TUTORIAL 7 : HYDRO-GENERATOR IN TRANSIENT OPERATING MODES

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1 Introduction

This tutorial shows you how to simulate the behavior of a hydro-generator during transient operating modes like: short circuits, earth fault and wrong synchronization. The figure 1.1 shows the example we want to study.

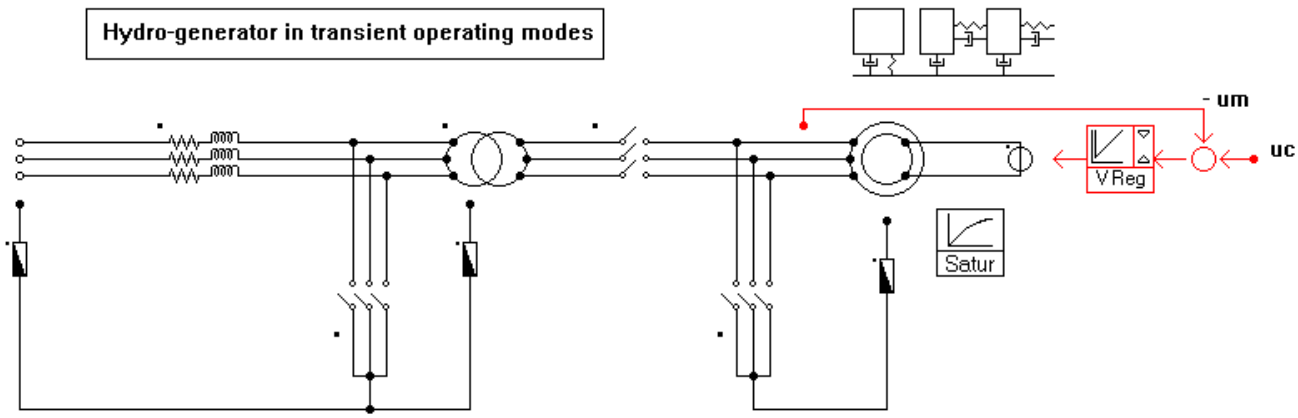


Figure 1.1: *studied example*

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. After having selected a submenu, you can place the corresponding element several times on the grid without going back to this submenu.

Elements	**Elements 3ph**	**Voltage Supply**	
Elements	**Elements 3ph**	**Transmission Line**	**RL**
Elements	**Elements 3ph**	**Transformer 2x3ph**	
Elements	**Elements 3ph**	**Circuit Breaker**	(3 times)
Elements	**Machines**	**Synchronous**	**3ph Laminated Rotor**
Elements	**Machines**	**Stator**	
Elements	**Machines**	**Mechanical Mass**	(2 times)
Elements	**Elements 1ph**	**Voltage Supply**	
Elements	**Special Elements**	**Neutral Terminal**	(3 times)
Elements	**Elements 1ph**	**RLC**	(3 times)
Elements	**Special Elements**	**Saturation : Satur**	

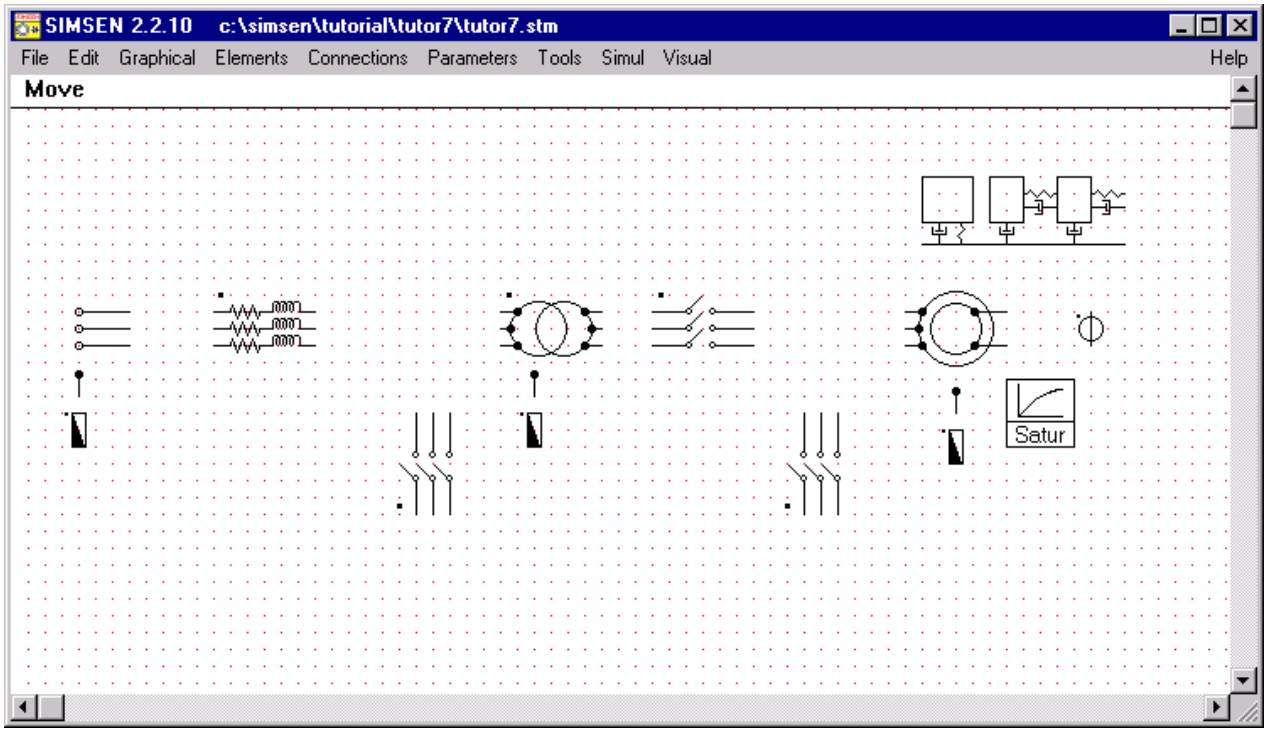


Figure 2.1.1: *Selecting and placing elements on the editing grid*

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

First connect the three-phase elements as shown in figure 2.2.1.

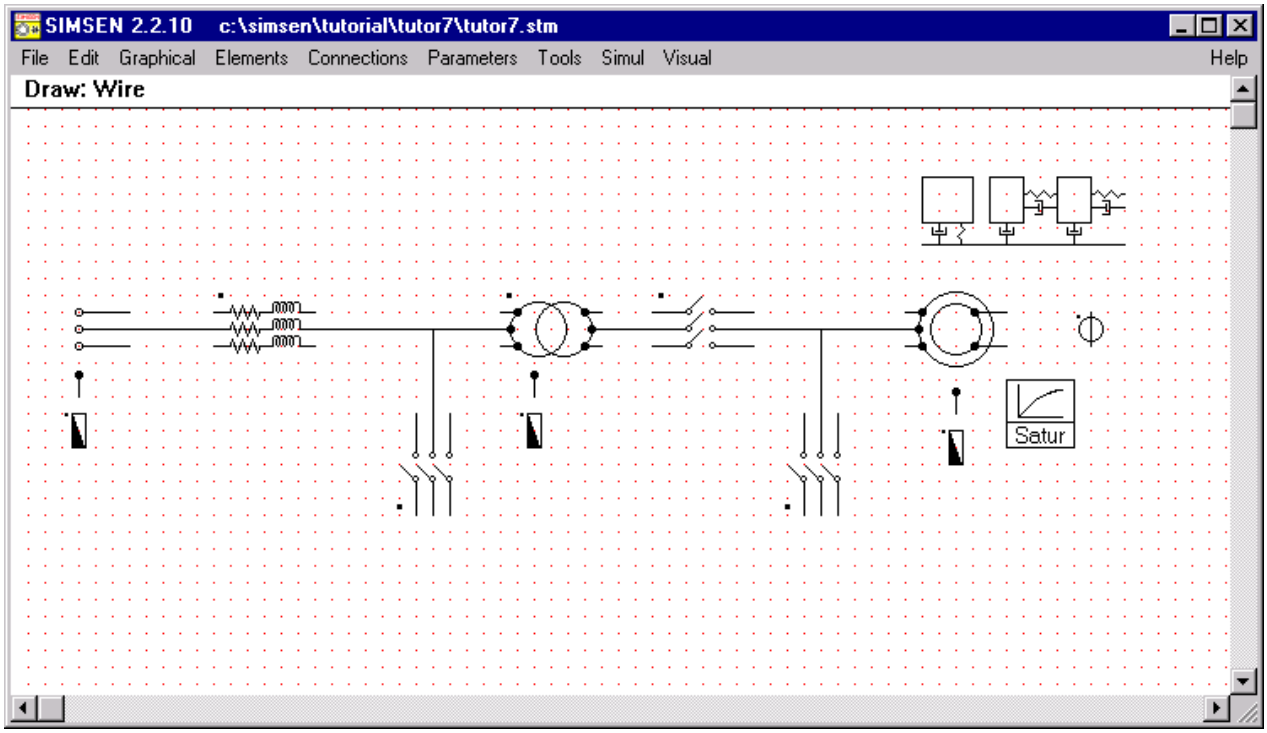


Figure 2.2.1: *Wiring the three-phase elements*

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.

Then, connect the side 1 of the two vertical circuit breakers as shown in figure 2.2.2.

