Simulation of very large grids in EMTP®

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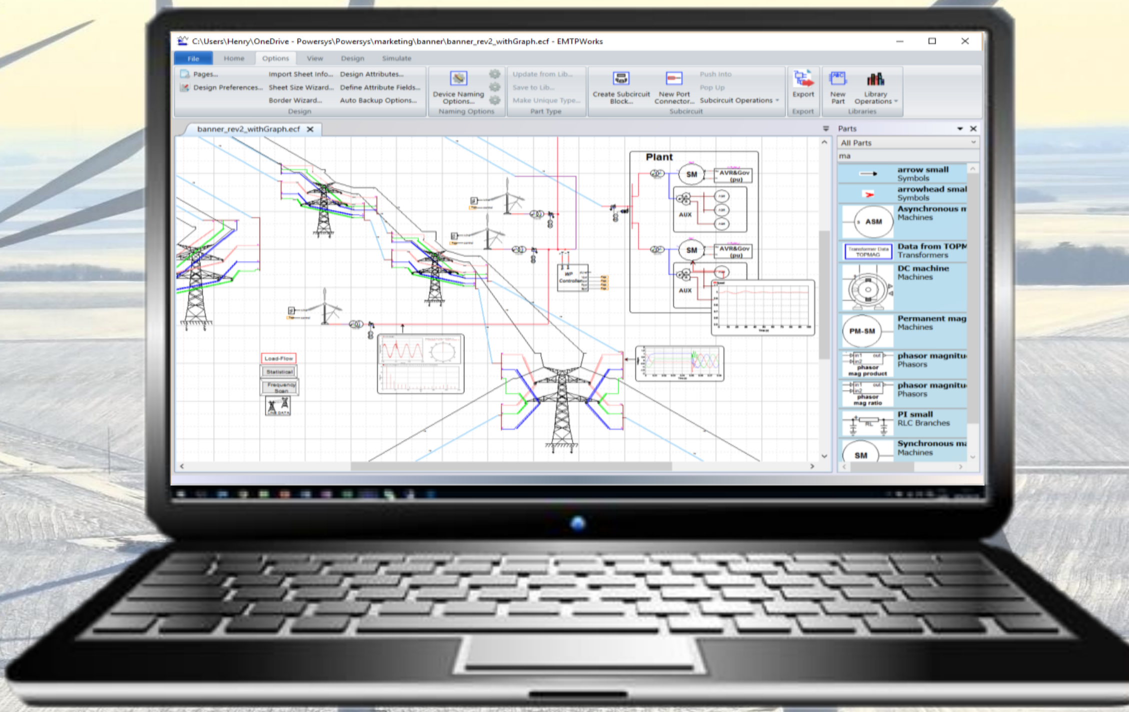

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Content

- Accurate off-line EMT simulations
  - Objectives and challenges
  - Solutions
- Simulation of very large grids with renewables
- IBR model conformity assessment

Introduction: Context

- Massive integration of renewable energy sources in modern power grids
- Inverter based resources (IBRs) will become predominant in power grids
- Accurate tools are required to simulate and study power grids with IBRs
- Existing classic simulation tools are encountering major difficulties for simulating IBRs
- New trend: unified environment with accurate models for studying both electromagnetic and electromechanical transients

EMT simulation objectives and challenges

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- 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
  - Manage database

