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UNIVERZITA  
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# Řešení přechodných dějů na transformátoru v nástroji Open Modelica

## Cvičení PJS

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FAKULTA ELEKTROTECHNICKÁ  
ZÁPADOČESKÉ UNIVERZITY  
V PLZNI

KATEDRA  
ELEKTROENERGETIKY

# Výpočet přechodného děje na transformátoru

Pro výpočet přechodného děje zapnutí do stavu nakrátko využít simulační nástroj OpenModelica a prostředí OMEdit:

<https://openmodelica.org/>



The screenshot shows the OpenModelica website homepage. The header features the 'OpenModelica' logo in blue and black text on a blue background with water droplets. A navigation menu below the header includes links for HOME, DOWNLOAD, TOOLS & APPS, USERS, DEVELOPERS, FORUM, EVENTS, and RESEARCH. The main content area is titled 'Introduction' and contains text about the project's goals and the Open Source Modelica Consortium (OSMC). A sidebar on the left features a logo for 'OMEdit' (Enhanced OpenModelica Connection Editor) with a gear icon.

## OpenModelica


Logi

HOME DOWNLOAD TOOLS & APPS USERS DEVELOPERS FORUM EVENTS RESEARCH

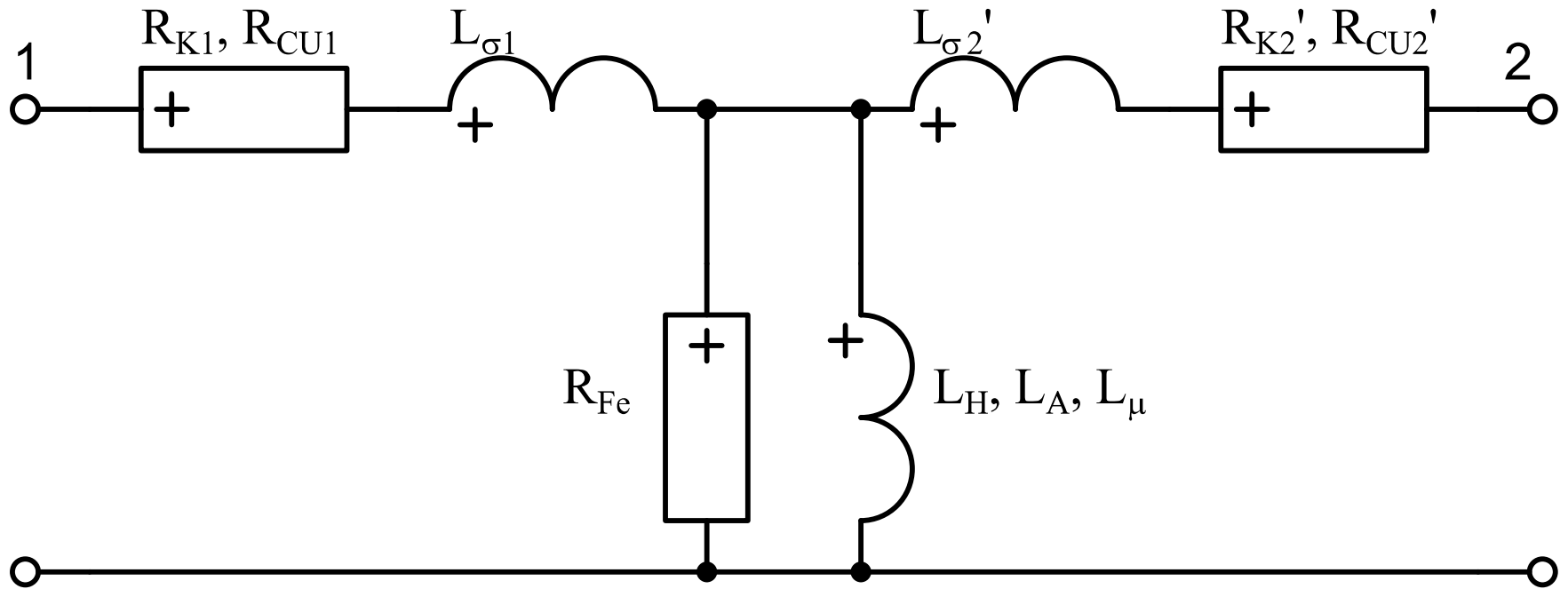
### Introduction

OPENMODELICA is an open-source Modelica-based modeling and simulation environment intended for industrial and academic usage. Its long-term development is supported by a non-profit organization – the [Open Source Modelica Consortium \(OSMC\)](#). An overview journal [paper](#) is available and [slides](#) about Modelica and OpenModelica.

The goal with the OpenModelica effort is to create a comprehensive Open Source Modelica modeling, compilation and simulation environment based on free software distributed in binary and source code form for research, teaching, and industrial usage. We invite researchers and students, or any interested developer to participate in the project and cooperate around OpenModelica, tools, and applications.

 **OMEdit**  
Enhanced OpenModelica  
Connection Editor.

# Náhradní schéma transformátoru



# Parametry transformátoru

$$u_K = 10 \%$$

$$i_0 = 1 \%$$

$$U_{N1} = 110 \text{ kV}$$

$$U_{N2} = 22 \text{ kV}$$

$$S_{NT} = 10 \text{ MVA}$$

$$\Delta P_0 = 0.3 \%$$

$$\Delta P_K = 1.0 \%$$

$$U_{kp} = 10 ;$$

$$I_0p = 1 ;$$

$$U_{n1} = 110 ;$$

$$U_{n2} = 22 ;$$

$$S_{nt} = 10 ;$$

$$dP_0p = 0.3 ;$$

$$dP_{kp} = 1 ;$$

# Parametry transformátoru

$$\omega = 2 \cdot \pi \cdot f$$

$$R_K = r_K Z_{NT} = \frac{\Delta p_{K\%}}{100} \cdot \frac{U_{N1}^2}{S_{NT}}$$

$$R_{K1} = \frac{R_K}{2}$$

$$Z_K = z_K Z_{NT} = \frac{u_{K\%}}{100} \cdot \frac{U_{N1}^2}{S_{NT}}$$

$$X_\sigma = \sqrt{Z_K^2 - R_K^2}$$

$$L_\sigma = \frac{X_\sigma}{\omega} \quad L_{\sigma 1} = \frac{L_\sigma}{2}$$

$$G_{Fe} = g_{Fe} Y_{NT} = \frac{\Delta p_{0\%}}{100} \cdot \frac{S_{NT}}{U_{N1}^2}$$

$$R_{Fe} = G_{Fe}^{-1}$$

$$Y_0 = y_0 Y_{NT} = \frac{i_{0\%}}{100} \cdot \frac{S_{NT}}{U_{N1}^2}$$

$$X_H = \left( \sqrt{Y_0^2 - G_{Fe}^2} \right)^{-1} L_H = \frac{X_H}{\omega}$$

**frekv=50;**

**omega=2\*pi\*frekv;**

**Rk= (dPkp/100) \* (Un1^2/Snt) ;**

**Rk1=Rk/2 ;**

**Zk= (Ukp/100) \* (Un1^2/Snt) ;**

**Xs=sqrt (Zk^2-Rk^2) ;**

**Ls=Xs/omega ;**

**Ls1=Ls/2 ;**

**Gfe= (dP0p/100) \* (Snt/Un1^2) ;**

**Rfe=1/Gfe ;**

**Y0= (I0p/100) \* (Snt/Un1^2) ;**

**Xh=1/sqrt (Y0^2-Gfe^2) ;**

**Lh=Xh/omega ;**

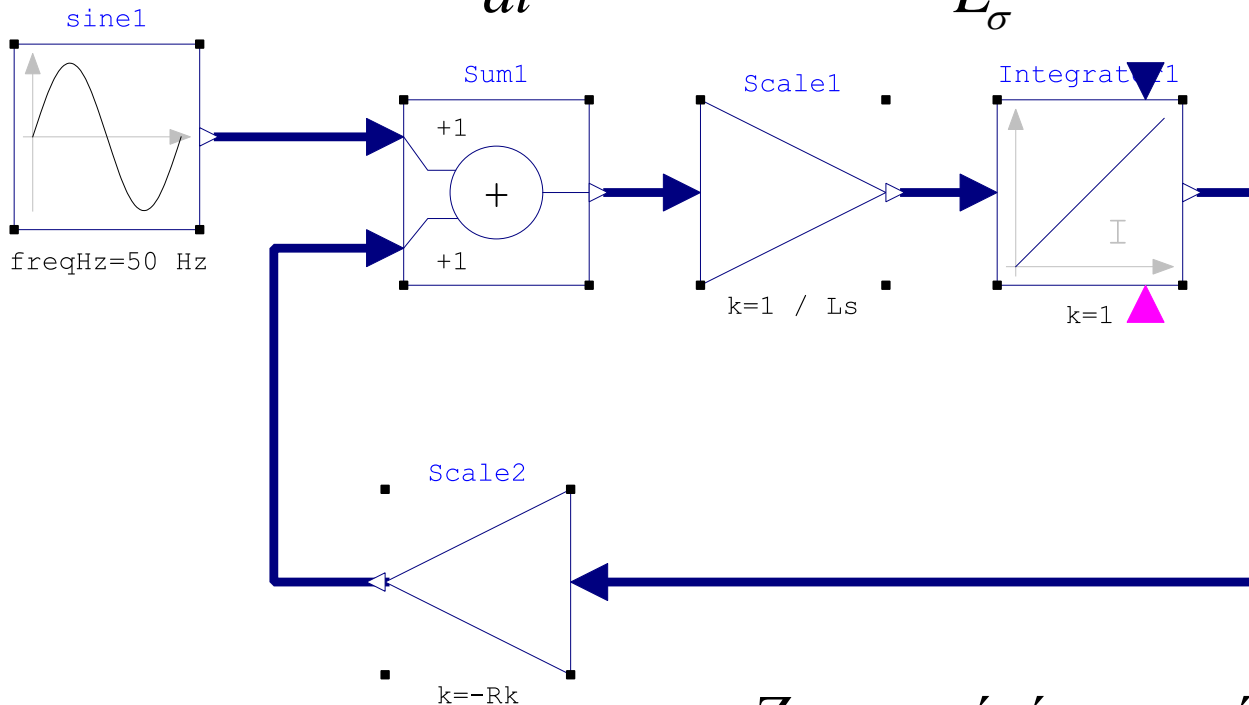
# Transformátor nakrátko

$$L_{\sigma} \frac{di_K}{dt} + i_K \cdot R_K = \frac{u_K [\%]}{100} U_m \sin(\omega \cdot t)$$

$$U_m = \frac{U_n}{\sqrt{3}} \sqrt{2}$$



$$\frac{di_K}{dt} = \frac{\frac{u_K [\%]}{100} U_m \sin(\omega \cdot t) - i_K \cdot R_K}{L_{\sigma}}$$



Zpracování pomocí bloků ala Simulink

# Transformátor nakrátko

The screenshot displays the OpenModelica Connection Editor interface. The main workspace shows a Simulink model for a transformer, labeled "TR\_AlaSimulink". The model consists of the following blocks:

- sine1**: A sine wave source with a frequency of 50 Hz.
- Sum1**: A summing junction with two inputs, each multiplied by a gain of +1.
- Scale1**: A gain block with a value of  $k=1 / L_s$ .
- Integrator1**: An integrator block with a gain of  $k=1$ .
- Scale2**: A gain block with a value of  $k=-R_k$ .