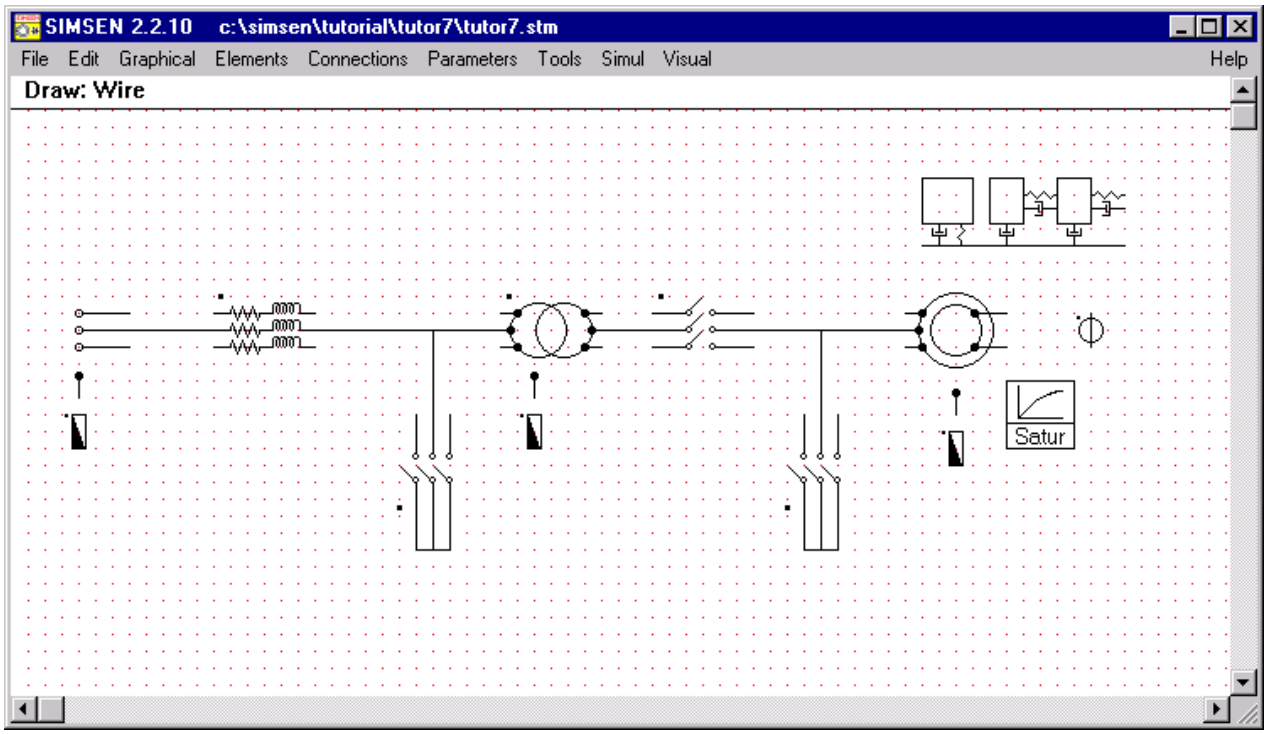


Figure 2.2.2: *Wiring the side 1 of circuit breakers*

Finally, wire the remaining elements, as shown in figure 2.2.3.

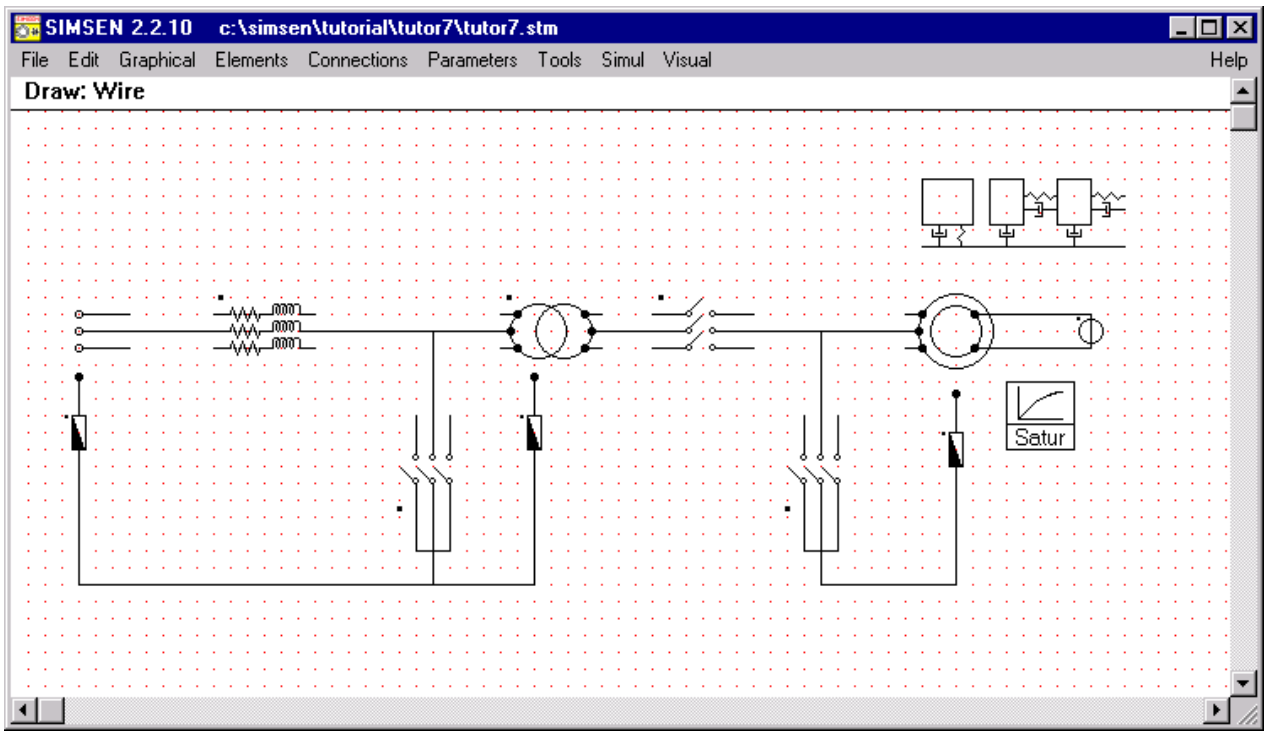


Figure 2.2.3: *Wiring the remaining elements*

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

Connections Crossing

Place the two crossings as shown in figure 2.2.4.

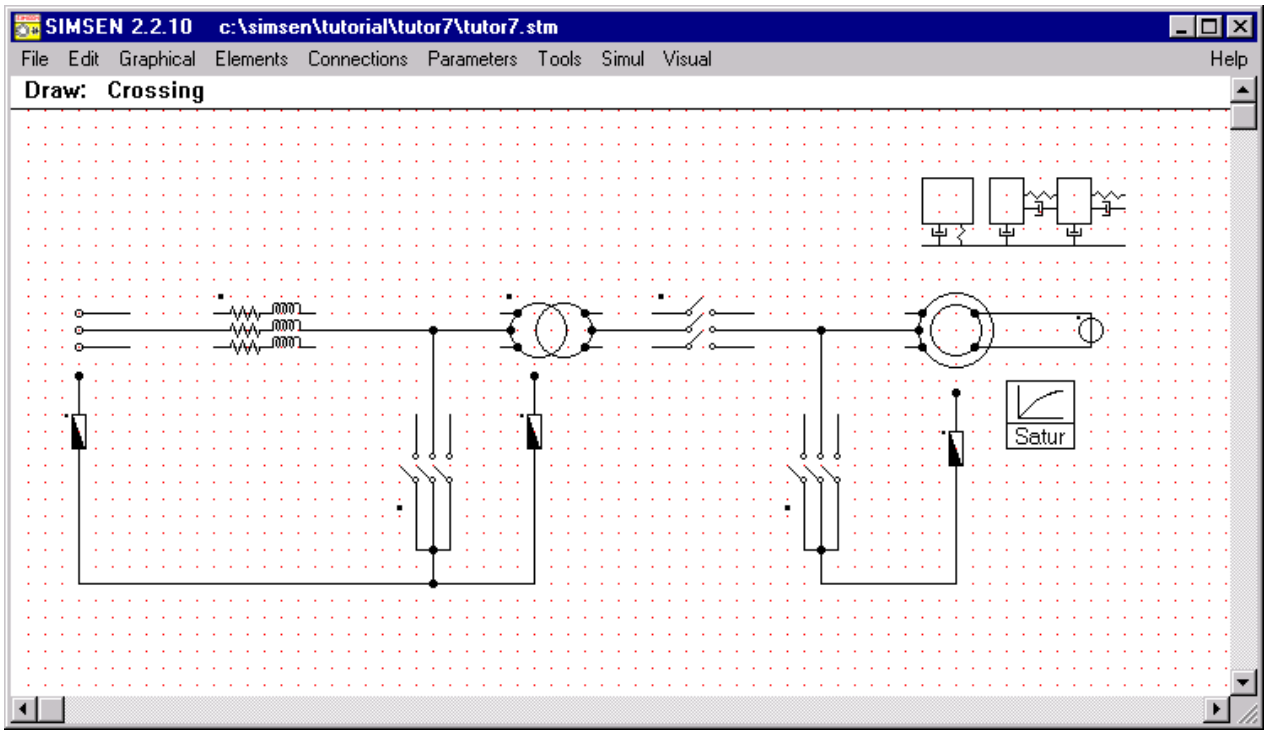


Figure 2.2.4: *Adding crossings*

2.3 Parameters of the power part

To recognize the elements, the figure 2.3.1 displays you the power part element's names.

