Introduction to EMTP®

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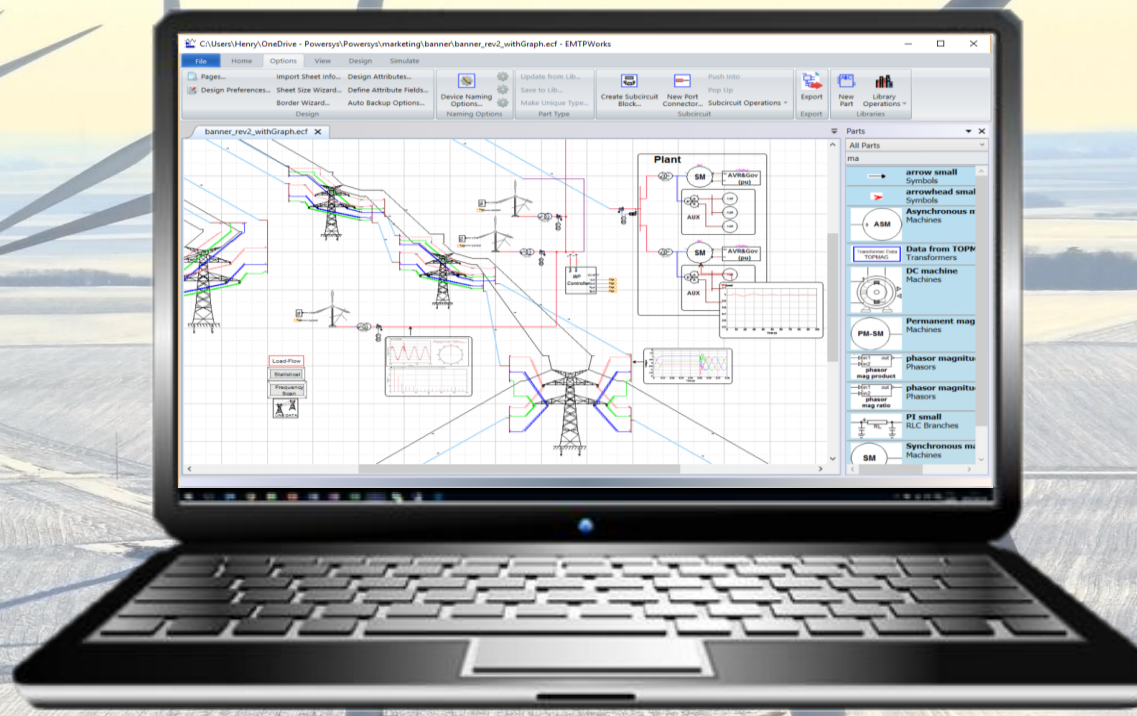

More info

www.EMTP.com

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Content

- Introduction to EMTP.
- Introduction to the user-interface.
- How to add a device and connect it to a circuit?
- How to change parameters? Include/Exclude?
- How to run load-flow and time-domain?
- How to visualize results?
- How to subcircuits?
- Overview of basics components (transformers, loads, machines, controls).
- How to import a simple case from PSS/E?
- Overview of IBR models?

EMT simulation objectives and challenges

- In the context of IBR integration, the main objectives of an offline EMT software are:
  - To provide reliable results
  - Provide results as fast as possible
  - Deliver user-friendly tools: easy to use, customizable, parametric options

- The challenges are:
  - Maintain accuracy and computational speed
  - Lack of experience
  - Manufacturer models: typically, black-box

EMT simulation objectives and challenges

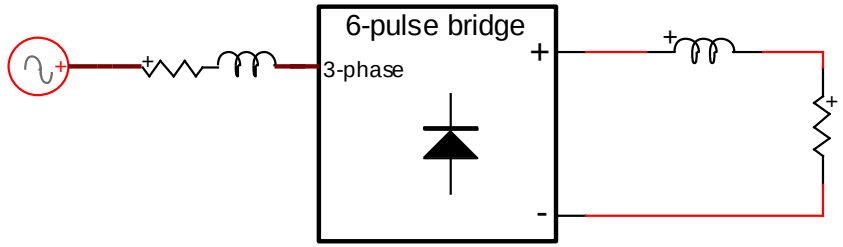
- How EMTP® answers the challenges?
- Precision: EMTP® provides a pure mathematical solver

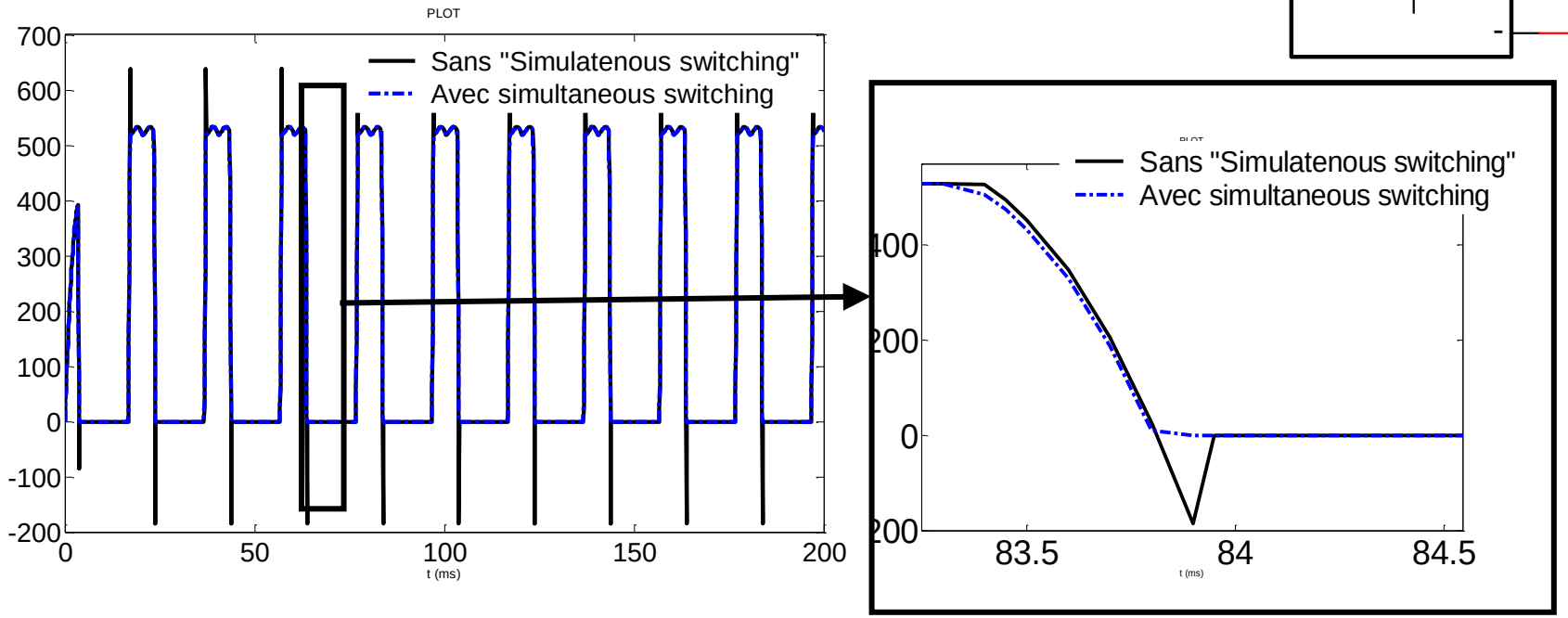
EMT simulation objectives and challenges

- How EMTP® answers the challenges?
- Precision: EMTP® provides a pure mathematical solver
  - Fully iterative solver for non-linear power components (IGBT, surge-arrester, saturation, etc)

EMT simulation objectives and challenges

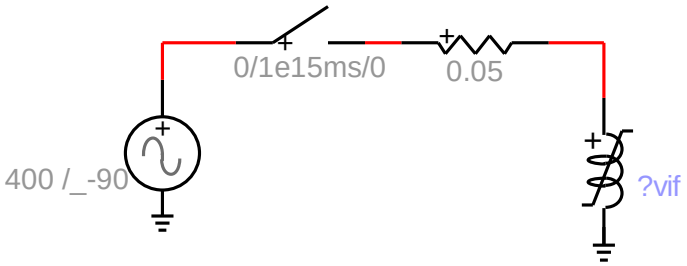
- Diode switching with no iteration

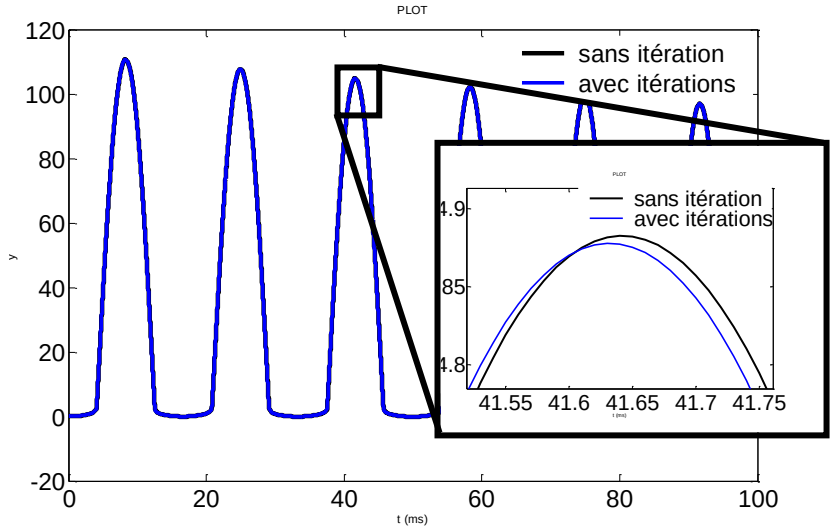


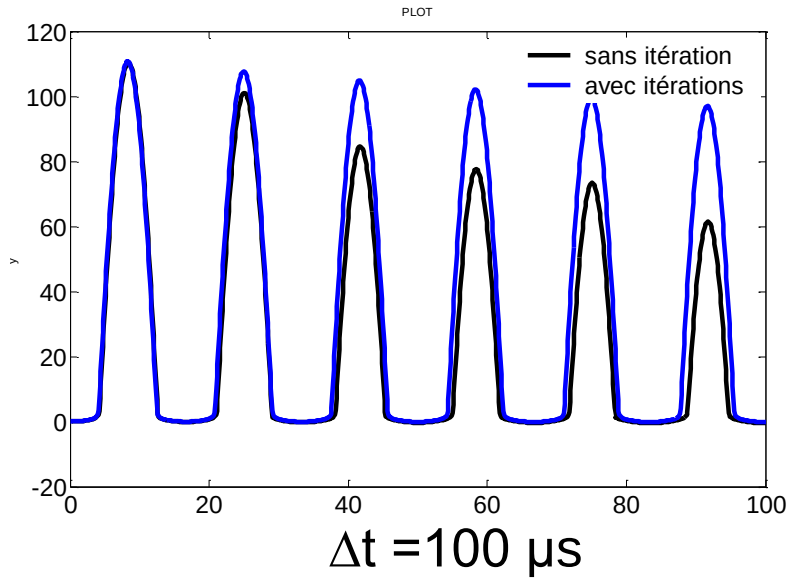


EMT simulation objectives and challenges

- Transformer energization with no iteration





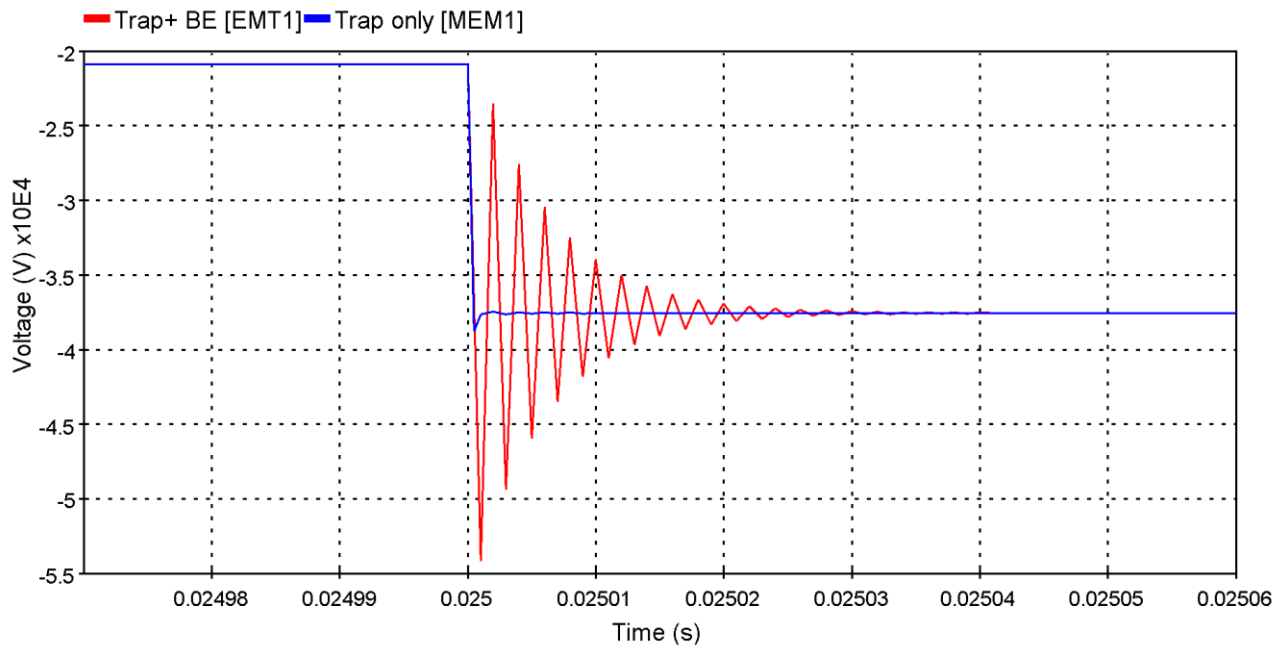


EMT simulation objectives and challenges

- How EMTP® answers the challenges?
- Precision: EMTP® provides a pure mathematical solver
  - Fully iterative solver for non-linear power components (IGBT, surge-arrester, saturation, etc)
  - Iterates control when algebraic loops are present