The signal flow is as follows: The sine wave source is connected to the Sum1 block. The output of Sum1 goes to Scale1, which then feeds into Integrator1. The output of Integrator1 is fed back into Scale2, which then feeds back into Sum1, forming a closed-loop system.

In the bottom right corner, a dialog box titled "OMedit - Check Model - TR\_AlaSimulink" is open, displaying the following text:

```
1 Check of TR_AlaSimulink completed successfully.  
2 Class TR_AlaSimulink has 12 equation(s) and 12 variable(s).  
3 8 of these are trivial equation(s).
```

Zpracování pomocí bloků ala Simulink

# Transformátor nakrátko

The screenshot displays the OMEdit - OpenModelica Connection Editor interface. The main window is titled "TR\_AlaSimulink" and shows a Simulink block diagram of a transformer short-circuit test. The diagram includes a sine wave block labeled "sine1" with a frequency of 50 Hz, a summing junction "Sum1", two gain blocks "Scale1" and "Scale2", and an integrator block "Integrator1".

The code editor on the left contains the following Modelica code:

```
1 model TR_AlaSimulink
2 import Modelica.Constants.pi;
3 Modelica.Blocks.Sources.Sine sine1(amplitude = Un1 * sqrt(2) / sqrt(3) * Ukp / 100, freqHz = 50) annotation( (...)
4 Modelica.Blocks.Math.Gain Scale1(k = 1 / Ls) annotation( (...);
5 Modelica.Blocks.Math.Gain Scale2(k = -Rk) annotation( (...);
6 Modelica.Blocks.Continuous.Integrator Integrator1 annotation( (...);
7 Modelica.Blocks.Math.Add Sum1 annotation( (...);
11 parameter Real Un1=110 "Jmenovite napeti prvniho vinuti";
12 parameter Real Snt=10 "Jmenovity vykon transformatoru";
13 parameter Real dP0p=0.3 "Procentni ztraty naprazdno";
14 parameter Real dPkp=1 "Procentni ztraty nakratko";
15 parameter Real Ukp=10 "Procentni napeti nakratko";
16 parameter Real I0p=1 "Procentni proud naprazdno";
17 parameter Real frekv=50 "Jmenovita frekvence";
18 parameter Real omega=2*pi*frekv;
19 parameter Real Rk=(dPkp/100)*(Un1^2/Snt);
20 parameter Real Rk1=Rk/2;
21 parameter Real Zk=(Ukp/100)*(Un1^2/Snt);
22 parameter Real Xs=sqrt(Zk^2-Rk^2);
23 parameter Real Ls=Xs/omega;
24 parameter Real Ls1=Ls/2;
25 parameter Real Gfe=(dP0p/100)*(Snt/Un1^2);
26 parameter Real Rfe=1/Gfe;
27 parameter Real Y0=(I0p/100)*(Snt/Un1^2);
28 parameter Real Xh=1/sqrt(Y0^2-Gfe^2);
29 parameter Real Lh=Xh/omega;
30 equation
31 connect(Scale1.y, Integrator1.u) annotation( (...);
32 connect(Scale2.u, Integrator1.y) annotation( (...);
33 connect(sine1.y, Sum1.u1) annotation( (...);
34 connect(Scale2.y, Sum1.u2) annotation( (...);
35 connect(Sum1.y, Scale1.u) annotation( (...);
36 annotation( (...);
37 annotation(uses(Modelica(version = "3.2.3")));
38 end TR_AlaSimulink;
```

The messages browser at the bottom shows two notifications:

- [1] 00:46:02 Scripting Notification: Automatically loaded package Complex 3.2.3 due to uses annotation.
- [2] 00:46:02 Scripting Notification

At the bottom right, the status bar indicates "Ln: 1, Col: 0" and shows icons for Welcome, Modeling, Plotting, and Debugging.

Zpracování pomocí bloků ala Simulink



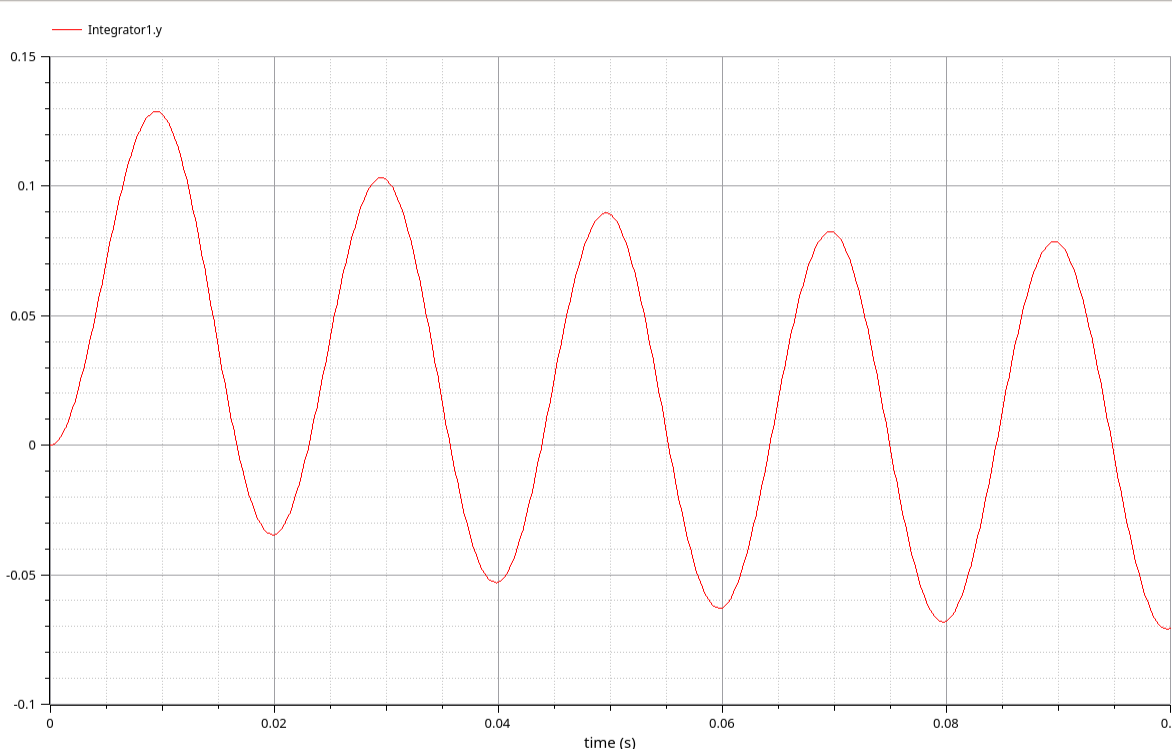
# Transformátor nakrátko

OMEdit - OpenModelica Connection Editor

File Edit View Simulation Debug SSP Sensitivity Optimization Tools Help

Libraries Browser: Filter Classes, Libraries (OpenModelica, ModelicaReference, ModelicaServices, Complex, Modelica, TR\_AlaSimulink)

Plot: 1: Auto Scale, Fit in View, Save, Print, Grid, Detailed Grid, No Grid, Log X, Log Y, Setup



Messages Browser: All, Notifications, Warnings, Errors. [1] 23:25:41 Scripting Notification: Check of TR\_AlaSimulink completed successfully.

Documentation Browser: TR\_AlaSimulink

Variables Browser: Filter Variables, Simulation Time Unit: s

Time: 0.0, Speed: 1

Variables	Value	Display Unit	Description
<input type="checkbox"/> Gfe	2.47934e-6		
<input type="checkbox"/> Iop	1.0		Procentni proud naprazdno
Integrator1			
<input type="checkbox"/> der(y)	2.23279		der(Connector of Real output signal)
<input type="checkbox"/> initType	3		Type of initialization (...te, 3,4: initial output)
<input type="checkbox"/> k	1.0	1	Integrator gain
<input type="checkbox"/> u	2.23279		Connector of Real input signal
<input checked="" type="checkbox"/> y	-0.0707156		Connector of Real output signal
<input type="checkbox"/> y_start	0.0		Initial or guess value of output (= state)
<input type="checkbox"/> Lh	403.752		
<input type="checkbox"/> Ls	0.383224		
<input type="checkbox"/> Ls1	0.191612		
<input type="checkbox"/> Rfe	403333		
<input type="checkbox"/> Rk	12.1		
<input type="checkbox"/> Rk1	6.05		
Scale1			
<input type="checkbox"/> Snt	10.0		Jmenovity vykon transformatoru
Scale2			
<input type="checkbox"/> Ukp	10.0		Procentni napeti nakratko
<input type="checkbox"/> Un1	110.0		Jmenovite napeti prvniho vinuti
<input type="checkbox"/> Xh	126842		
<input type="checkbox"/> Xs	120.393		
<input type="checkbox"/> YO	8.26446e-6		
<input type="checkbox"/> Zk	121		
<input type="checkbox"/> dPp	0.3		Procentni ztraty naprazdno
<input type="checkbox"/> dPkp	1.0		Procentni ztraty nakratko
<input type="checkbox"/> frekv	50.0		Jmenovita frekvence
<input type="checkbox"/> omega	314.159		
sine1			

Ln: 39, Col: 40 Welcome Modeling Plotting Debugging

Zpracování pomocí bloků ala Simulink

# Transformátor nakrátko

Řešení implicitní numerickou metodou bez zanedbání  $L_H$ :