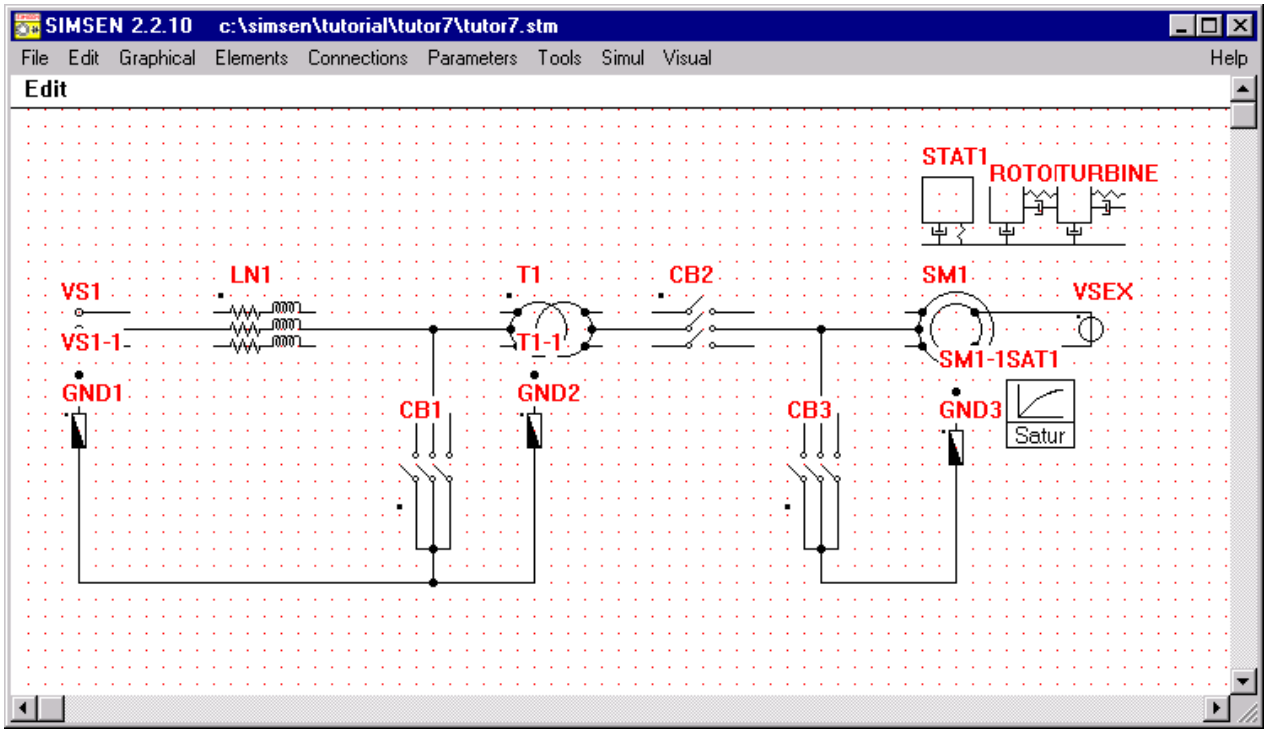


Figure 2.3.1: *Power part element's names*

Note that the three **Neutral Elements** have the name of their related three-phase element (**VS1-1**, **T1-1** and **SM1-1**). 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 = NO

- RATED VALUES :

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

- PARAMETERS :

Ulrms    [V] =  0.00000000000E+0000
Fs      [Hz] =  0.00000000000E+0000
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.

2.3.2 Transmission Line 3ph **LN1**

```
- GENERAL DATA :

Name    = LN1
Comment =
Writing = SI

- RATED VALUES :

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

- PARAMETERS :

unsym    [1] =  0.00000000000E+0000
Ra     [Ohm] =  0.00000000000E+0000
La       [H] =  0.00000000000E+0000
Ca       [F] =  0.00000000000E+0000
Rb     [Ohm] =  0.00000000000E+0000
Lb       [H] =  0.00000000000E+0000
Cb       [F] =  0.00000000000E+0000
Rc     [Ohm] =  0.00000000000E+0000
Lc       [H] =  0.00000000000E+0000
Cc       [F] =  0.00000000000E+0000
Lmab     [H] =  0.00000000000E+0000
Lmbc     [H] =  0.00000000000E+0000
Lmca     [H] =  0.00000000000E+0000

- INITIAL CONDITIONS :

Ia       [A] =  0.00000000000E+0000
Ib       [A] =  0.00000000000E+0000
Ic       [A] =  0.00000000000E+0000
UCa      [V] =  0.00000000000E+0000
UCb      [V] =  0.00000000000E+0000
UCc      [V] =  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
Laeff    [H] =  0.00000000000E+0000
Lbeff    [H] =  0.00000000000E+0000
Lceff    [H] =  0.00000000000E+0000
```

2.3.3 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] =  0.00000000000E+0000
dT     [sec] =  0.00000000000E+0000

- 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
```

2.3.4 Transformer 2x3ph **T1**

```
- GENERAL DATA :

Name     = T1
Comment =
Writing = pu

- RATED VALUES :

Sn       [VA] =  0.00000000000E+0000
Un1       [V] =  0.00000000000E+0000
Un2       [V] =  0.00000000000E+0000
Fn       [Hz] =  0.00000000000E+0000
Connect   [-] =  Yd5

- PARAMETERS :

rcc     [p.u] =  0.00000000000E+0000
xcc     [p.u] =  0.00000000000E+0000
xh1     [p.u] =  0.00000000000E+0000
type      [1] =  0.00000000000E+0000

- 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

- 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:

Output results in per unit (Writing = **pu**). The connection of the transformer has to be defined in its own window of parameters (Connect [-] = **Yd5**) because the connection is part of the electrical circuit.

2.3.5 Circuit Breaker 3ph **CB2**

```
- GENERAL DATA :

Name    = CB2
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] =  0.00000000000E+0000
dT     [sec] =  0.00000000000E+0000

- INITIAL CONDITIONS :

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

- STATE OF PHASES :

a        [1] =  1.00000000000E+0000
b        [1] =  1.00000000000E+0000
c        [1] =  1.00000000000E+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
```

2.3.6 Circuit Breaker 3ph **CB3**

```
- GENERAL DATA :

Name    = CB3
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] =  0.00000000000E+0000
dT     [sec] =  0.00000000000E+0000

- 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
```

2.3.7 Synchronous Machine LR 3ph **SM1**

```
- GENERAL DATA :

Name    = SM1
Comment =
Writing = PU

- MECHANICAL SYSTEM :

STAT1 -1.0
ROTOR  1.0

- RATED VALUES :

Sn      [VA] =  0.00000000000E+0000
Un       [V] =  0.00000000000E+0000
Fn      [Hz] =  0.00000000000E+0000
Pp       [1] =  0.00000000000E+0000
Ifd0     [A] =  0.00000000000E+0000
Connect  [-] =  Y

- PARAMETERS :

rs     [p.u] =  0.00000000000E+0000
xss    [p.u] =  0.00000000000E+0000
xad    [p.u] =  0.00000000000E+0000
xsDf   [p.u] =  0.00000000000E+0000
rf     [p.u] =  0.00000000000E+0000
xsf    [p.u] =  0.00000000000E+0000
rD     [p.u] =  0.00000000000E+0000
xsD    [p.u] =  0.00000000000E+0000
xaq    [p.u] =  0.00000000000E+0000
rQ     [p.u] =  0.00000000000E+0000
xsQ    [p.u] =  0.00000000000E+0000

- INITIAL CONDITIONS :

Ila      [A] =  0.00000000000E+0000
Ilb      [A] =  0.00000000000E+0000
Ilc      [A] =  0.00000000000E+0000
Ip       [A] =  0.00000000000E+0000
iD     [p.u] =  0.00000000000E+0000
If       [A] =  0.00000000000E+0000
iQ     [p.u] =  0.00000000000E+0000
Thm    [deg] =  0.00000000000E+0000
N      [rpm] =  0.00000000000E+0000

- SPECIFIED OPERATING POINT :

Ulrms    [V] =  0.00000000000E+0000
Ths    [deg] =  0.00000000000E+0000
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
Rf     [Ohm] =  0.00000000000E+0000
```

Explanation:

The results are saved in per unit (Writing = **pu**). 100% (coefficient **1.000**) of the electromagnetic torque is transferred to the mechanical mass **ROTOR** and –100% (coefficient **–1.000**) of the electromagnetic torque is transferred to the stator **STAT1**. The simulation takes into account the influence of the stator vibrations

2.3.8 Voltage Supply 1ph **VSEX**

```
- GENERAL DATA :

Name     = VSEX
Comment =
Writing = NO

- RATED VALUES :

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

- PARAMETERS :

type     [1] =  1.00000000000E+0000
U        [V] =  0.00000000000E+0000
Fs      [Hz] =  0.00000000000E+0000
Ths    [deg] =  0.00000000000E+0000

- INITIAL CONDITIONS :

I        [A] =  0.00000000000E+0000
```

Explanation:

Output results of this voltage supply are not saved (Writing = **NO**). Type **1** corresponds to a DC voltage supply. The Load-Flow program *INISIM* will add automatically the missing parameters.

