The future of RMS simulation

Sydney, 18/02/20

POWER SYSTEM SOLUTIONS
MADE IN GERMANY

The Issue of Power Electronic Dominated Networks

- Very fast controls (in comparison with synchronous machines)
- Mostly non-linear controls and manufacturer specific
- Typically grid-following controls, injecting P and Q against voltage magnitude and angle
- Assumptions may be wrong if the connected networks are too weak

→ Concerns are raised that classical RMS-simulations may not be sufficient anymore.

Running a model in RMS or EMT?

RMS Simulation

- Less modelling efforts
- Fast simulations
- Allows full-scale model simulations
- Less detailed results, which might not show all consequences
- Typically run for 0.5 – 60 seconds

EMT Simulation

- High modelling efforts
- High performance impacts
- Typically only parts of networks will be represented
- Full detail assessments are possible if detailed (manufacturer specific) models are available
- Typically run for 0.02 – 1 second

The problem of availability, portability and confidentiality

- Is a network/controller model available?
  - Is it accurate?
  - Is it precise?
  - Is it build for the correct simulation?
- On which platform/simulation tool can I use my model?
  - Is it created for the correct tool?
  - Is it a cross platform model?
- May I forward the model to external stakeholder?
  - Is it encrypted/compiled?
  - May I forward at all?

Accuracy of models - not only the method

- EMT simulations:
  - Can be used for more precise results (on the cost of performance)
  - May show different, yet critical phenomena in comparison to RMS
  - Therefore requires a very high modelling precision

- The models need to consider:
  - Correct modelling of passive network components (lines, transformers, etc.)
  - Accurate behavior of the dynamic components using validated models (manufacturer made)
  - Tools that are able to consider all required components and their electro-magnetic behavior

How can I use my model on any platform?

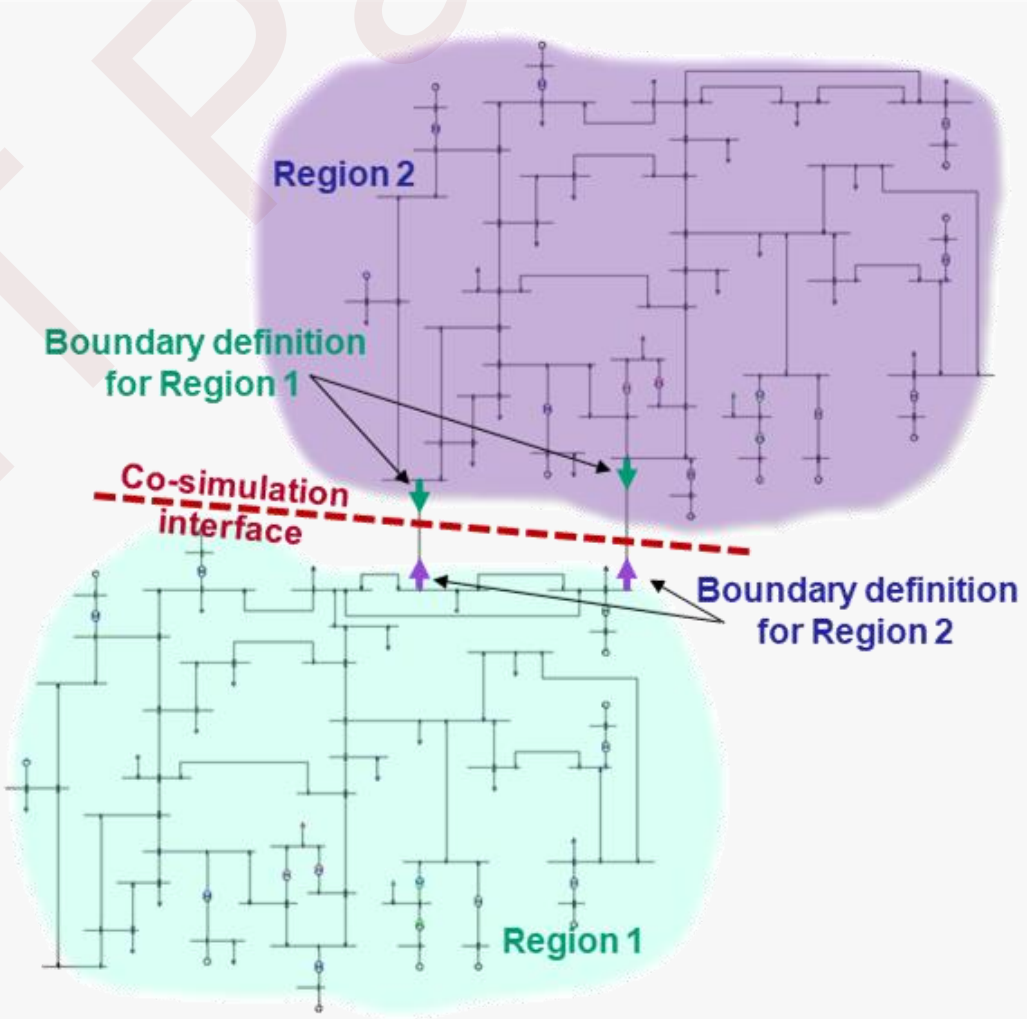
- Most models are only based on a single tool
- Common modelling languages, such as the FMI (Modellica Association) can help for multi-platform models
- Compiled, real-code modelling approaches allow the portability - IEC 61400-27-1 (Annex F)