- 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

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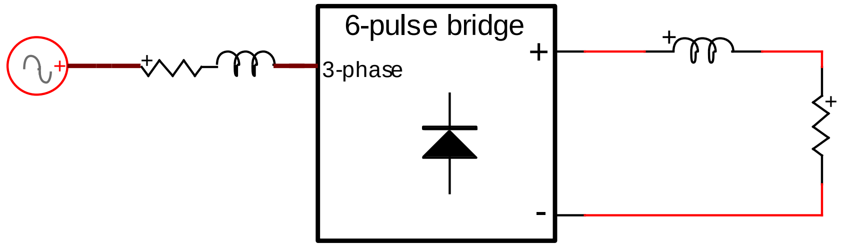
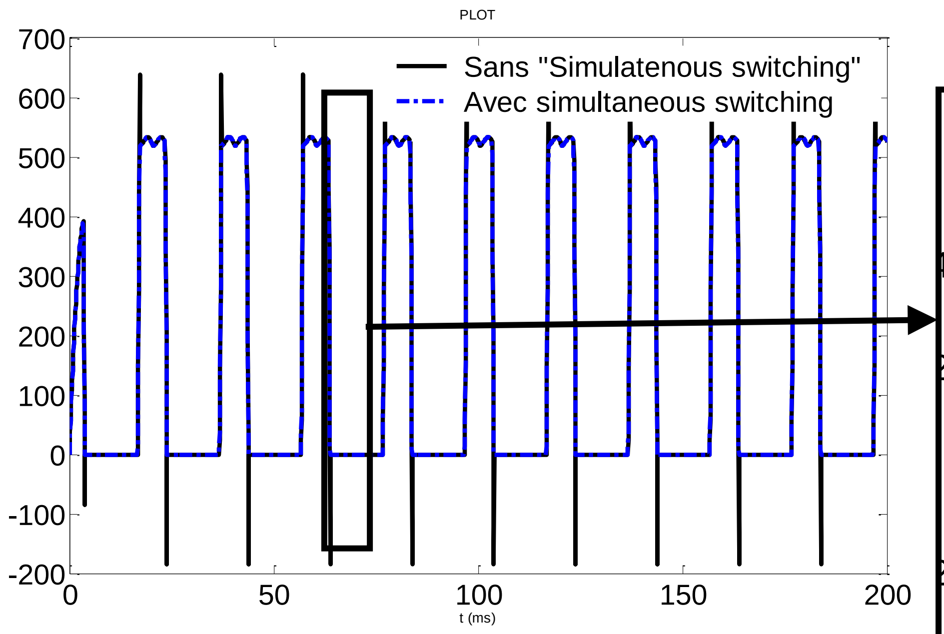
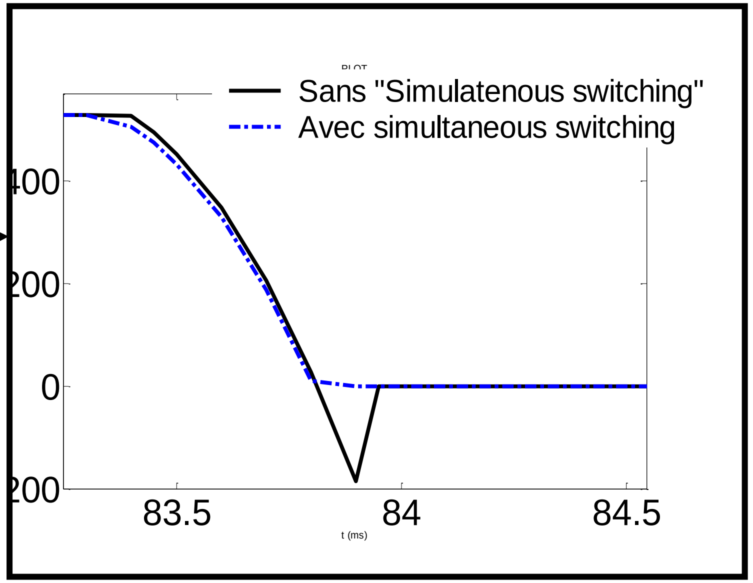
  - Fully iterative solver for non-linear power components (IGBT, surge-arrester, saturation, etc.)