2.3.9 Stator **STAT1**

```
- GENERAL DATA :

Name    = STAT1
Comment =
Writing = PU

- RATED VALUES :

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

- PARAMETERS :

J       [kgm2] =  0.00000000000E+0000
K     [Nm/rad] =  0.00000000000E+0000
D    [Nms/rad] =  0.00000000000E+0000
R          [m] =  0.00000000000E+0000

- INITIAL CONDITIONS :

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

2.3.10 Mechanical Mass **ROTOR**

```
- GENERAL DATA :

Name    = ROTOR
Comment =
Writing = PU

- MECHANICAL MASS CONNECTED :

TURBINE

- RATED VALUES :

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

- INERTIA PARAMETERS :

J       [kgm2] =  0.00000000000E+0000
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
```

Explanation:

The present mechanical mass **ROTOR** is connected to the mechanical mass **TURBINE**.

2.3.11 Mechanical Mass **TURBINE**

```
- GENERAL DATA :

Name    = TURBINE
Comment =
Writing = PU

- MECHANICAL MASS CONNECTED :


- RATED VALUES :

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

- INERTIA PARAMETERS :

J       [kgm2] =  0.00000000000E+0000
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
```

2.3.12 RLC Impedance 1ph **GND1**

```
- GENERAL DATA :

Name    = GND1
Comment =
Writing = SI

- RATED VALUES :

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

- PARAMETERS :

R   [Ohm] =  0.00000000000E+0000
L     [H] =  0.00000000000E+0000
C     [F] =  0.00000000000E+0000

- INITIAL CONDITIONS :

I     [A] =  0.00000000000E+0000
UC    [V] =  0.00000000000E+0000

- CALCULATED VALUES :

Leff  [H] =  0.00000000000E+0000
```

2.3.13 RLC Impedance 1ph **GND2**

```
- GENERAL DATA :

Name    = GND2
Comment =
Writing = SI

- RATED VALUES :

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

- PARAMETERS :

R   [Ohm] =  0.00000000000E+0000
L     [H] =  0.00000000000E+0000
C     [F] =  0.00000000000E+0000

- INITIAL CONDITIONS :

I     [A] =  0.00000000000E+0000
UC    [V] =  0.00000000000E+0000

- CALCULATED VALUES :

Leff  [H] =  0.00000000000E+0000
```

2.3.14 RLC Impedance 1ph **GND3**

```
- GENERAL DATA :

Name    = GND3
Comment =
Writing = SI

- RATED VALUES :

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

- PARAMETERS :

R   [Ohm] =  0.00000000000E+0000
L     [H] =  0.00000000000E+0000
C     [F] =  0.00000000000E+0000

- INITIAL CONDITIONS :

I     [A] =  0.00000000000E+0000
UC    [V] =  0.00000000000E+0000

- CALCULATED VALUES :

Leff  [H] =  0.00000000000E+0000
```

2.3.15 Saturation : Satur **SAT1**

```
- GENERAL DATA :

Name    = SAT1
Comment =
Writing = YES

- REFERENCES X :

SM1

- DATA REACTANCE 1 :


- DATA REACTANCE 2 :

i1  [p.u] : 0.5000  u1  [p.u] : 0.5000
i2  [p.u] : 0.8050  u2  [p.u] : 0.8000
i3  [p.u] : 1.0750  u3  [p.u] : 1.0000
i4  [p.u] : 1.2820  u4  [p.u] : 1.1000
i5  [p.u] : 1.5370  u5  [p.u] : 1.1800
i6  [p.u] : 1.8740  u6  [p.u] : 1.2500
i7  [p.u] : 2.7450  u7  [p.u] : 1.3500
i8  [p.u] : 7.0170  u8  [p.u] : 1.5500

- DATA REACTANCE 3 :
```

Explanation:

The saturation act on the machine **SM1**. The introduced points correspond to the saturation effect in the **d** axis (DATA REACTANCE 2:) of the main magnetic fields of the synchronous machine.

2.3.16 Neutral Terminal **VS1-1**

```
- Element Name and Terminal Number :

VS1-1
```

This element allows the connection of the star point of the voltage supply **VS1**.

2.3.17 Neutral Terminal **T1-1**

```
- Element Name and Terminal Number :

T1-1
```

This element allows the connection of the star point on the primary side of the transformer **T1**.

2.3.18 Neutral Terminal **SM1-1**

```
- Element Name and Terminal Number :

SM1-1
```

This element allows the connection of the star point of the synchronous machine **SM1**.

2.4 Construction of the regulation part

Select the following submenus and place the element on the editing grid as shown in figure 2.4.1.

Elements Special Elements Voltage Regulator : VReg

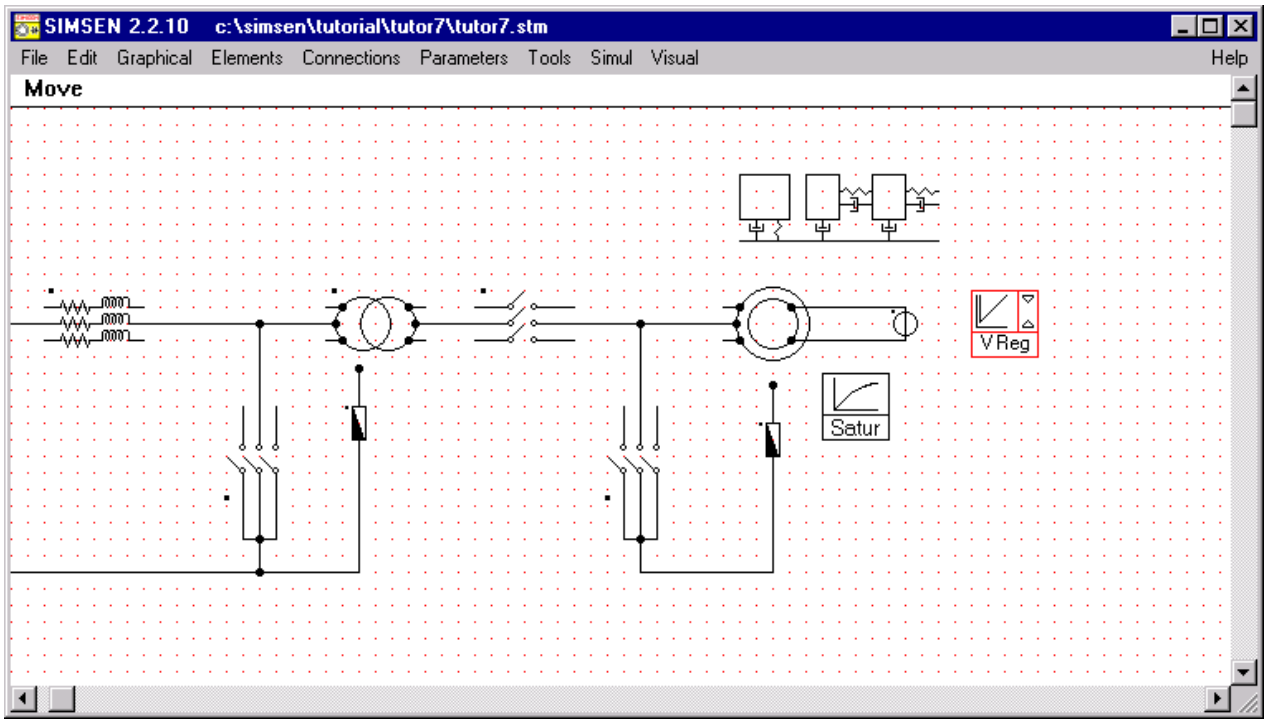


Figure 2.4.1: *Selecting and placing elements on the editing grid*

2.5 Parameters of the regulation part

To recognize the elements, the figure 2.5.1 shows you the regulation part element's names.

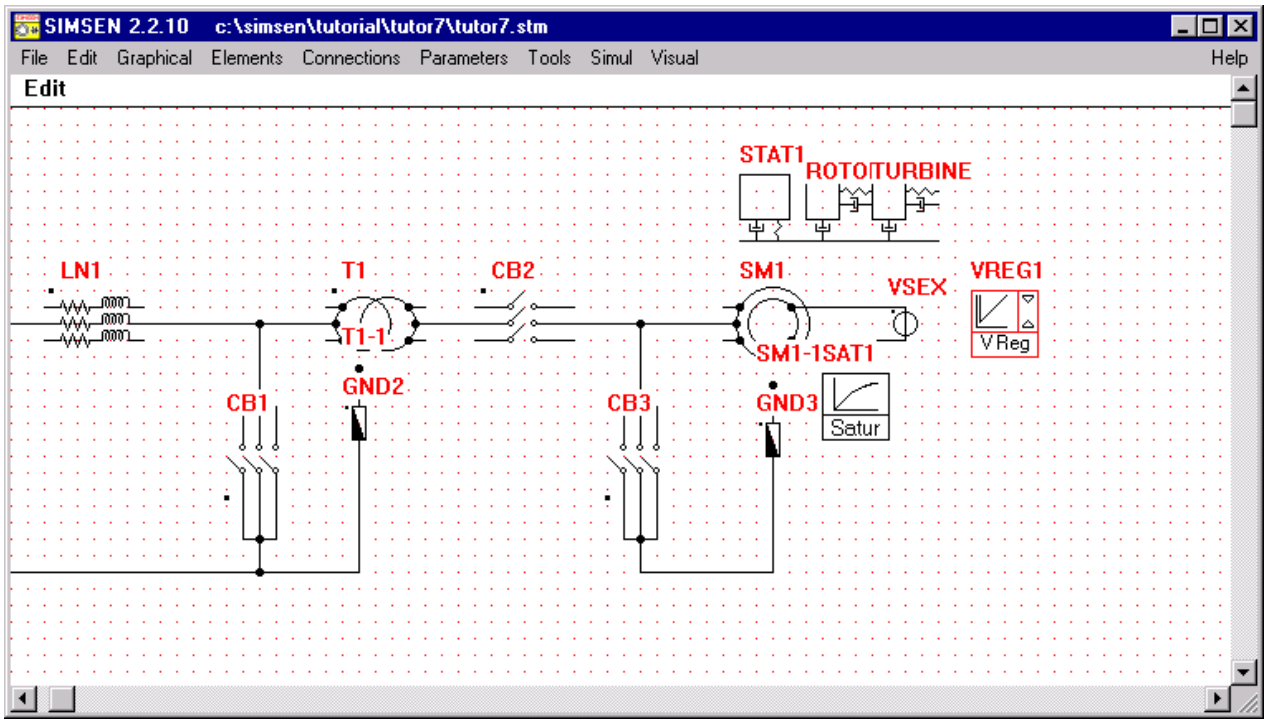


Figure 2.5.1: *Regulation part element's names*

2.5.1 Voltage Regulator : VReg **VREG1**