We have a model, but no one else may use it

- Due to confidentiality reasons, detailed models often must not be forwarded to external stakeholder
- Therefore a common approach is to go back to generic or less detailed models
- This jeopardizes any detailed analysis by consultants or partner
- If a compiled model is treated equally, this is similar to a deadlock

Co-Simulation as a solution to get the best of both worlds?

- Splitting up the network in multiple sub-networks
- Allowing to consider different parts of the network to be considered in multiple time-domains
- Allowing to make use of multi-processor architecture
- Connecting multiple simulation instances (w/o different simulation tools)



Single- vs. Multiple Time Domain Simulation

Single Time Domain

- All sub-networks are simulated in the same time domain
  - RMS (balanced)/RMS (balanced)
  - RMS (unbalanced)/RMS (unbalanced)
  - EMT/EMT
- Used to make use of multiple processors

Multiple Time Domain

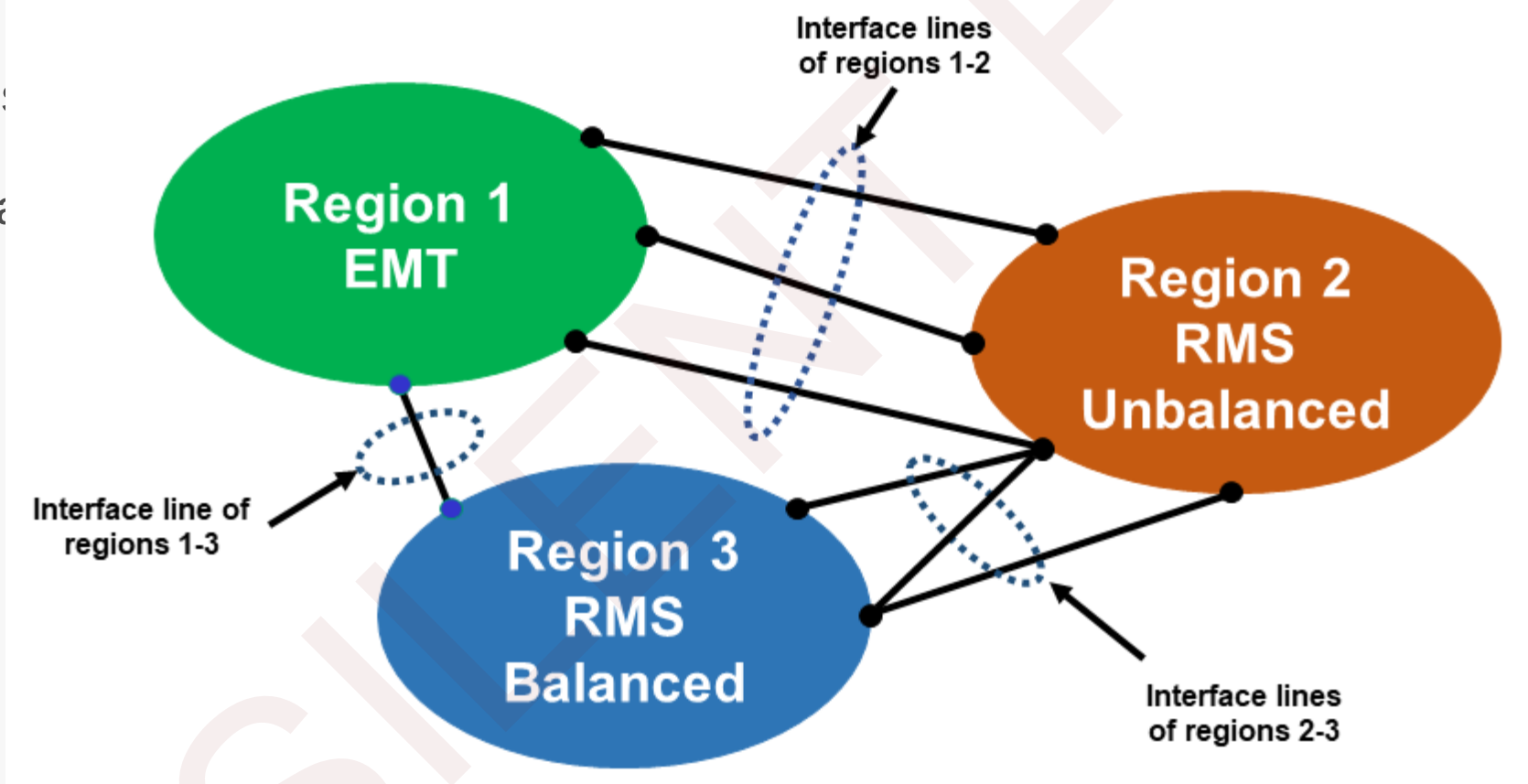
- Sub-networks are considered in different time domains:
  - RMS (balanced)/ RMS (unbalanced)
  - RMS (balanced)/ EMT
  - RMS (unbalanced)/ EMT
  - RMS (balanced)/ RMS (unbalanced)/ EMT
- Used to split up the network according to needs
- Also makes use of parallel processing