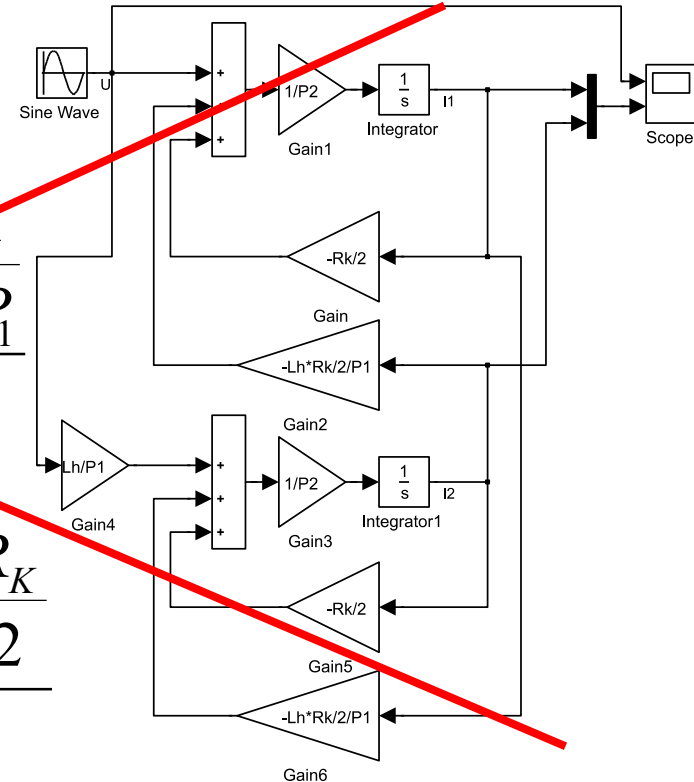
$$\frac{L_\sigma}{2} \frac{di_1}{dt} + i_1 \cdot \frac{R_K}{2} + L_h \frac{di_1}{dt} - L_h \frac{di_2}{dt} = \frac{u_K [\%]}{100} U_m \sin(\omega \cdot t)$$

$$-L_h \frac{di_1}{dt} + L_h \frac{di_2}{dt} + \frac{L_\sigma}{2} \frac{di_2}{dt} + i_2 \cdot \frac{R_K}{2} = 0 \quad \rightarrow$$

$$P_1 = \frac{L_\sigma}{2} + L_h \qquad P_2 = \frac{L_\sigma}{2} + L_h - \frac{L_h^2}{P_1}$$

$$\frac{di_1}{dt} = \frac{\frac{u_K [\%]}{100} U_m \sin(\omega \cdot t) - i_1 \cdot \frac{R_K}{2} - L_h \cdot i_2 \cdot \frac{R_K}{2} \cdot \frac{1}{P_1}}{P_2}$$

$$\frac{di_2}{dt} = \frac{L_h \cdot \frac{u_K [\%]}{100} U_m \sin(\omega \cdot t)}{P_1} - \frac{L_h \cdot i_1 \cdot \frac{R_K}{2}}{P_1} - i_2 \frac{R_K}{2}$$



# Transformátor nakrátko

Řešení implicitní numerickou metodou bez zanedbání  $L_H$ :

$$\frac{L_\sigma}{2} \frac{di_1}{dt} + i_1 \cdot \frac{R_K}{2} + L_h \frac{di_1}{dt} - L_h \frac{di_2}{dt} = \frac{u_K [\%]}{100} U_m \sin(\omega \cdot t)$$
$$- L_h \frac{di_1}{dt} + L_h \frac{di_2}{dt} + \frac{L_\sigma}{2} \frac{di_2}{dt} + i_2 \cdot \frac{R_K}{2} = 0 \quad \rightarrow$$

---

$$Ls1*der(i1) + Rk1*i1 + Lh*der(i1) -$$

$$Lh*der(i2) = Un1/sqrt(3)*sqrt(2)*Ukp/100*sin(omega*time);$$

$$- Lh*der(i1) + Lh*der(i2) + Ls1*der(i2) + Rk1*i2 = 0;$$

Zpracování pomocí soustavy implicitních diferenciálních rovnic

# Transformátor nakrátko

Řešení implicitní numerickou metodou bez zanedbání  $L_H$ :

The screenshot displays the OMEdit - OpenModelica Connection Editor interface. The main window shows the model definition for TR\_Rovnice2, which includes parameters, initial conditions, and equations. A yellow oval highlights a message box that states: "Check of TR\_Rovnice2 completed successfully. Class TR\_Rovnice2 has 14 equation(s) and 14 variable(s). 5 of these are trivial equation(s)." The Messages Browser at the bottom shows a notification: "[1] 22:52:16 Scripting Notification Check of TR\_Rovnice6 completed successfully." The status bar at the bottom indicates "Ln: 1, Col: 0" and shows icons for Welcome, Modeling, Plotting, and Debugging.

```
1 model TR_Rovnice2
2   Real i1, i2;
3   parameter Real Un1=110;
4   parameter Real Snt=10;
5   parameter Real dP0p=0.3;
6   parameter Real dPkp=1;
7   parameter Real Ukp=10;
8   parameter Real I0p=1;
9   parameter Real frekv=50;
10  Real omega, Rk, Rk1, Zk, Xs, Ls, Ls1, Gfe, Rfe, Y0, Xh, Lh;
11
12  import Modelica.Constants.pi;
13
14  initial equation
15    i1 = 0;
16    i2 = 0;
17
18  equation
19    omega=2*pi*frekv;
20    Rk=(dPkp/100)*(Un1^2/Snt);
21    Rk1=Rk/2;
22    Zk=(Ukp/100)*(Un1^2/Snt);
23    Xs=sqrt(Zk^2-Rk^2);
24    Ls=Xs/omega;
25    Ls1=Ls/2;
26    Gfe=(dP0p/100)*(Snt/Un1^2);
27    Rfe=1/Gfe;
28    Y0=(I0p/100)*(Snt/Un1^2);
29    Xh=1/sqrt(Y0^2-Gfe^2);
30    Lh=Xh/omega;
31
32    Ls1*der(i1) + Rk1*i1 + Lh*der(i1) - Lh*der(i2) = Un1/sqrt(3)*sqrt(2)*Ukp/100*sin(om
33    - Lh*der(i1) + Lh*der(i2) + Ls1*der(i2) + Rk1*i2 = 0;
34
35  annotation(experiment(StartTime=0,StopTime=0.1));
36
37 end TR_Rovnice2;
```

1 Check of TR\_Rovnice2 completed successfully.  
2 Class TR\_Rovnice2 has 14 equation(s) and 14 variable(s).  
3 5 of these are trivial equation(s).

[1] 22:52:16 Scripting Notification  
Check of TR\_Rovnice6 completed successfully.

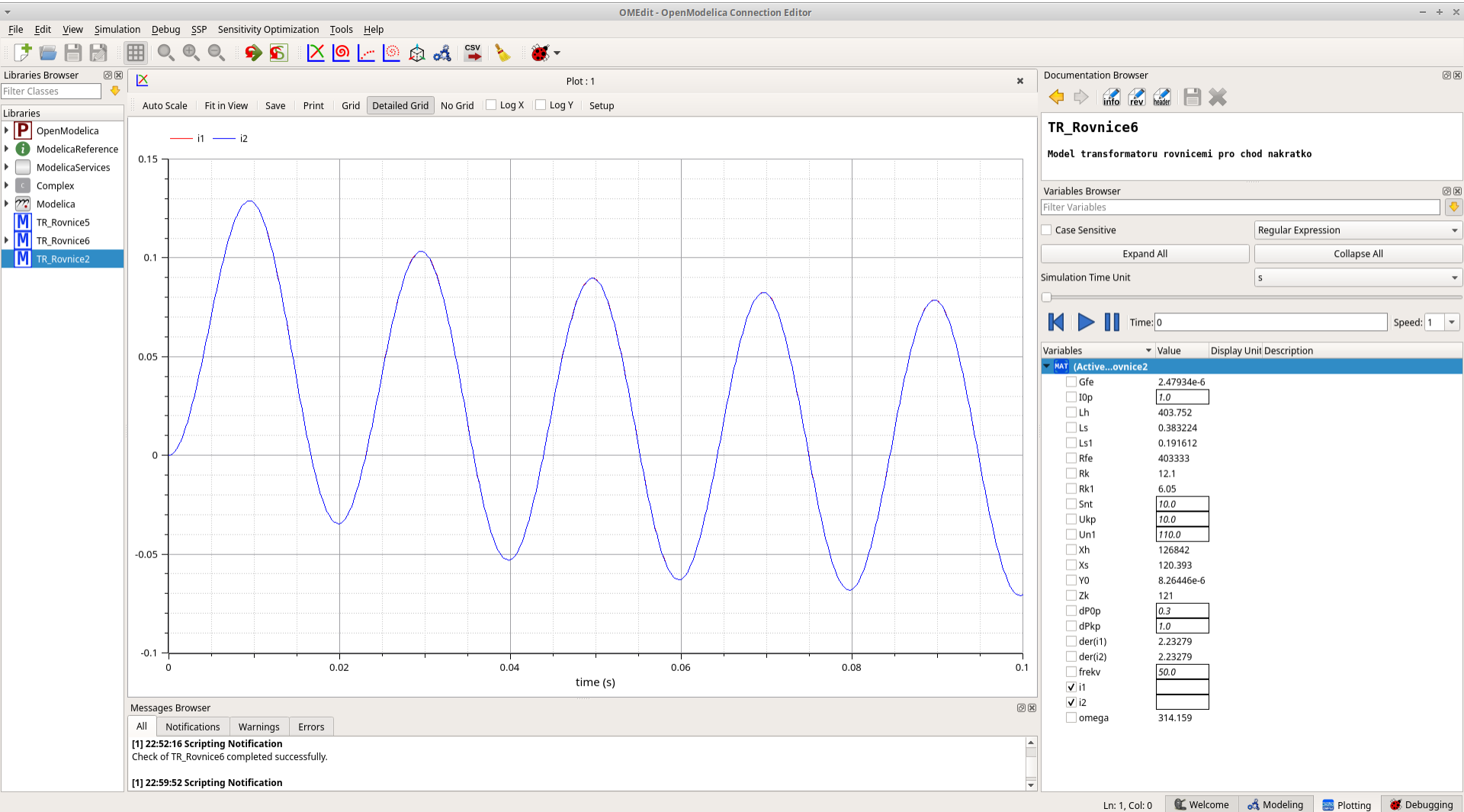
[1] 22:59:52 Scripting Notification

Ln: 1, Col: 0 Welcome Modeling Plotting Debugging

Zpracování pomocí soustavy implicitních diferenciálních rovnic

# Transformátor nakrátko

Řešení implicitní numerickou metodou bez zanedbání  $L_H$ :



Zpracování pomocí soustavy implicitních diferenciálních rovnic

# Transformátor nakrátko

Řešení implicitní numerickou metodou bez zanedbání  $L_H$ :