EMT simulation objectives and challenges

- Diode switching with no iteration

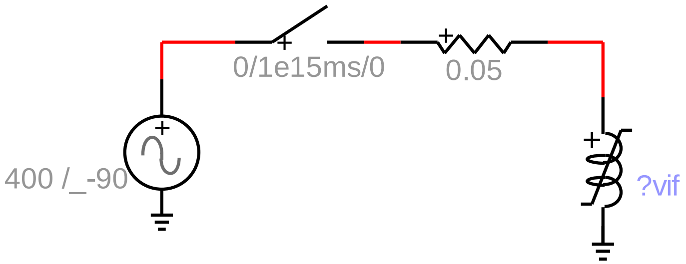


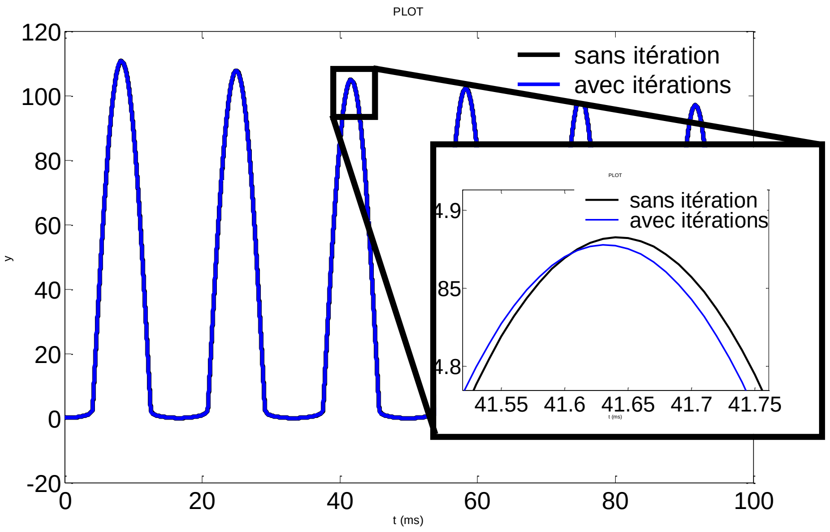


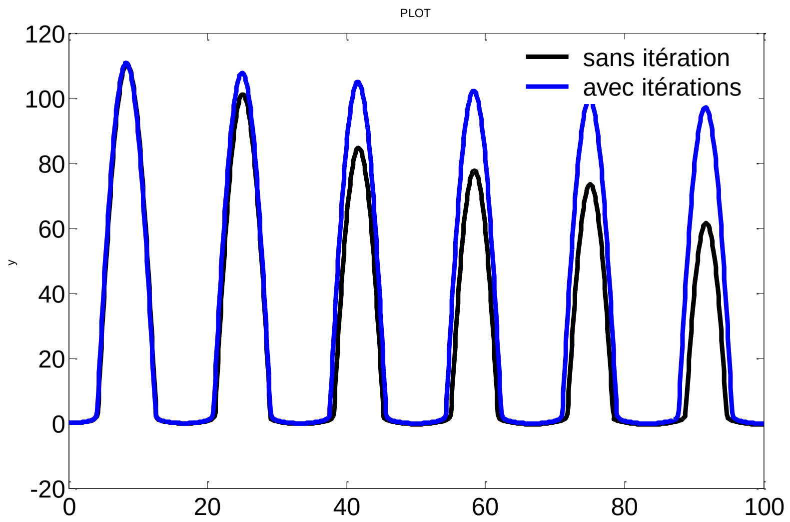


EMT simulation objectives and challenges

- Transformer energization with no iteration







$\Delta t = 100\ \mu s$

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  - Fully iterative solver for non-linear power components (IGBT, surge-arrester, saturation, etc.)
  - Iterates control when algebraic loops are present

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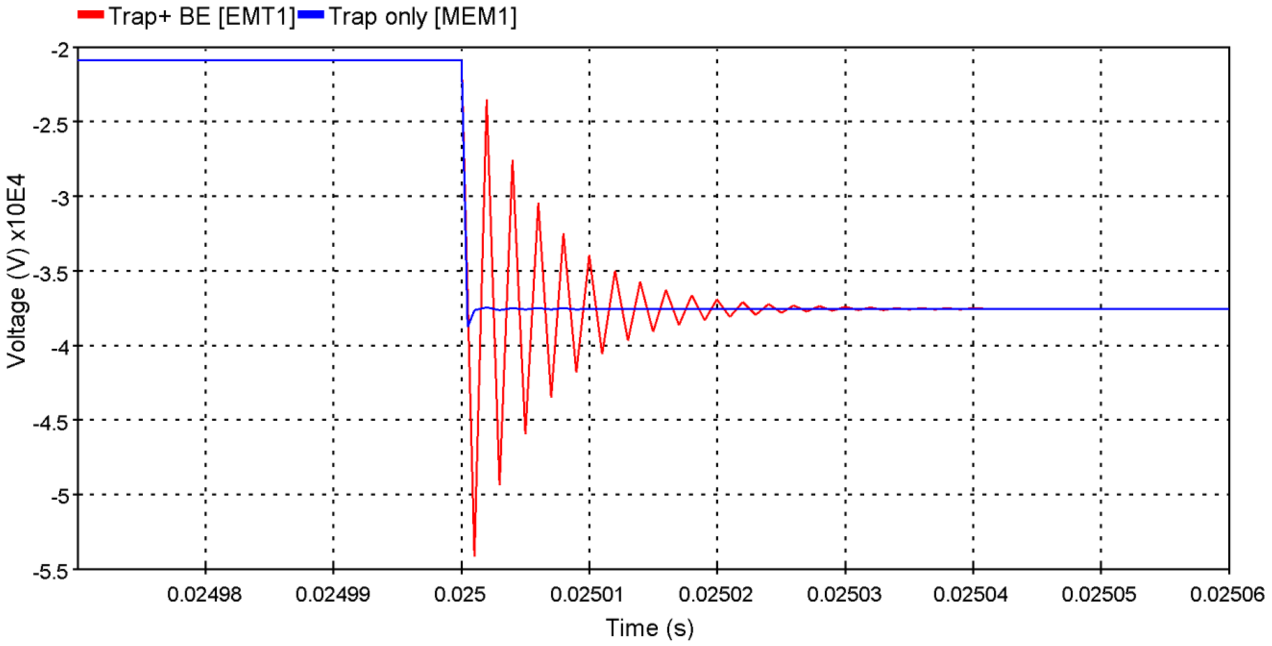
  - Iterates control when algebraic loops are present
  - Use multiple integration methods (trapezoidal and Backward Euler) to avoid numerical problems



