ai   [Nms/rad] =  0.00000000000E+0000
r          [1] =  0.00000000000E+0000
Tcoupl    [Nm] =  0.00000000000E+0000
state      [1] =  0.00000000000E+0000

- INITIAL CONDITIONS :

N        [rpm] =  1.80004776783E+0003
Thm      [deg] =  0.00000000000E+0000
```

Explanation:

The mechanical Mass is under a load with an external torque **Text = - 5.3 kNm** (motor).

6 Second simulation

6.1 Simulation parameters

Select the following submenu command:

Parameters Simulation

Fill the main file as follows:

```
- COMMENT :


- SIMULATION PARAMETERS :

Time min                          [sec] =   5.0000000000000
Time max                          [sec] =   6.0000000000000
Integration step                  [sec] =   0.0002000000000
Precision for immediate events      [%] =   1.0000000000000
Precision for simultaneous events   [%] =   1.0000000000000
Integration process                 [-] = RK45
Write in output files every         [1] = 5
Initial conditions from           [E/M] = E
Disturbances activated            [Y/N] = NO

- CONSTANT DATA :


- PARAMETERS :


- INITIAL CONDITIONS :


- DISTURBANCES :

0.05:CB1.abc=1
```

Explanation:

Now the disturbances are not activated (Disturbances activated [Y/N] = **NO**). The second simulation duration is from the time **5** sec to **6** sec (the previous simulation data are kept).
You can start the second simulation.

At the end of the simulation, wait until you can read the last simulation **message** :
'End of simulation: <s> = save and update, <any other key> = quit'.

Close the simulation window without saving the last calculated point by **pressing <any other key>**.

7 Second results

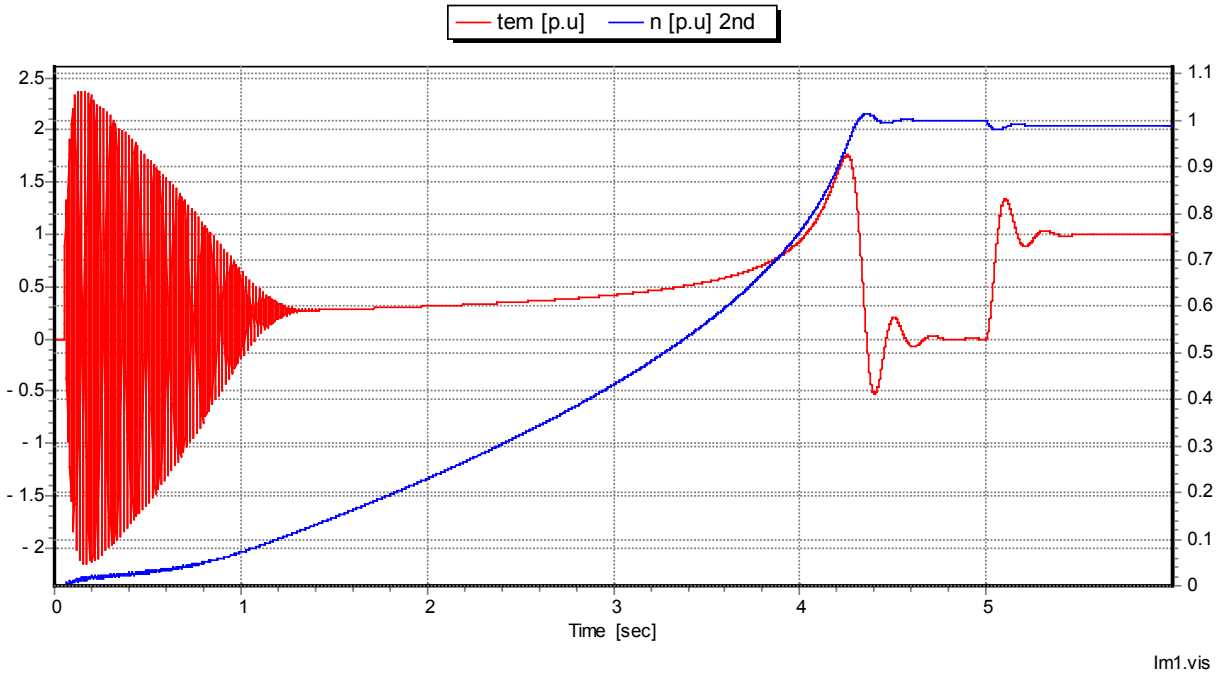

Figure 7.1: *Air-gap torque and speed of the machine*

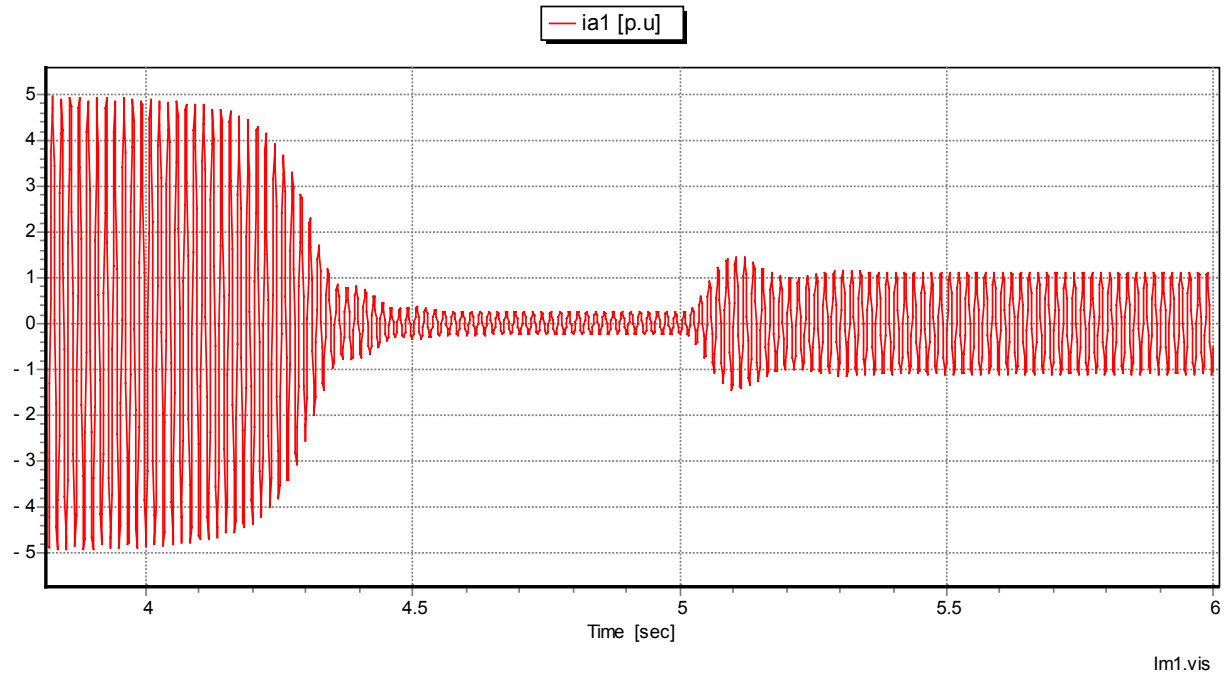

Figure 7.2: *Stator current in the phase a*

End of Tutorial