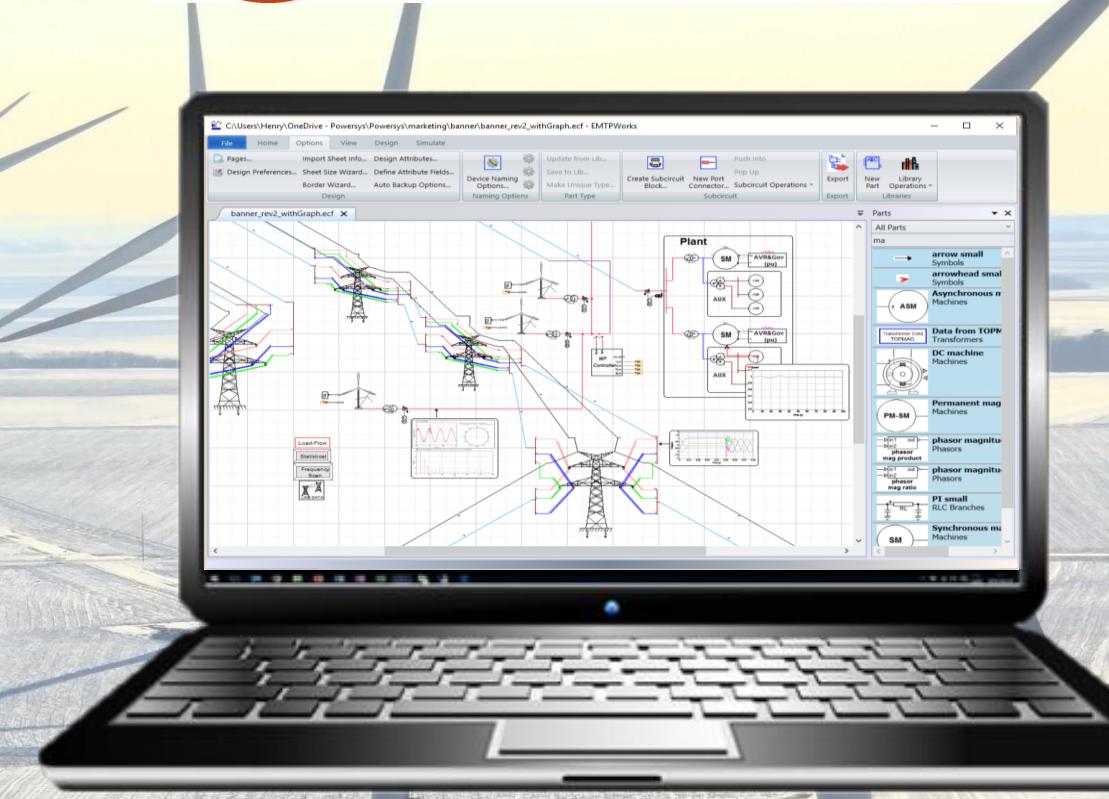


Introduction to EMTP®

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COO

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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?

- 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



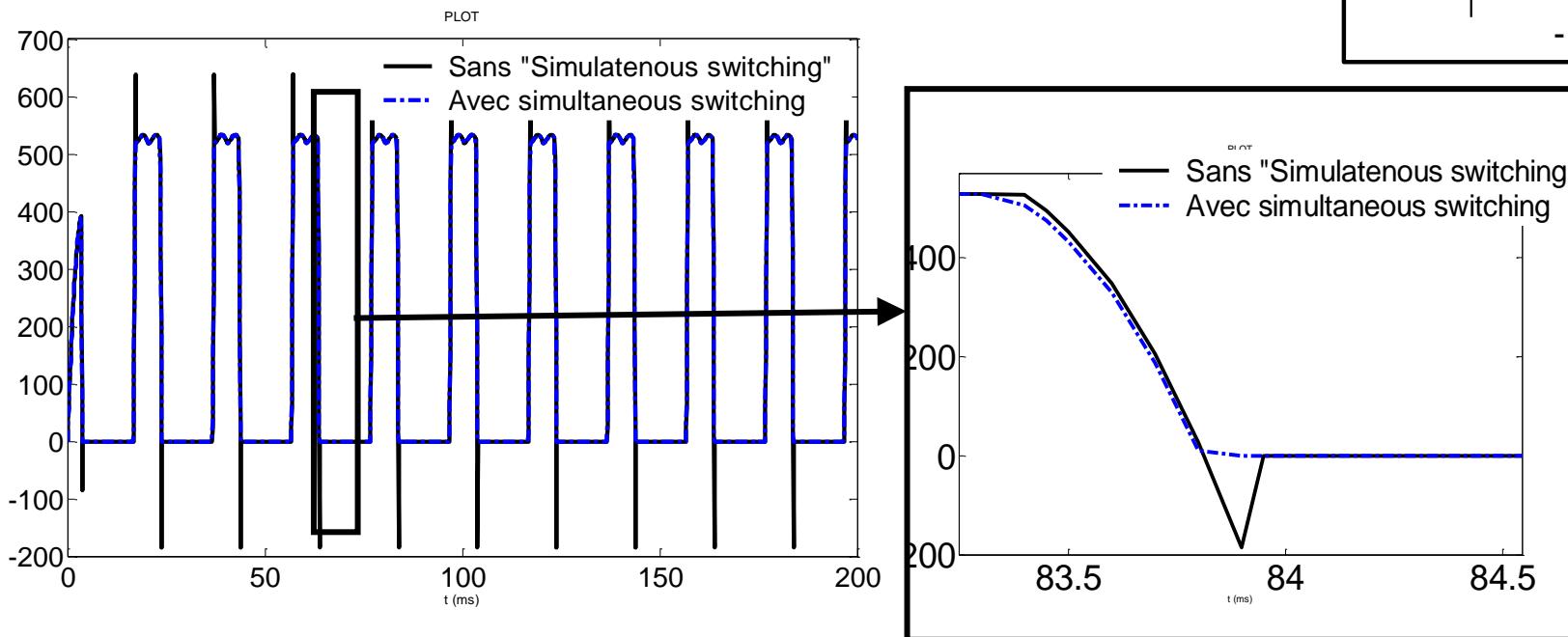
- How EMT[®] answers the challenges?
- Precision: EMT[®] provides a pure mathematical solver
 - Fully iterative solver for non-linear power components (IGBT, surge-arrester, saturation, etc)



EMT simulation objectives and challenges



- Diode switching with no iteration

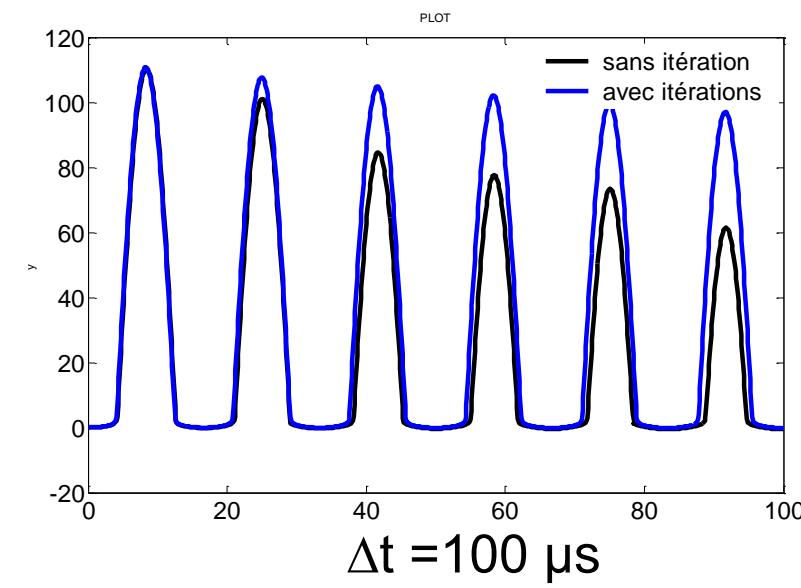
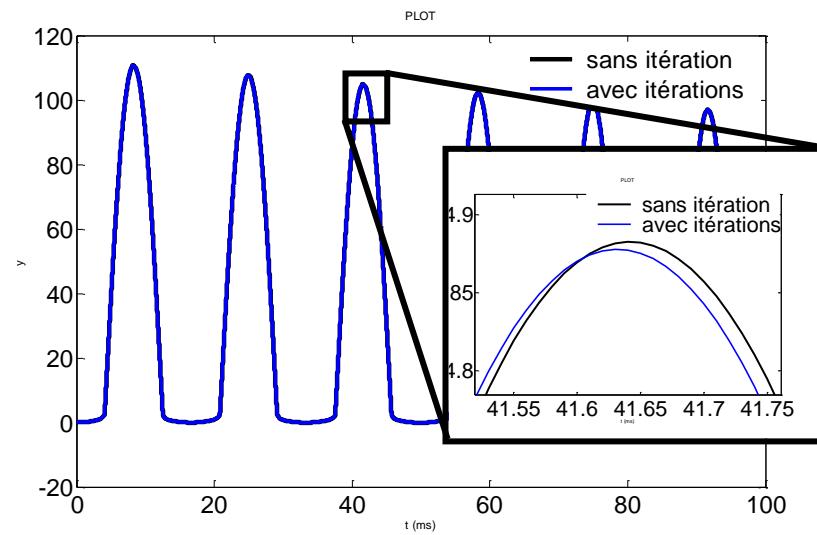
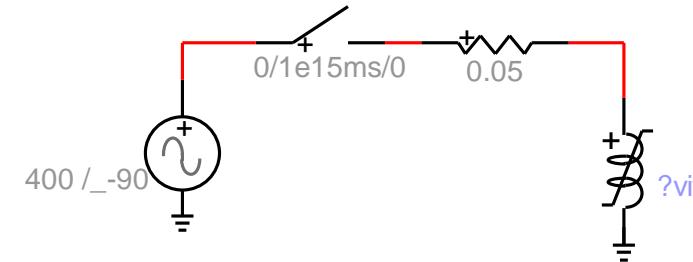




EMT simulation objectives and challenges



- Transformer energization with no iteration



EMT simulation objectives and challenges

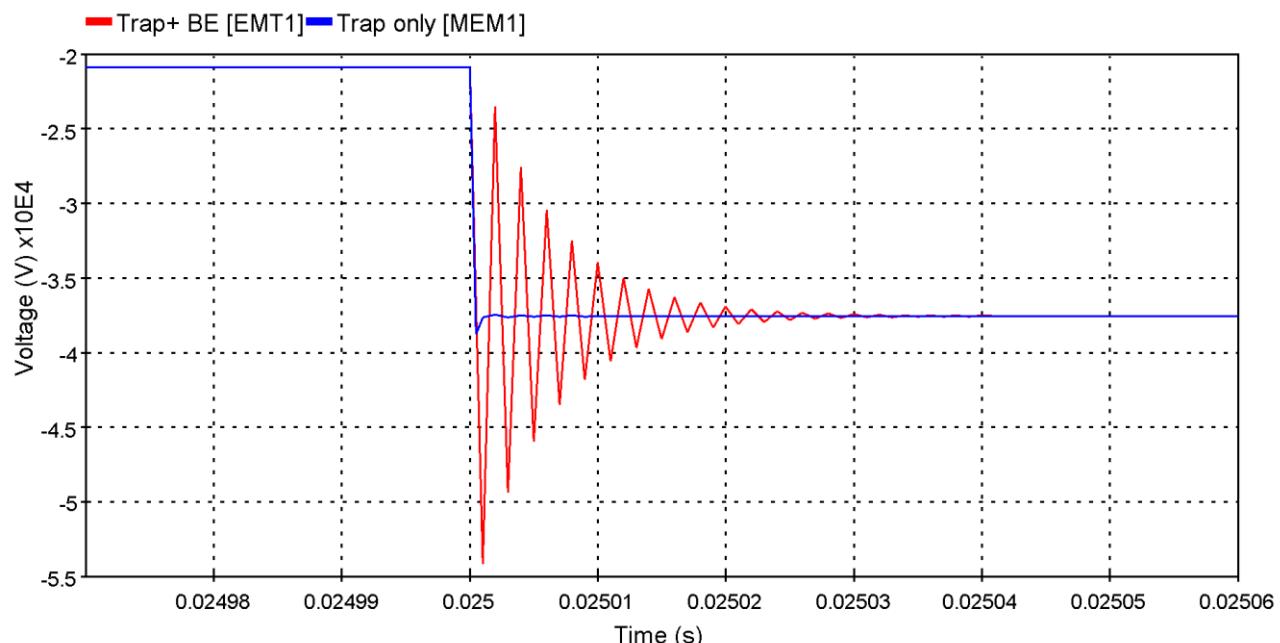


- How EMTP® answers the challenges?
- Precision: EMTP® provides a pure mathematical solver
 - Fully iterative solver for non-linear power components (IGBT, surge-arrester, saturation, etc)
 - Iterates control when algebraic loops are present