$$v(t) = L\frac{di(t)}{dt}$$

Phasor domain

$$\bar{V} = j\omega L.\bar{I}$$

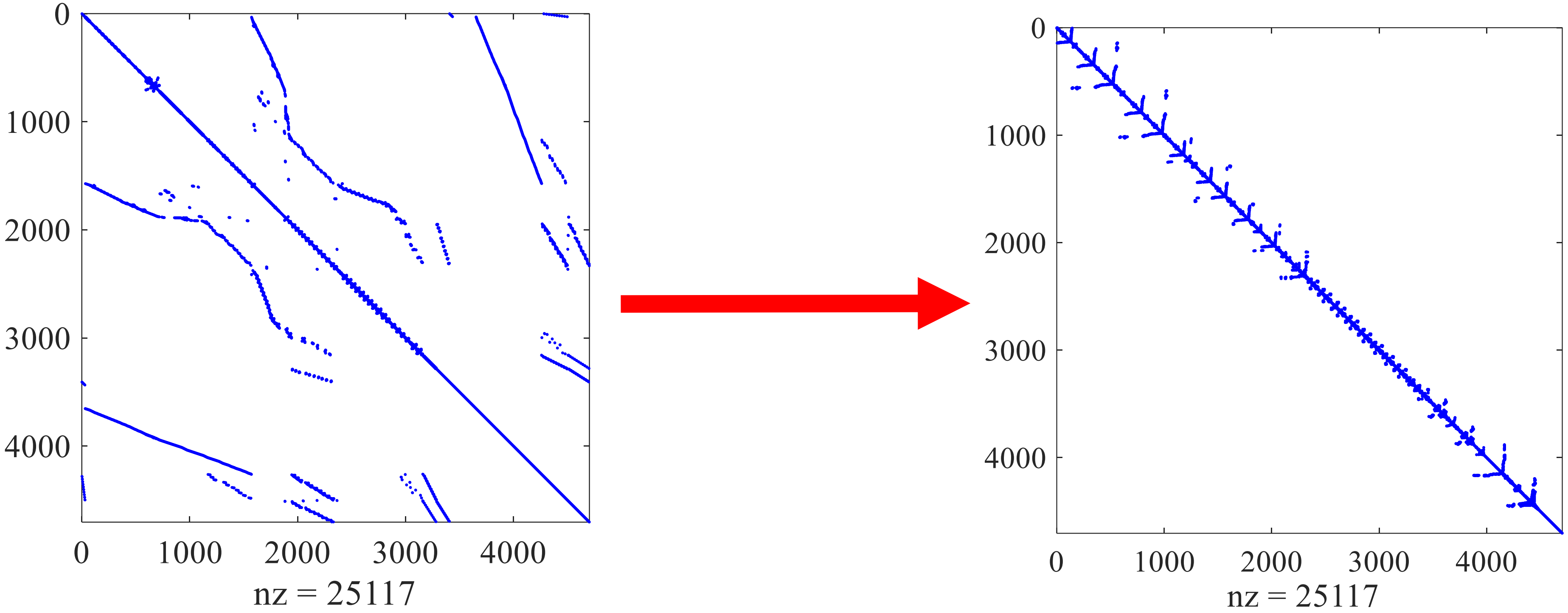
Time domain

$$\frac{v(t)+v(t-\Delta t)}{2} = L\frac{i(t)-i(t-\Delta t)}{\Delta t}$$

$$\Leftrightarrow v(t) = \frac{L}{\Delta t/2}i(t) - L\frac{i(t-\Delta t)}{\Delta t/2} - v(t-\Delta t)$$