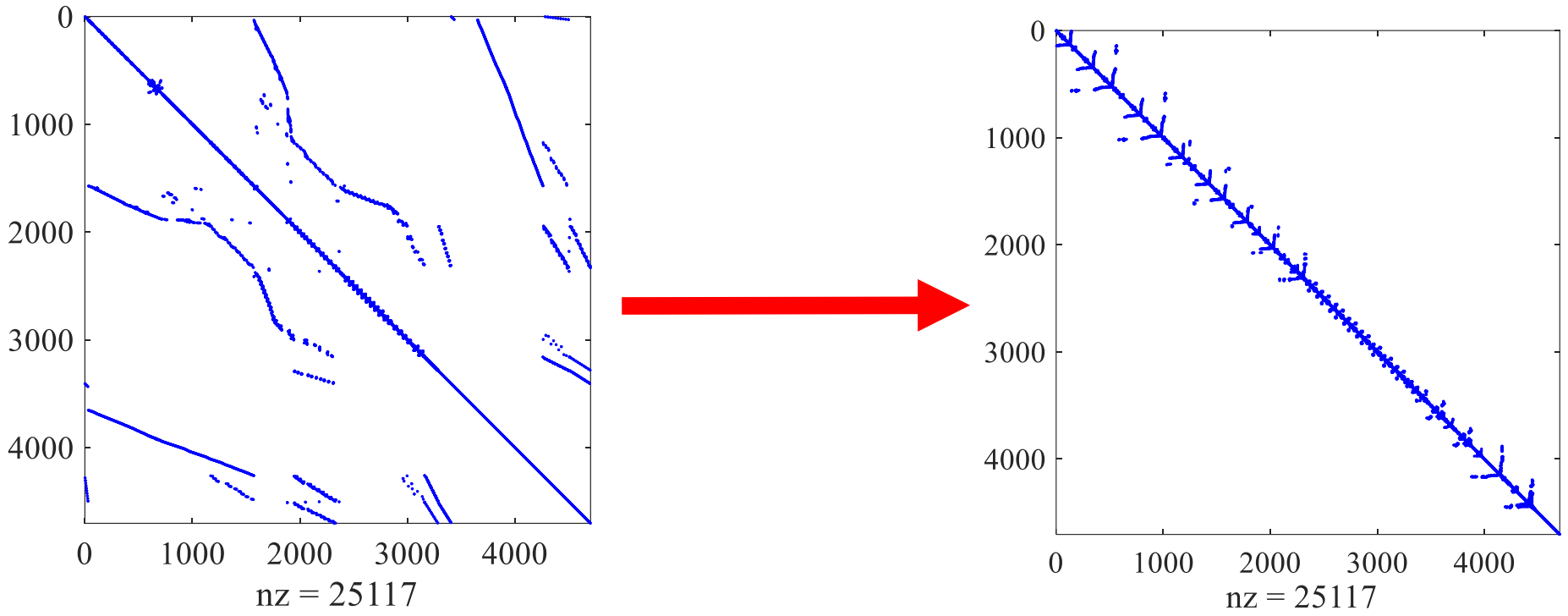
EMT simulation objectives and challenges

- How EMTP® answers the challenges?
- Precision: EMTP® provides a pure mathematical solver
  - Fully iterative solver for non-linear power components (IGBT, surge-arrester, saturation, etc)
  - Iterates control when algebraic loops are present
  - Use multiple integration methods (trapezoidal and Backward Euler) to avoid numerical problems



EMT simulation objectives and challenges

- How EMTP® answers the challenges?
- Speed: EMTP® uses innovative matrix solver technics
  - Modified augmented nodal analysis - example: power amplifier
  - Uses KLU-based sparse matrix solver
  - Uses partial refactorization
  - User parallele processing (costly)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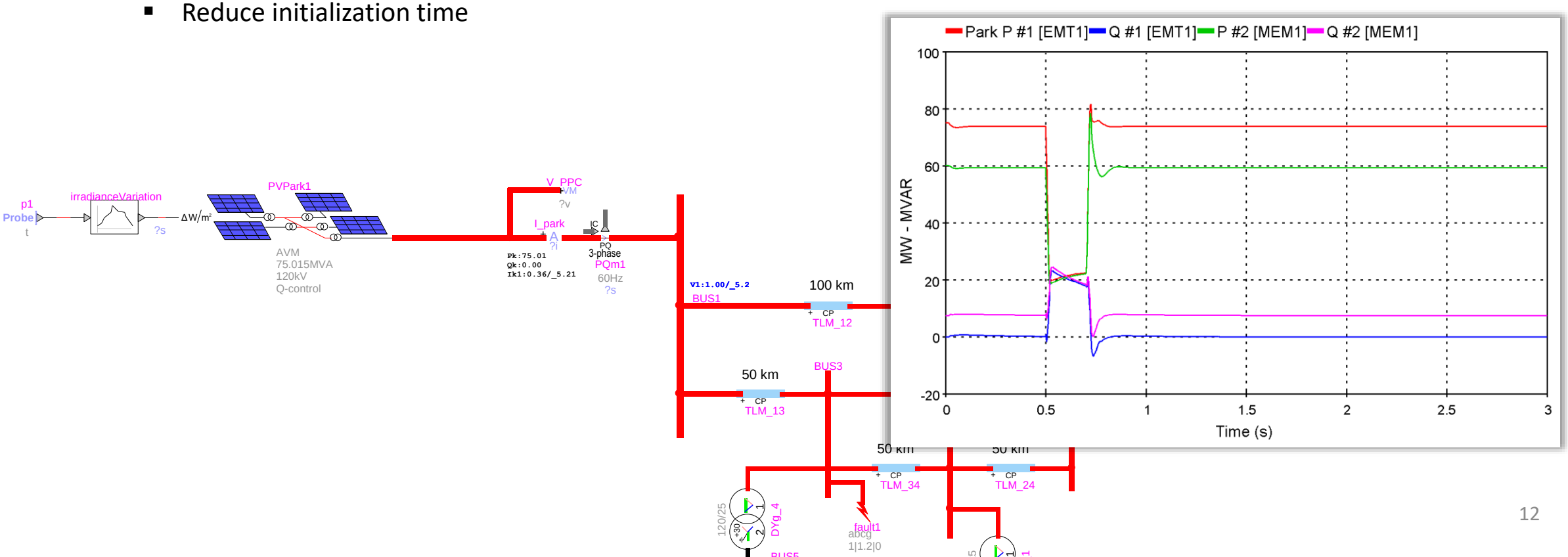
EMT simulation objectives and challenges

- How EMTP® answers the challenges?
- Speed: EMTP® uses innovative matrix solver technics
  - Uses KLU-based sparse matrix solver
  - Uses partial refactorization
  - User parallele processing (costly)
  - Reduce initialization time



Presentation of the GUI: EMTPWorks

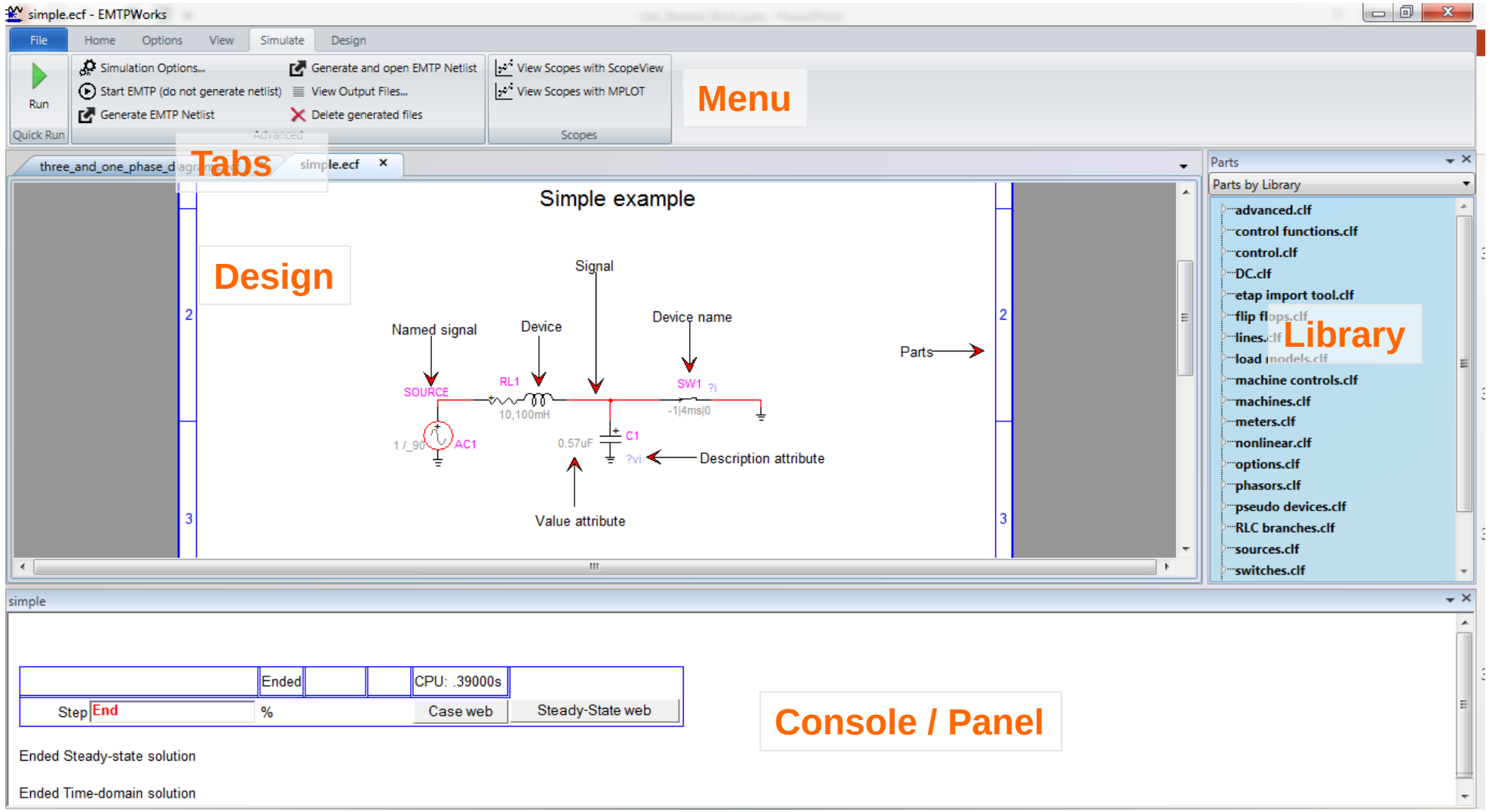
Objective

The objective is to give to beginner participants a good first hands-on experience on the graphical user interface (GUI) of EMTP.