```
- GENERAL DATA :

Name    = VREG1
Comment =
Writing = YES

- REFERENCES X :

SM1 Ulrms 1/UN 0 um [pu]

- REFERENCES Y :

VSEX U Ufd0 0 Uex [V]

- PARAMETERS :

uc     [p.u] =  0.00000000000E+0000
k        [1] =  0.00000000000E+0000
T1     [sec] =  0.00000000000E+0000
T2     [sec] =  0.00000000000E+0000
T3     [sec] =  0.00000000000E+0000
T4     [sec] =  0.00000000000E+0000
Tms    [sec] =  0.00000000000E+0000
Tst    [sec] =  0.00000000000E+0000
poF1   [p.u] =  0.00000000000E+0000
puF1   [p.u] =  0.00000000000E+0000
poF2   [p.u] =  0.00000000000E+0000
puF2   [p.u] =  0.00000000000E+0000
poF3   [p.u] =  0.00000000000E+0000
puF3   [p.u] =  0.00000000000E+0000

- INITIAL CONDITIONS :

umg    [p.u] =  0.00000000000E+0000
uC1    [p.u] =  0.00000000000E+0000
uC2    [p.u] =  0.00000000000E+0000
u2st   [p.u] =  0.00000000000E+0000
```

Explanation:

This unit reads the line voltage **Ulrms** of the synchronous machine **SM1**. This value is multiplied by **1/UN** to have per unit. The output of the present unit is automatically memorized in the variable **ureg** and can be read from other units. This output value is multiplied by **Ufd0** to have SI values. The result is sent to the voltage supply **VSEX** to modify its parameter **U**.

2.6 Graphical features

It is advised to add some graphical elements to make your example more understandable. Select:

Graphical Color Red
Graphical Line

Add graphical lines as shown in figure 2.6.1.

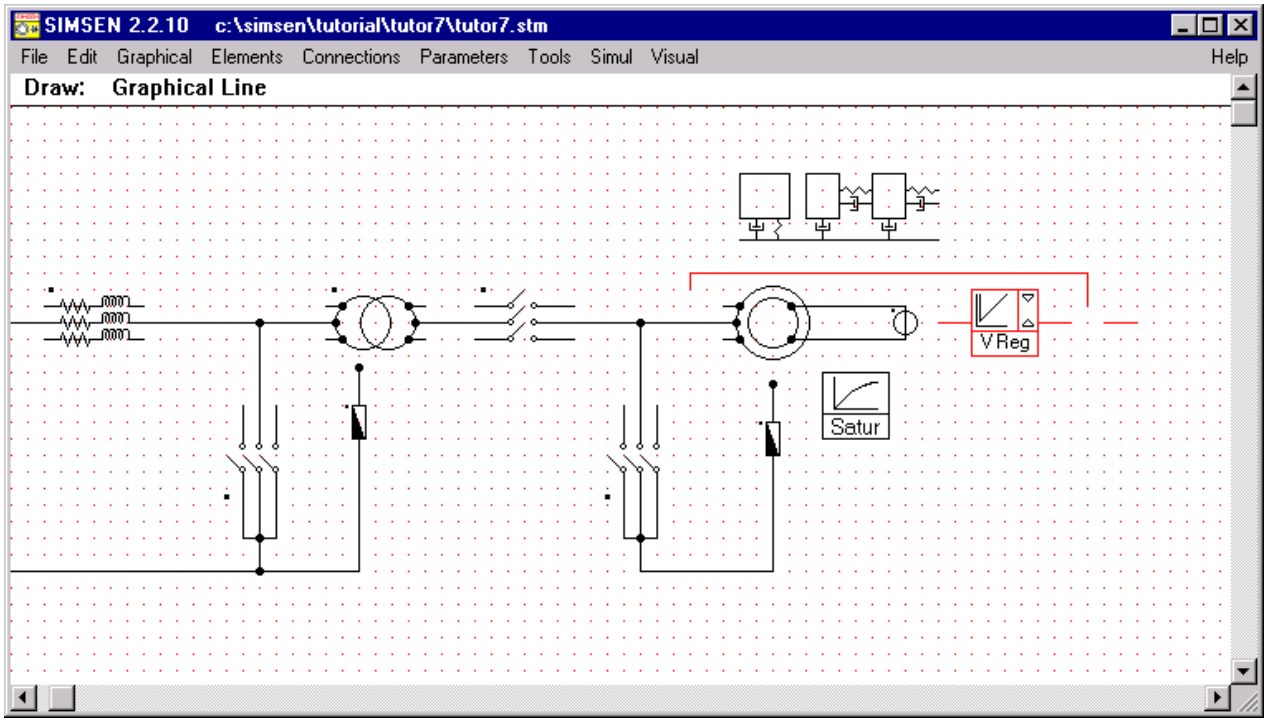


Figure 2.6.1: *Adding graphical lines*

Add the remaining graphical symbols by selecting:

Graphical	**Circle**	**Big**	(big circle for sum or difference)
Graphical	**Circle**	**Small**	(small circle for value or connection)
Graphical	**Arrow**		(arrows)
Graphical	**Label**		(text)

Your example can look like the figure 2.6.2.

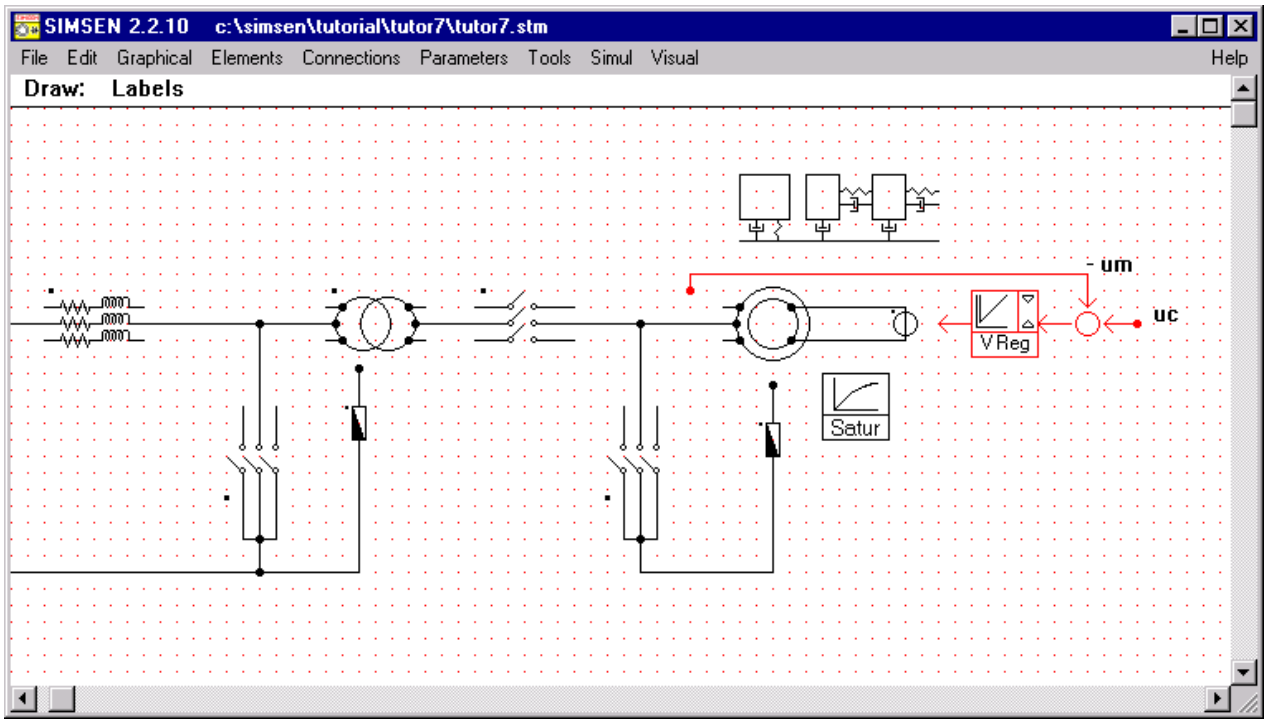


Figure 2.6.2: *Adding the remaining graphical features*

You can add more graphical features to custom your example as well as a title.

2.7 Simulation parameters and rated values

That example is totally parameterized from the main file. Select the following submenu command

Parameters Simulation

Fill the main file as follows:

```
- COMMENT :


- SIMULATION PARAMETERS :

Time min                          [sec] =   0.0000000000000
Time max                          [sec] =   2.0000000000000
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 :

;-----------------------------------------------------------
;Rated values
;-----------------------------------------------------------
SN    = 83E6    ; Nominal Power in [VA]
UN    = 17.5E3  ; Nominal voltage in [V]
FN    = 50      ; Nominal frequency
PN    = 5       ; Pole pair
;-----------------------------------------------------------
;Synchronous machine parameters
;-----------------------------------------------------------
rs    =  0.00181     [p.u]
xss   =  0.112       [p.u]
xad   =  1.027       [p.u]
xsDf  = -0.021       [p.u]
rf    =  0.0004974   [p.u]
xsf   =  0.1968189   [p.u]
rD    =  0.0100658   [p.u]
xsD   =  0.0828562   [p.u]
xaq   =  0.602       [p.u]
rQ    =  0.0161368   [p.u]
xsQ   =  0.0779325   [p.u]
Ifd0  =  578.3       [A]
;-----------------------------------------------------------
;Specified operation point of the machine
;-----------------------------------------------------------
Ulrms =  17500       [V]
Ths   =  210         [deg]
Pc    = -74.7E6      [W]
Qc    = -36.1789E6   [Var]
;-----------------------------------------------------------
;Stator
;-----------------------------------------------------------
```

```
JSTAT = 208.1E3    [kgm2]
KSTAT = 1.182E9    [Nm/rad]
DSTAT = 0.00       [Nms/rad]
RSTAT = 2.07       [m]
;-----------------------------------------------------------
;Mechanical shaft
;-----------------------------------------------------------
JROTOR = 168.3E3   [kgm2]
kpext1 = 0.0       [1]
k12    = 12.656E9  [Nm/rad]
JTURB  = 8.415E3   [kgm2]
kpext2 = 1.0       [1]
;-----------------------------------------------------------
;Transformer
;-----------------------------------------------------------
SNT1 = 84E6    [VA]
UN1  = 220E3   [V]
UN2  = 17.5E3  [V]
rcc  = 0.003   [p.u]
xcc  = 0.14    [p.u]
xh1  = 1E3     [p.u]
type = 1       [0/1]
;-----------------------------------------------------------
;Network and transmission line
;-----------------------------------------------------------
URN = 220E3  [V]
UR  = 205E3  [V]
RL  = 0.01   [Ohm]
LL  = 0.1    [H]
;-----------------------------------------------------------
;Circuit breaker
;-----------------------------------------------------------
Ron  = 0.0     [Ohm]
Roff = 1E8     [Ohm]
dt   = 0.0001  [sec]
;-----------------------------------------------------------
;Grounds
;-----------------------------------------------------------
RGRND = 1E8    [Ohm]
;-----------------------------------------------------------
;Voltage regulator
;-----------------------------------------------------------
k    =  250     [1]
T1   =  0.1     [sec]
T2   =  0.02    [sec]
T3   =  1.0     [sec]
T4   =  5.0     [sec]
Tms  =  0.04    [sec]
Tst  =  0.005   [sec]
poF1 =  0.04    [p.u]
puF1 = -0.05    [p.u]
poF2 =  5.5     [p.u]
puF2 = -4.5     [p.u]
poF3 =  5.5     [p.u]
puF3 = -4.5     [p.u]
;-----------------------------------------------------------
ON   = 1
OFF  = 0
TON  = 0.04
TOFF = 0.24
;-----------------------------------------------------------
```

```
;Calculation
;-------------------------------------------------------
aux  = (xad*Ifd0)^2
RF   = rf*SN/aux      ; field circuit resistance in [Ohm]
Ufd0 = RF*Ifd0        ; no-load field circuit voltage

- PARAMETERS :

;-------------------------------------------------------
;Synchronous machine
;-------------------------------------------------------
SM1.SN   = SN
SM1.UN   = UN
SM1.Fn   = FN
SM1.Pp   = PN
SM1.Ifd0 = Ifd0
SM1.rs   = rs
SM1.xss  = xss
SM1.xad  = xad
SM1.xsDf = xsDf
SM1.rf   = rf
SM1.xsf  = xsf
SM1.rD   = rD
SM1.xsD  = xsD
SM1.xaq  = xaq
SM1.rQ   = rQ
SM1.xsQ  = xsQ
SM1.Ulrms= Ulrms
SM1.Ths  = Ths
SM1.Pc   = Pc
SM1.Qc   = Qc
;-------------------------------------------------------
;Stator
;-------------------------------------------------------
STAT1.Pn = SN
STAT1.Nn = 60*FN/PN
STAT1.J  = JSTAT
STAT1.K  = KSTAT
STAT1.D  = DSTAT
STAT1.R  = RSTAT
;-------------------------------------------------------
;Mechanical shaft
;-------------------------------------------------------
ROTOR.Pn      = SN
ROTOR.Nn      = 60*FN/PN
ROTOR.J       = JROTOR
ROTOR.kpext   = kpext1
ROTOR.K       = k12
ROTOR.r       = 1
TURBINE.Pn    = SN
TURBINE.Nn    = 60*FN/PN
TURBINE.J     = JTURB
TURBINE.kpext = kpext2
;-------------------------------------------------------
;Transformer
;-------------------------------------------------------
T1.SN    =SNT1
T1.UN1   = UN1
T1.UN2   = UN2
T1.Fn    = FN
T1.rcc   = rcc
```

```
T1.xcc  = xcc
T1.xh1  = xh1
T1.type = type
;-------------------------------------------------------
;Network
;-------------------------------------------------------
VS1.Sn   = SN
VS1.Un   = URN
VS1.Fn   = FN
VS1.Ulrms= UR
VS1.Fs   = FN
;-------------------------------------------------------
;transmission line
;-------------------------------------------------------
LN1.Sn   = SN
LN1.Un   = URN
LN1.Fn   = FN
LN1.Ra   = RL
LN1.La   = LL
;-------------------------------------------------------
;Circuit breaker
;-------------------------------------------------------
CB1.Ron  = Ron
CB1.Roff = Roff
CB1.dt   = dt
CB1.Fn   = FN
CB2.Ron  = Ron
CB2.Roff = Roff
CB2.dt   = dt
CB2.Fn   = FN
CB3.Ron  = Ron
CB3.Roff = Roff
CB3.dt   = dt
CB3.Fn   = FN
;-------------------------------------------------------
;Grounds
;-------------------------------------------------------
GND1.R   = RGRND
GND1.Fn  = FN
GND2.R   = RGRND
GND2.Fn  = FN
GND3.R   = RGRND
GND3.Fn  = FN
;-------------------------------------------------------
;Voltage regulator
;-------------------------------------------------------
VREG1.k    = k
VREG1.T1   = T1
VREG1.T2   = T2
VREG1.T3   = T3
VREG1.T4   = T4
VREG1.Tms  = Tms
VREG1.Tst  = Tst
VREG1.poF1 = poF1
VREG1.puF1 = puF1
VREG1.poF2 = poF2
VREG1.puF2 = puF2
VREG1.poF3 = poF3
VREG1.puF3 = puF3

- INITIAL CONDITIONS :
```

```
- DISTURBANCES :

TON:CB3.ABC=ON
TOFF:CB3.ABC=OFF
```

Explanation:

Simulation of the circuit behavior during **2.0s** with an integration step of **200us**. To reduce the results size, only each **5**th calculated point is saved. Note that the disturbances are activated (Disturbances [Y/N] = **YES**).

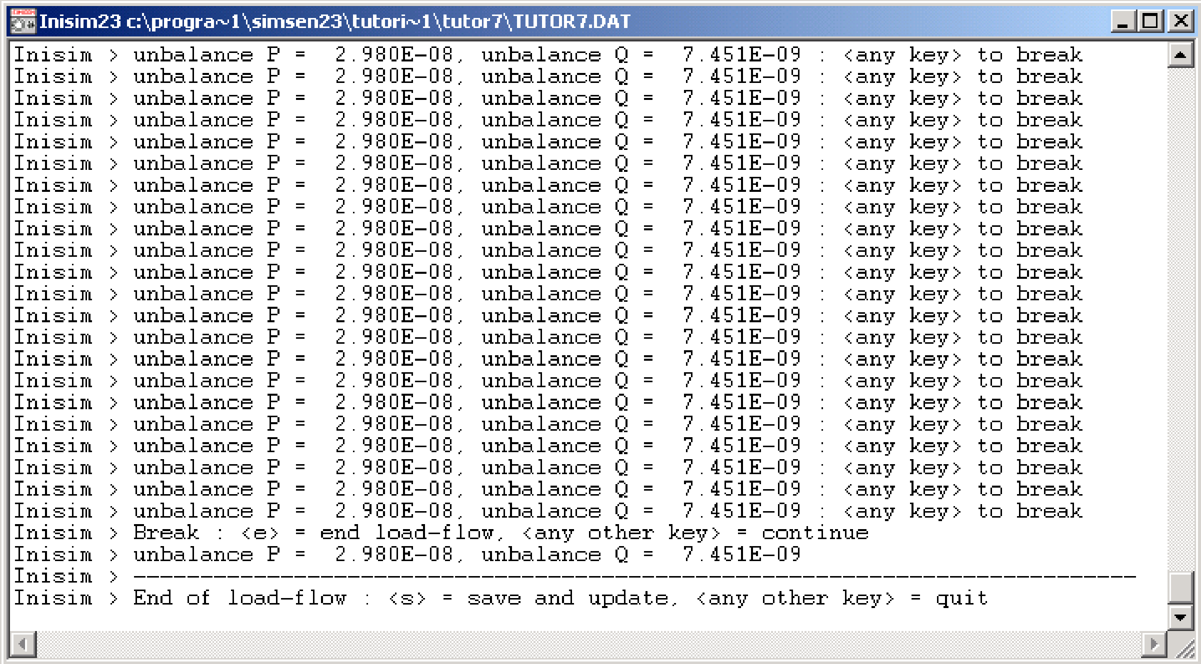
Rated values, parameters for each element and some calculations are defined in the section – CONSTANT DATA:

Each element is getting its parameters from the main file in the section – PARAMETERS:. The three-phase voltage supply **VS1** will be the infinite voltage bus (**Pc=Qc=0**) used as reference by the Load-Flow program *INISIM*. This means that the Load-Flow program *INISIM* will adjust the first specified values of **Ulrms** and **Ths** of the synchronous machine **SM1** in order to reach the specified operating point (**Pc**, **Qc**) specified for the machine. Note that these two values have been set taking into account no-load operations (**Ulrms=UN**) and phase shifting of the transformer (**Ths=210** corresponds to the **Yd5** phase shifting if the voltage angle **Ths** of the three-phase voltage supply **VS1** is equal to **0**). The mass **TURBINE** which represents the turbine will provide 100% (coefficient **kpext**) of the total mechanical torque. The ratio coefficient **r** of all the mass **ROTOR** has been set to **1** (no gearbox).

Two disturbances are defined in the section – DISTURBANCES: the three phases of the circuit breaker **CB3** will be switched on (**a = b = c = 1**) at the time **TON** and switched off at the time **TOFF**.

3 Simulation

Click the **Simul** menu to enter simulation mode. Then click the **Inisim** menu. The Load-Flow program starts. After few seconds, when the calculation has converged, press any key to stop the calculation. Press <**e**> to end the load-flow.
You can see the following information in the window as shown in figure 3.1.