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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- How EMTP® answers the challenges?
- Speed: EMTP® uses innovative matrix solver technics
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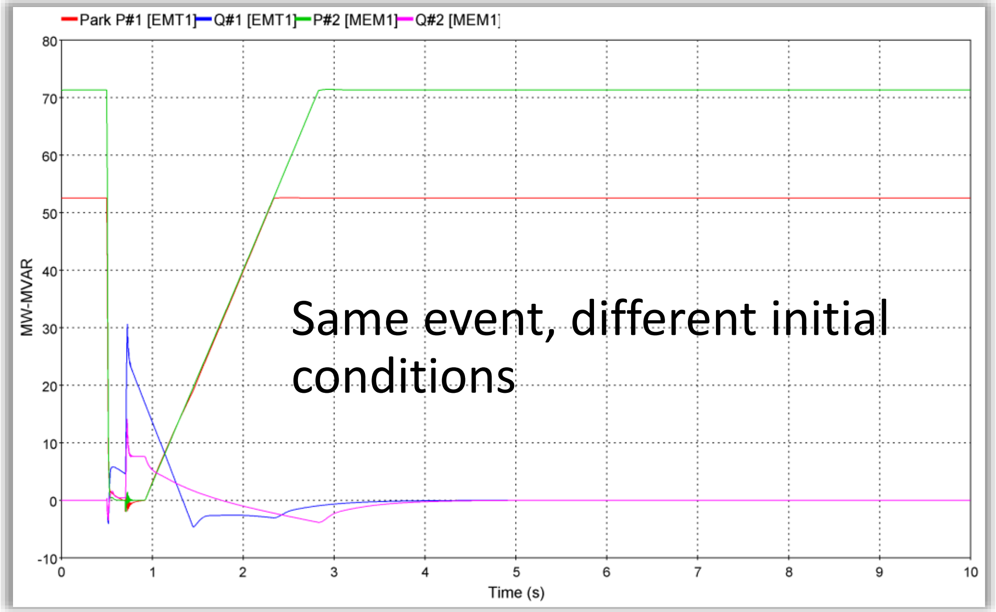
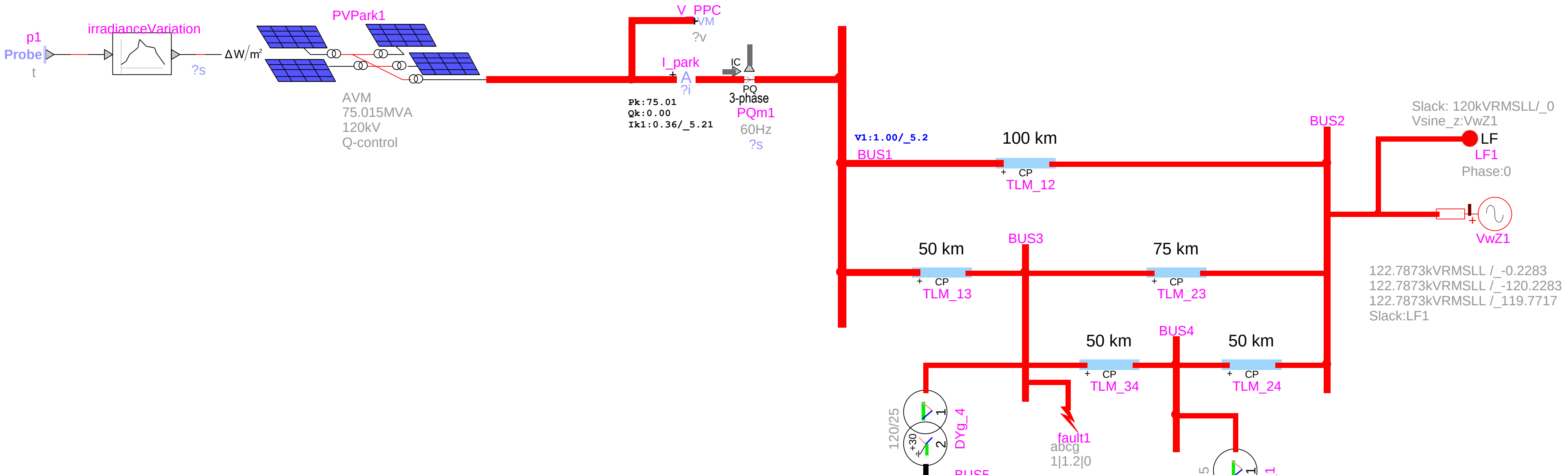
  - Reduce initialization time





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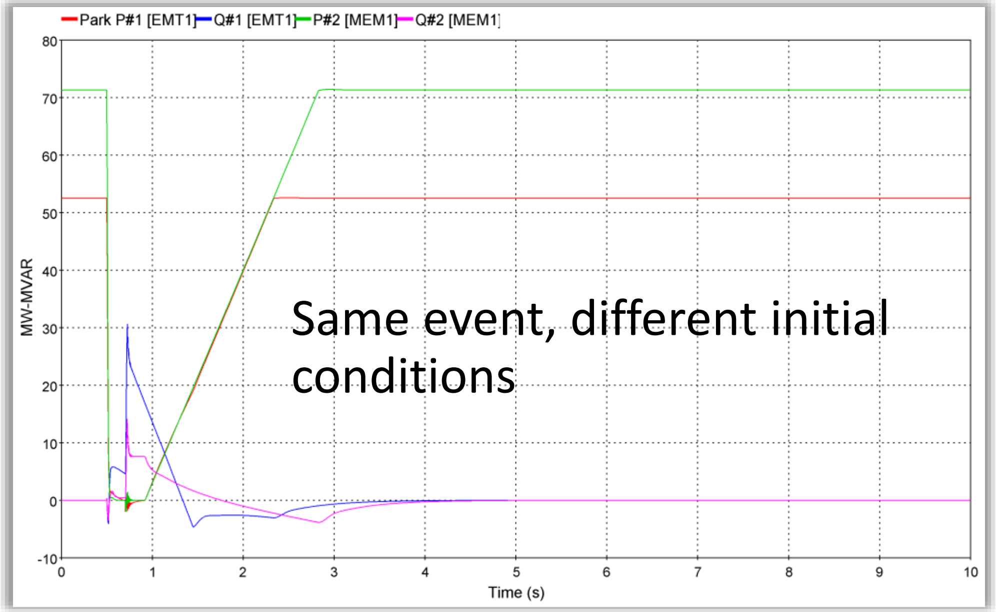