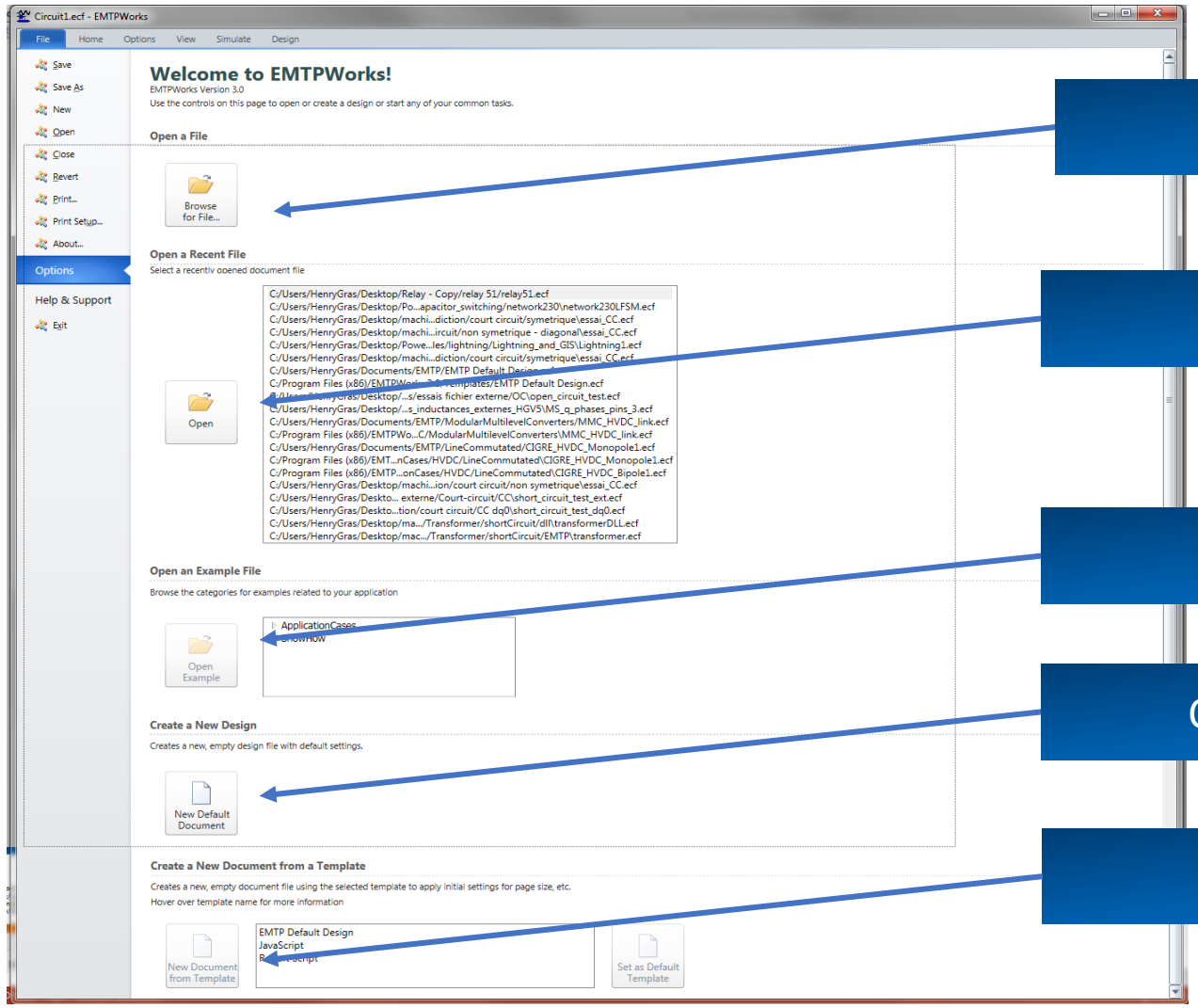
Organization

Every participant must have a running copy of EMTP on his computer

Presentation of the GUI: EMTPWorks



Presentation of the GUI: EMTPWorks



Open an existing file

Open an recent file

Open an example

Create a new blank design

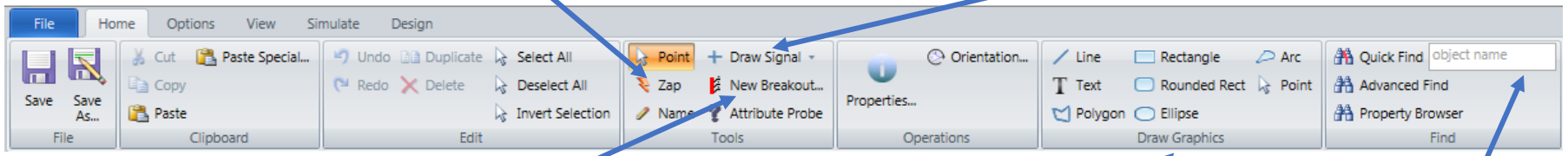
Create a new document:
design or script

Presentation of the GUI: EMTPWorks

➢Home menu

Zap : Delete individual signal sections or attribute

Draw signal : Draw 1/3 phase and buses



New Breakout : Multiplexing

Quick find: find devices by name

Draw Graphics

- Undo/Redo (Ctrl+Z/Ctrl+Shift+Z)
- Cut/Copy/Paste(Ctrl+X, Ctrl+C, Ctrl+V)

(Compatible with MS Office)

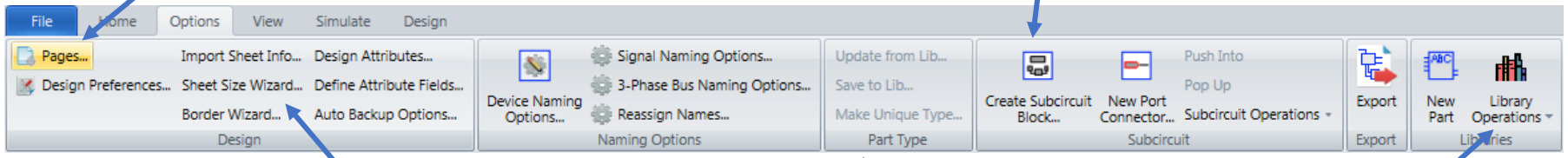
- Flip/Rotate components (Ctrl+Y, Ctrl+R)

Presentation of the GUI: EMTPWorks

➢Options menu

Pages: Possibility to have multiple pages

Create Subcircuit Block ….



Sheet Size Wizard: Update size display

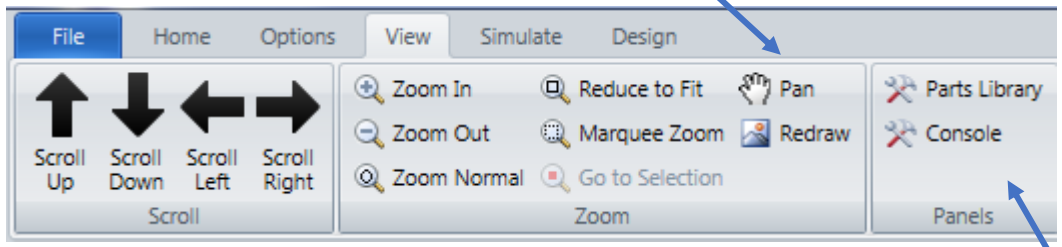
Part Type: Create and Manage devices

Libraries: Create and manage libraries

Presentation of the GUI: EMTPWorks

➢View menu

Pan (Ctrl + click)