The screenshot displays the OMEdit - OpenModelica Connection Editor interface. The main window shows a Modelica script for a transformer model named TR\_Rovnice5. The script includes parameters for voltage, current, frequency, and various impedances and inductances. It also defines initial conditions and a system of differential equations for the currents in two windings. A red oval highlights the differential equations section, and a yellow oval highlights the parameter declarations at the top.

```
1 model TR_Rovnice5 "Model transformatoru rovnicemi pro chod nakratko"
2 import Modelica.Constants.pi;
3 Real i1(unit="kA") "Proud prvnioho vinuti";
4 Real i2(unit="kA") "Proud druheho vinuti";
5 parameter Real Un1(unit="kV")=110 "Jmenovite napeti prvnioho vinuti";
6 parameter Real Snt(unit="MVA")=10 "Jmenovity zdanlivy vykon";
7 parameter Real dP0p(unit="procenta")=0.3 "Procentni ztraty naprazdno";
8 parameter Real dPkp(unit="procenta")=1 "Procentni ztraty nakratko";
9 parameter Real Ukp(unit="procenta")=10 "Procentni napeti nakratko";
10 parameter Real I0p(unit="procenta")=1 "Procentni proud naprazdno";
11 parameter Real frekv(unit="Hz")=50 "Jmenovita frekvence";
12 parameter Real omega(unit="rad/s")=2*pi*frekv "Jmenovita uhlova frekvence";
13 parameter Real Rk(unit="Ohm")=(dPkp/100)*(Un1^2/Snt) "Souctovy cinny odpor vinuti";
14 parameter Real Rk1(unit="Ohm")=Rk/2 "Cinny odpor prvnioho vinuti";
15 parameter Real Zk(unit="Ohm")=(Ukp/100)*(Un1^2/Snt) "Celkova podelna impedance";
16 parameter Real Xs(unit="Ohm")=sqrt(Zk^2-Rk^2) "Souctova rozptylova reaktance";
17 parameter Real Ls(unit="H")=Xs/omega "Souctova rozptylova indukcnost";
18 parameter Real Ls1(unit="H")=Ls/2 "Rozptylova indukcnost prvnioho vinuti";
19 parameter Real Gfe(unit="S")=(dP0p/100)*(Snt/Un1^2) "Cinny pricny svod";
20 parameter Real Rfe(unit="Ohm")=1/Gfe "Cinny pricny nahradni odpor";
21 parameter Real Y0(unit="S")=(I0p/100)*(Snt/Un1^2) "Celkova pricna admittance";
22 parameter Real Xh(unit="Ohm")=1/sqrt(Y0^2-Gfe^2) "Magnetizacni reaktance";
23 parameter Real Lh(unit="H")=Xh/omega "Magnetizacni indukcnost";
24 initial equation
25   i1 = 0 "Pocatecni podminka proudu i1";
26   i2 = 0 "Pocatecni podminka proudu i2";
27 equation
28   // Diferencialni rovnice pro dve smycky chodu nakratko
29   // Ls1*i1' + Rk1*i1 + Lh*i1' + Lh*i2' = Ukm*sin(omega*t)
30   // - Lh*i1' + Lh*i2' + Ls1*i2' + Rk1*i2 = 0
31   Ls1*der(i1) + Rk1*i1 + Lh*der(i1) - Lh*der(i2) = Un1/sqrt(3)*sqrt(2)*Ukp/100*sin(omega*t)
32   - Lh*der(i1) + Lh*der(i2) + Ls1*der(i2) + Rk1*i2 = 0;
33 annotation(experiment(StartTime=0,StopTime=0.1));
34 end TR_Rovnice5;
```

A dialog box titled "OMEdit - Check Model - TR\_Rovnice3" is open, displaying the following text:

```
1 Check of TR_Rovnice3 completed successfully.
2 Class TR_Rovnice3 has 2 equation(s) and 2 variable(s).
3 0 of these are trivial equation(s).
```

The Messages Browser at the bottom shows a notification: "[1] 22:52:16 Scripting Notification Check of TR\_Rovnice6 completed successfully."

Zpracování pomocí soustavy implicitních diferenciálních rovnic

# Transformátor nakrátko

Řešení implicitní numerickou metodou bez zanedbání  $L_H$ :

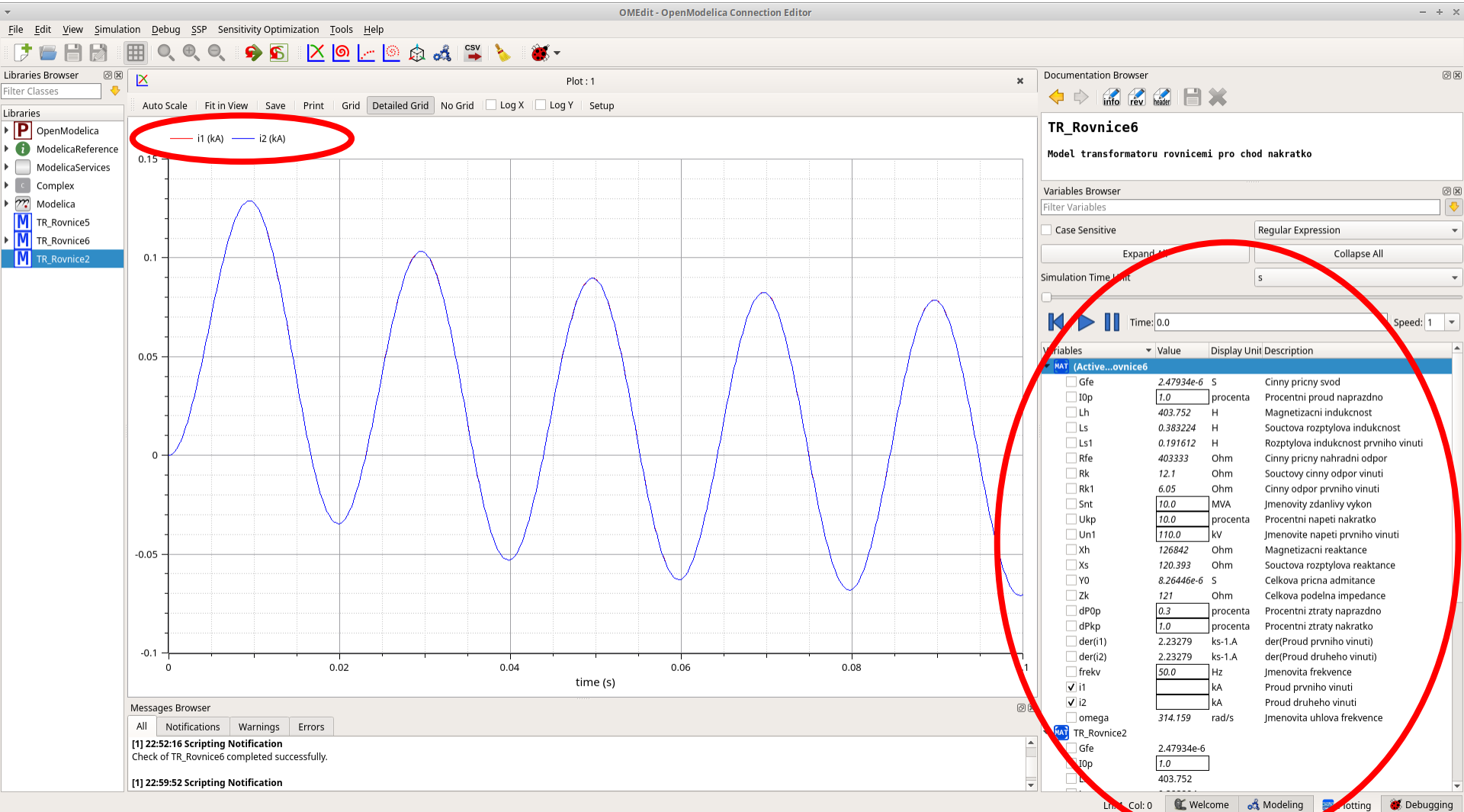
The screenshot shows the OMEdit interface with the following code in the main editor:

```
1 model TR_Rovnice6 "Model transformatoru rovniciemi pro chod nakratko"
2   import Modelica.Constants.pi;
3   type Napeti= Real(unit="kV");
4   type Proud= Real(unit="kA");
5   type ZdanlivyVykon= Real(unit="MVA");
6   type ProcentniParametr=Real(unit="procenta");
7   type Frekvence= Real(unit="Hz");
8   type UhlovaFrekvence= Real(unit="rad/s");
9   type Impedance= Real(unit="Ohm");
10  type Admitance= Real(unit="S");
11  type Indukcnost= Real(unit="H");
12  Proud i1 "Proud prvnio vinuti";
13  Proud i2 "Proud druheho vinuti";
14  parameter Napeti Un1=110 "Jmenovite napeti prvnio vinuti";
15  parameter ZdanlivyVykon Snt=10 "Jmenovity zdanlivy vykon";
16  parameter ProcentniParametr dP0p=0.3 "Procentni ztraty naprazdno";
17  parameter ProcentniParametr dPkp=1 "Procentni ztraty nakratko";
18  parameter ProcentniParametr Ukp=10 "Procentni napeti nakratko";
19  parameter ProcentniParametr I0p=1 "Procentni proud naprazdno";
20  parameter Frekvence frekv=50 "Jmenovita frekvence";
21  parameter UhlovaFrekvence omega=2*pi*frekv "Jmenovita uhlova frekvence";
22  parameter Impedance Rk=(dPkp/100)*(Un1^2/Snt) "Souctovy cinny odpor vinuti";
23  parameter Impedance Rk1=Rk/2 "Cinny odpor prvnio vinuti";
24  parameter Impedance Zk=(Ukp/100)*(Un1^2/Snt) "Celkova podelna impedance";
25  parameter Impedance Xs=sqrt(Zk^2-Rk^2) "Souctova rozptylova reaktance";
26  parameter Indukcnost Ls=Xs/omega "Souctova rozptylova indukcnost";
27  parameter Indukcnost Ls1=Ls/2 "Rozptylova indukcnost prvnio vinuti";
28  parameter Admitance Gfe=(dP0p/100)*(Snt/Un1^2) "Cinny pricny svod";
29  parameter Impedance Rfe=1/Gfe "Cinny pricny nahradni odpor";
30  parameter Admitance Y0=(I0p/100)*(Snt/Un1^2) "Celkova pricna admitance";
31  parameter Impedance Xh=1/sqrt(Y0^2-Gfe^2) "Magnetizacni reaktance";
32  parameter Indukcnost Lh=Xh/omega "Magnetizacni indukcnost";
33  initial equation
34    i1 = 0 "Pocatecni podminka proudu i1";
35    i2 = 0 "Pocatecni podminka proudu i2";
36  equation
37    // Diferencialni rovnice pro dve smycky chodu nakratko
38    // Ls1*i1' + Rk1*i1 + Lh*i1' + Lh*i2' = Ukm*sin(omega*t)
39    // - Lh*i1' + Lh*i2' + Ls1*i2' + Rk1*i2 = 0
40    Ls1*der(i1) + Rk1*i1 + Lh*der(i1) - Lh*der(i2) = Un1/sqrt(3)*sqrt(2)*Ukp/100*sin(omega*time);
41    - Lh*der(i1) + Lh*der(i2) + Ls1*der(i2) + Rk1*i2 = 0;
42  annotation(experiment(StartTime=0,StopTime=0.1));
43 end TR_Rovnice6;
```