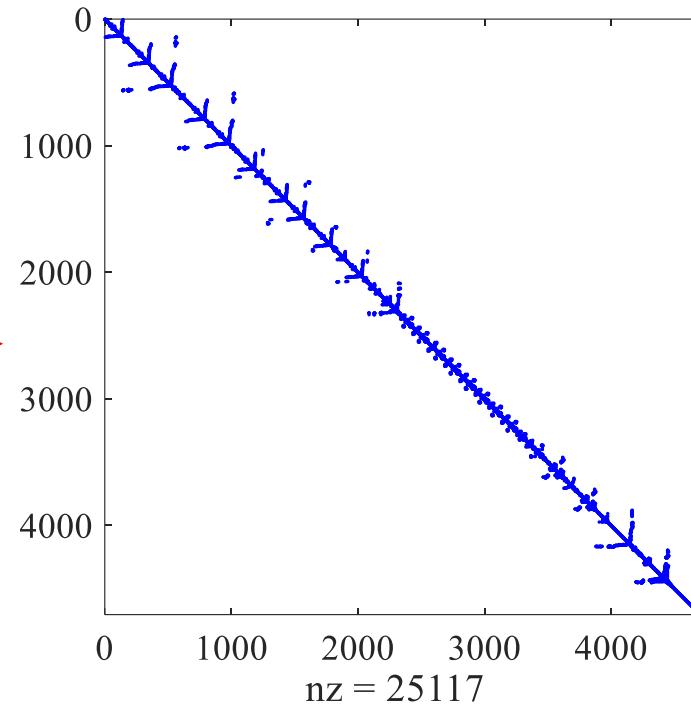
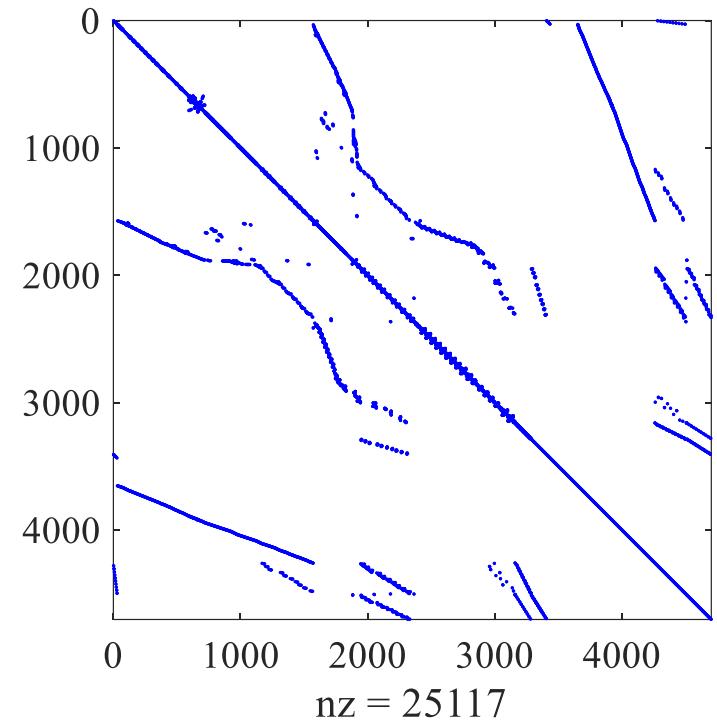
EMT simulation objectives and challenges



- 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



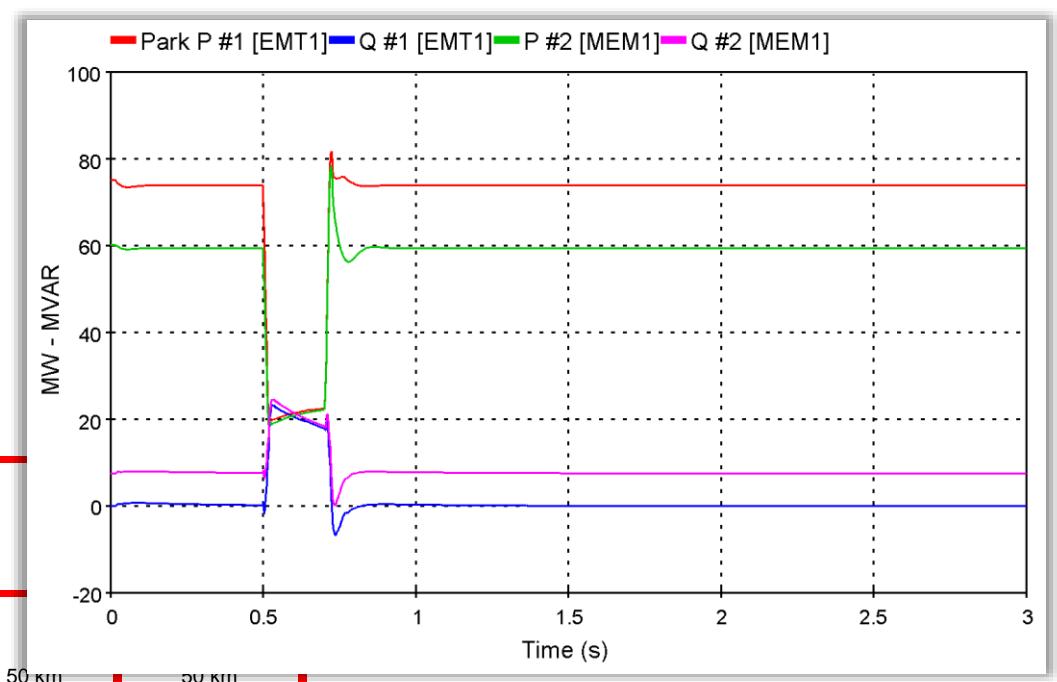
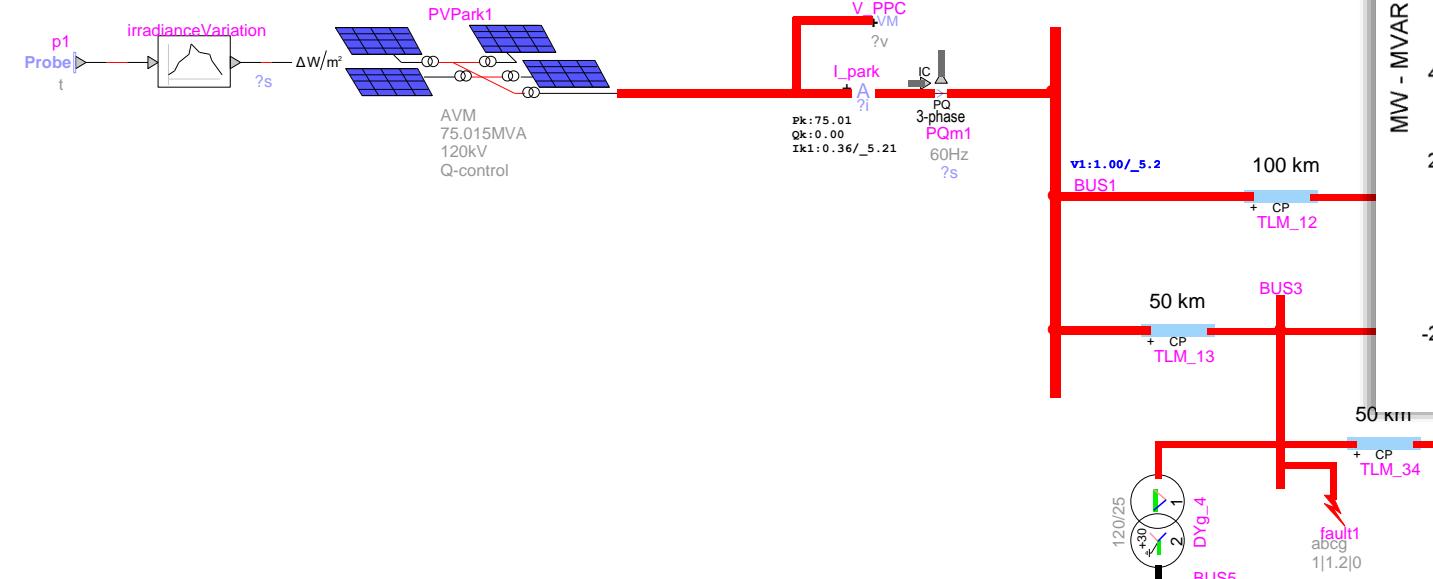
- How EMTP® answers the challenges?
- Speed: EMTP® uses innovative matrix solver technics
 - Modified augmented nodal analysis - example: power amplifier
 - Uses KLU-based sparse matrix solver
 - Uses partial refactorization
 - User parallel processing (costly)



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 parallel 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



simple.ecf - EMTPWorks

Menu

Tabs

Design

Simple example

Diagram illustrating the design interface:

- Named signal: SOURCE
- Device: RL1
- Device name: SW1
- Value attribute: 0.57uF
- Description attribute: ?vi

Library

Parts by Library

- advanced.clf
- control functions.clf
- control.clf
- DC.clf
- etap import tool.clf
- flip flops.clf
- lines.clf
- load models.clf
- machine controls.clf
- machines.clf
- meters.clf
- nonlinear.clf
- options.clf
- phasors.clf
- pseudo devices.clf
- RLC branches.clf
- sources.clf
- switches.clf