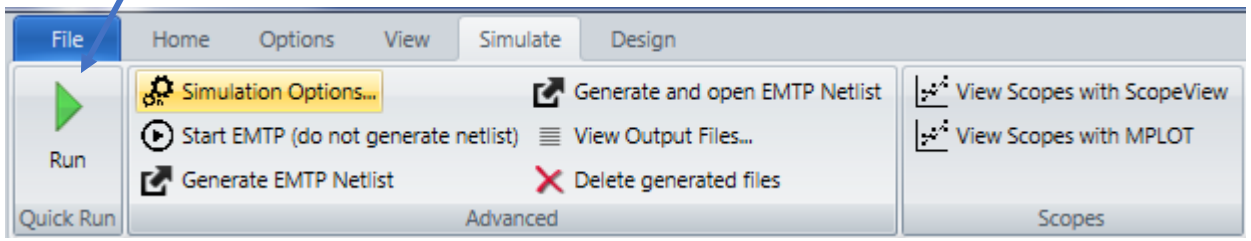


Display/Hide Console & Libraries

Presentation of the GUI: EMTPWorks

➢Simulate menu

Run a simulation



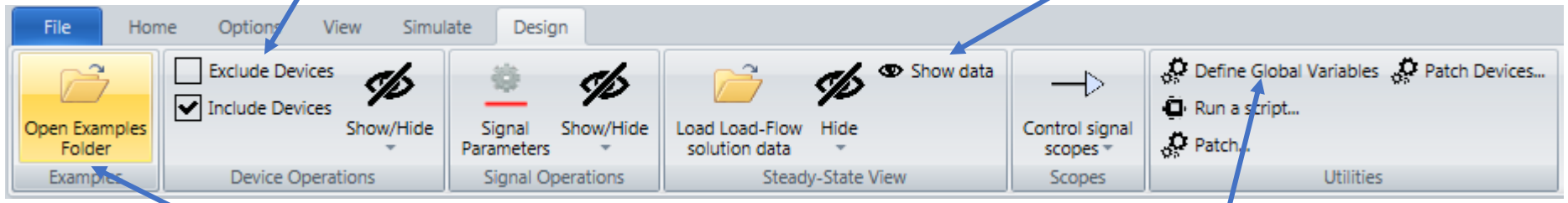
Open ScopeView and MPLOT

Presentation of the GUI: EMTPWorks

➢Design menu

Possibility to Exclude/Include devices

Possibility to display and refresh Steady-State Data



Open Examples Folder

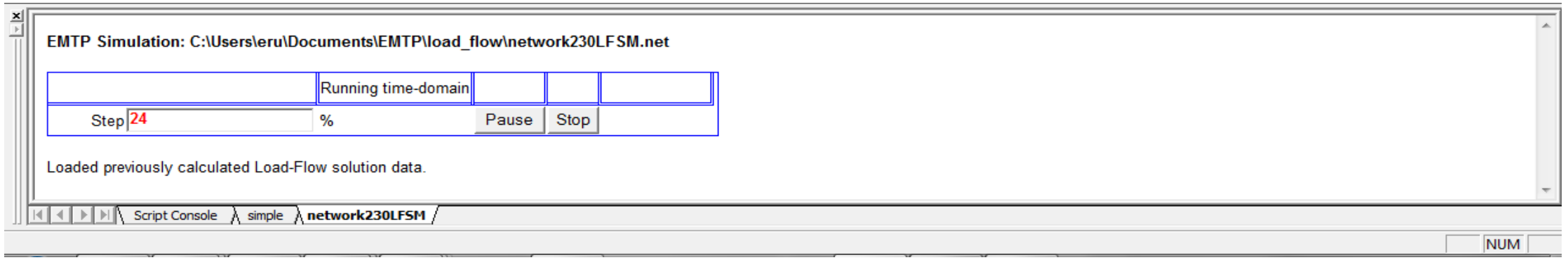
Possibility to define Global Variables

Presentation of the GUI: EMTPWorks

Console

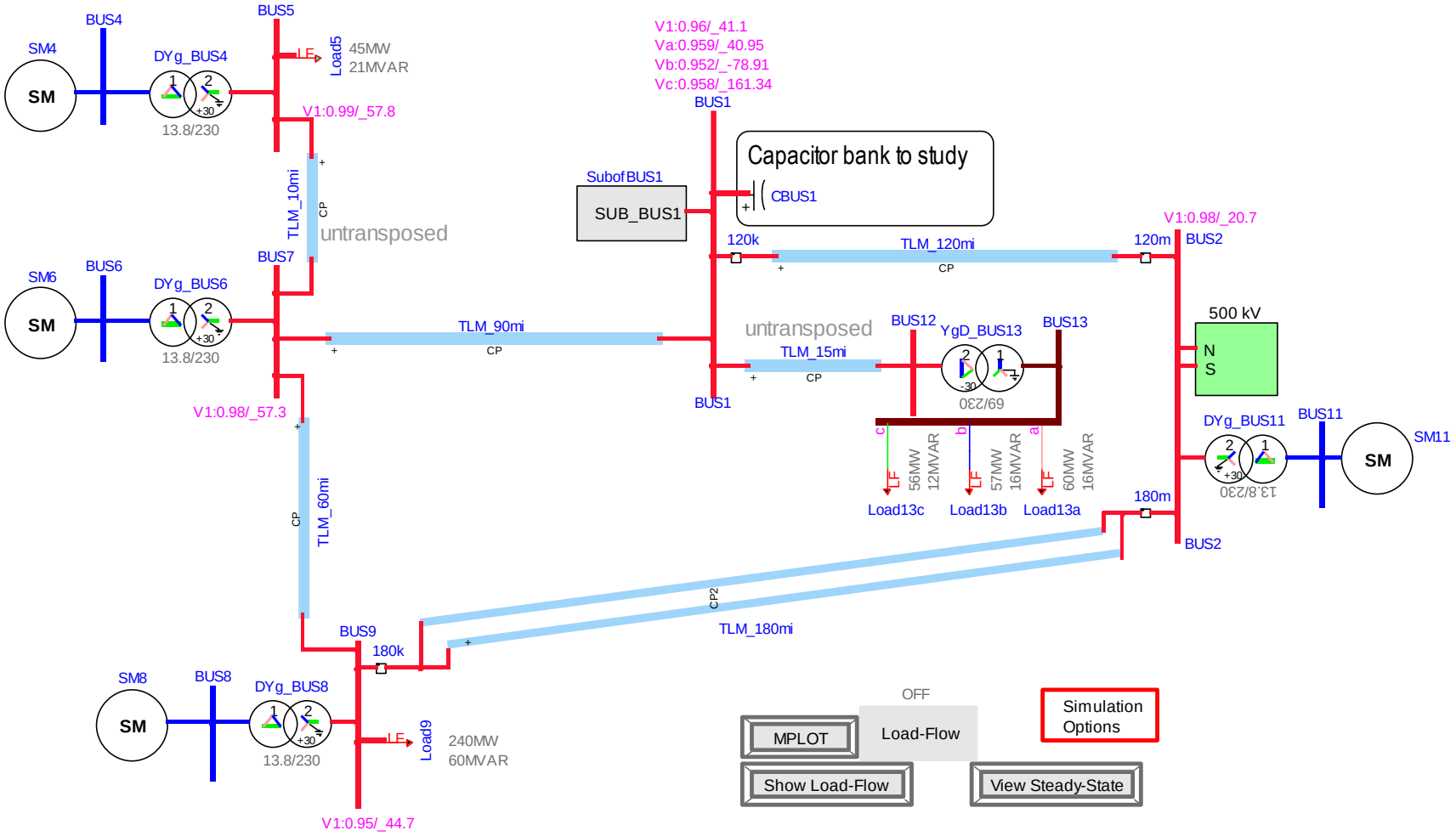
5. The Console

- Simulation status
- Simulation Control *(Pause/Stop)*
- Error notification

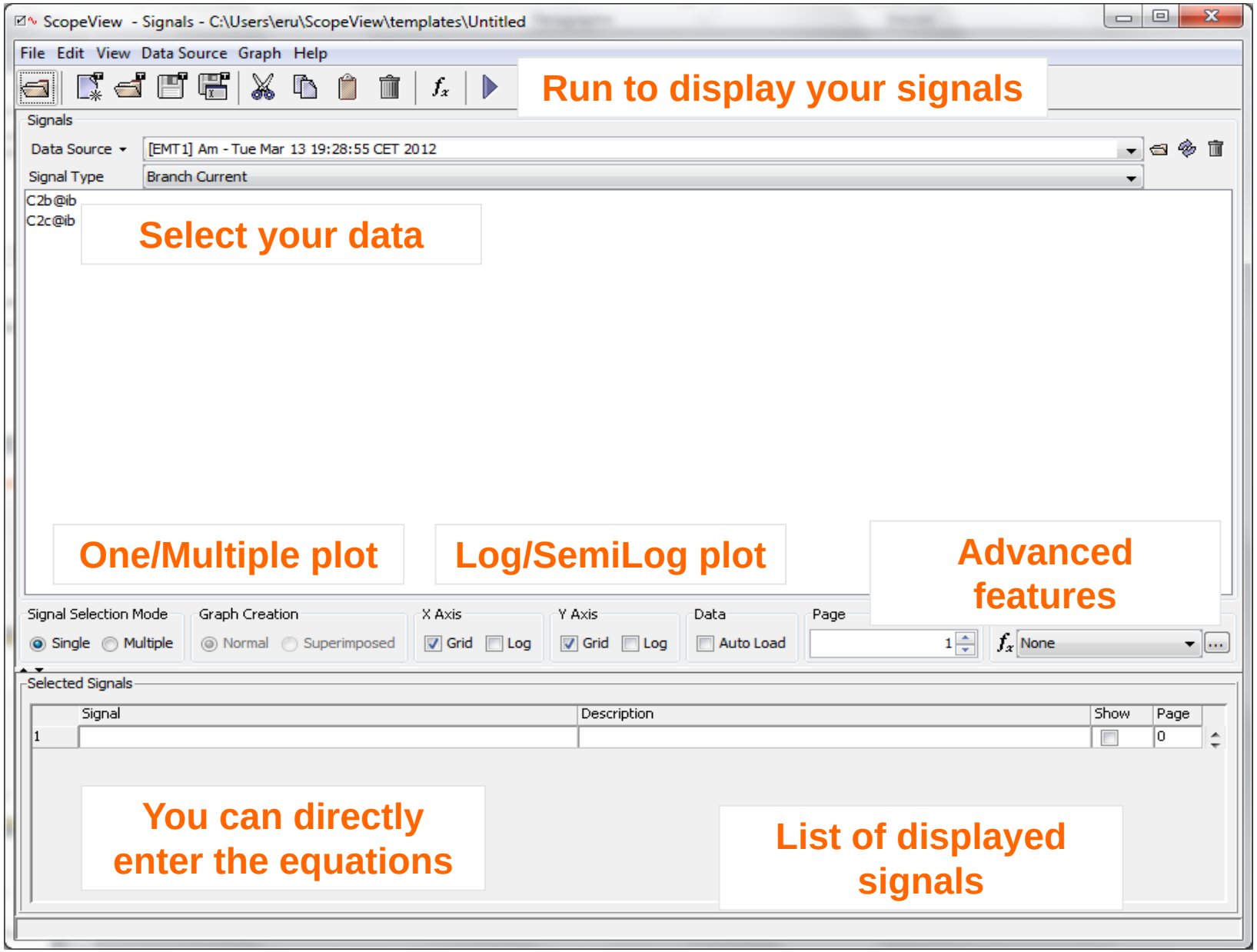


Lab 1

- Open the network230LFSM.ecf examples and test the different options demonstrated in the previous slides.



ScopeView


ScopeView - Signals - C:\Users\eru\ScopeView\templates\Untitled
File Edit View Data Source Graph Help
Run to display your signals
Signals
Data Source
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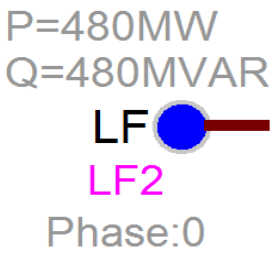
Signal Type
Branch Current
C2b@ib
C2c@ib
Select your data
One/Multiple plot
Log/SemiLog plot
Advanced features
Signal Selection Mode
Single
Multiple
Graph Creation
Normal
Superimposed
X Axis
Grid
Log
Y Axis
Grid
Log
Data
Auto Load
Page
None
Selected Signals
Signal
Description
Show
Page
You can directly enter the equations
List of displayed signals

Load Flow devices

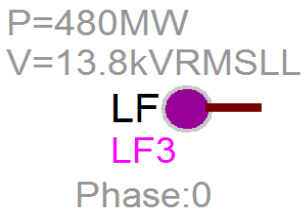
- Device : Load Flow Bus (Library : Source)

Slack Bus

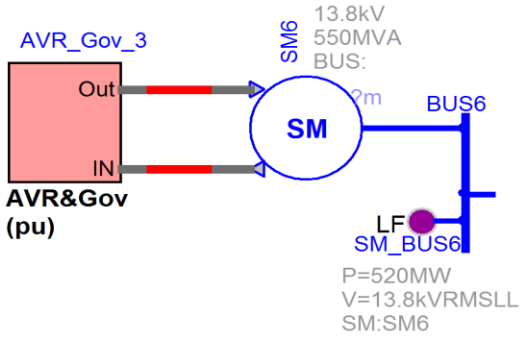
PQ Bus



PV Bus

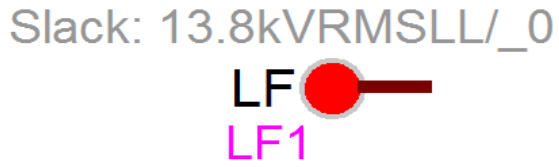


- Can automatically retrieve impedance data from synchronous machine



Slack Bus

- **Used to model ideal network (infinite power)**
- **User specifies the voltage and the frequency**



Load-Flow bus

Bus type: Slack bus | Frequency: 60 Hz

Controlled Voltage: 13.8 kVRMSLL | Controlled Phase: 0 deg

Retrieve Impedance data from (reference)

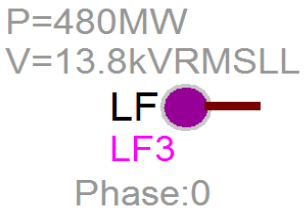
Source impedance R Ω — Sequence Data ☑

	zero	positive	negative
R	0.00076176	0.00076176	0.00076176

Source impedance L Ω — Sequence Data ☑

	zero	positive	negative
L	0.038088	0.30870324	0.09808655

PV Bus



- **Voltage and Active Power are controlled**
- **Possibility to “remote control” (use a remote voltage value)**

Load-Flow bus

Bus type: PV control | Frequency: 60 Hz

Controlled Voltage: 13.8 kVRMSLL | Phase: 0 deg

Control type: Phase-a-to-ground Voltage

Remote k-node | Remote m-node

P: 480 MW

Q_{min}: -1000 MVAR | Q_{max}: 1000 MVAR

Retrieve Load-Flow solution data ☑ Load now

PQ Load

- **Library Load Models> PQ Load Device**
- **1-phase or 3-phase load**
- **Can be used in Load-Flow and Time-Domain simulation**

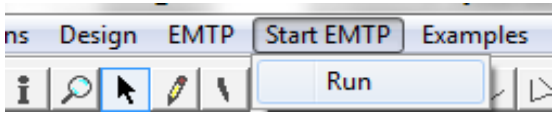
PQ Load

Help

1-phase data

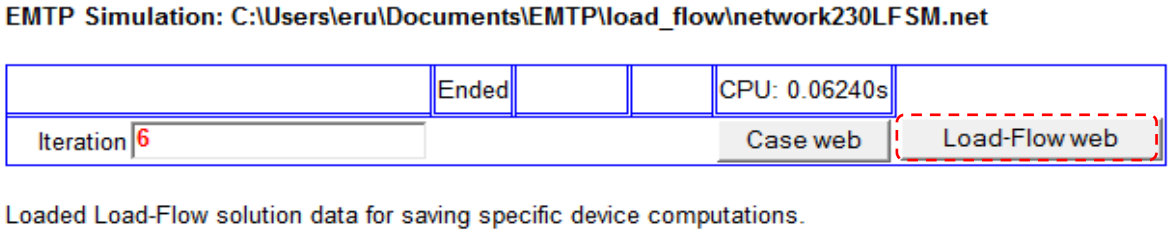
Voltage	230	kVRMSLL		
Active Power (P)	15	MW	Np	0
Reactive Power (Q)	7	MVAR	Nq	0

Results



- Start EMTP > Run to start the Load-Flow Analysis
  - To visualize: 2 solutions

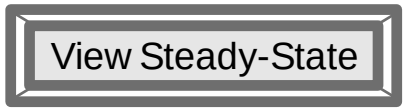
- Click-on Load-Flow Web to visualize the results as an HTML tab of ALL nodes and devices of the network



- Display the results on the GUI.

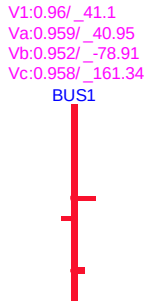
Bring this device from options.clf

And set the visualization options



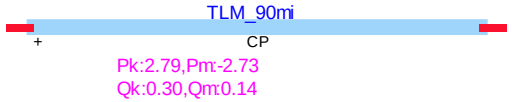
Display the voltages on the bus:

Click right/ Signal Parameters



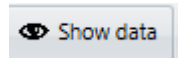
Display the powers through the devices:

Click right/ Signal Parameters

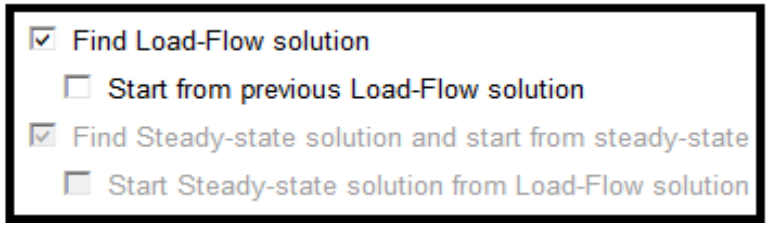


For refreshing

Design/Show data



Load-Flow Solution



- The electrical network equations are solved using **complex phasors**. The active (source) devices are **only the Load-Flow devices** (LF-devices). A load device is used to enter PQ load constraint equations.

- Only single (fundamental) frequency solutions are achievable. The solution frequency is specified by ‘Default Power Frequency’ and used in passive network lumped model calculations.

- **The same network used for transient simulations can be used in load-flow analysis**. The EMTP Load-Flow solution can work with multiphase and unbalanced networks.