Zpracování pomocí soustavy implicitních diferenciálních rovnic

# Transformátor nakrátko

Řešení implicitní numerickou metodou bez zanedbání  $L_H$ :

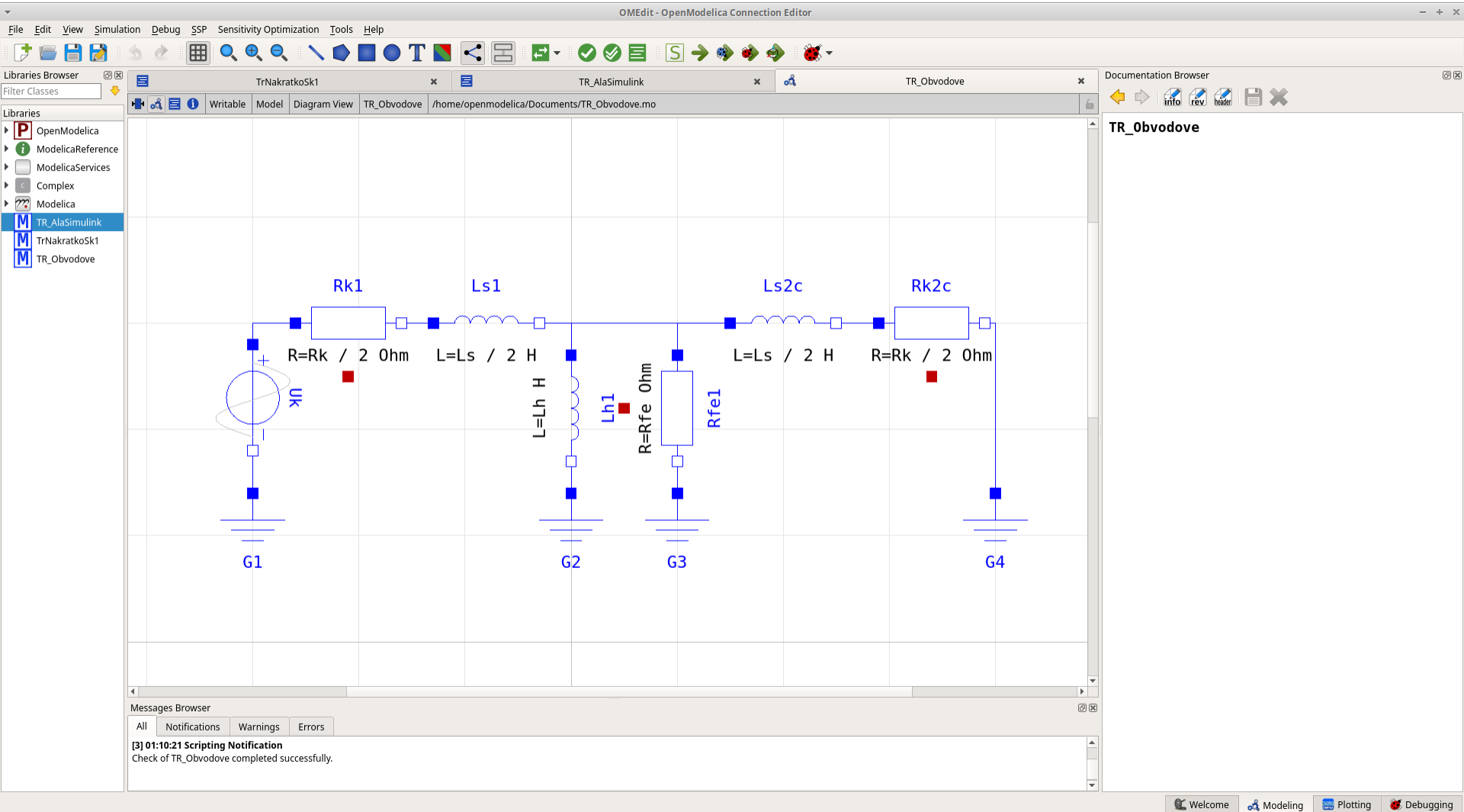


Zpracování pomocí soustavy implicitních diferenciálních rovnic



# Transformátor nakrátko

Řešení numerickou metodou s kompletní topologií:



Zpracování pomocí obvodového schéma

# Transformátor nakrátko

Řešení numerickou metodou s kompletní topologií:

The screenshot displays the OpenModelica Connection Editor interface. The main window shows the model definition for 'TR\_Obvodove' in a text editor. The code includes parameter declarations for various electrical properties and component connections. A dialog box titled 'OMEdit - Check Model TR\_Obvodove' is overlaid on the right, indicating that the model check was successful. The dialog text is circled in yellow.

```
1 model TR_Obvodove
2 import Modelica.Constants.pi;
3 parameter Real Un1=110 "Jmenovite napeti prvnioho vinuti";
4 parameter Real Snt=10 "Jmenovity vykon transformatoru";
5 parameter Real dP0p=0.3 "Procentni ztraty naprazdno";
6 parameter Real dPkp=1 "Procentni ztraty nakratko";
7 parameter Real Ukp=10 "Procentni napeti nakratko";
8 parameter Real I0p=1 "Procentni proud naprazdno";
9 parameter Real frekv=50 "Jmenovita frekvence";
10 parameter Real omega=2*pi*frekv;
11 parameter Real Rk=(dPkp/100)*(Un1^2/Snt);
12 parameter Real Zk=(Ukp/100)*(Un1^2/Snt);
13 parameter Real Xs=sqrt(Zk^2-Rk^2);
14 parameter Real Ls=Xs/omega;
15 parameter Real Gfe=(dP0p/100)*(Snt/Un1^2);
16 parameter Real Rfe=1/Gfe;
17 parameter Real Y0=(I0p/100)*(Snt/Un1^2);
18 parameter Real Xh=1/sqrt(Y0^2-Gfe^2);
19 parameter Real Lh=Xh/omega;
20 Modelica.Electrical.Analog.Basic.Ground G1 annotation( ...);
21 Modelica.Electrical.Analog.Sources.SineVoltage Uk(V = Un1 * sqrt(2) / sqrt(3) * Ukp
22 Modelica.Electrical.Analog.Basic.Resistor Rk1(R = Rk/2) annotation( ...);
23 Modelica.Electrical.Analog.Basic.Inductor Ls1(L = Ls/2, i(fixed = true)) annotation( ...);
24 Modelica.Electrical.Analog.Basic.Inductor Ls2c(L = Ls/2, i(fixed = true)) annotation( ...);
25 Modelica.Electrical.Analog.Basic.Resistor Rk2c(R = Rk/2) annotation( ...);
26 Modelica.Electrical.Analog.Basic.Ground G2 annotation( ...);
27 Modelica.Electrical.Analog.Basic.Ground G3 annotation( ...);
28 Modelica.Electrical.Analog.Basic.Ground G4 annotation( ...);
29 Modelica.Electrical.Analog.Basic.Inductor Lh1(L = Lh) annotation( ...);
30 Modelica.Electrical.Analog.Basic.Resistor Rfe1(R = Rfe) annotation( ...);
31
32 equation
33 connect(Rk2c.n, G4.p) annotation( ...);
34 connect(Rfe1.p, Ls2c.p) annotation( ...);
35 connect(Lh1.p, Ls1.n) annotation( ...);
36 connect(Rfe1.n, G3.p) annotation( ...);
37 connect(Lh1.n, G2.p) annotation( ...);
38 connect(Uk.p, Rk1.p) annotation( ...);
39 connect(G1.p, Uk.n) annotation( ...);
40 connect(Rk1.n, Ls1.p) annotation( ...);
41 connect(Ls2c.n, Rk2c.p) annotation( ...);
42 connect(Ls1.n, Ls2c.p) annotation( ...);
43 annotation( ...);
44 end TR_Obvodove;
```

OMEdit - Check Model TR\_Obvodove

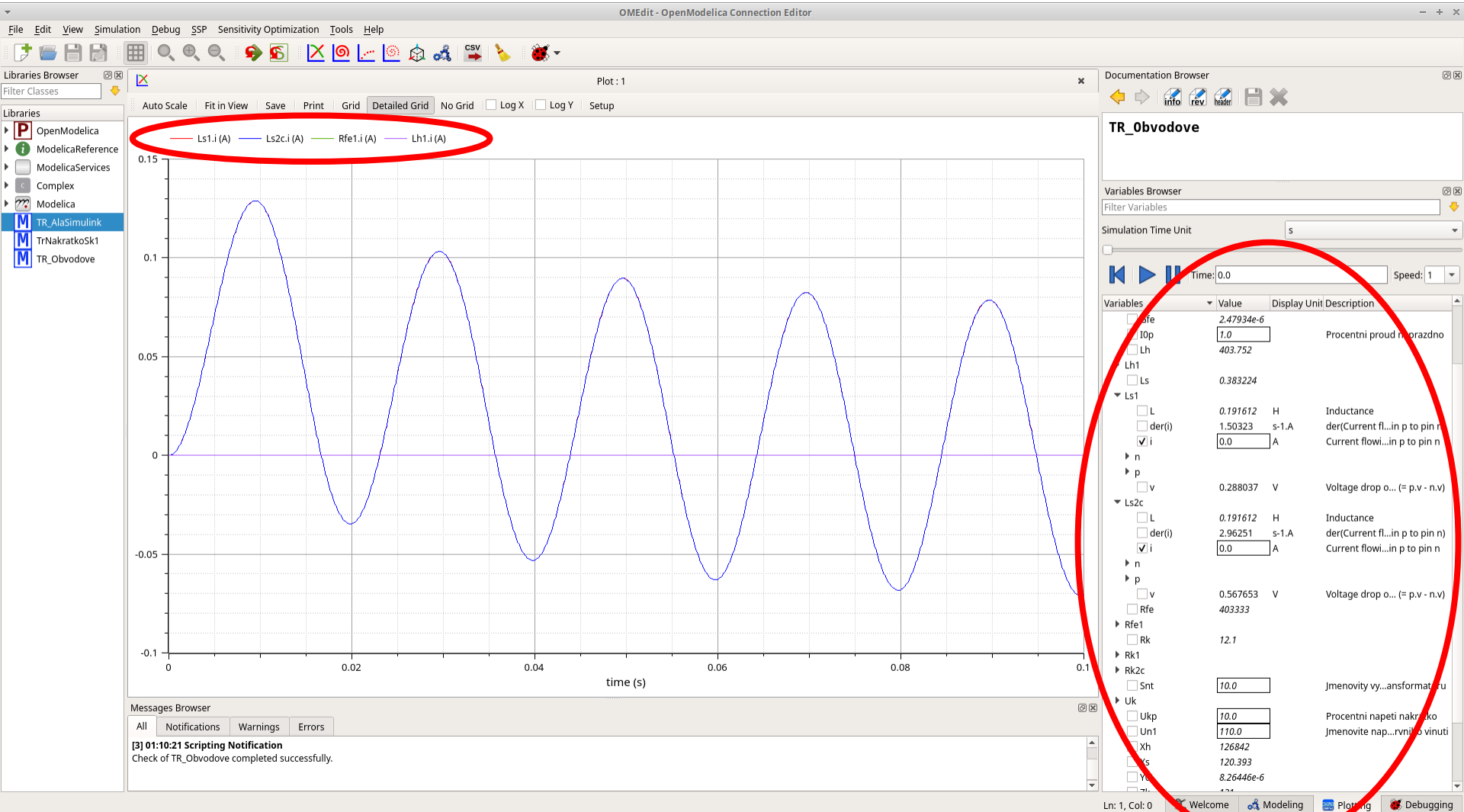
```
1 Check of TR_Obvodove completed successfully.
2 Class TR_Obvodove has 60 equation(s) and 60 variable(s).
3 40 of these are trivial equation(s).
```