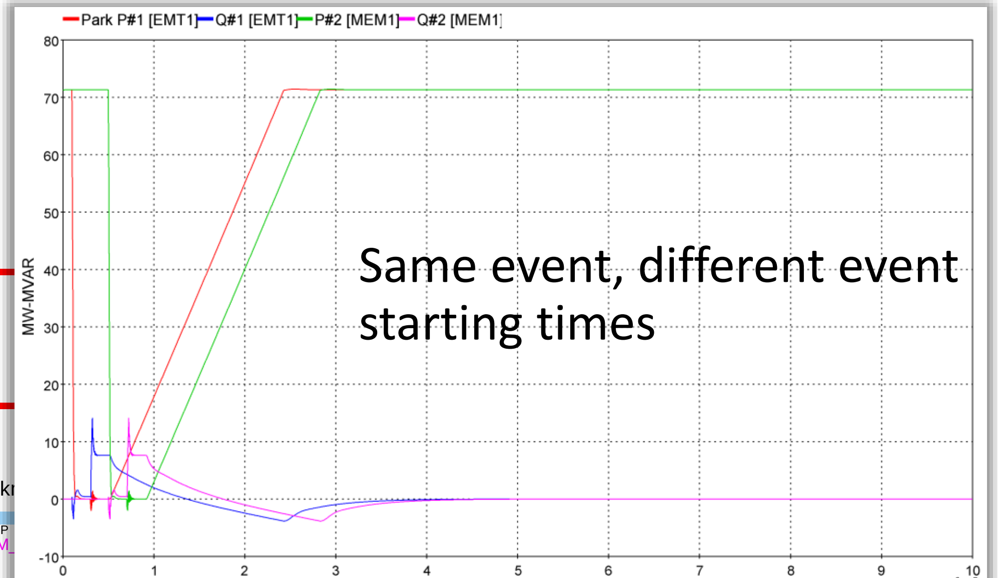

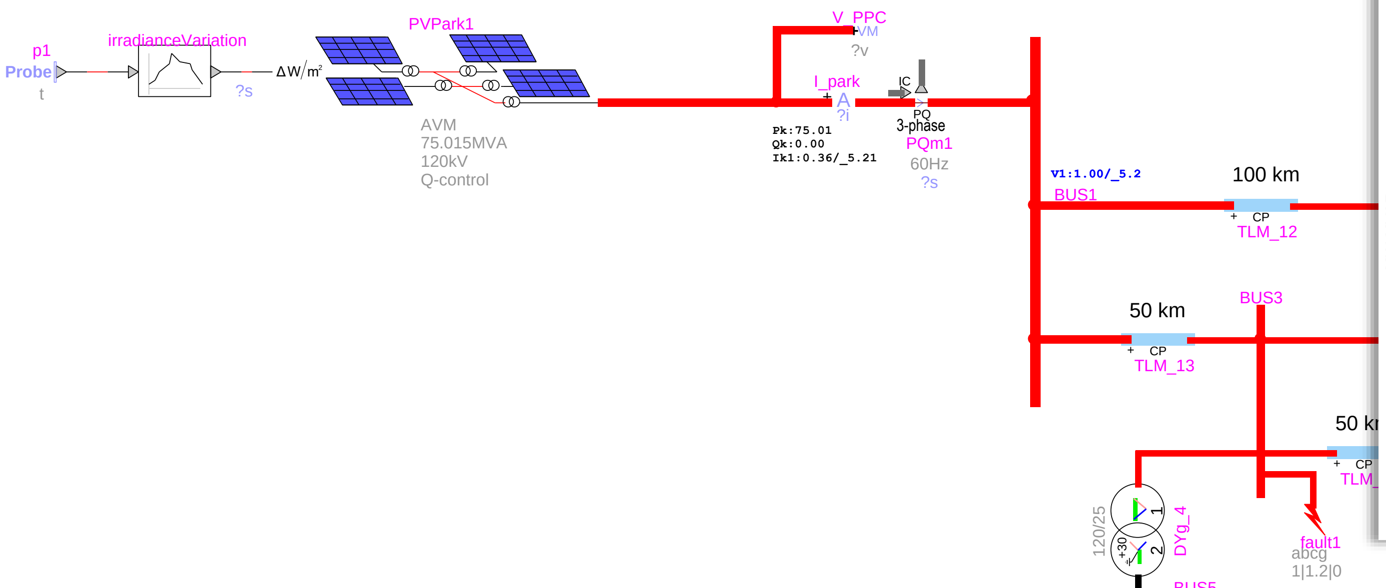

EMT simulation objectives and challenges

- How EMTP® answers the challenges?
- User friendly:
  - Easy and intuitive GUI
  - No need to add artificial delays
  - Personalized technical support
  - Database management and contingency analysis tools available
  - Customized developments to fit individual needs
  - Provide CIGRE standard DLL interface