```
Inisim23 c:\progra~1\simsen23\tutori~1\tutor7\TUTOR7.DAT
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09 : <any key> to break
Inisim > Break : <e> = end load-flow, <any other key> = continue
Inisim > unbalance P =  2.980E-08, unbalance Q =  7.451E-09
Inisim > ---------------------------------------------------------------------------
Inisim > End of load-flow : <s> = save and update, <any other key> = quit
```

Figure 3.1: *Load-Flow calculation*

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

Press on <**s**> key to **save the reached operating point of the system**.

Click the **Sim** menu, and answer **Yes** to the next question. The simulation starts. When the simulation is terminated, the simulation window will appear as in figure 3.2.

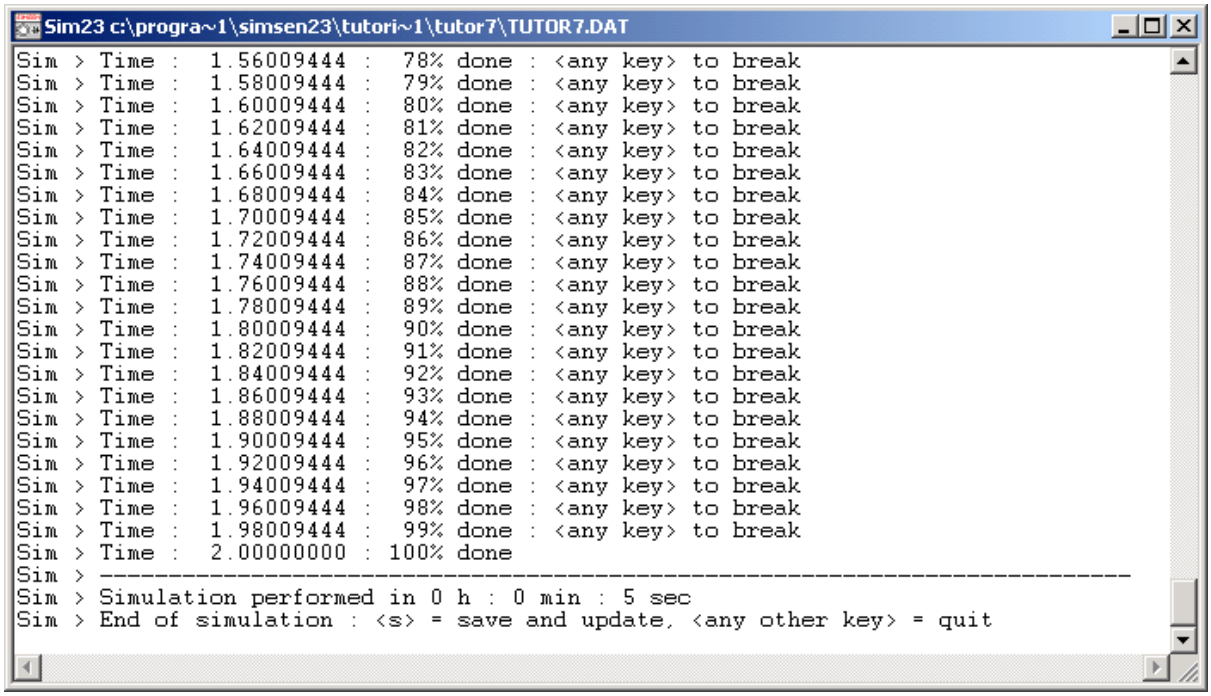


Figure 3.2: *End of the simulation*

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>**.

4 Results

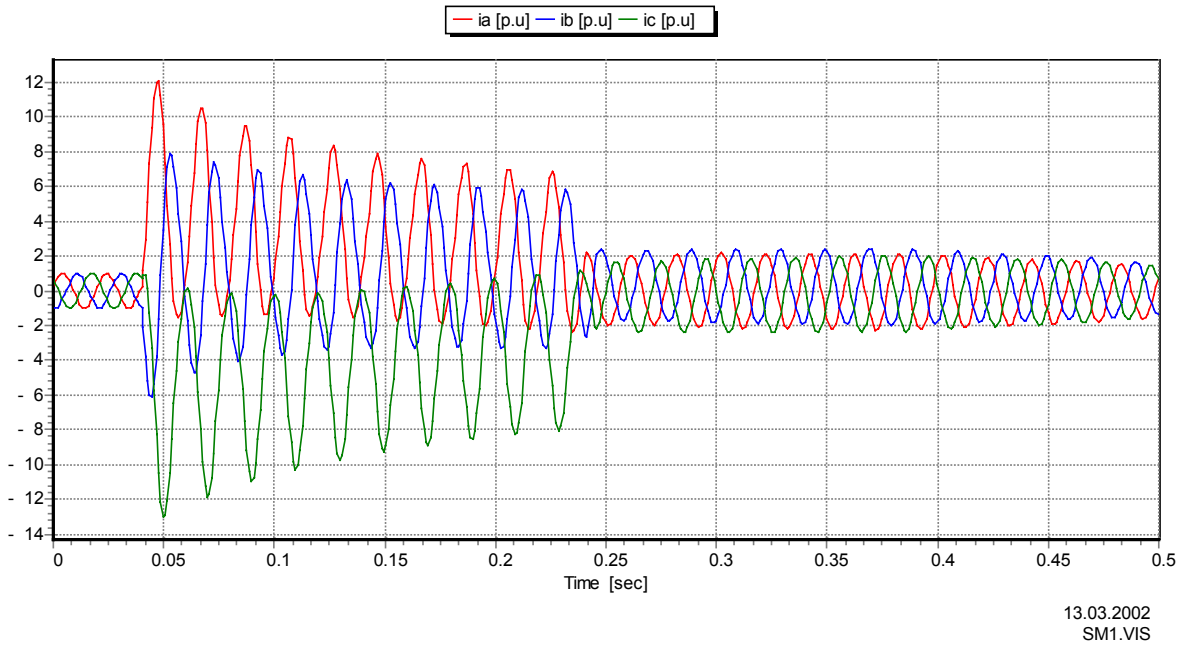


Figure 4.1: *Stator currents of the synchronous machine*

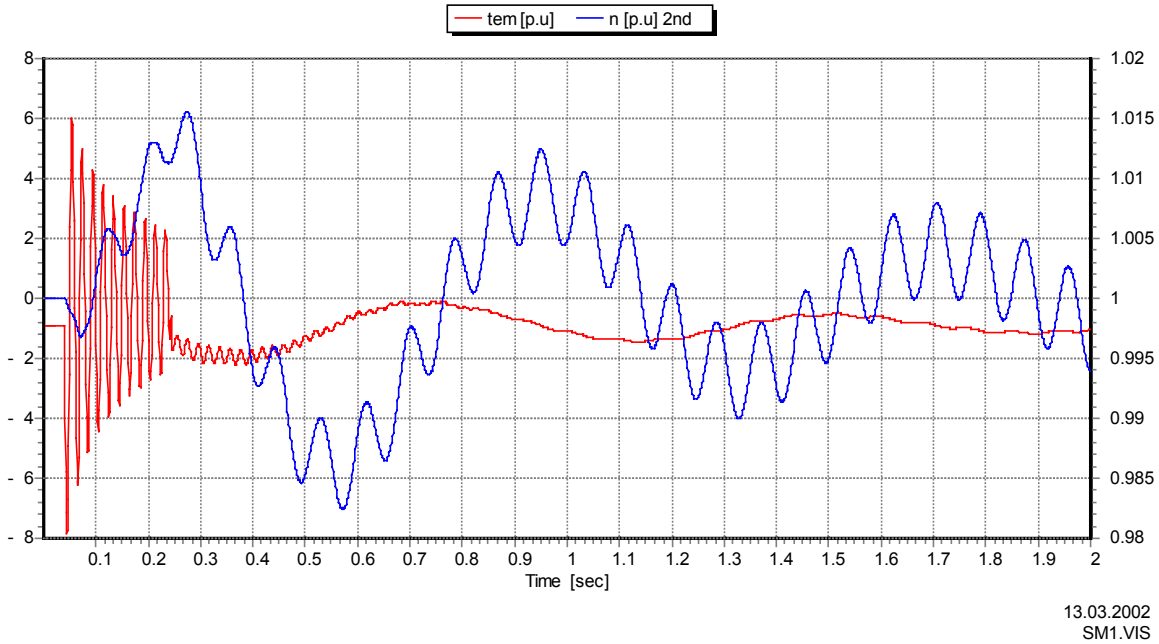


Figure 4.2: *Air-gap torque and rotor speed of the synchronous machine*

5 Simulation of an out-of-phase synchronizing

Click the **Editor** menu, which reverts to the edition mode. Select the submenu

Parameters Simulation

and modify the Simulation main window as shown in figure 5.1.

Only modify the **specified operation point of the machine** and the **– DISTURBANCES** : of the main file as follow :