Ln: 1, Col: 0 | Welcome | Modeling | Plotting | Debugging

Zpracování pomocí obvodového schéma

# Transformátor nakrátko

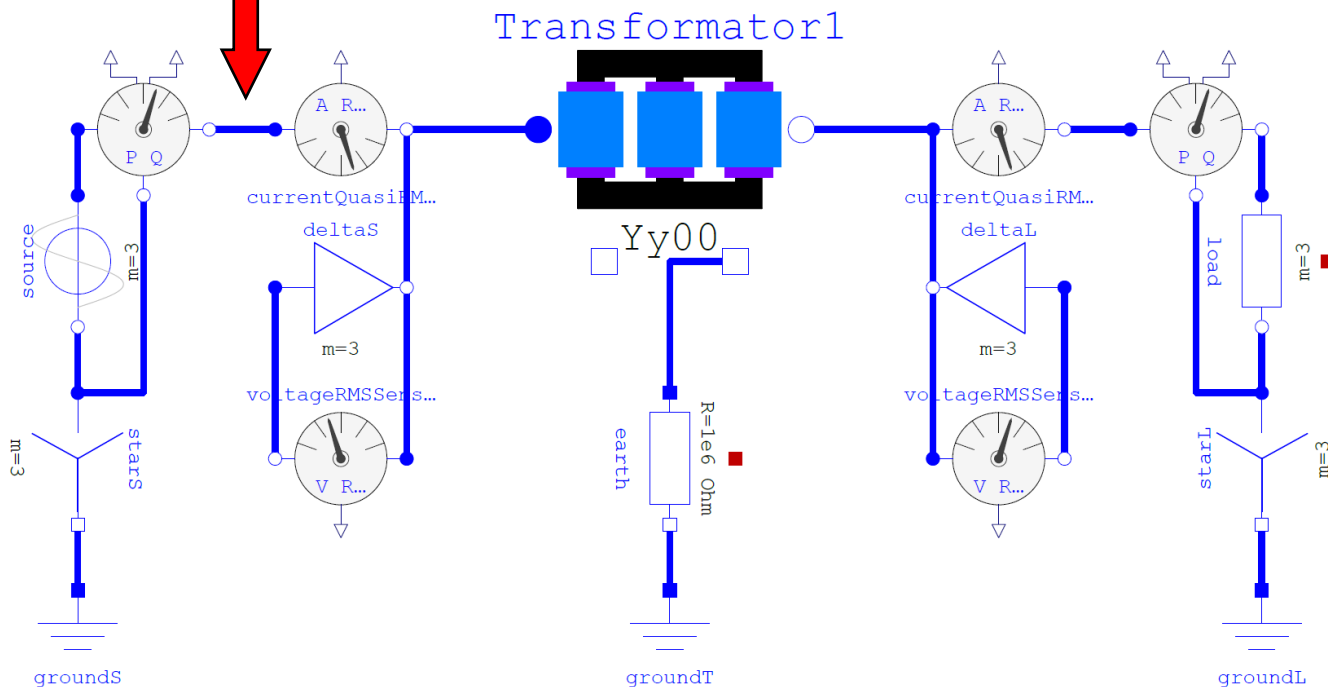
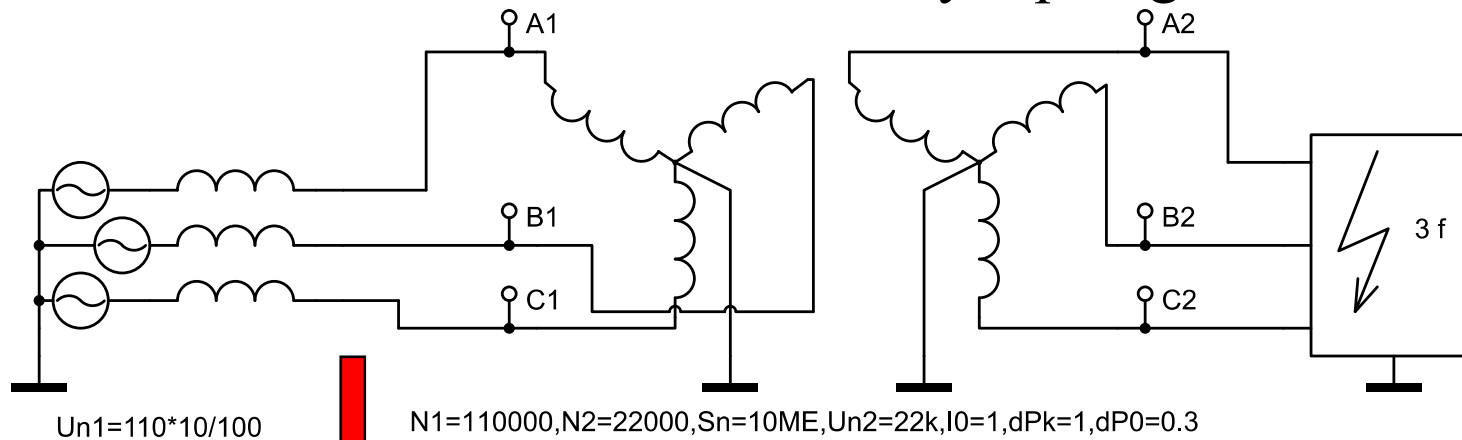
Řešení numerickou metodou s kompletní topologií:



Zpracování pomocí obvodového schéma

# Transformátor nakrátko

Řešení numerickou metodou 3f varianty topologie:



Zpracování pomocí obvodového schéma a knihovny Electrical/Machines

# Transformátor nakrátko

Řešení numerickou metodou 3f varianty topologie:

The screenshot displays the OpenModelica Connection Editor interface. The main workspace shows a 3-phase transformer test bench circuit. The circuit includes a transformer model labeled 'transformerData' connected to 'Transformer1' (Yy00). The primary side features a three-phase source connected to a star point 'starts', with a current sensor 'currentQuasiRMSSen...' and a voltage sensor 'voltageRMSSensorS'. The secondary side features a three-phase load connected to a star point 'starL', with a current sensor 'currentQuasiRMSSen...' and a voltage sensor 'voltageRMSSensorL'. The transformer has a leakage inductance 'L=1e6 Ohm' and is grounded at 'groundT'. The primary and secondary windings are grounded at 'groundS' and 'groundL' respectively. The interface includes a Libraries Browser on the left, a Messages Browser at the bottom, and a Documentation Browser on the right.

**Transformer2021**

**Transformer test bench**

**Information**

**Transformer test bench:**

You may choose different connections as well as vary the load (even not symmetrical).

**Please pay attention** to proper grounding of the primary and secondary part of the whole circuit. The primary and secondary starpoint are available as connectors, if the connection is not delta (D or d).

In some cases it may be necessary to ground the transformer's starpoint even though the source's or load's starpoint are grounded:

- Yy ... Grounding of transformer's primary or secondary starpoint with reasonable high earthing resistance is necessary.
- Yd ... No grounding necessary.
- Yz ... Grounding of transformer's primary starpoint with reasonable high earthing resistance is necessary.
- Dy ... No grounding necessary.
- Dd ... No grounding necessary.
- Dz ... No grounding necessary.

Messages Browser

All Notifications Warnings Errors

[3] 00:10:16 Scripting Notification  
Check of Transformer2021 completed successfully.

Zpracování pomocí obvodového schéma a knihovny Electrical/Machines

# Transformátor nakrátko

Řešení numerickou metodou 3f varianty topologie:

The screenshot displays the OMEdit - OpenModelica Connection Editor interface. The main workspace shows a transformer model labeled 'transformerData' on a grid. A red arrow points from the 'transformerData' label to the 'Parameters' dialog box. The dialog box is titled 'OMEdit - Element Parameters - transformerData in Transformer2021' and has a 'Parameters' tab selected. It contains the following information:

**Parameters**

General Result Modifiers

Component

Name: transformerData

Class

Path: Modelica.Electrical.Machines.Utilities.TransformerData  
Comment: Calculates Impedances from nominal values

Parameters

Parameter	Value	Unit	Description
f	50	Hz	Nominal frequency
V1	110E3	V	Primary nominal line-to-line voltage (RMS)
C1	Modelica.Utilities.Strings.substring(Transformerator1.VectorGroup, 1, 1)		Choose primary connection
V2	22E3	V	Secondary open circuit line-to-line voltage (RMS) @ primary nominal voltage
C2	Modelica.Utilities.Strings.substring(Transformerator1.VectorGroup, 2, 2)		Choose secondary connection
SNominal	Snt	V.A	Nominal apparent power
v_sc	Ukp / 100		Impedance voltage drop pu
P_sc	dPkp / 100 * Snt	W	Short-circuit (copper) losses

Buttons: OK, Cancel

Documentation Browser (Transformer2021):

**Transformer2021**

Transformer test bench

**Information**

Transformer test bench:

You may choose different connections as well as vary the load (even not symmetrical).

**Please pay attention** to proper grounding of the primary and secondary part of the whole circuit. The primary and secondary starpoint are available as connectors, if the connection is not delta (D or d).

In some cases it may be necessary to ground the transformer's starpoint even though the source's or load's starpoint are grounded:

- Yy ... Grounding of transformer's primary or secondary starpoint with reasonable high earthing resistance is necessary.
- Yd ... No grounding necessary.
- Yz ... Grounding of transformer's primary starpoint with reasonable high earthing resistance is necessary.
- Dy ... No grounding necessary.
- Dd ... No grounding necessary.
- Dz ... No grounding necessary.