EMT simulation objectives and challenges

- How EMTP® answers the challenges?
- Manage Database: EMTP® provides import tools from PSS/E or CIM formats
  - No limit in the number of buses
  - Allow to import reduced networks
  - Allow to update existing EMTP design with a PSS/E file.
  - Allow to import custom devices, such as manufacturer specific model.
  - Auto-validate the importation using EMTP and PSS/E load-flow solvers.

EMTP® Numerical Performance for IBRs, example

- Number of IBRs: 75 (PVs and Wind turbines), AVM, average number of blocks: 1500
- Number of Synchronous Machines: 60
- Transformers with magnetization curves, average of 2 iterations per time-point
- Grid size: 300 transmission lines in CP mode
- Simulation interval: 1s
- Numerical integration time-step: 50us

EMTP® Numerical Performance for IBRs, example

- 8-CPUs (i7-11850H), simple laptop
  - Control systems DLL based (manufacturer type): 8s
  - Network equations (1-CPU): 21s
  - With all accuracy options, iterations, trapezoidal+Backward Euler integration

Offline screening tool E-Interconnect

Objectives

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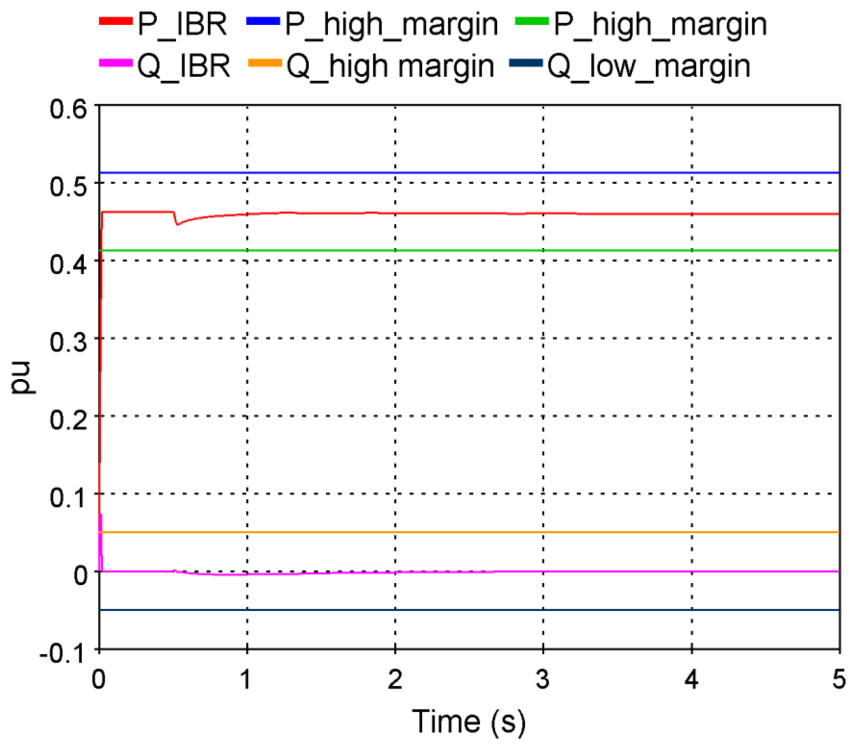
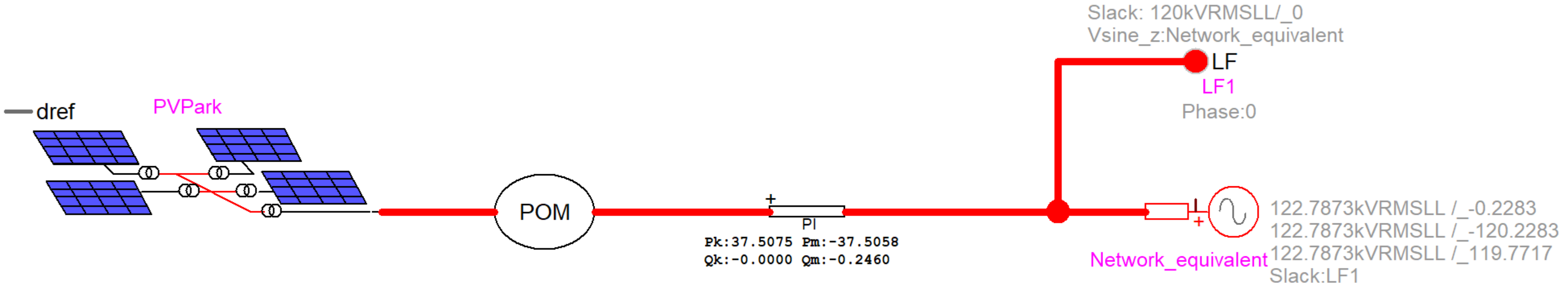
- Automate everything which can be automated.
- Embed in the tool some of the expertise we built over the years on IBR modeling and model verification.
- Automatically verify grid-code compliance.
- Propose an automatic validation method capable of giving the green light to the majority of cases.
- This tool would only help to accept model, not to refuse.
- Some cases will still require engineering judgment to be accepted. The goal is to reduce the amount with time.
- The same tool is used by the GO and the ISO.