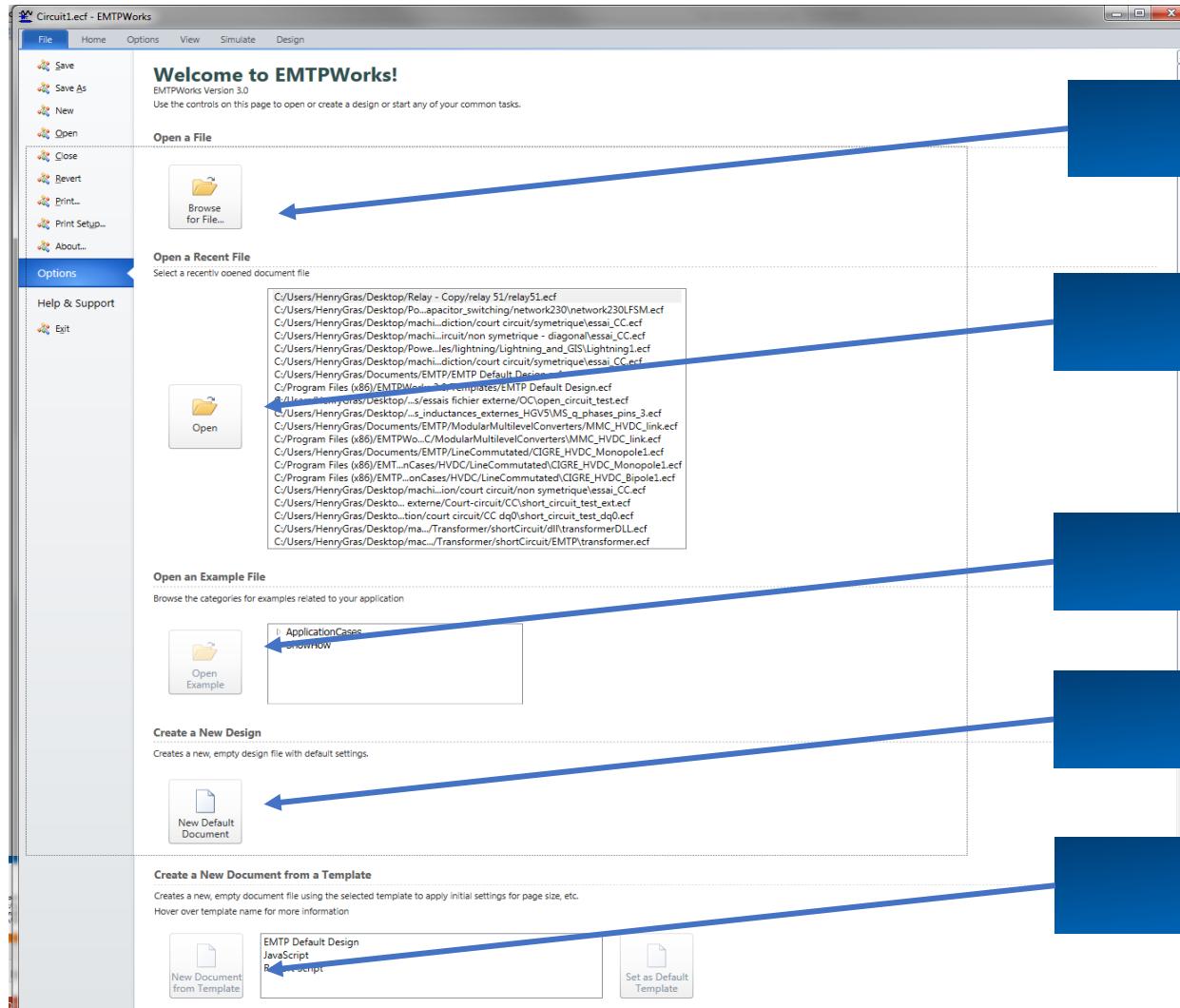
Console / Panel

simple

	Ended		CPU: .39000s
Step	End	%	Case web Steady-State web

Ended Steady-state solution
Ended Time-domain solution

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

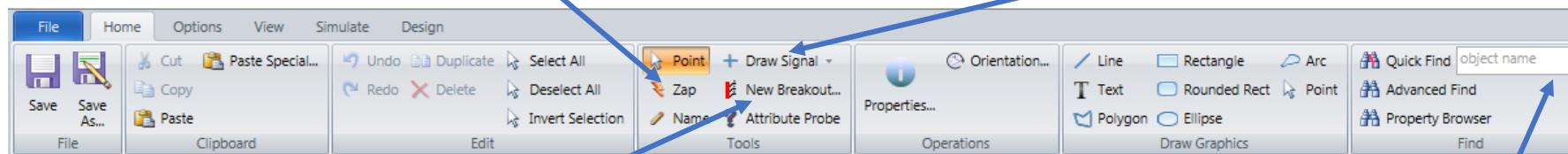
Presentation of the GUI: EMTPWorks



➤ 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

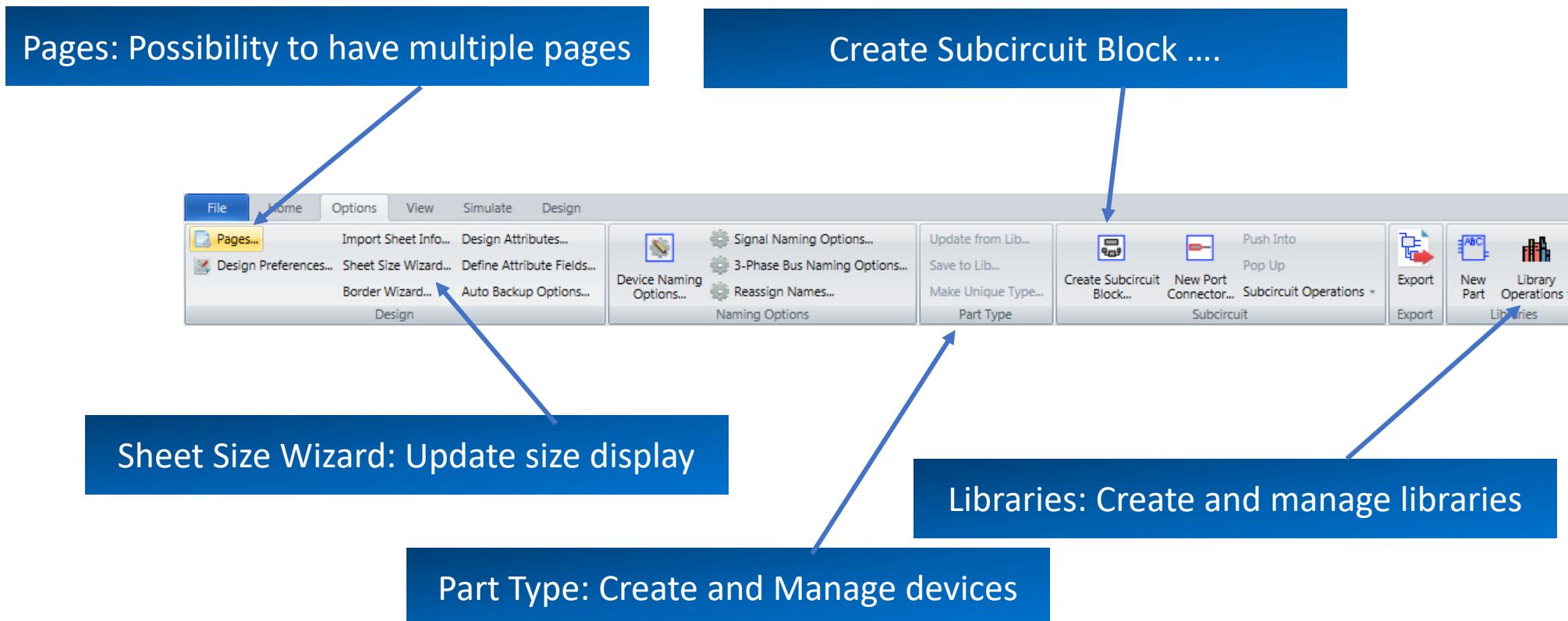
Draw Graphics

- 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



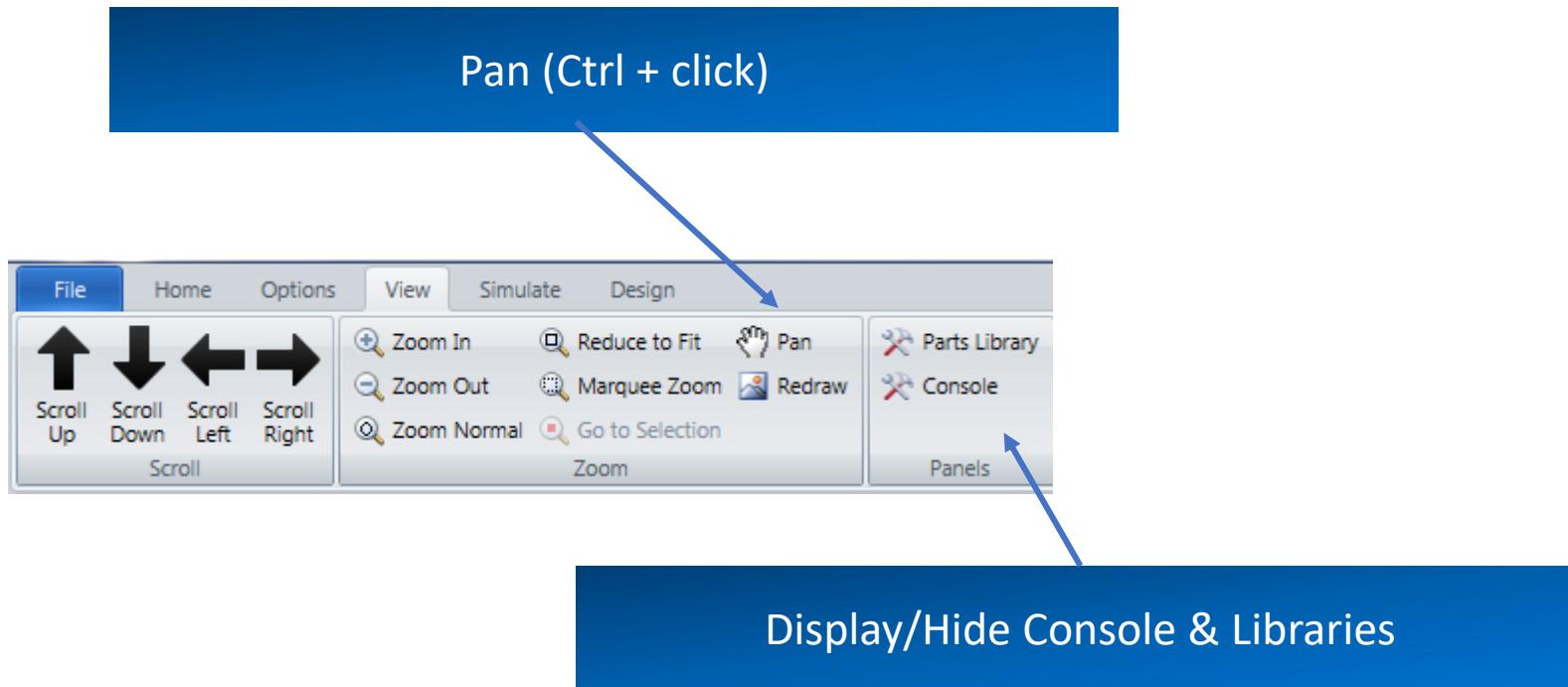
➤ Options menu



Presentation of the GUI: EMTPWorks



➤View menu

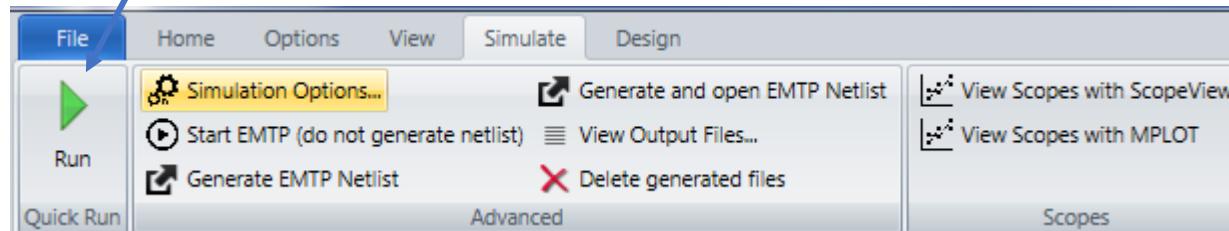


Presentation of the GUI: EMTPWorks



➤ Simulate menu

Run a simulation



Open ScopeView and MPLOT

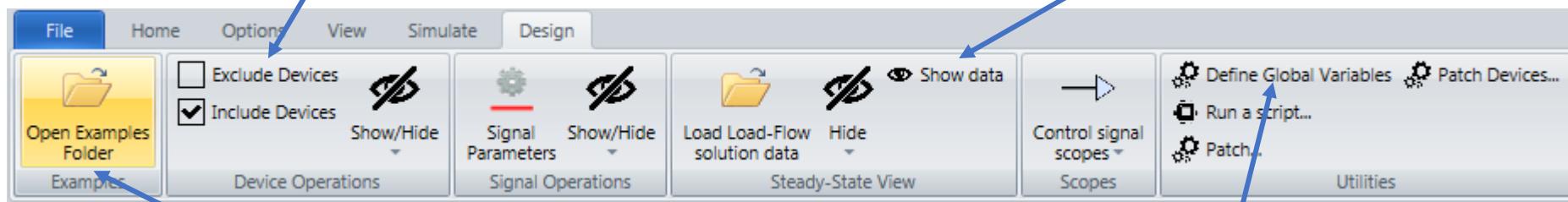
Presentation of the GUI: EMTPWorks



➤ Design menu

Possibility to Exclude/Include devices

Possibility to display and refresh
Steady-State Data



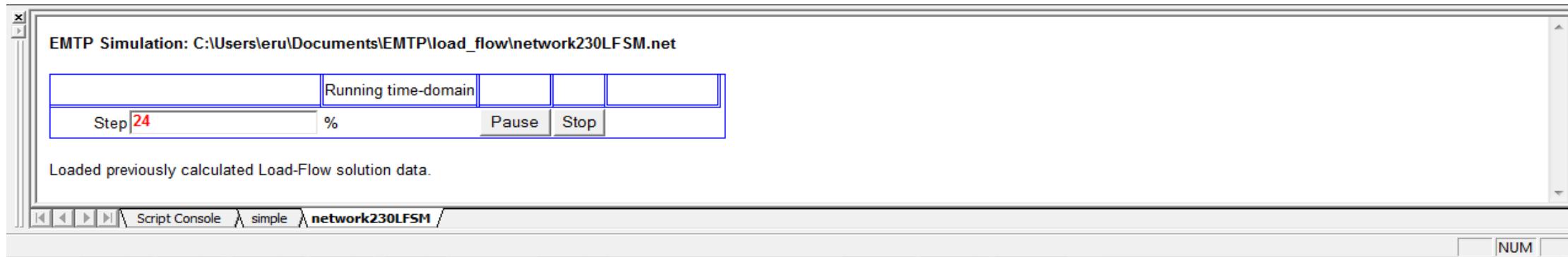
Open Examples Folder

Possibility to define Global Variables

➤Console

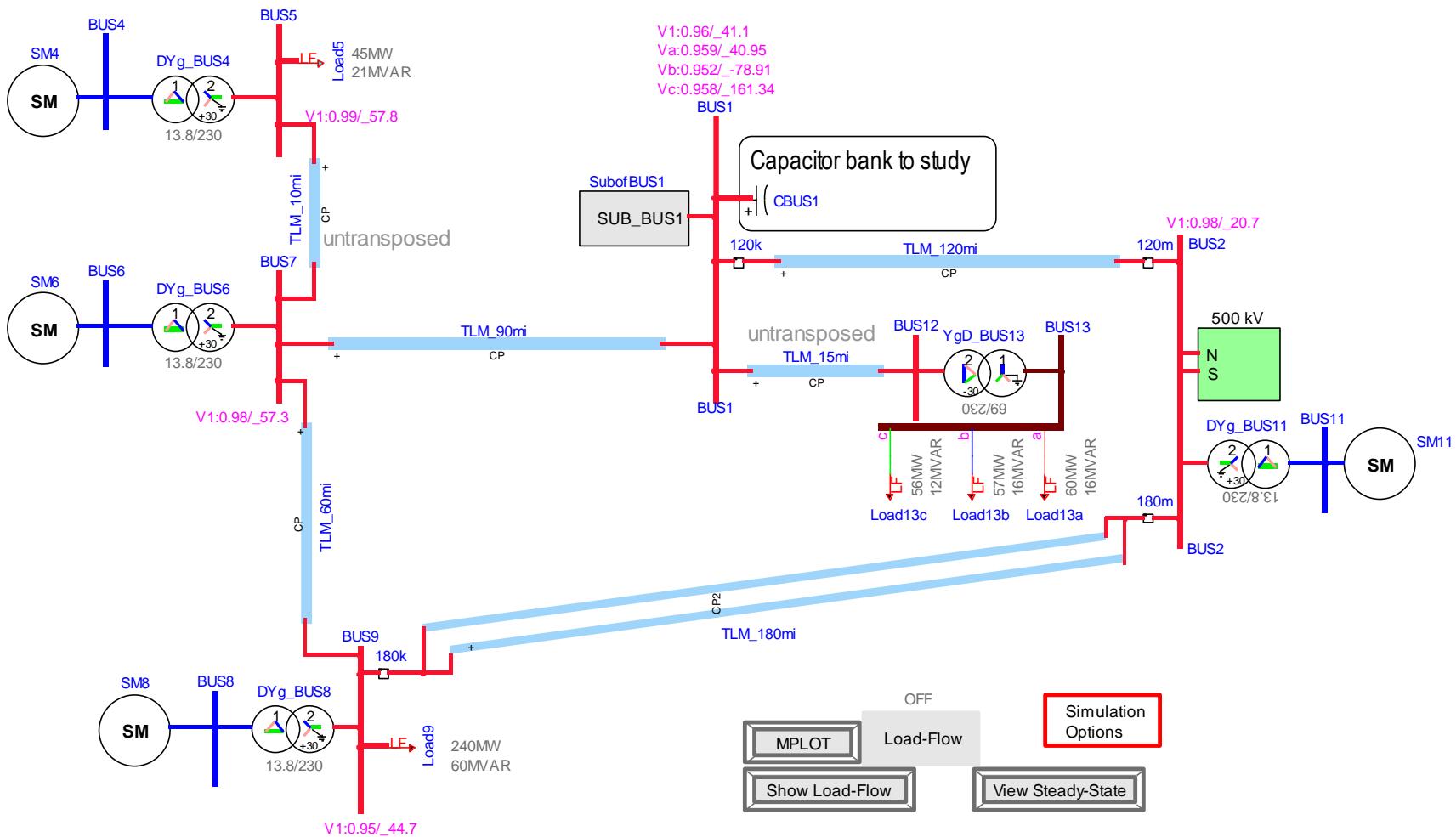
5. The Console

- 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



The screenshot shows the ScopeView application window. At the top, there's a menu bar with File, Edit, View, Data Source, Graph, and Help. Below the menu is a toolbar with various icons for file operations like Open, Save, and Print. A status bar at the bottom displays the Data Source as [EMT1] Am - Tue Mar 13 19:28:55 CET 2012 and the Signal Type as Branch Current. The main area is titled "Run to display your signals". On the left, under "Signals", there are two entries: C2b@ib