- **The control system devices are disconnected and not solved**

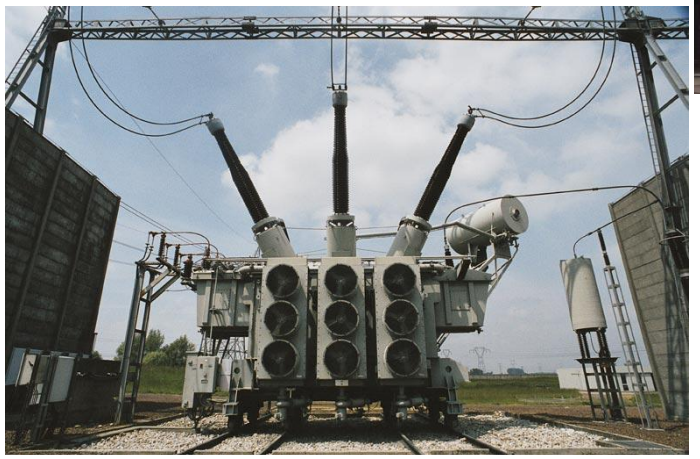
- The solution results can be loaded for **automatically initialization**

Transformer models

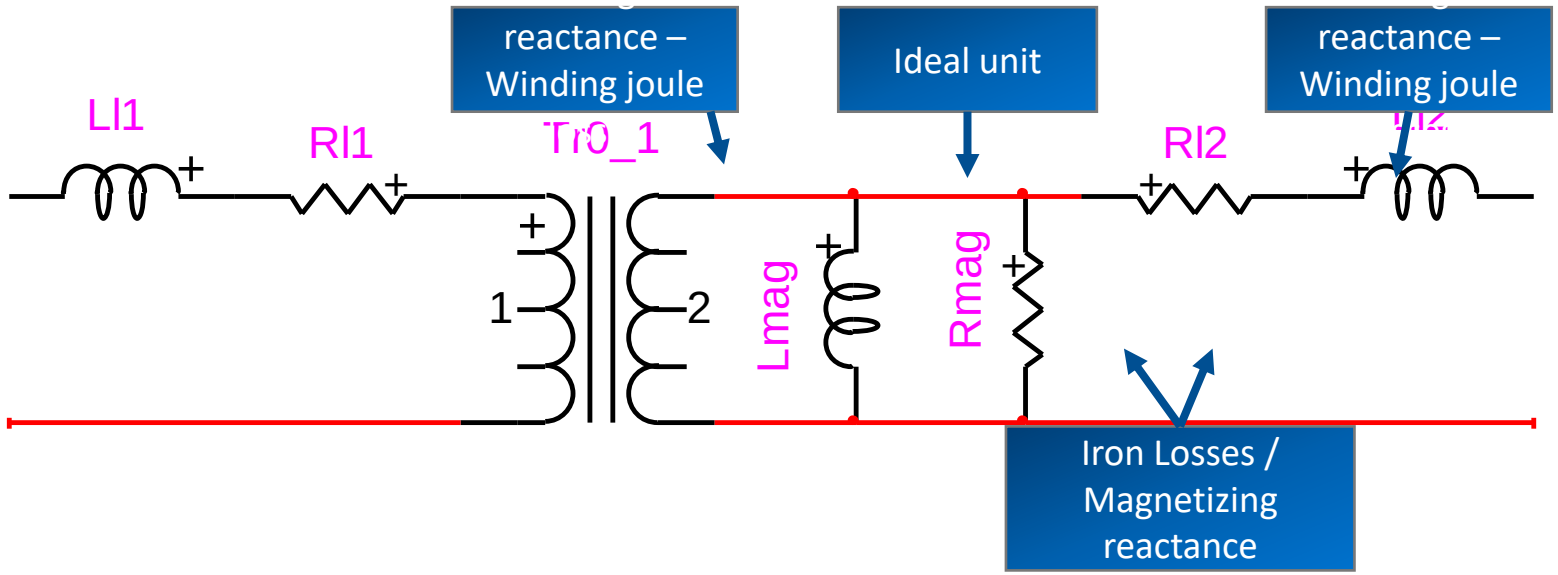
1.3 Basics on power transformers

3 single phase units in power plant

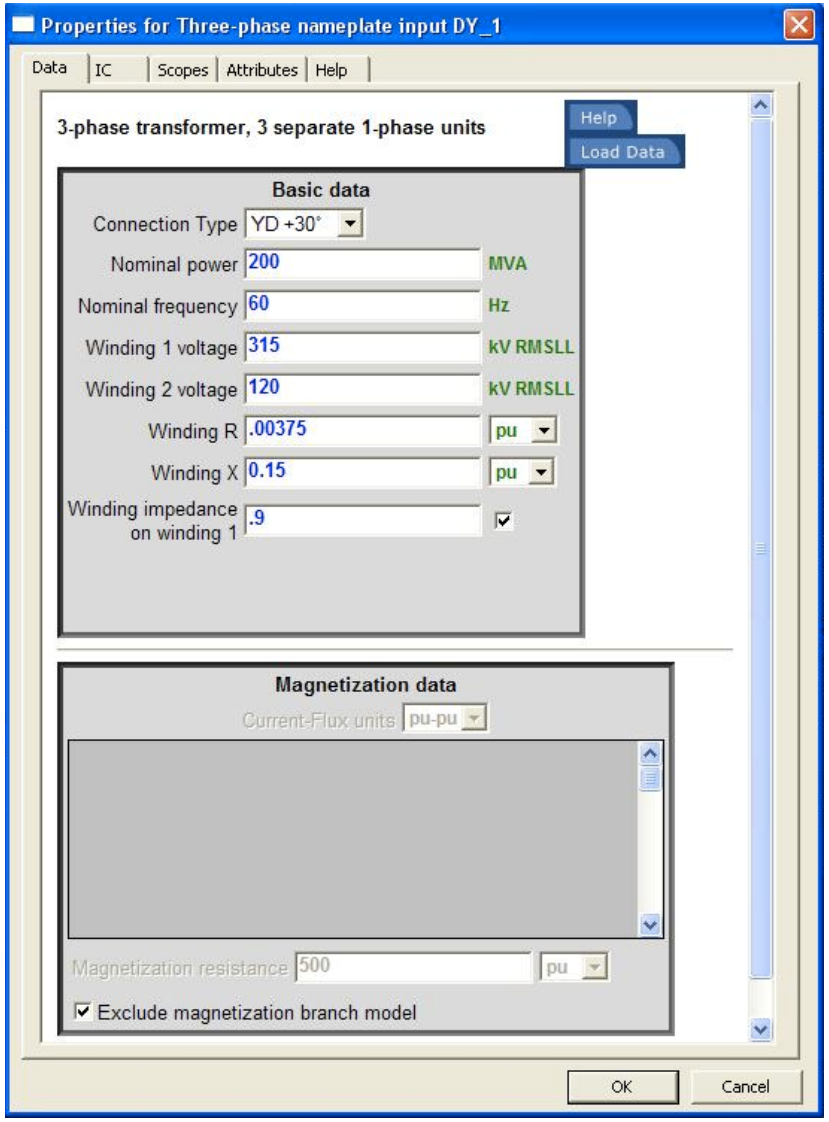
3-phase unit, transmission system network



Transformer model – Non-ideal 1 phase unit



Transformer models – Three-phase nameplate input



Transformers.clf > Three-phase nameplate input

Input data:

- Connection Type
- Nominal power & frequency
- Windings voltages
- Winding impedance
- Magnetization data (for saturation)

The “L non Linear Data Function” calculates the magnetization data from excitation tests.

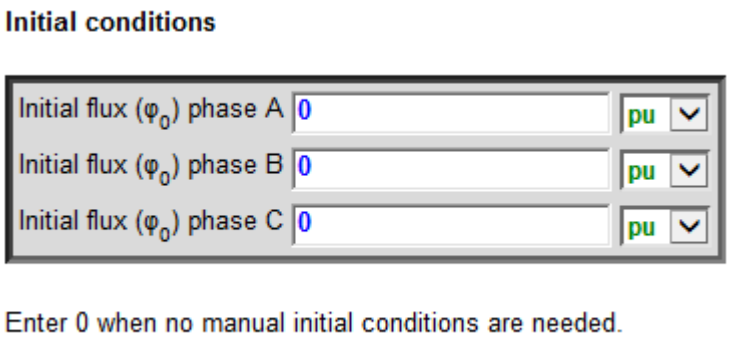
L nonlinear
Data function

Transformer models – Three-phase nameplate input

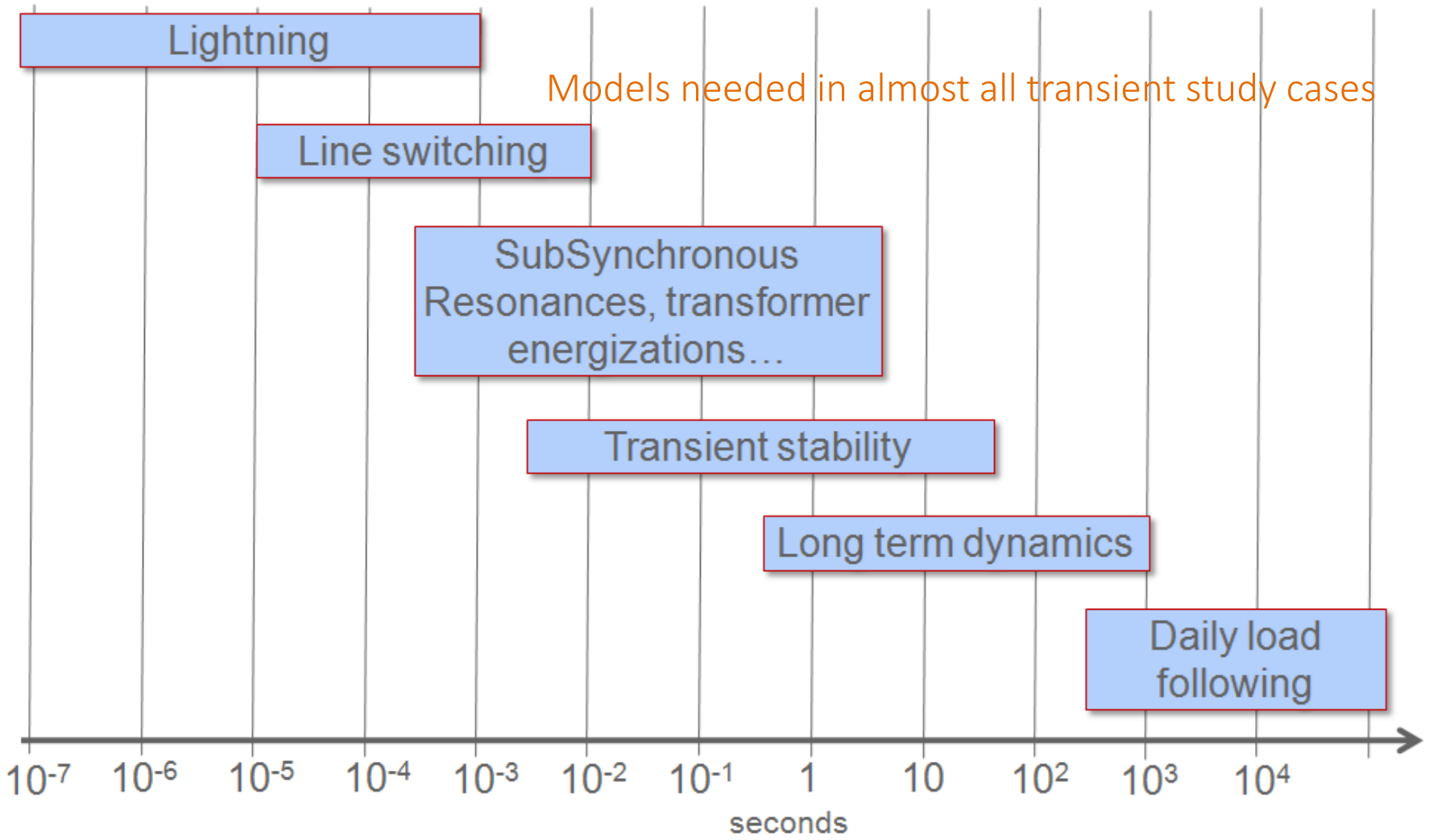
Transformer.clf > Three-phase nameplate input

Initial conditions:

- Possibility to set initial flux on each winding unit to simulate residual flux.