```
- COMMENT :


- SIMULATION PARAMETERS :

Time min                          [sec] =   0.0000000000000
Time max                          [sec] =   2.0000000000000
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 :

      .
      .
      .
;-------------------------------------------------------
;Specified operation point of the machine
;-------------------------------------------------------
Ulrms =  17500      [V]
Ths   =  330        [deg]
Pc    =  0          [W]
Qc    =  0          [Var]
;-------------------------------------------------------
      .
      .
      .

- DISTURBANCES :

TON:CB2.ABC=ON
;TON:CB3.ABC=ON
;TOFF:CB3.ABC=OFF
```

Explanation:

Instead of switching ON the circuit breaker **CB3**, we want to switch ON the circuit breaker **CB2**. To disable the disturbances relative to the circuit breaker **CB3**, just add a **";"** at the beginning of the command lines.
In the section – CONSTANT DATA:, **specified operation point of the machine**, the load conditions of the synchronous machine are specified. This means that the Load-Flow program *Inisim* will keep the first specified values of **Ulrms** and **Ths** of the synchronous

machine **SM1** because the specified values of **Pc** and **Qc** are set to zero. The value 330° of **Ths** correspond to a 120° wrong synchronization, taking into account the 210° phase shifting angle of the transformer. The three-phase voltage supply **VS1** remains the infinite voltage bus (**Pc=Qc=0**) used as reference by the Load-Flow program *Inisim*.

Then, close the window clicking on the OK button and select the submenu

Parameters Elements

Open the parameters window for the circuit breaker **CB2**. Modifiy the parameters as follow:

```
- GENERAL DATA :

Name     = CB2
Comment =
Writing = SI

- RATED VALUES :

Sn       [VA] =  0.00000000000E+0000
Un        [V] =  0.00000000000E+0000
Fn       [Hz] =  5.00000000000E+0001

- PARAMETERS :

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

- INITIAL CONDITIONS :

Ia         [A] =  1.97156544085E+0003
Ib         [A] = -3.47891337665E+0003
Ic         [A] =  1.50734793581E+0003

- STATE OF PHASES :

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

- CALCULATED VALUES :

Ilrms      [A] =  2.46725261453E+0003
Ulrms1     [V] =  1.75006871856E+0004
P1         [W] = -7.46999969403E+0007
Q1       [Var] = -3.61788990388E+0006
Ulrms2     [V] =  1.75006871856E+0004
P2         [W] =  7.46999969403E+0007
Q2       [Var] =  3.61788990388E+0006
```

Explanation:

The circuit breaker is switched OFF at the beginning of the simulation.

6 Results

Repeat the operation of point 3. Display the results as shown in figure 6.1 and 6.2.

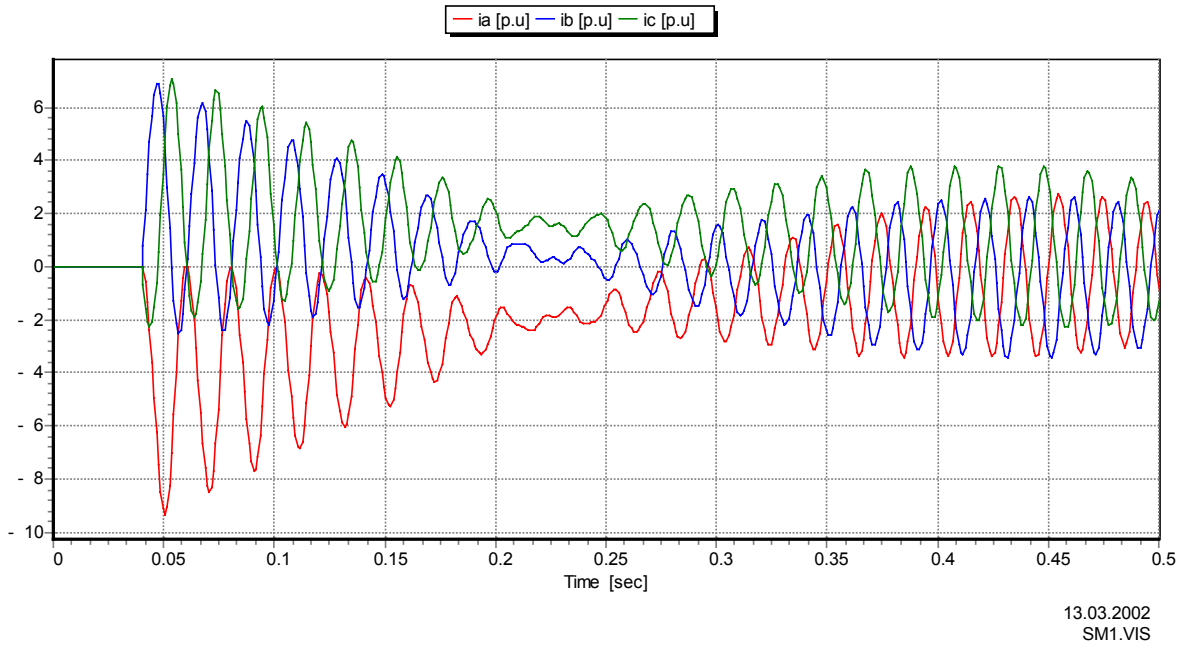


Figure 6.1: *Stator currents of the synchronous machine*

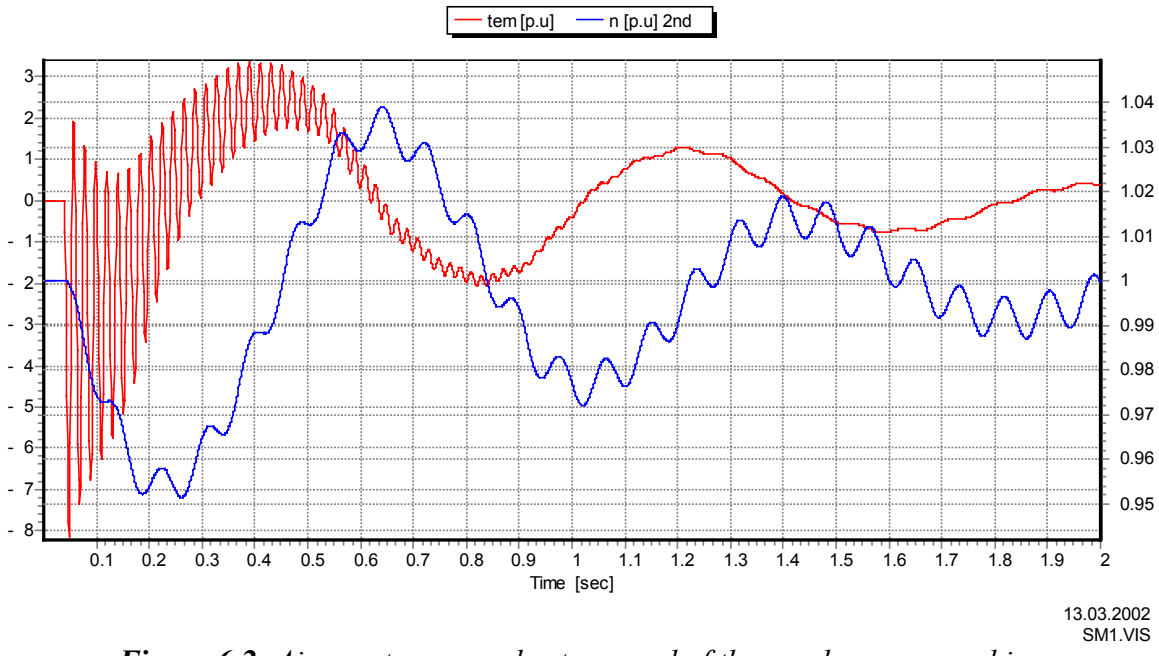


Figure 6.2: *Air-gap torque and rotor speed of the synchronous machine*

You may test other cases as adjusting the ground impedance in order to simulate earth fault.

End of Tutorial