and C2c@ib. A large orange callout box labeled "Select your data" points to the signal list. In the center, there are three buttons: "One/Multiple plot", "Log/SemiLog plot", and "Advanced features". Below these buttons is a control panel with "Signal Selection Mode" (radio buttons for Single and Multiple), "Graph Creation" (radio buttons for Normal and Superimposed), and "X Axis" and "Y Axis" settings (checkboxes for Grid and Log scales). There are also "Data" and "Page" tabs, and a page number input field set to 1. The bottom section is titled "Selected Signals" and contains a table:

Signal	Description	Show	Page
1		<input type="checkbox"/>	0

Two additional callout boxes are overlaid on the bottom left and right: "You can directly enter the equations" and "List of displayed signals".

Load Flow devices

- Device : Load Flow Bus (Library : Source)

Slack Bus

Slack: 13.8kVRMSLL/_0



LF1

PQ Bus

P=480MW
Q=480MVAR



LF2

Phase:0

PV Bus

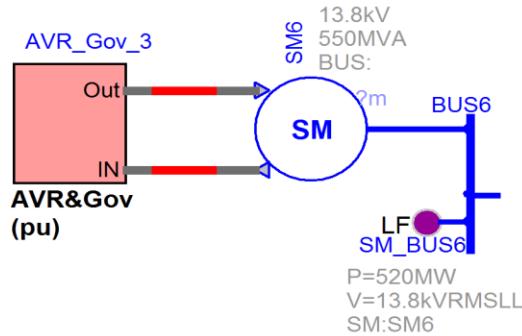
P=480MW
V=13.8kVRMSLL



LF3

Phase:0

- Can automatically retrieve impedance data from synchronous machine



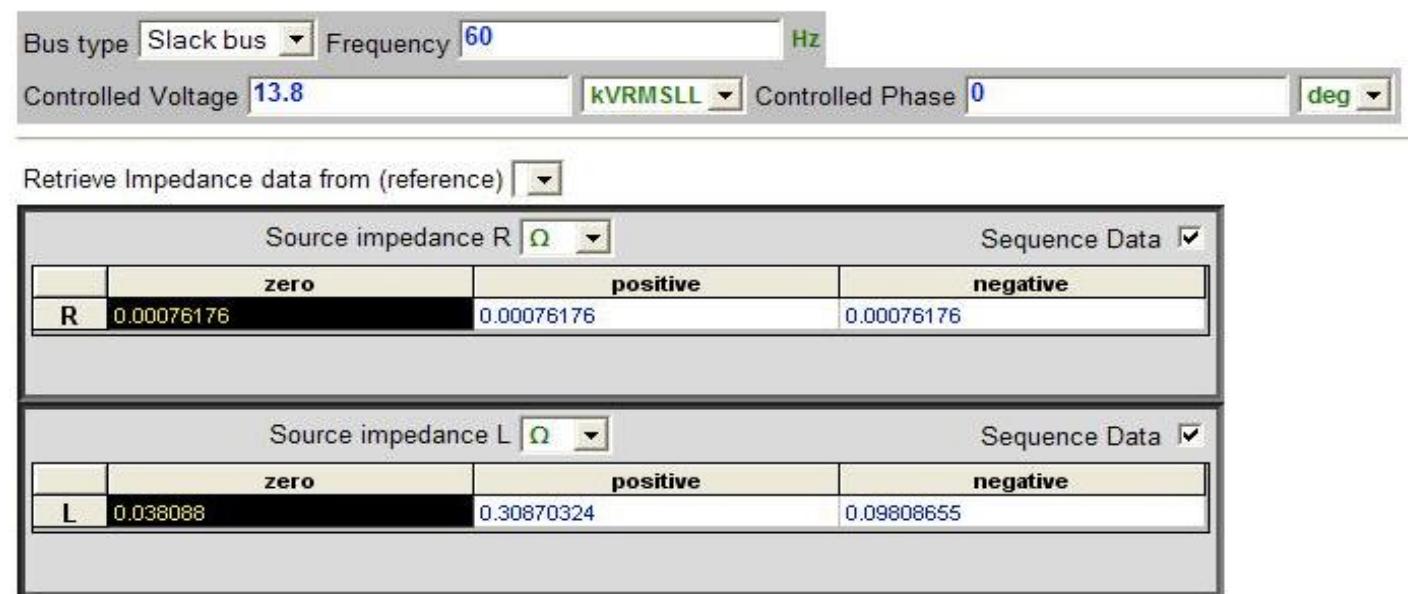
Slack Bus

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

Slack: 13.8kVRMSLL/_0



Load-Flow bus



The screenshot shows the "Load-Flow bus" configuration window. At the top, there are dropdown menus for "Bus type" (set to "Slack bus"), "Frequency" (set to 60 Hz), and "Controlled Voltage" (set to 13.8 kVRMSLL). The "Controlled Phase" is set to 0 degrees. Below these, there is a dropdown for "Retrieve Impedance data from (reference)". Two tables are displayed for source impedances:

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

P=480MW
V=13.8kVRMSLL
LF 
LF3
Phase:0

- **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

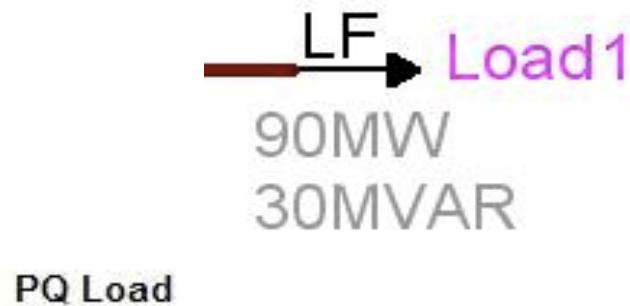
Control type Phase-a-to-ground Voltage

Remote k-node Remote m-node

P 480 MW

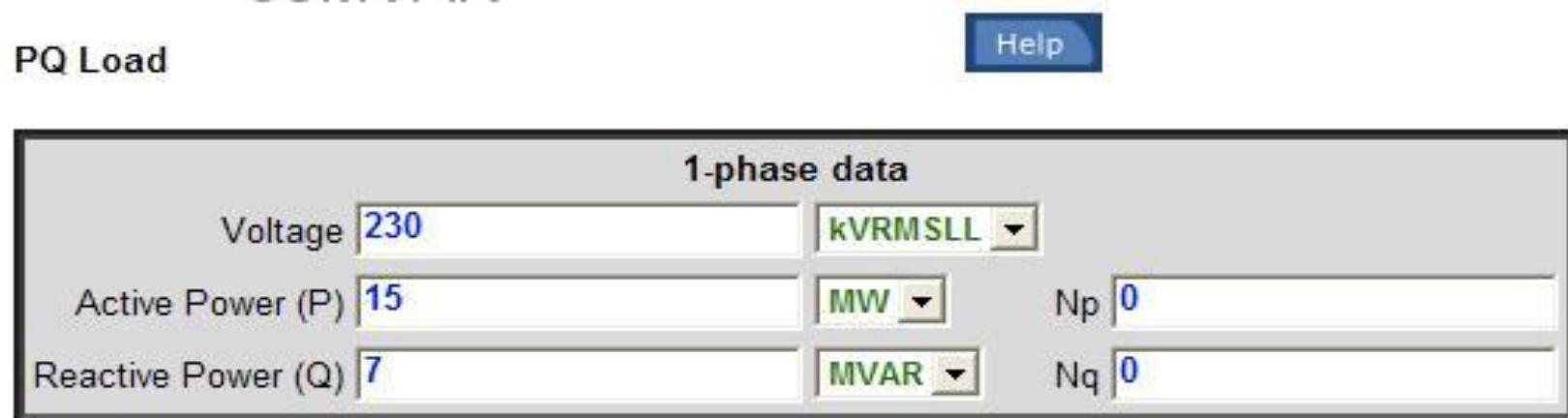
Q_{min} -1000 MVAR Q_{max} 1000 MVAR

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



A screenshot of a software interface showing the configuration for a PQ Load device. At the top, there is a blue "Help" button. Below it is a section titled "1-phase data" with the following parameters:

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

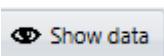
V1:0.96/_41.1
Va:0.959/_40.95
Vb:0.952/_78.91
Vc:0.958/_161.34



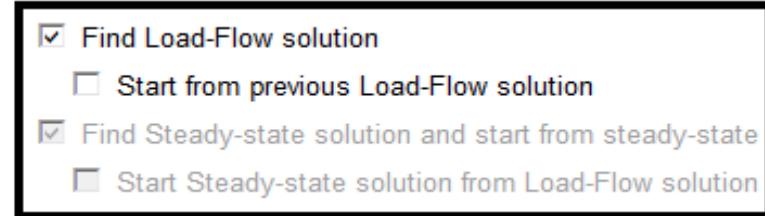
- Display the powers through the devices:
Click right/ Signal Parameters



For refreshing
Design>Show data



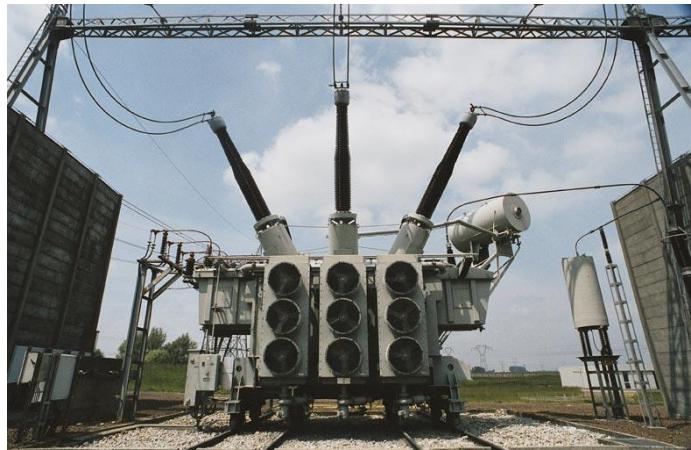
Load-Flow Solution



- 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**

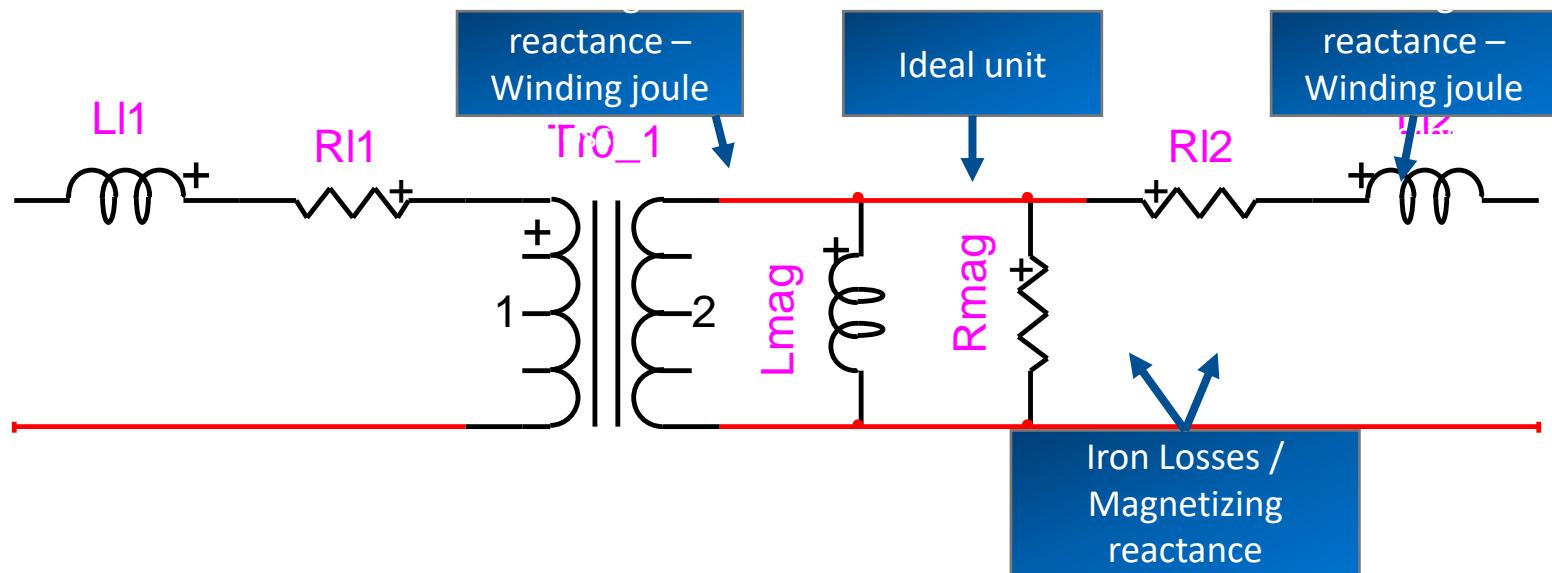
1.3 Basics on power transformers

3-phase unit, transmission system network

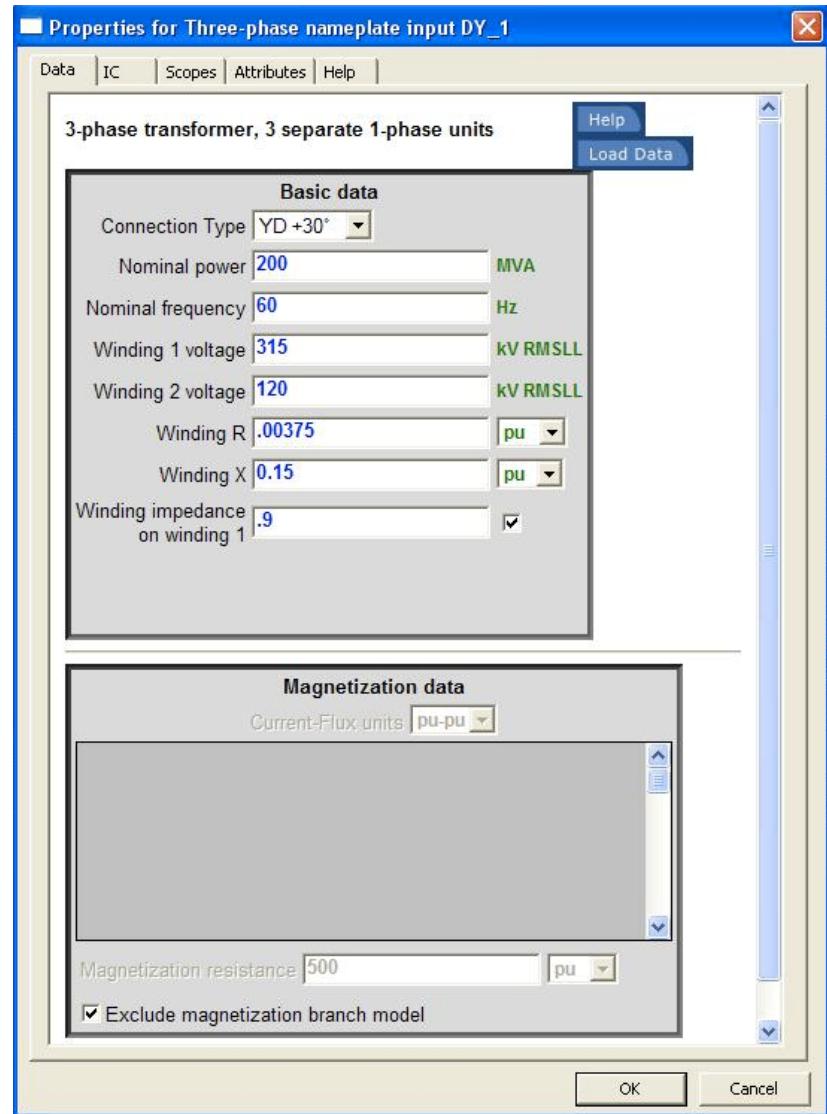


3 single phase units in power plant

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.clf > Three-phase nameplate input

Initial conditions:

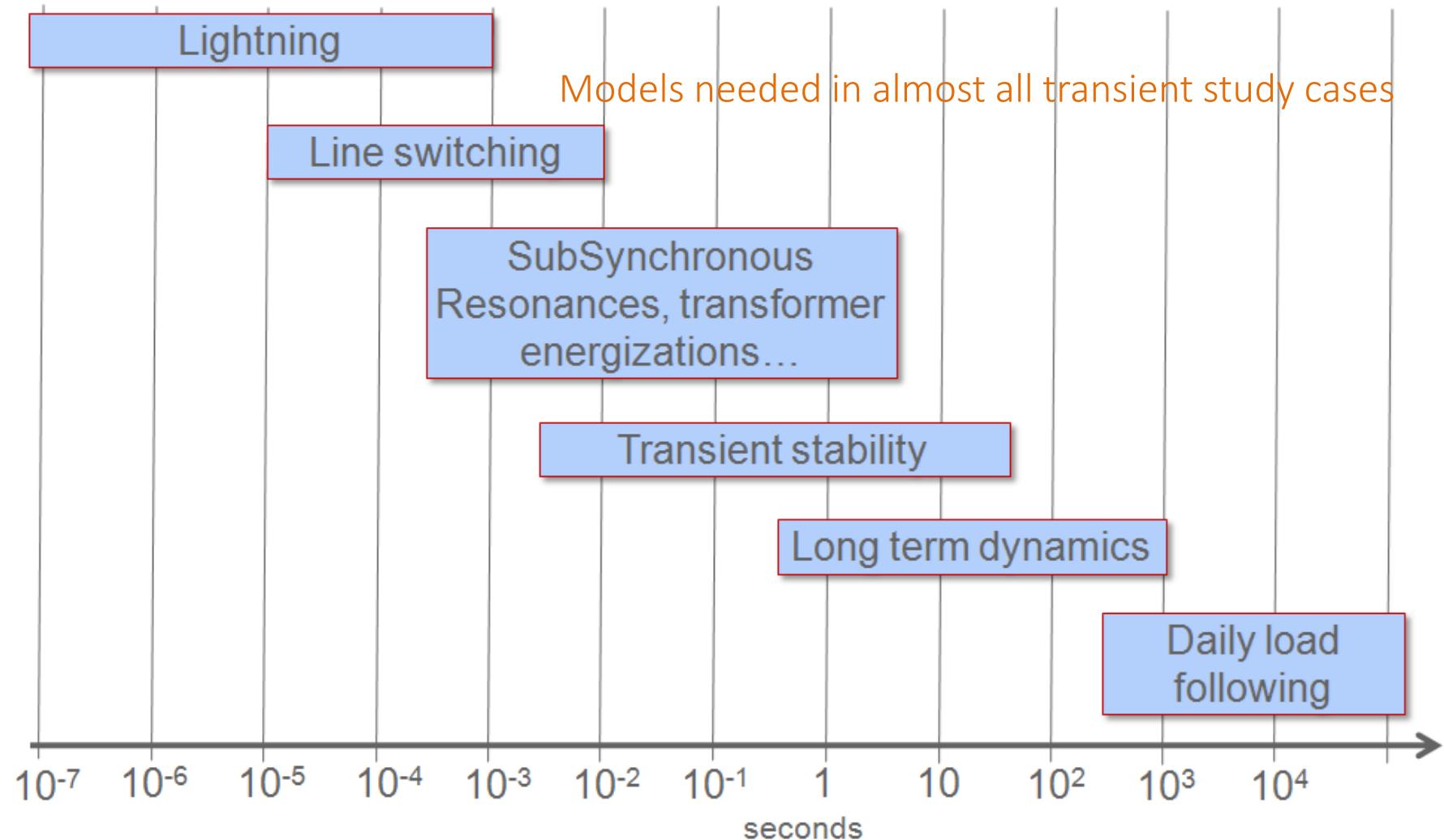
- Possibility to set initial flux on each winding unit to simulate residual flux.

Initial conditions

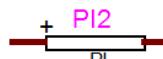
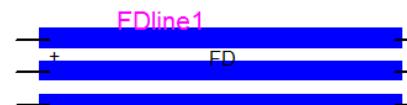
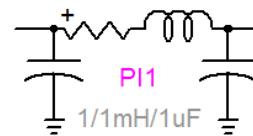
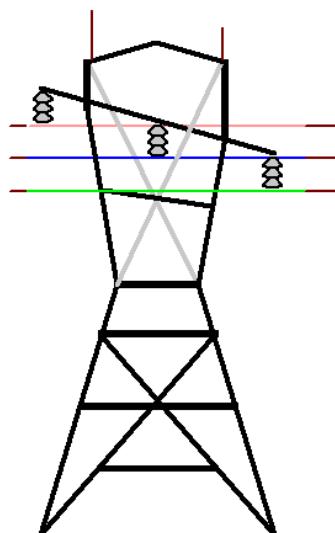
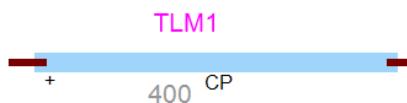
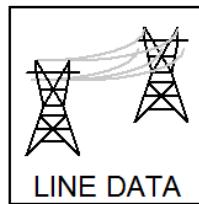
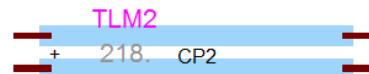
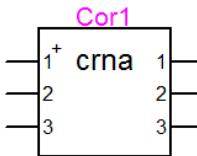
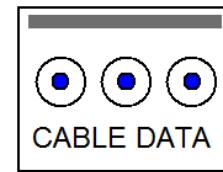
Initial flux (ϕ_0) phase A	0	pu	▼
Initial flux (ϕ_0) phase B	0	pu	▼
Initial flux (ϕ_0) phase C	0	pu	▼

Enter 0 when no manual initial conditions are needed.

Transmission line models

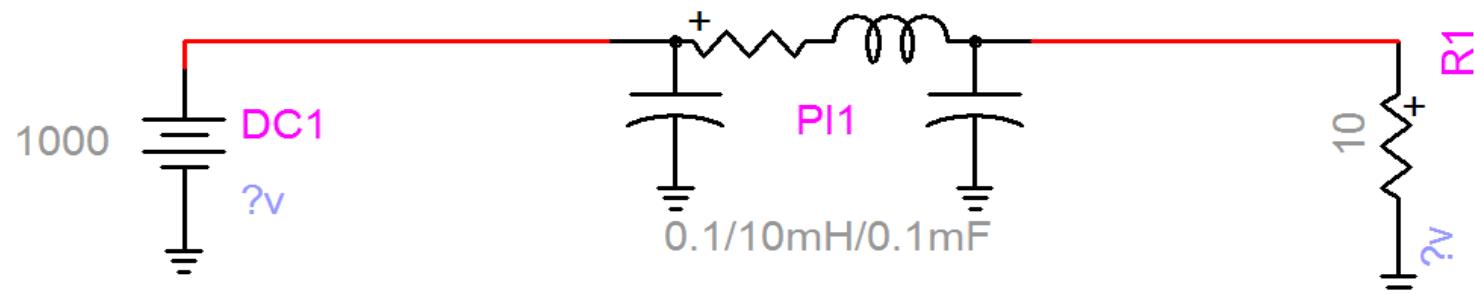


EMTP lines Library



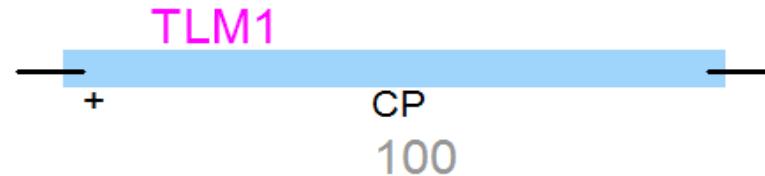
PI models

- 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



An infinite number of PI cells in series

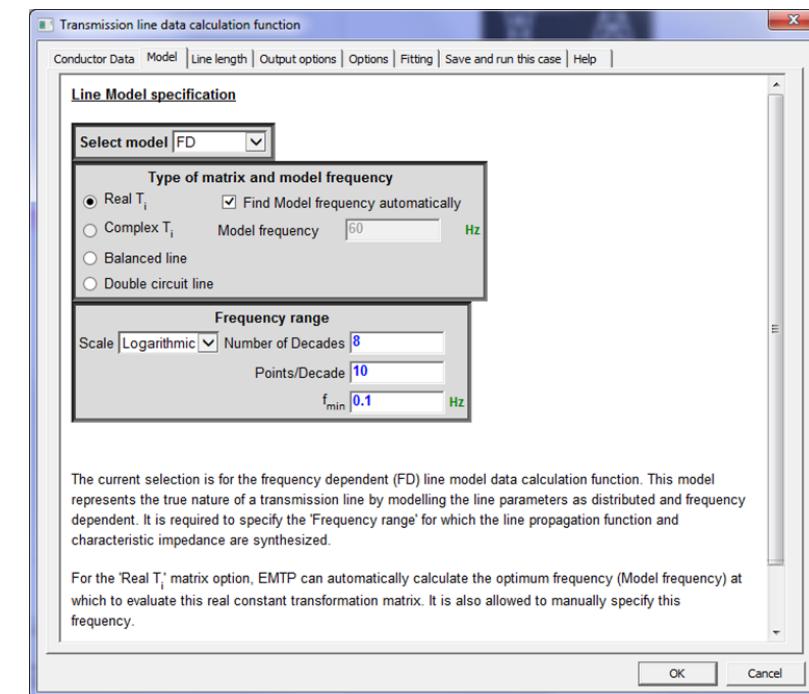
- Propagation taken into account
- Not accurate on a large frequency band
- Only for time-domain



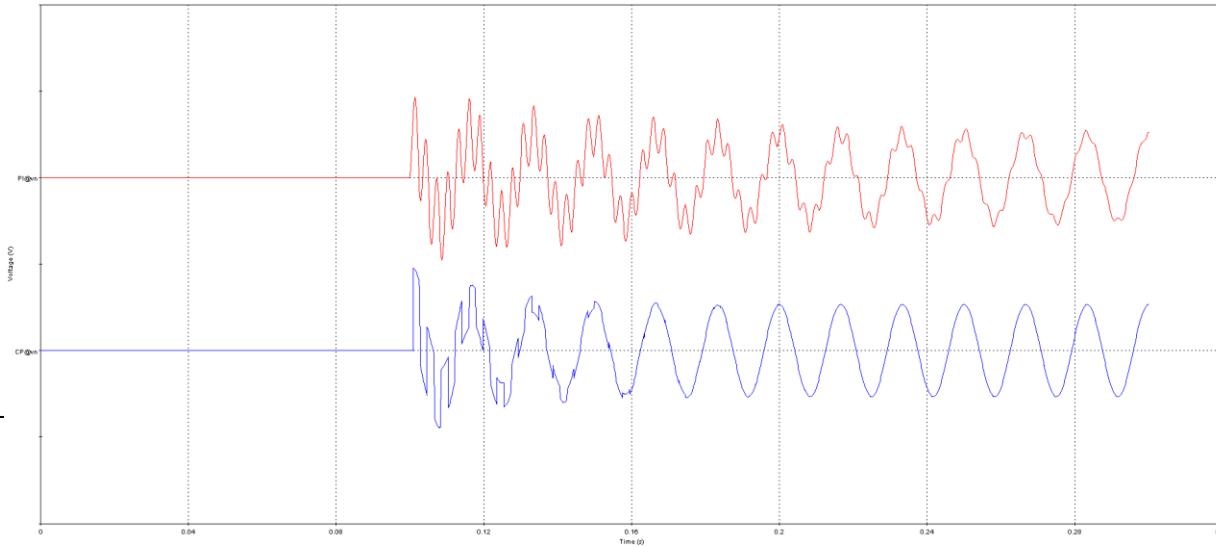
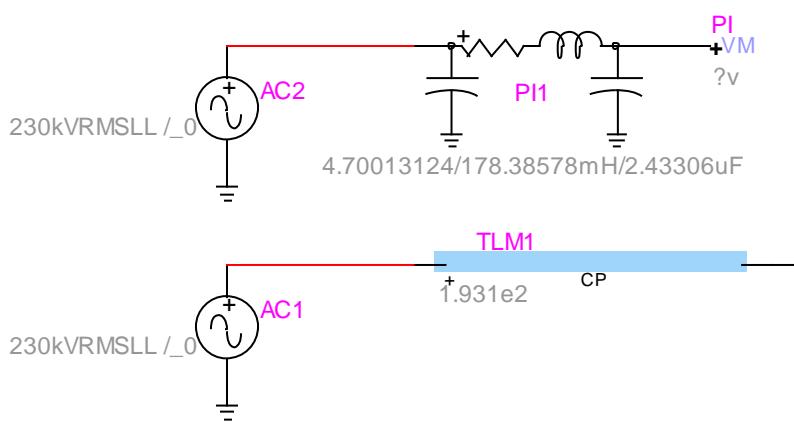
FD / FD-Q models