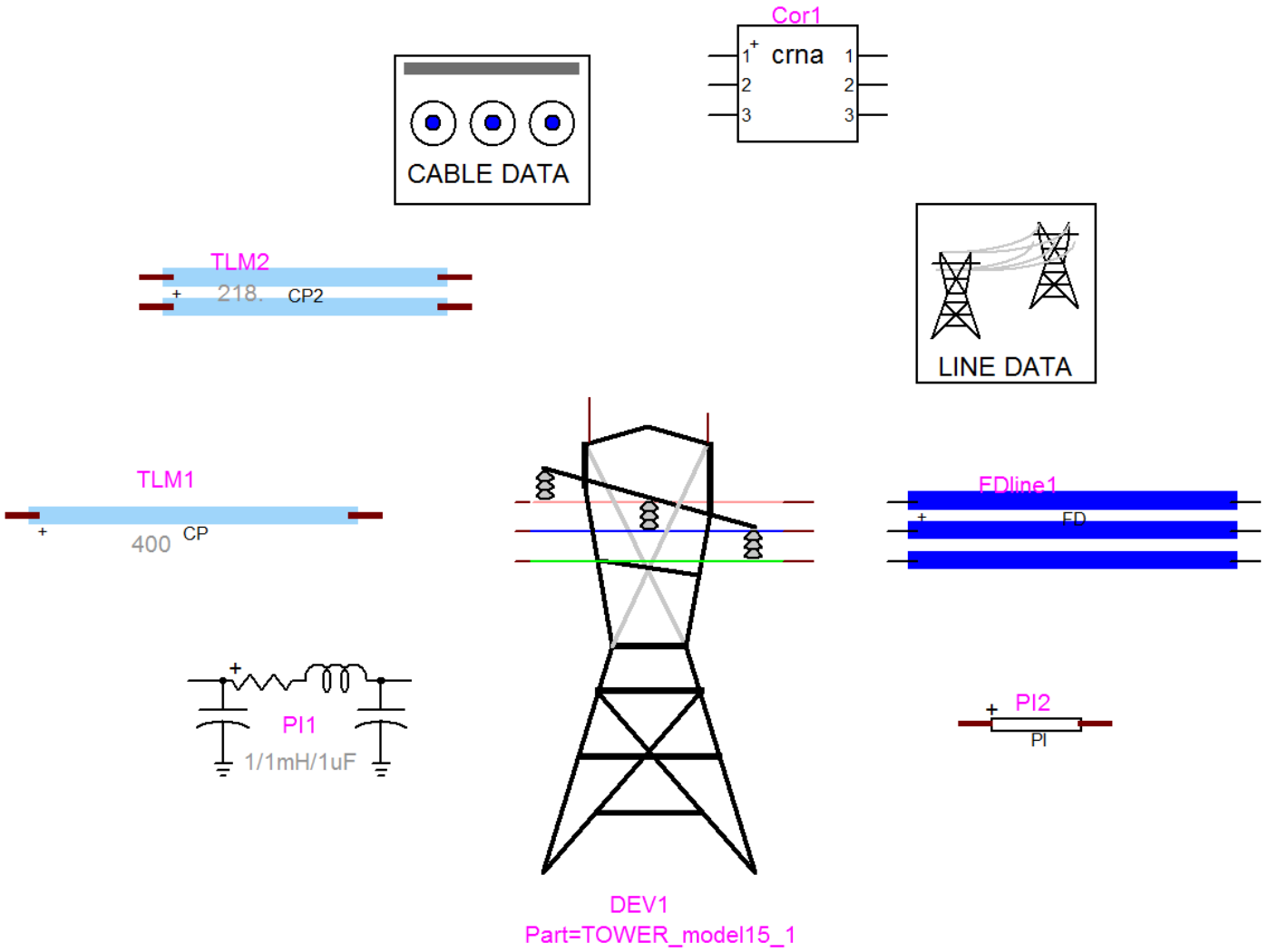


Transmission line models



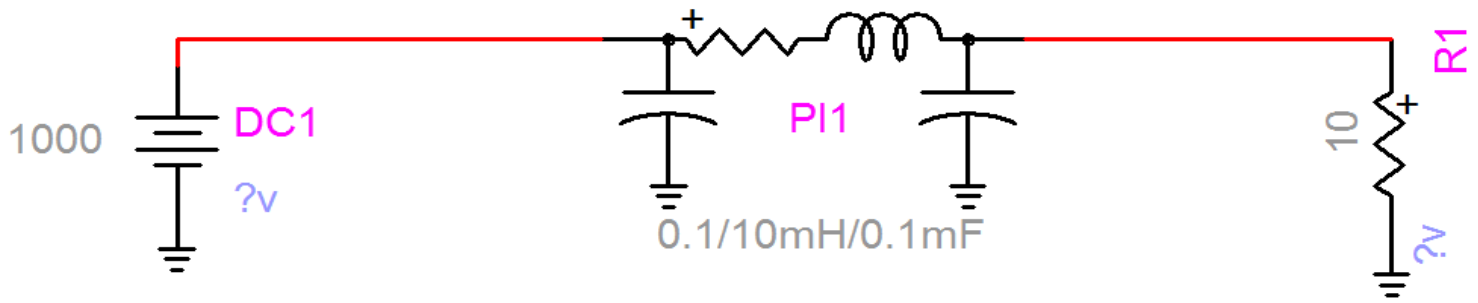
Models needed in almost all transient study cases

EMTP lines Library



PI models

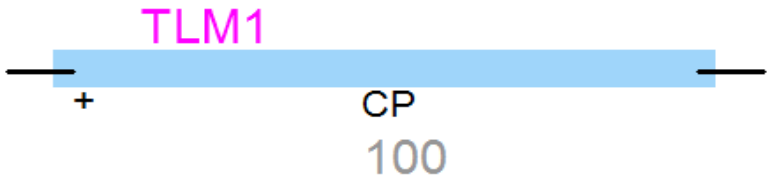
- simple and fastest model
- Valid for phasor domain
- Propagation not taken into account
- Not accurate on a large frequency band
- Valid for short cable/line



CP models

An infinite number of PI cells in series

- Propagation taken into account
- Not accurate on a large frequency band
- Only for time-domain



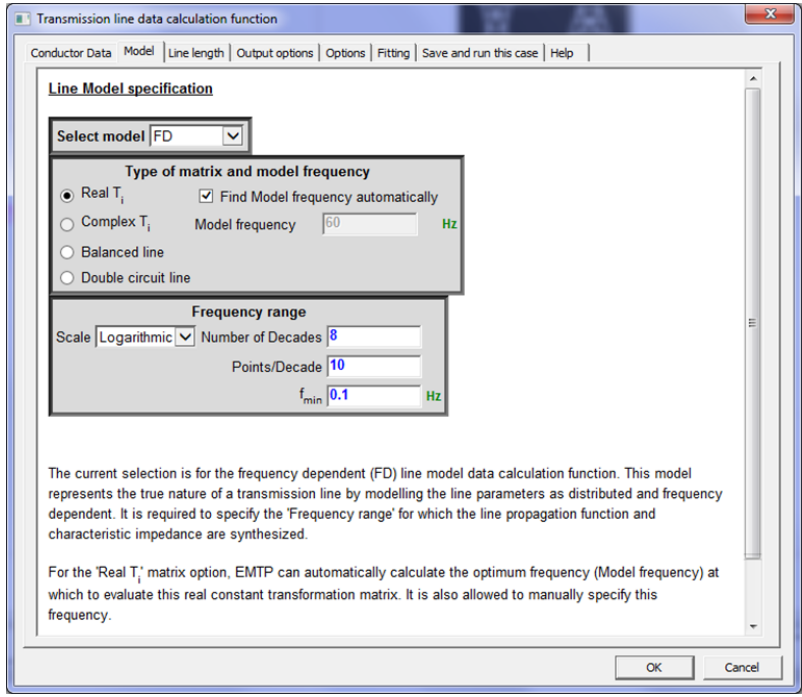
FD / FD-Q models

- FD/FD-Q model :
  - Propagation taken into account accurate on a large frequency band
  - The Ti of the FDQ is frequency-dependent. It is usually used for cables only.

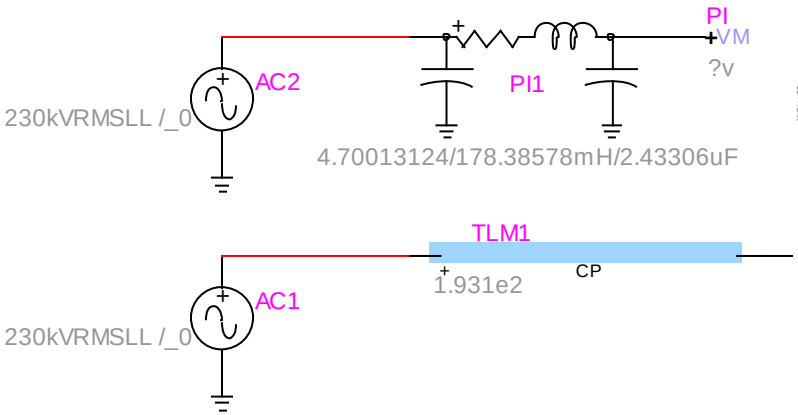
- **WB** model :