Proposed solution

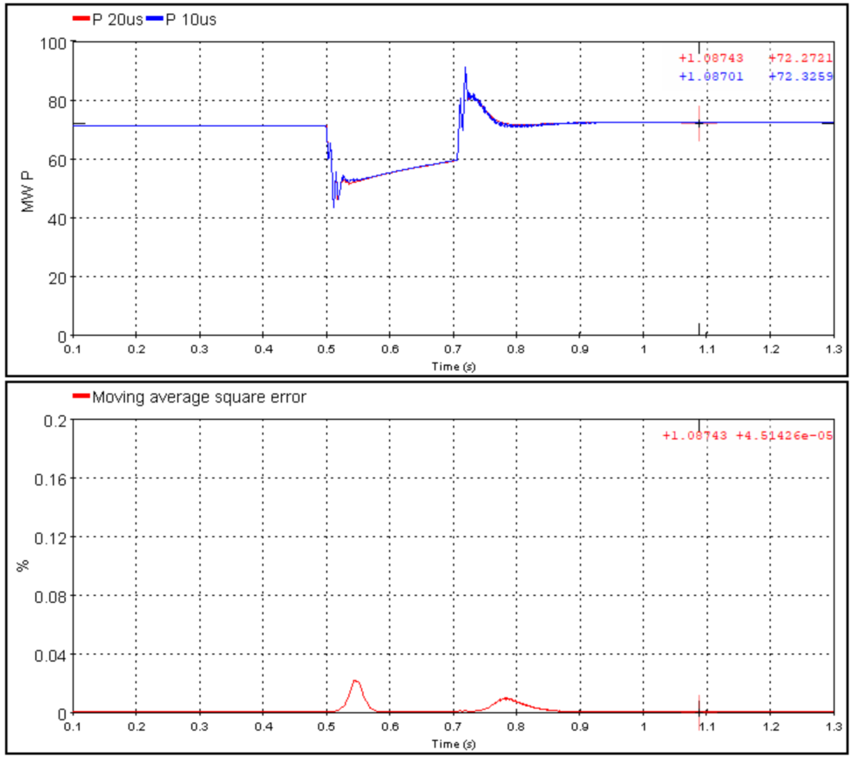
- The proposed solution is being used already by the French ISO.
- It is ISO specific.
- An IEEE 2800 version is in development.
- For automatic validations, we are waiting for the outcome of current IEEE 2800 and NERC works but we have already some solutions available.
- Once properly setup, the entire verification last few hours and ISO engineers may focus on more advanced validations.

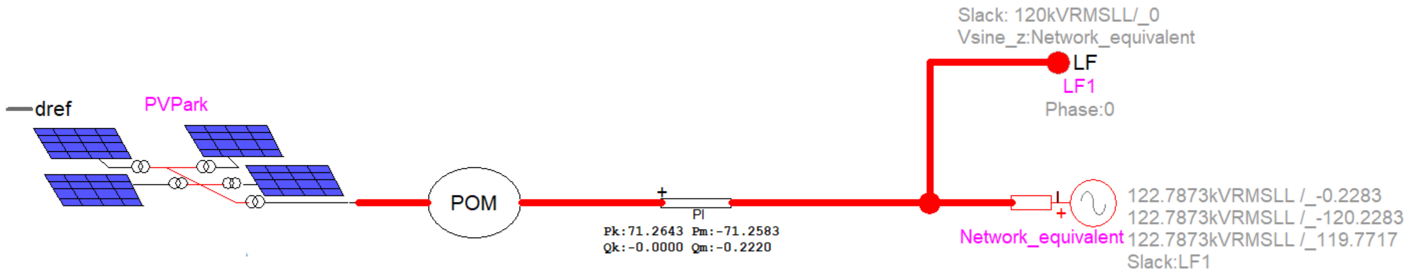
Example: flat start with 5% tolerance





Example: testing different time-steps





Coming tools and research projects

- Data management and calculation speed keep being improved
- Easy automation of contingency analysis (no code tool)
- Digital twin application for online security assessment in control rooms.
- Much more (confidential)

QUESTIONS

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