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

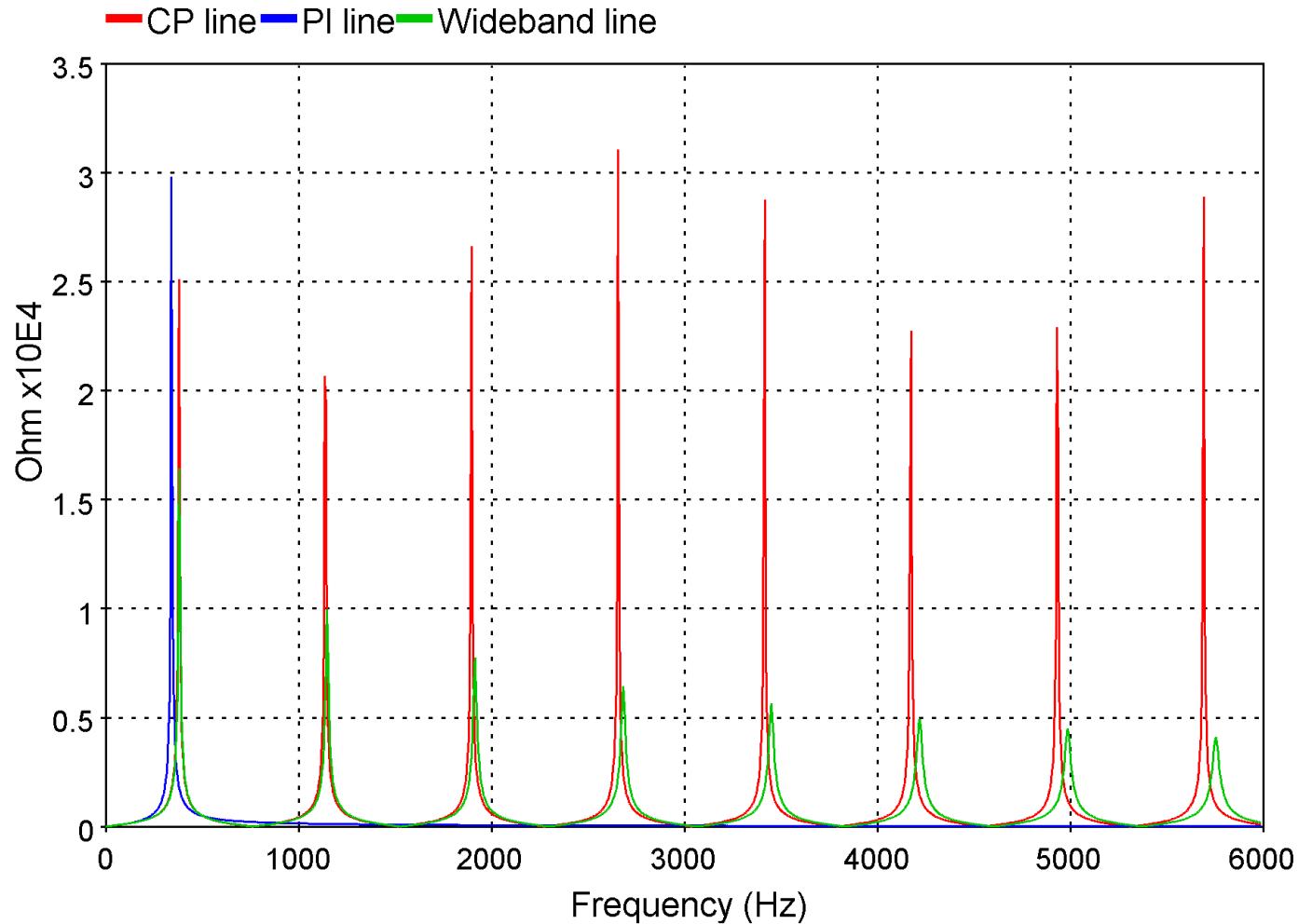
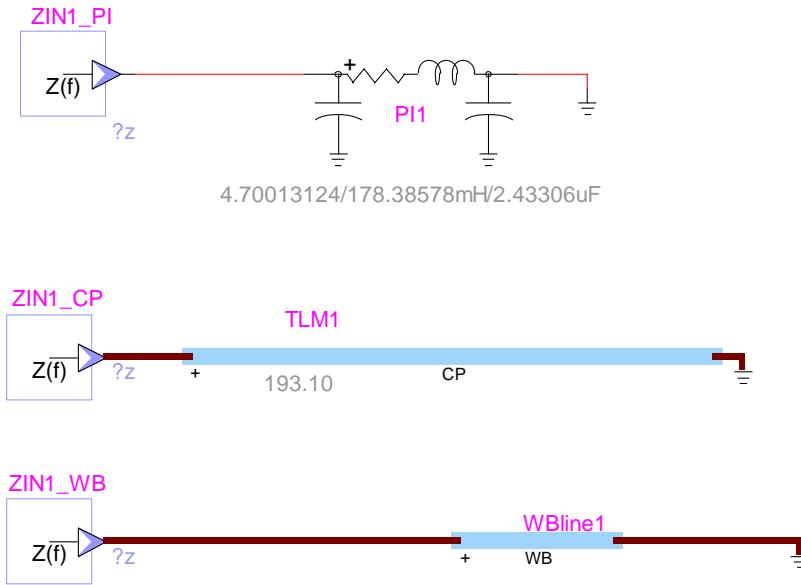
- WB model :
 - Complex model
 - Very accurate
 - Require the Wideband line/cable fitter



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.

General Advanced Line Model Debugging Logging

Input .RAW File C:\Users\...\Documents\PSSE Examples\V_D29_seq_dyr\IEEE_PSRC_D29_2016_02_04.raw

EMTP Output File C:\Users\...\Documents\PSSE Examples\V_D29_seq_dyr\IEEE_PSRC_D29_2016_02_04.ecf

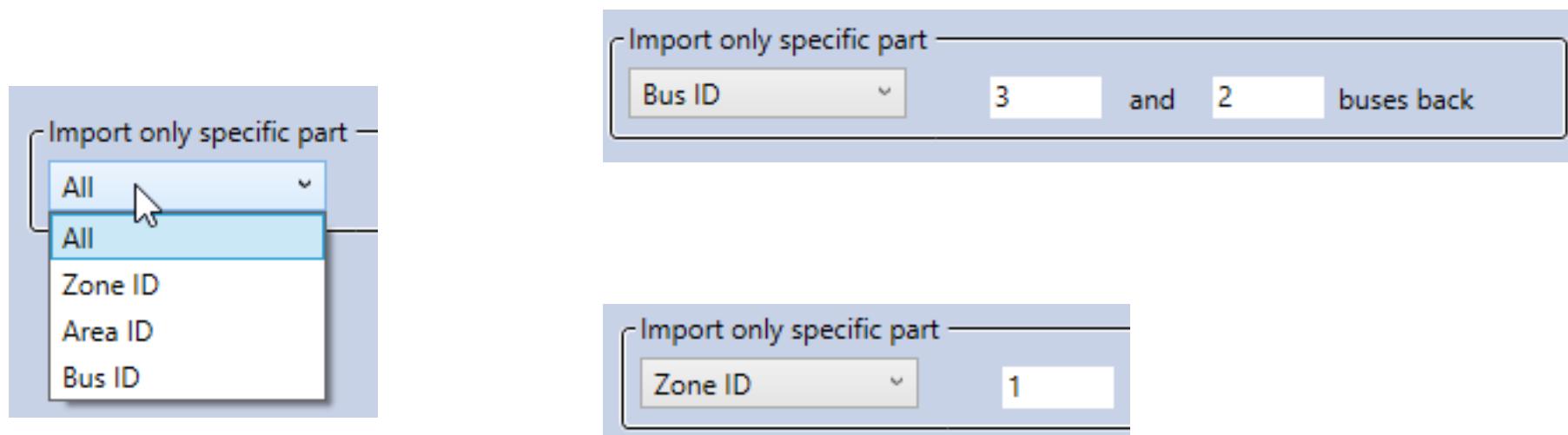
Include Sequence (.SEQ) File C:\Users\...\Documents\PSSE Examples\V_D29_seq_dyr\IEEE_PSRC_D29_2016_02_04.seq

Include Dynamics (.DYR) File (Synchronous machines set as generators) C:\Users\...\Documents\PSSE Examples\V_D29_seq_dyr\IEEE_PSRC_D29_2016_02_04.dyr

Include Location (.LOC) File C:\Users\...\Documents\PSSE Examples\V_D29_seq_dyr\IEEE_PSRC_D29_2016_02_04.loc

Scale

- How to import using system reduction.