Single- vs Cross-Platform Co-Simulation

Single-platform simulation

- Used on a s
- Only uses a
- Makes use

Cross-platform simulation



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Co-Simulation Methods

Implicit Method

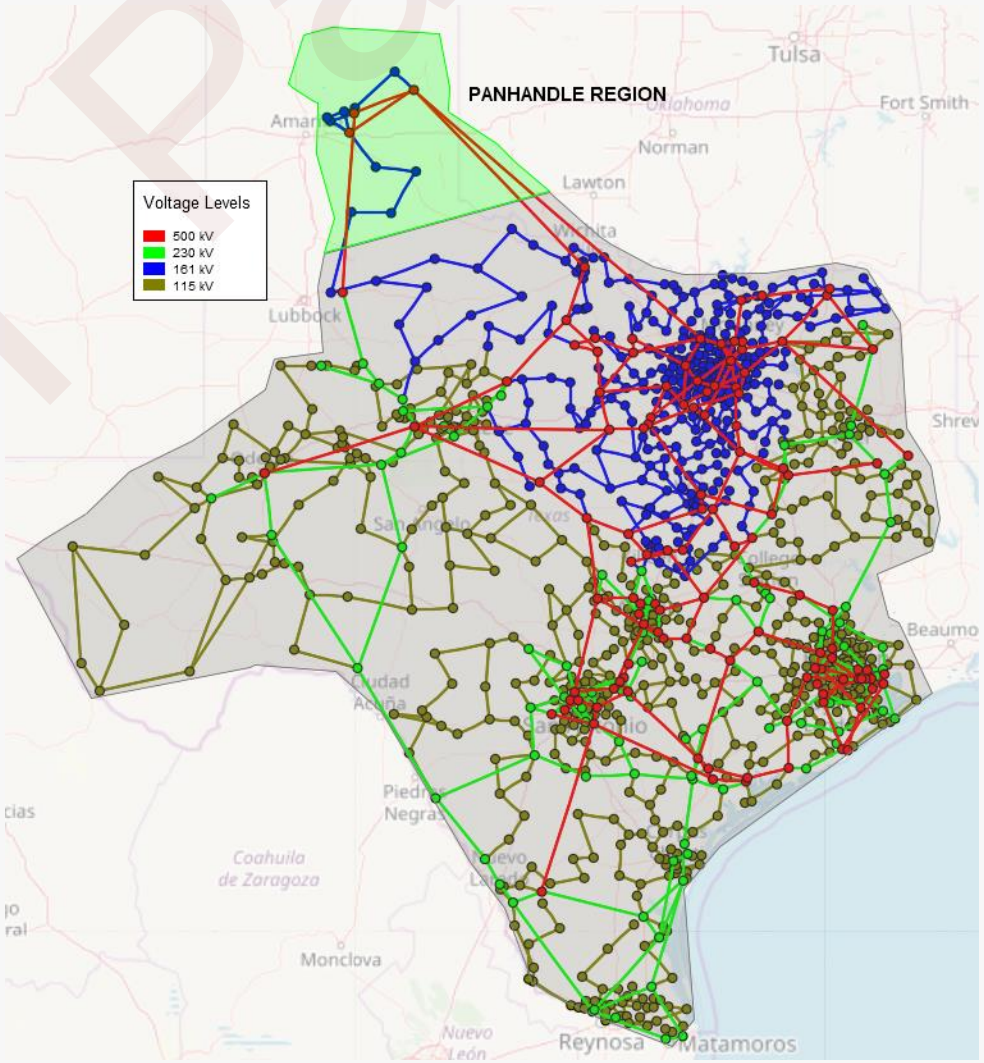
- Exact simulation results
- Using long wave traveling times on long lines
- Requires small step sizes according to the traveling times
- Might have a negative impact on the performance if the lines are not long enough