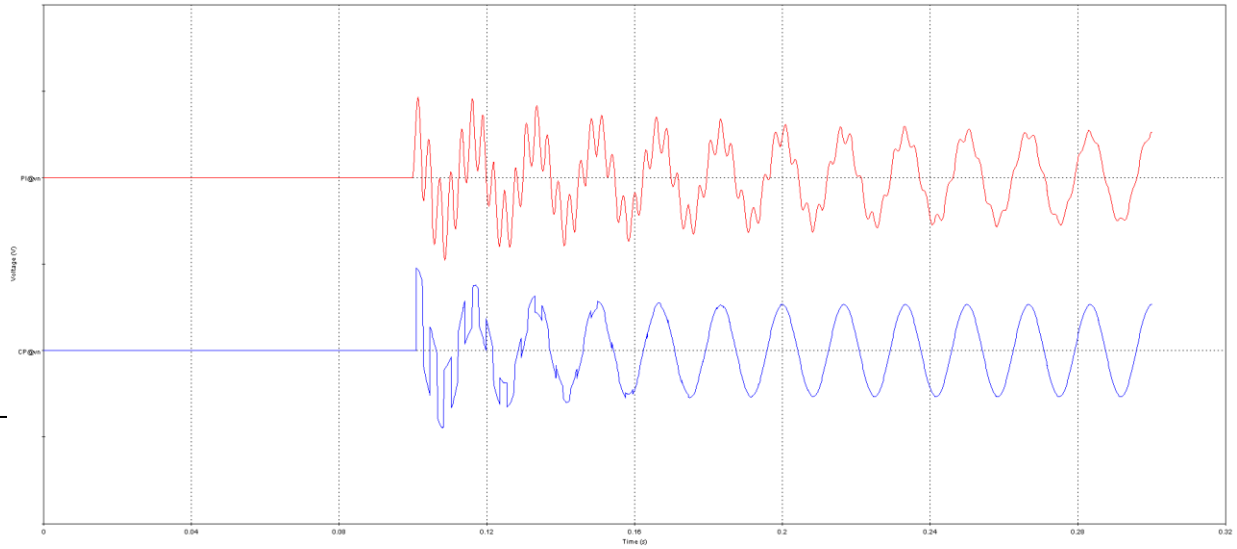
  Complex model
  Very accurate

  Require the Wideband line/cable fitter

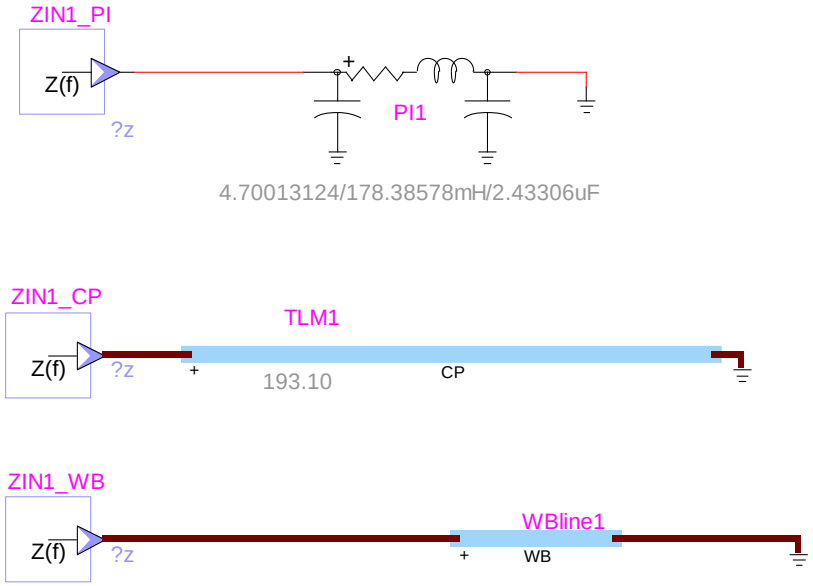


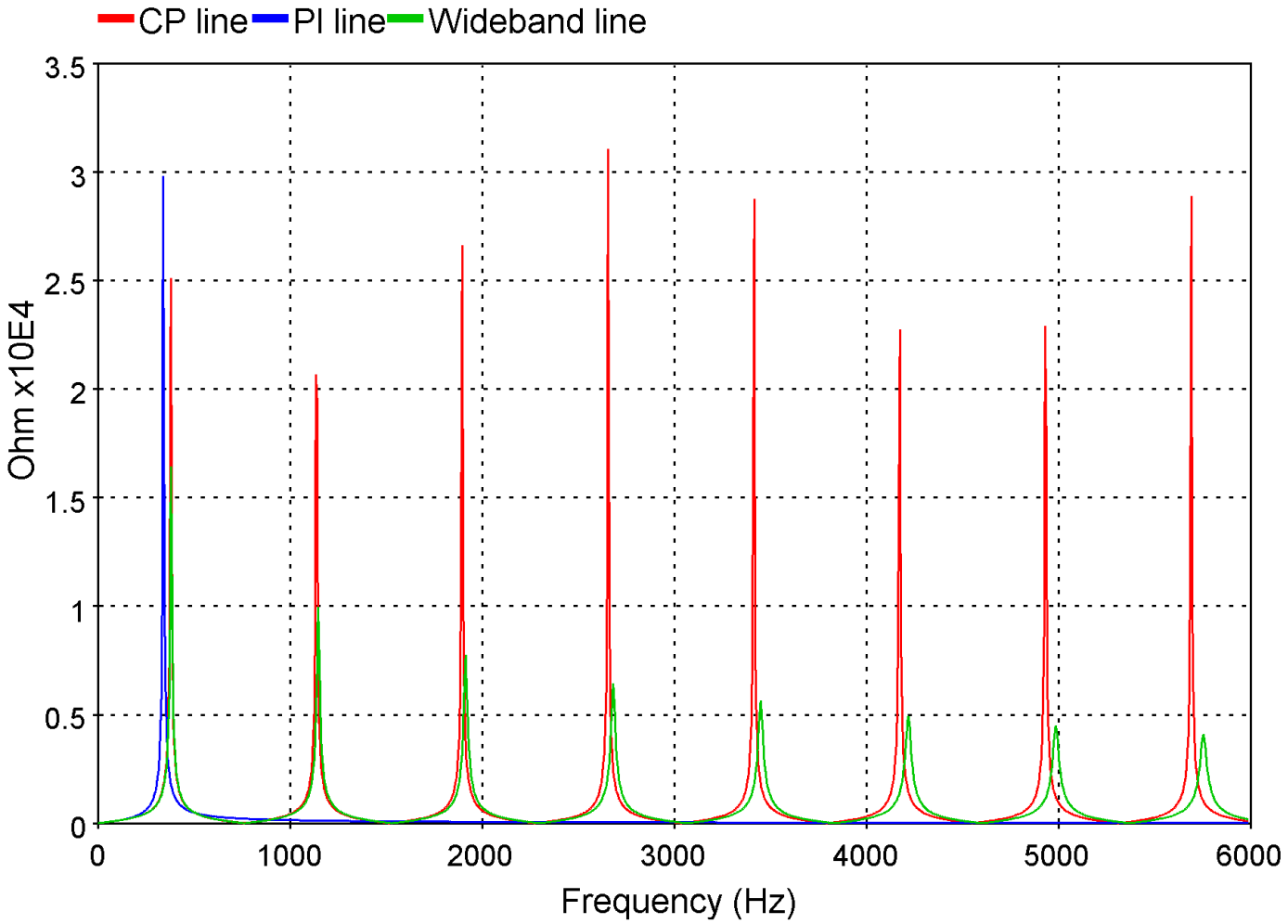
Model comparison (PI & CP)





Model comparison (PI & CP)



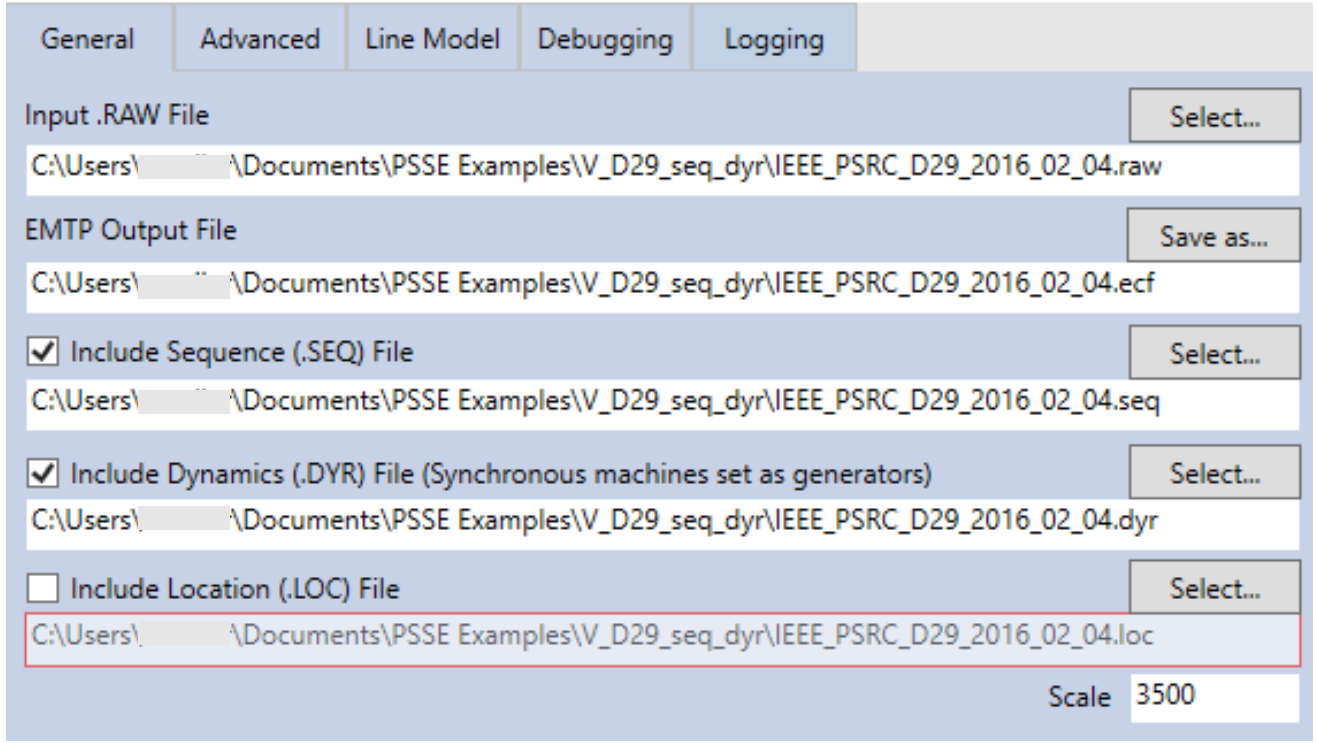


Line and cable models

Study	PI	Exact-PI	CP	CP @50kHz	FD	WB
Load-Flow and low-frequency transients	OK		OK		OK	OK
Harmonic analysis		OK in Frequency Domain			OK	OK
Switching Analysis					OK	OK
Ferroresonance					OK for Lines	OK
Lightning				OK	OK	OK

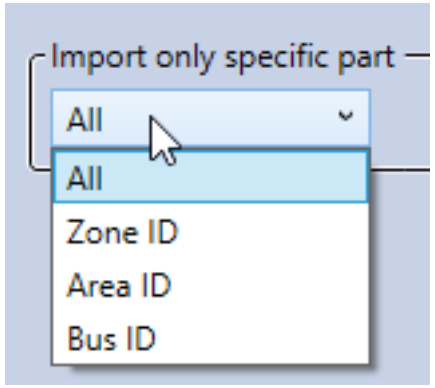
PSS/E import tool

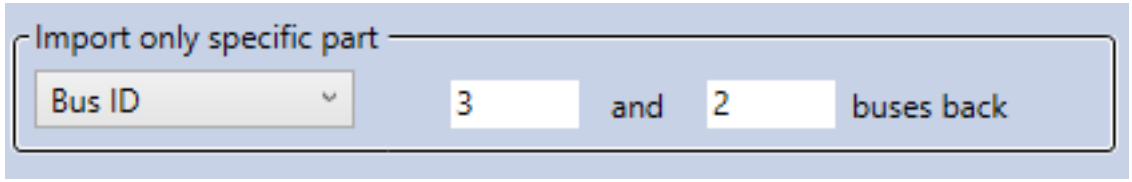
- How to import complete PSS/E case.

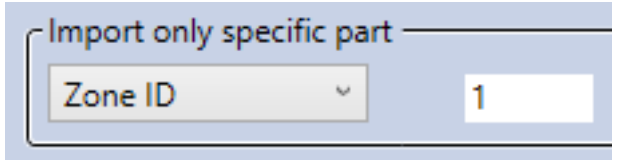


PSS/E import tool

➢How to import using system reduction.