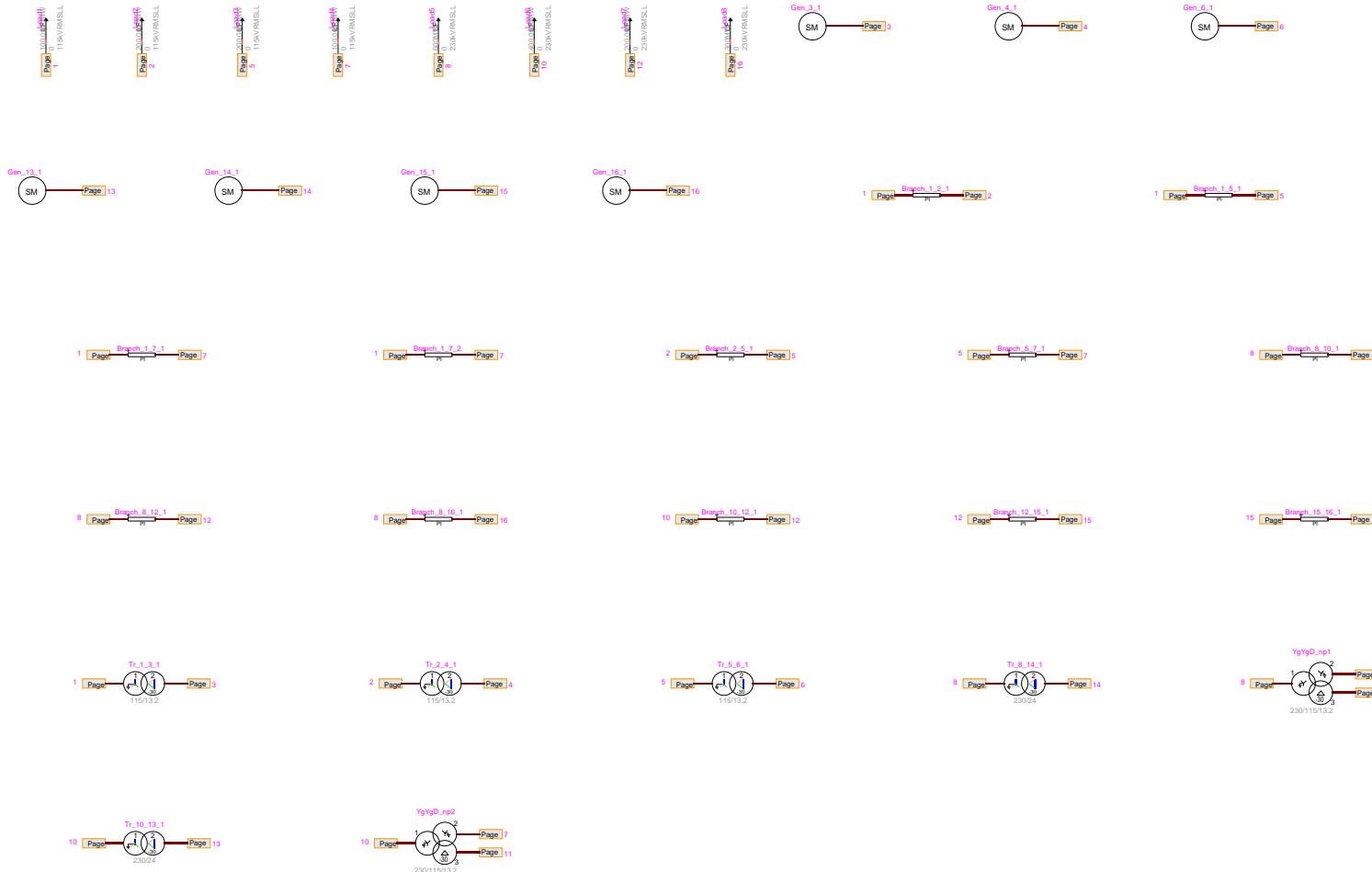


PSS/E import tool



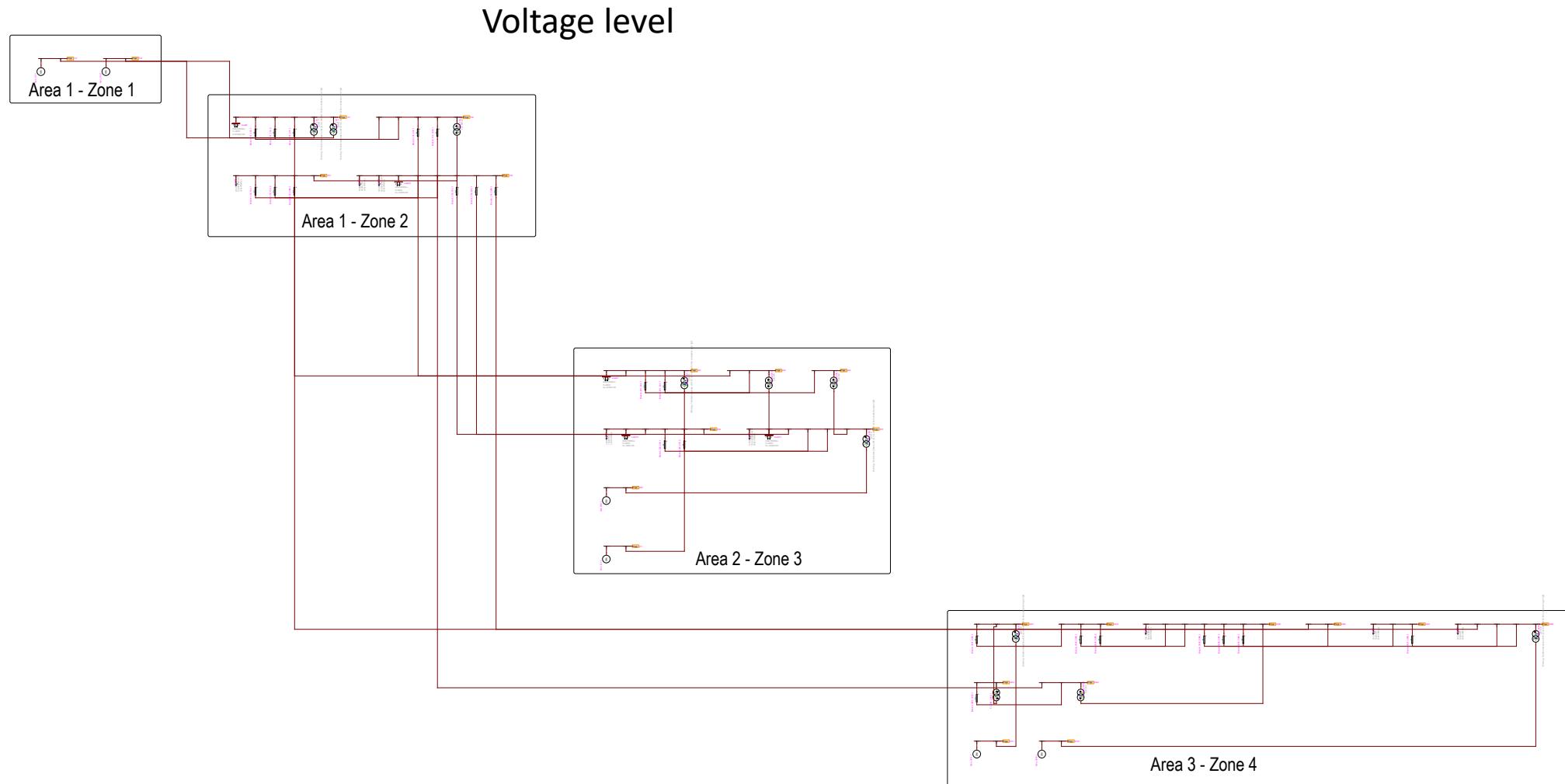
➤ Import options if not .loc.

Virtual connections



PSS/E import tool

➤ Import options if not .loc.



PSS/E import tool



➤ User custom devices.

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						

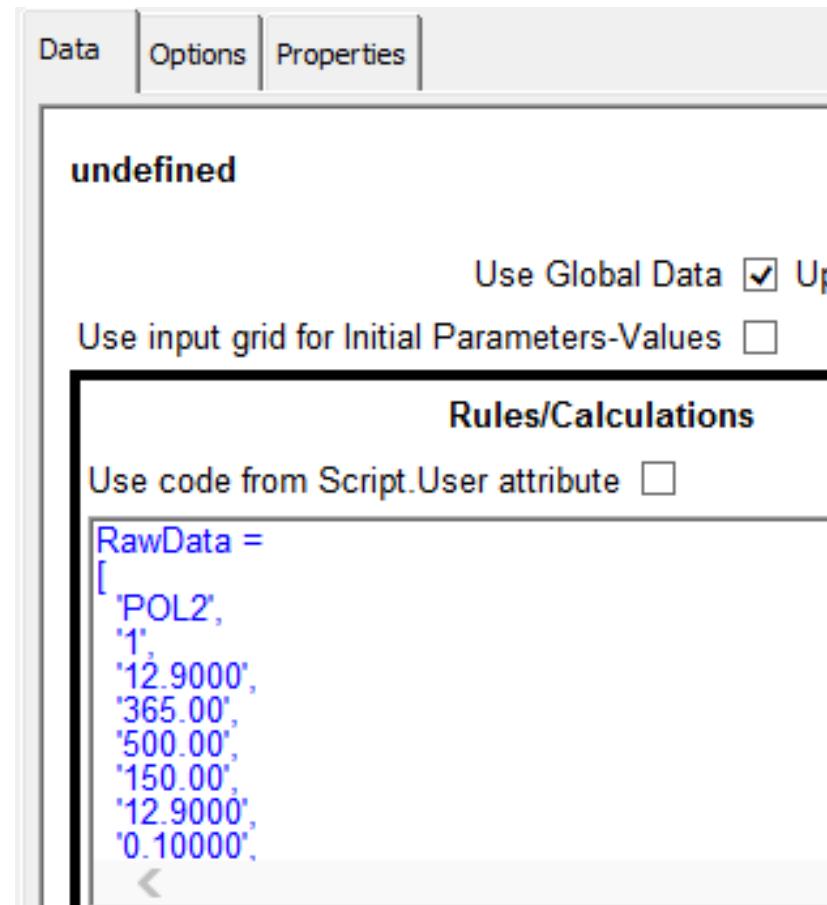
If 'Identifier' of the device is indicated then user's script for importing will be used only for importing device(s) having same 'Identifier'.
If 'Identifier' of the device is not indicated then user's script for importing will be used for importing all devices in this section.

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

➤ User custom devices.



The screenshot shows the 'Data' tab selected in the top navigation bar. The main content area displays the text 'undefined'. Below this, there are two checkboxes: 'Use Global Data' (checked) and 'Up' (unchecked). A horizontal line separates this from the 'Rules/Calculations' section. In the 'Rules/Calculations' section, there is another checkbox 'Use code from Script.User attribute' (unchecked). Below this checkbox is a code editor containing the following script:

```
RawData =  
[  
  'POL2',  
  '1',  
  '12.9000',  
  '365.00',  
  '500.00',  
  '150.00',  
  '12.9000',  
  '0.10000',  
  <
```

Data to be used in script for custom device

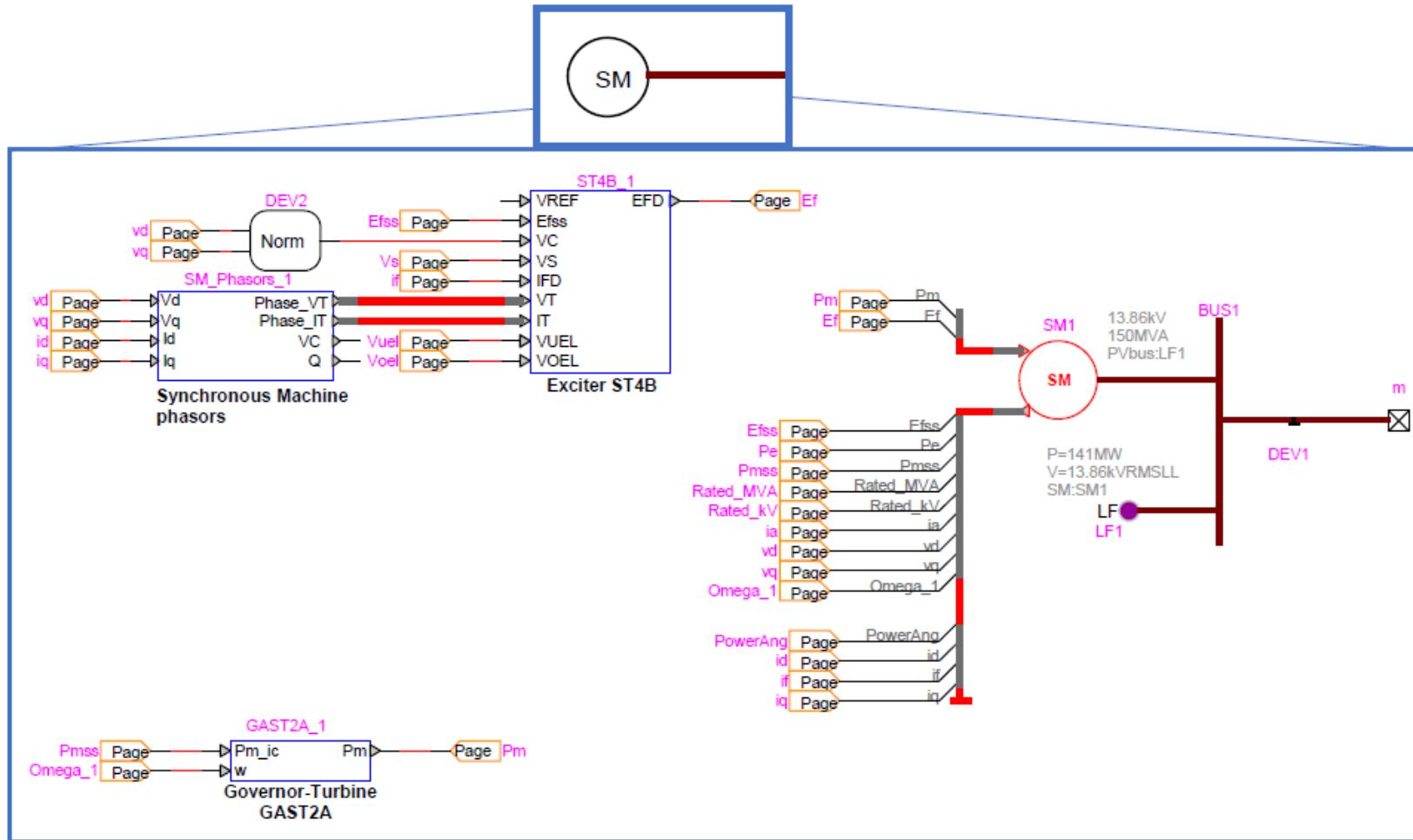
➤ Line options

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

PSS/E import tool



➤ Machines



QUESTIONS

Henry Gras
COO