Bottom status bar: Welcome, Modeling, Plotting, Debugging

Zpracování pomocí obvodového schéma a knihovny Electrical/Machines

# Transformátor nakrátko

Řešení numerickou metodou 3f varianty topologie:

The screenshot displays the OpenModelica Connection Editor interface. The main workspace shows a circuit diagram for a transformer test bench. The circuit includes a three-phase source (m=3) connected to a transformer (Yy00) with a primary resistance of 1e6 Ohm. The secondary side is connected to a load (m=3) through a delta connection (deltaL). The circuit is equipped with various measurement instruments: power meters (P Q), current meters (A RMS), and voltage meters (V RMS). The transformer is connected to a ground (groundT) through an earth connection (R=1e6 Ohm). The interface also shows a Libraries Browser on the left, a Documentation Browser on the right, and a Messages Browser at the bottom.

The Documentation Browser displays the following information for the Transformer2021 component:

**Transformer2021**  
Transformer test bench  
**Information**  
Transformer test bench:  
You may choose different connections as well as vary the load (even not symmetrical).  
**Please pay attention** to proper grounding of the primary and secondary part of the whole circuit. The primary and secondary starpoint are available as connectors, if the connection is not delta (D or d).  
In some cases it may be necessary to ground the transformer's starpoint even though the source's or load's starpoint are grounded:

- Yy ... Grounding of transformer's primary or secondary starpoint with reasonable high earthing resistance is necessary.
- Yd ... No grounding necessary.
- Yz ... Grounding of transformer's primary starpoint with

The Messages Browser shows a notification: [3] 00:10:16 Scripting Notification Check of Transformer2021 completed successfully.

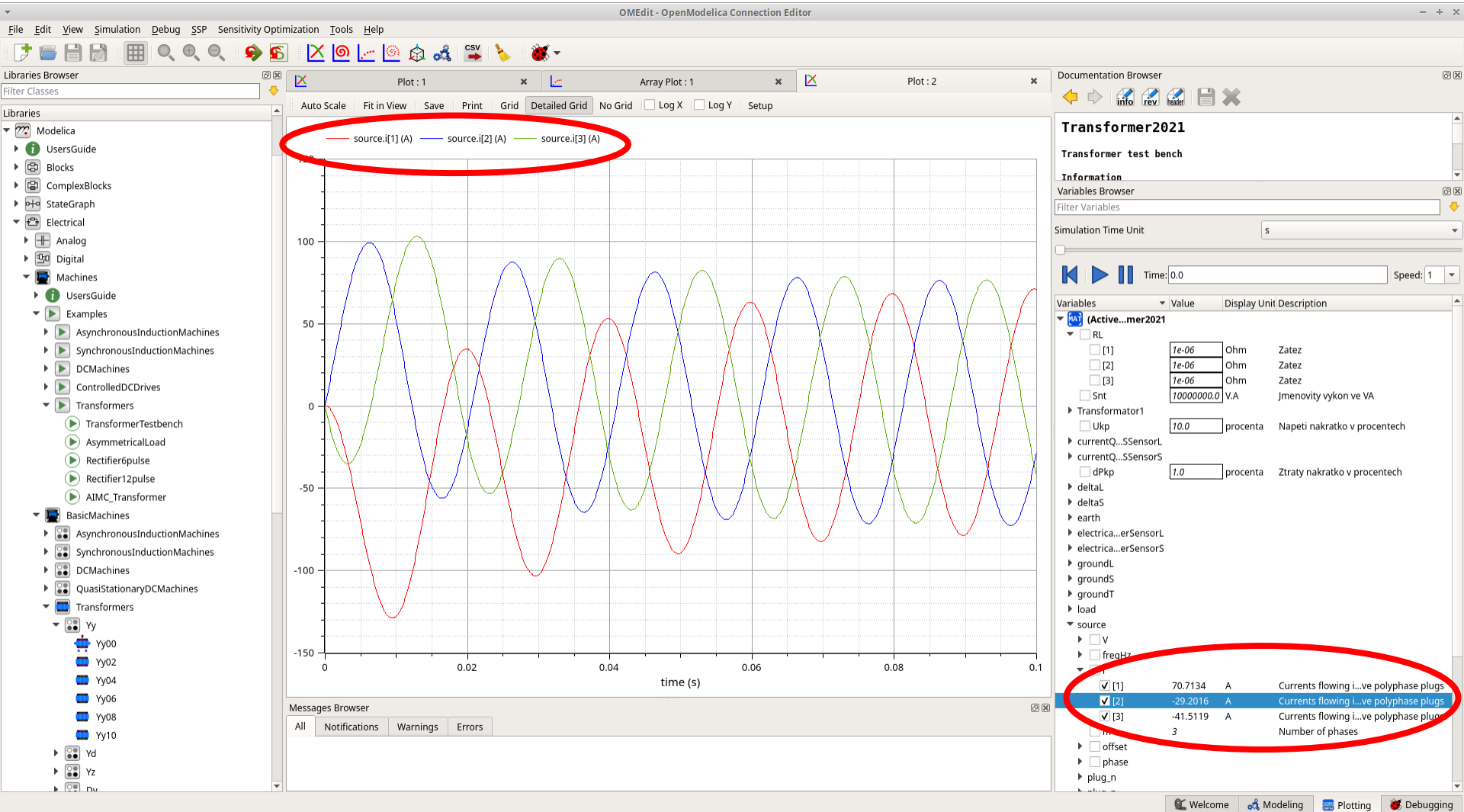
The Check Model dialog box displays the following message:

```
1 Check of Transformer2021 completed successfully.  
2 Class Transformer2021 has 758 equation(s) and 758  
   variable(s).  
3 574 of these are trivial equation(s).
```

Zpracování pomocí obvodového schéma a knihovny Electrical/Machines

# Transformátor nakrátko

Řešení numerickou metodou 3f varianty topologie:

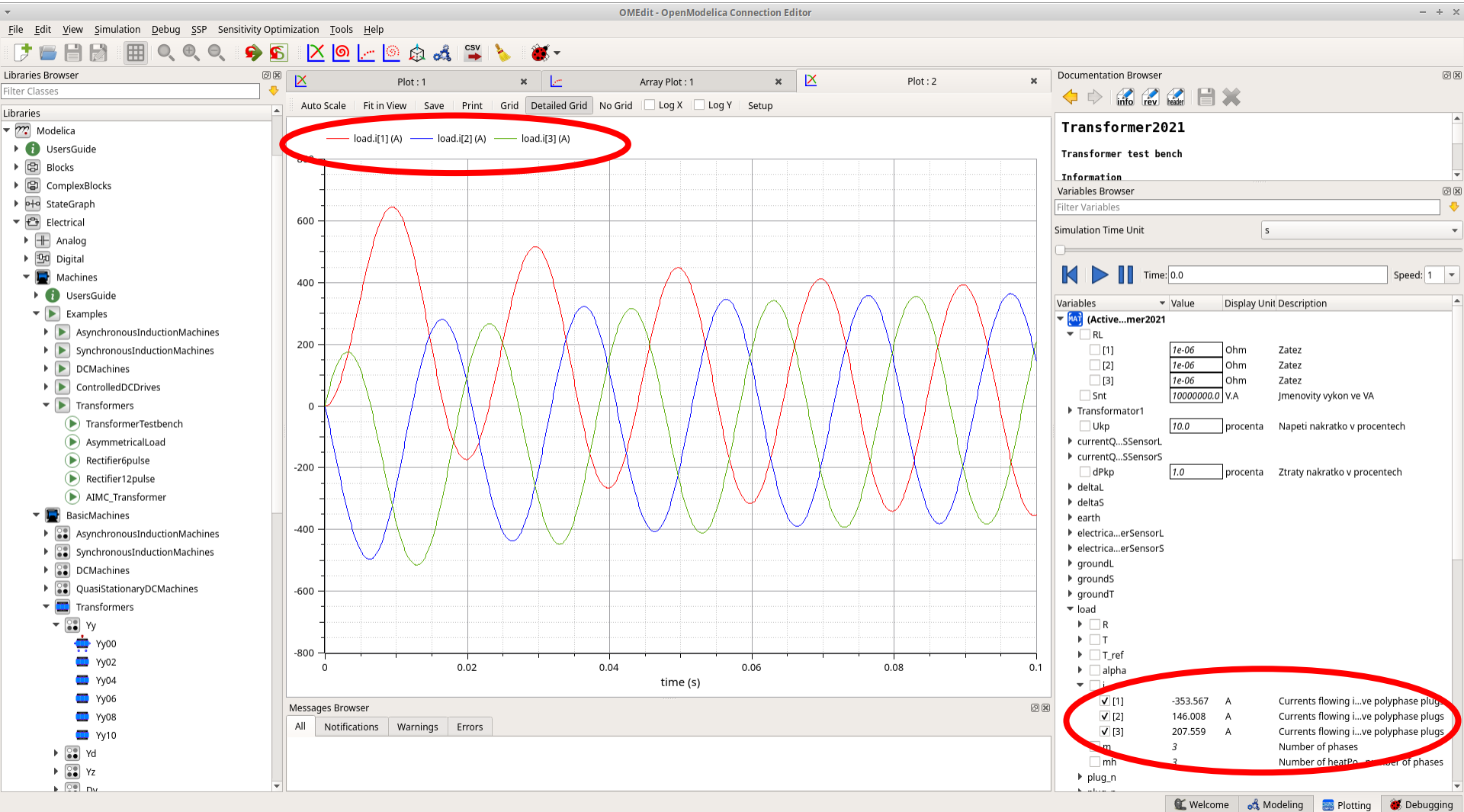


Zpracování pomocí obvodového schéma a knihovny Electrical/Machines



# Transformátor nakrátko

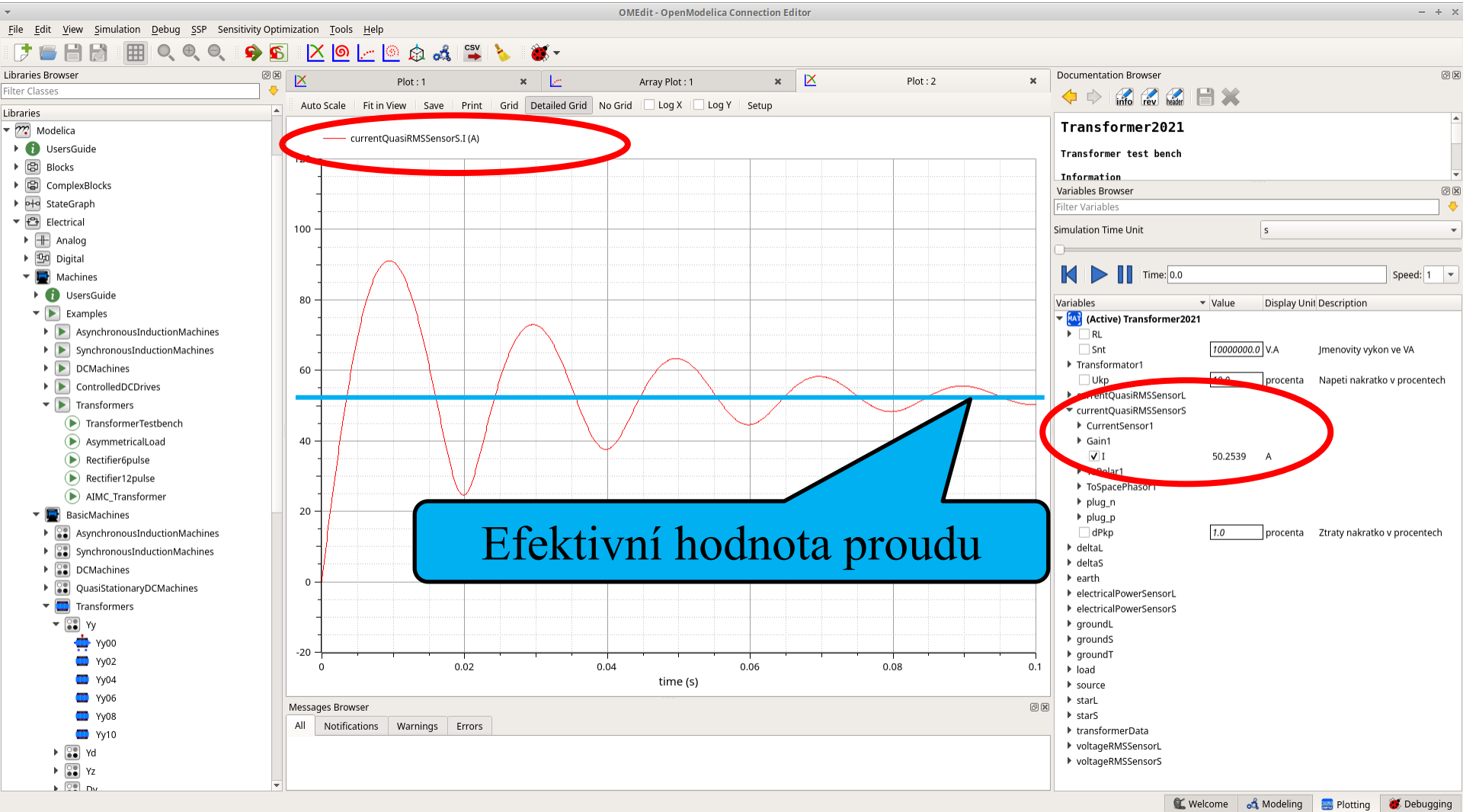
Řešení numerickou metodou 3f varianty topologie:



Zpracování pomocí obvodového schéma a knihovny Electrical/Machines

# Transformátor nakrátko

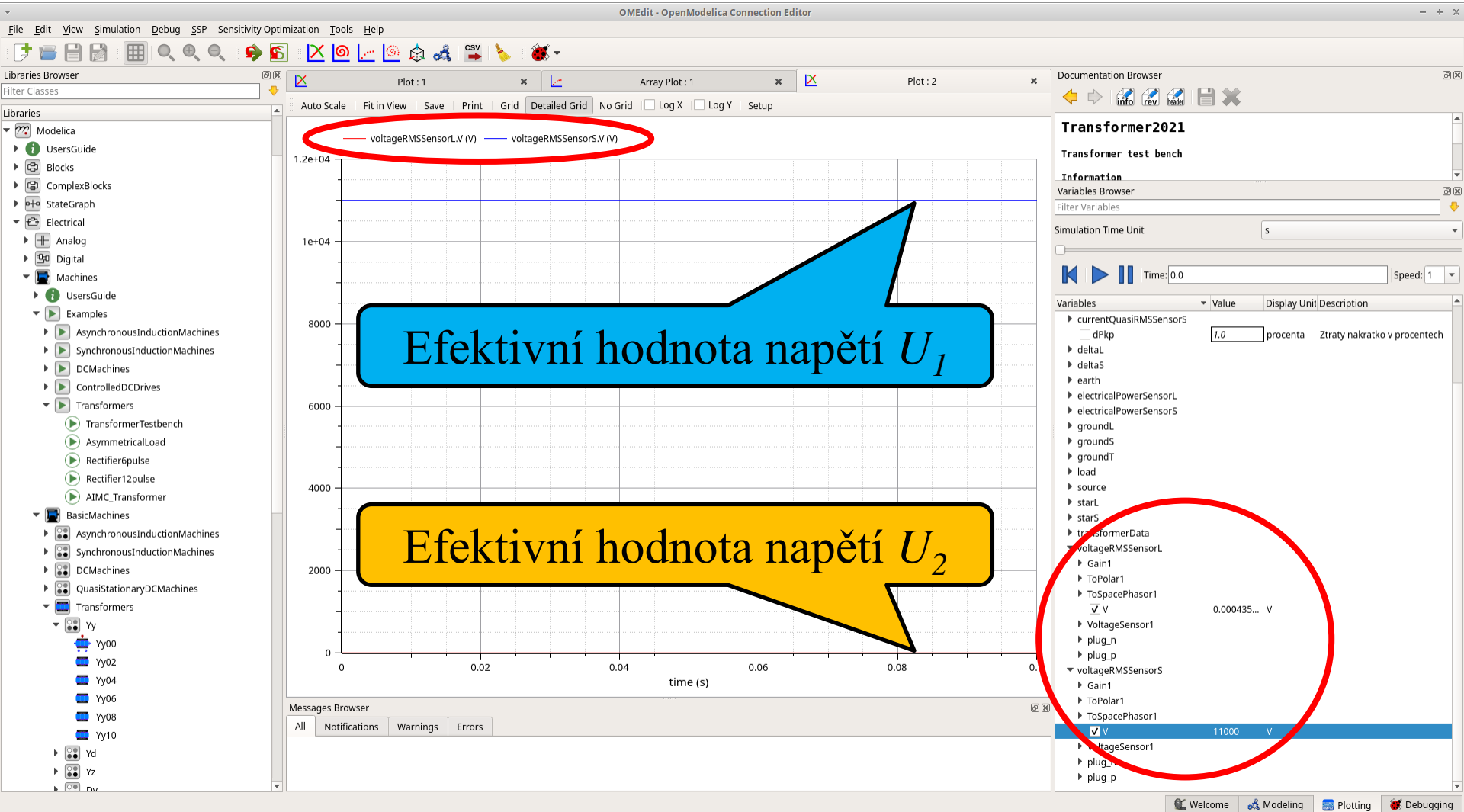
Řešení numerickou metodou 3f varianty topologie:



Zpracování pomocí obvodového schéma a knihovny Electrical/Machines

# Transformátor nakrátko

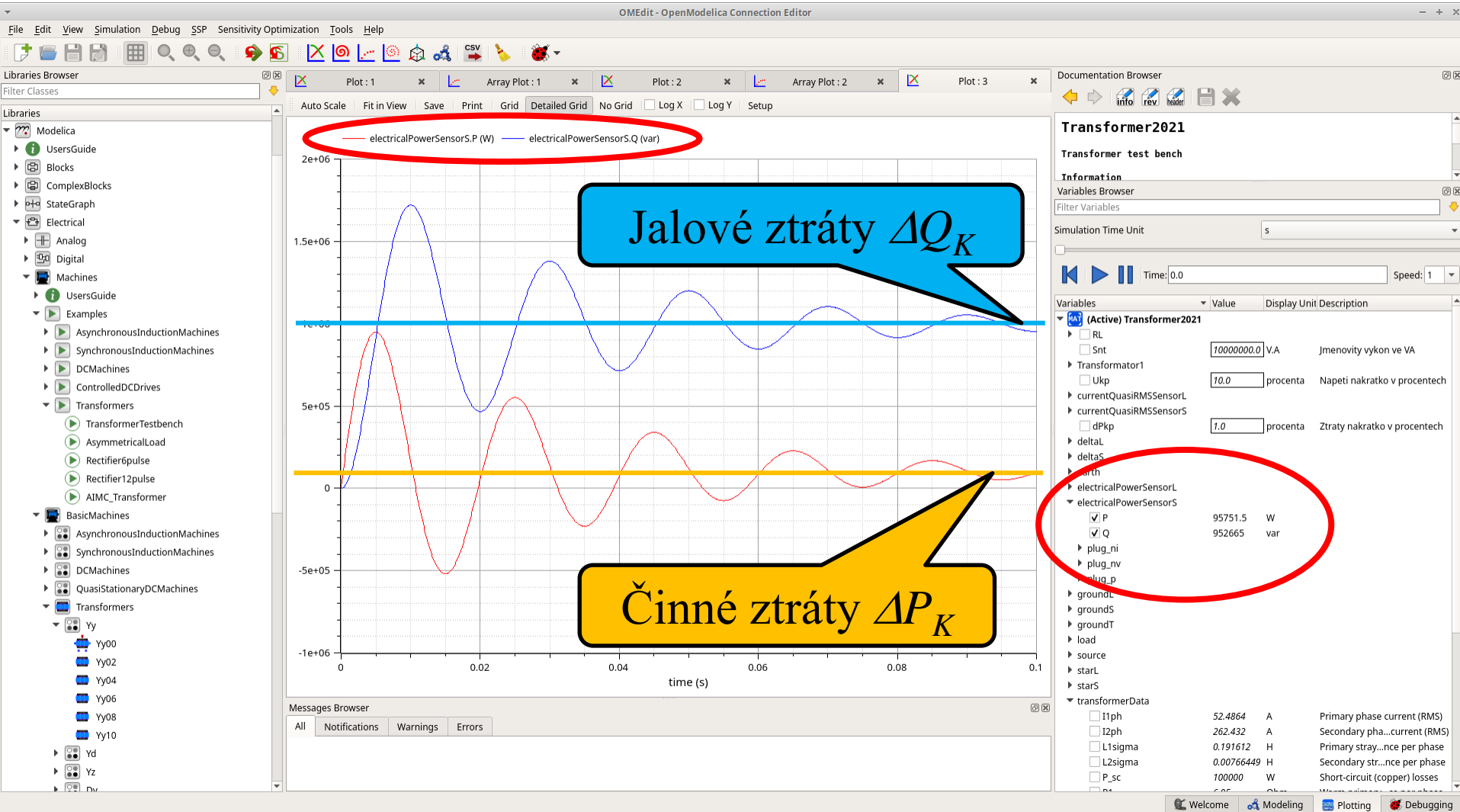
Řešení numerickou metodou 3f varianty topologie:



Zpracování pomocí obvodového schéma a knihovny Electrical/Machines

# Transformátor nakrátko

Řešení numerickou metodou 3f varianty topologie:



Zpracování pomocí obvodového schéma a knihovny Electrical/Machines