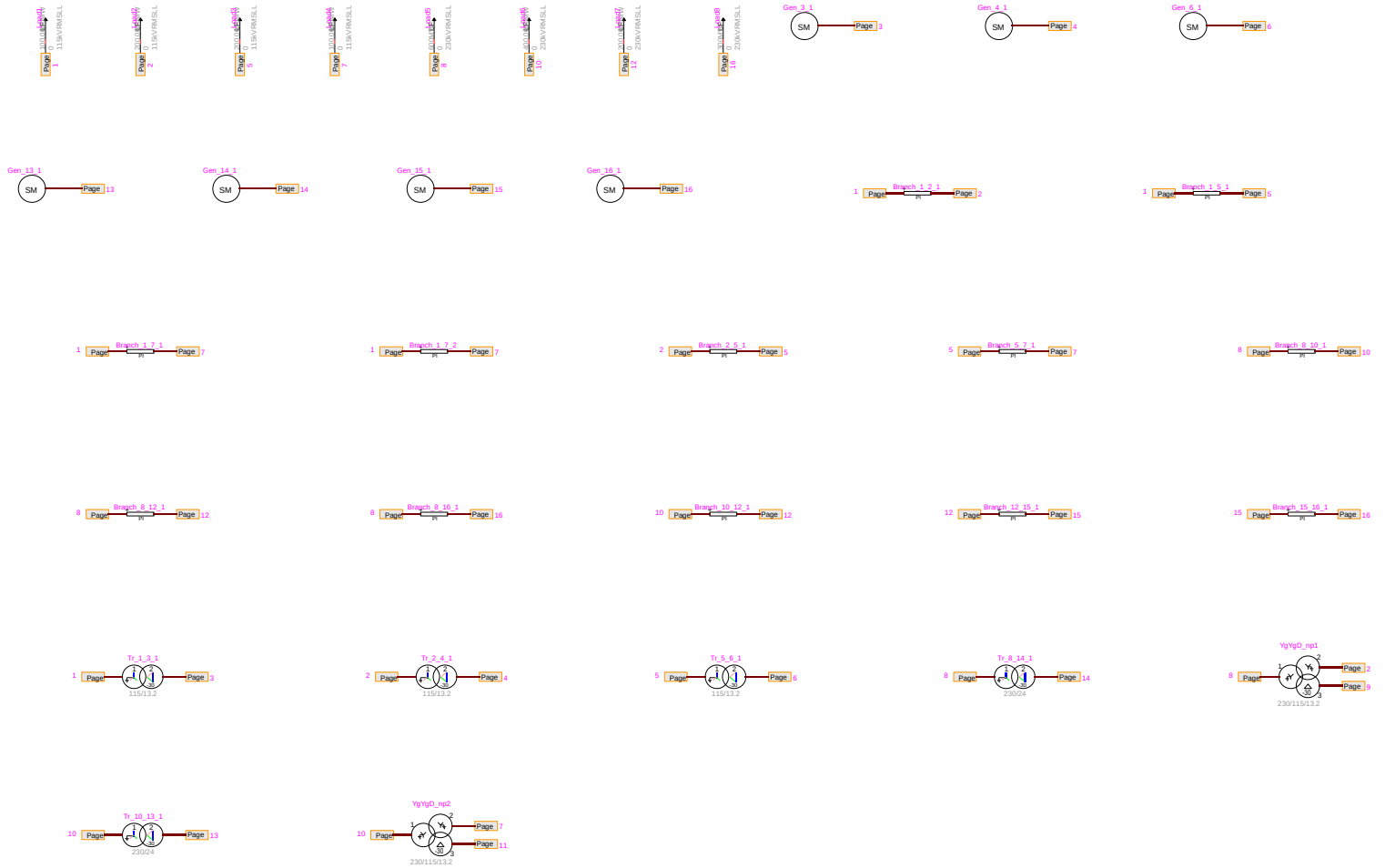




PSS/E import tool

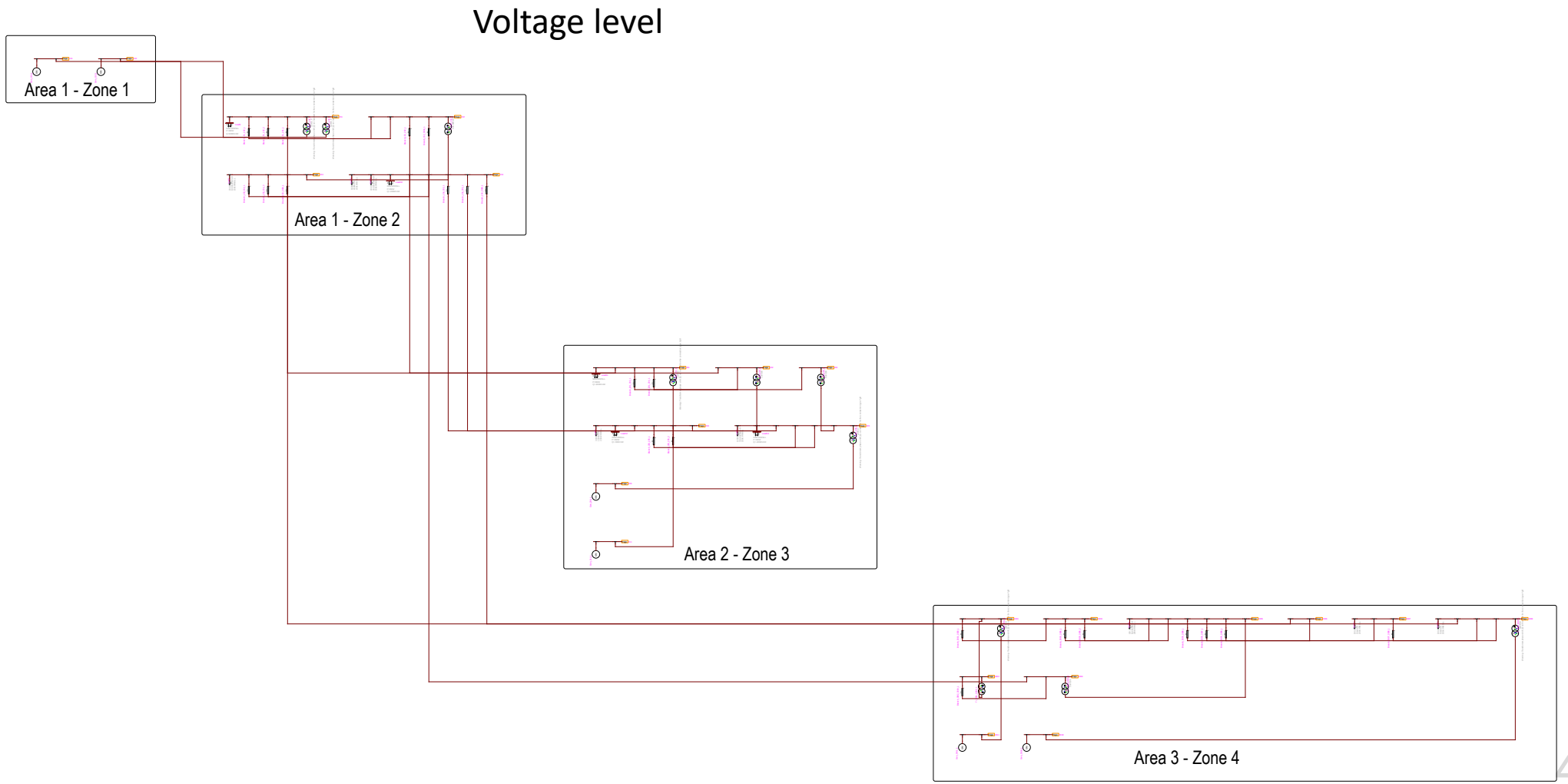
- Import options if not .loc.

Virtual connections



PSS/E import tool

- Import options if not .loc.



PSS/E import tool

➢User custom devices.

ID of the section in RAW file

Relative position of the row in RAW file where is the 'Identifier' of device

Relative position of the column in RAW file where is the 'Identifier' of device

Library containing user custom device

Name of the Part in the library containing user custom device

	A	B	C	D	E	F	G
1	Section	row of the Identifier	column of the Identifier	Identifier	full path to the library file	Part Name	full path to the script file
2	TWO-TERMINAL DC	1	1	POL1	C:\\myscripts\\testLib.clf	testPartA	C:\\myscripts\\testScript.dwj
3	TWO-TERMINAL DC	1	1		C:\\myscripts\\testLib.clf	testPartB	C:\\myscripts\\testScript.dwj
4	TWO-TERMINAL DC	1	1	POL2	C:\\myscripts\\testLib.clf	testPartA	C:\\myscripts\\testScriptB.dwj
5							

If 'Identifier' of the device is indicated then user's script for importing will be used only for importing device(s) having same 'Identifier'.
If 'Identifier' of the device is not indicated then user's script for importing will be used for importing all devices in this section.

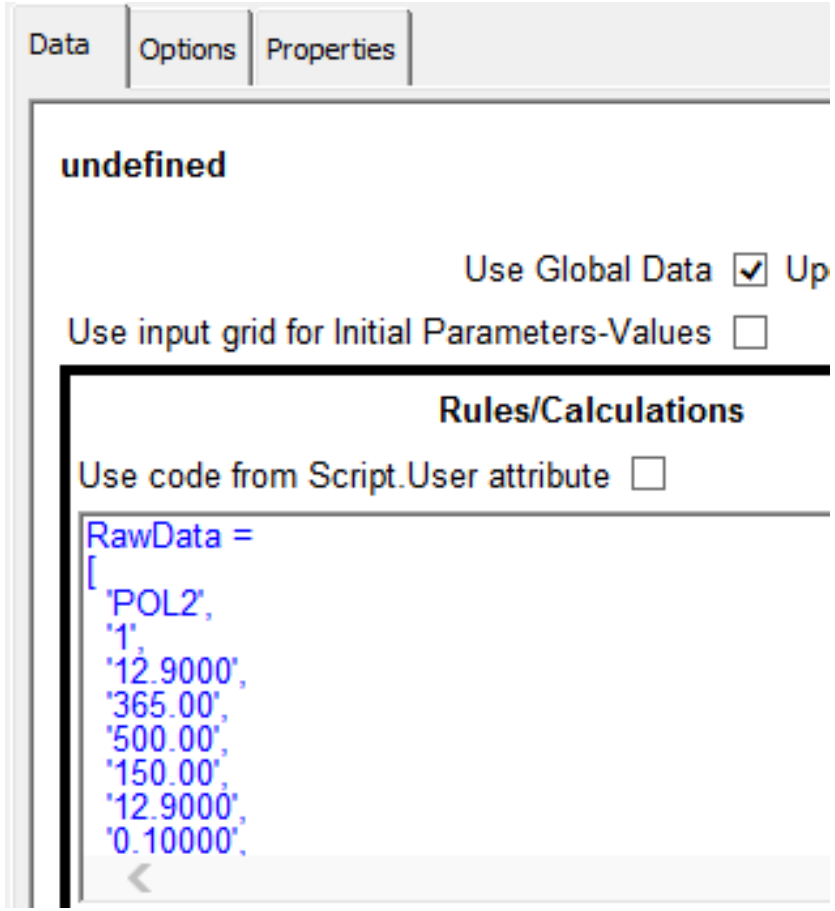
Script used to load the user custom device

```
41  0 / END OF AREA DATA, BEGIN TWO-TERMINAL DC DATA
42  ...
43  "POL2         ",1,    12.9000,     365.00,     500.00,     150.00,    12.9000,    0.10000,'I',       0.00,   20, 800.00000
44  2339,   2,18.00,12.50, 0.2570,10.2760, 400.0,0.51950,1.04000,1.20000,0.94000,0.01000,      0,      0,      0,'1 ', 0.0000,   0
45  8050,   2,22.00,18.00, 0.2570,10.2760, 400.0,0.51950,1.04000,1.20000,0.94000,0.01000,      0,      0,      0,'1 ', 0.0000,   0
46  "POL1         ",1,    12.9000,     365.00,     500.00,     150.00,    12.9000,    0.10000,'I',       0.00,   20, 800.00000
47  2339,   2,18.00,12.50, 0.2570,10.2760, 400.0,0.51950,1.04000,1.20000,0.94000,0.01000,      0,      0,      0,'1 ', 0.0000,   0
48  8050,   2,22.00,18.00, 0.2570,10.2760, 400.0,0.51950,1.04000,1.20000,0.94000,0.01000,      0,      0,      0,'1 ', 0.0000,   0
49  ...
50  0 / END OF TWO-TERMINAL DC DATA, BEGIN VSC DC LINE DATA
```

Notice that in this example device 'POL2' spans on 3 rows beginning on row 43 and the Identifier 'POL2' is on the first row therefor in CSV file the 'row of the Identifier' is 1

PSS/E import tool

- User custom devices.



Data to be used in script for custom device

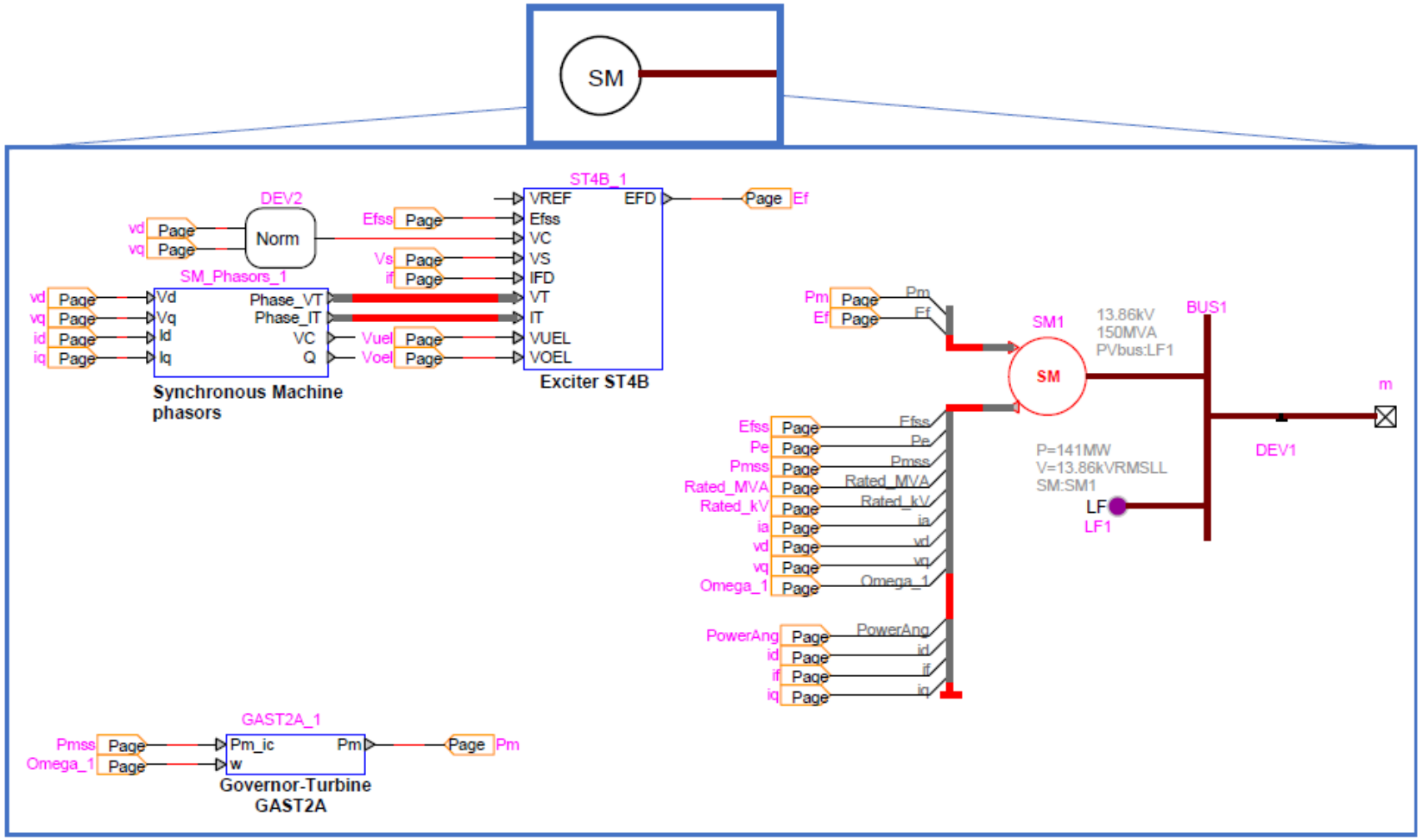
PSS/E import tool

- Line options

Line length may be estimated and distributed line model may be used.

PSS/E import tool

- Machines



QUESTIONS

Henry Gras
COO