Explicit Method

- Approximate approach
- Does not require long lines
- Creating dynamic equivalents for the exchange of signals
- Might not be precise

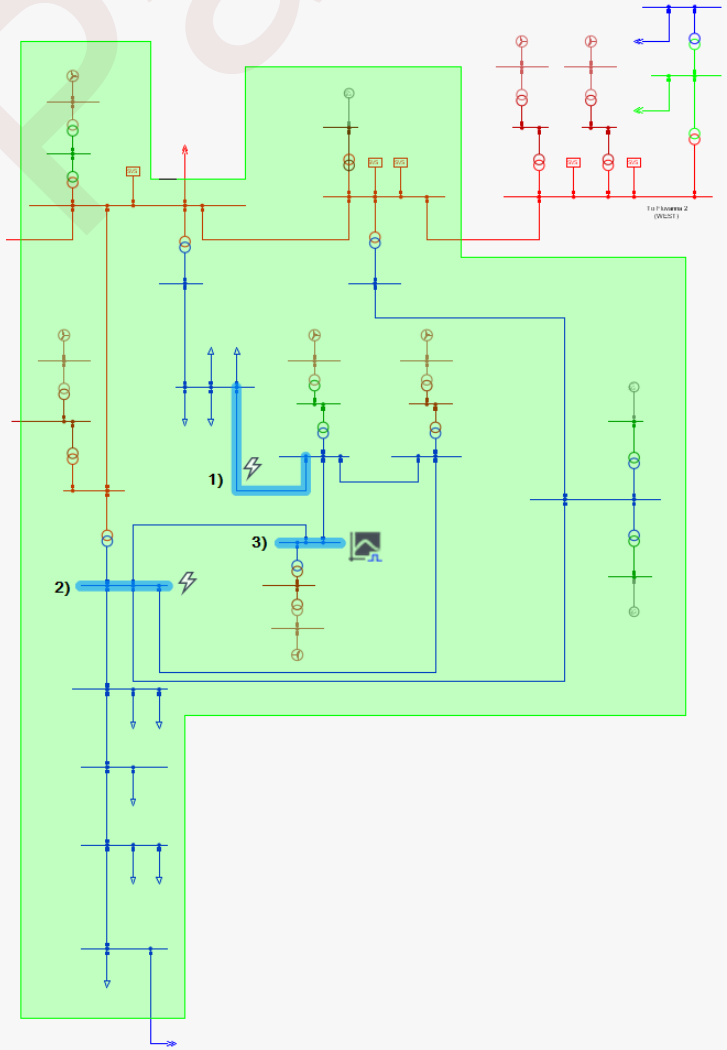
Illustrative Study Case for Co-Simulation

- Synthetically created 2.000 bus example
- 432 running generation units
- Panhandle-Region includes only wind generation (627 MW)
- Four simulations have been considered:
  - Full RMS (balanced)
    - 0.15 ms step size
  - Full RMS (unbalanced)
    - 0.15 ms step size
  - Full EMT
    - 0.05 ms step size
  - RMS (blanced)/EMT co-simulation
    - 0.1 ms (RMS); 0.01 ms (EMT)



Example Simulations on the test network

- 1) Line fault with line switching after 100ms
- 2) Busbar fault with bubar switching after 100ms
- Voltages are recorded and shown for the busbar indicated as 3)
- EMT results are represented as RMS values



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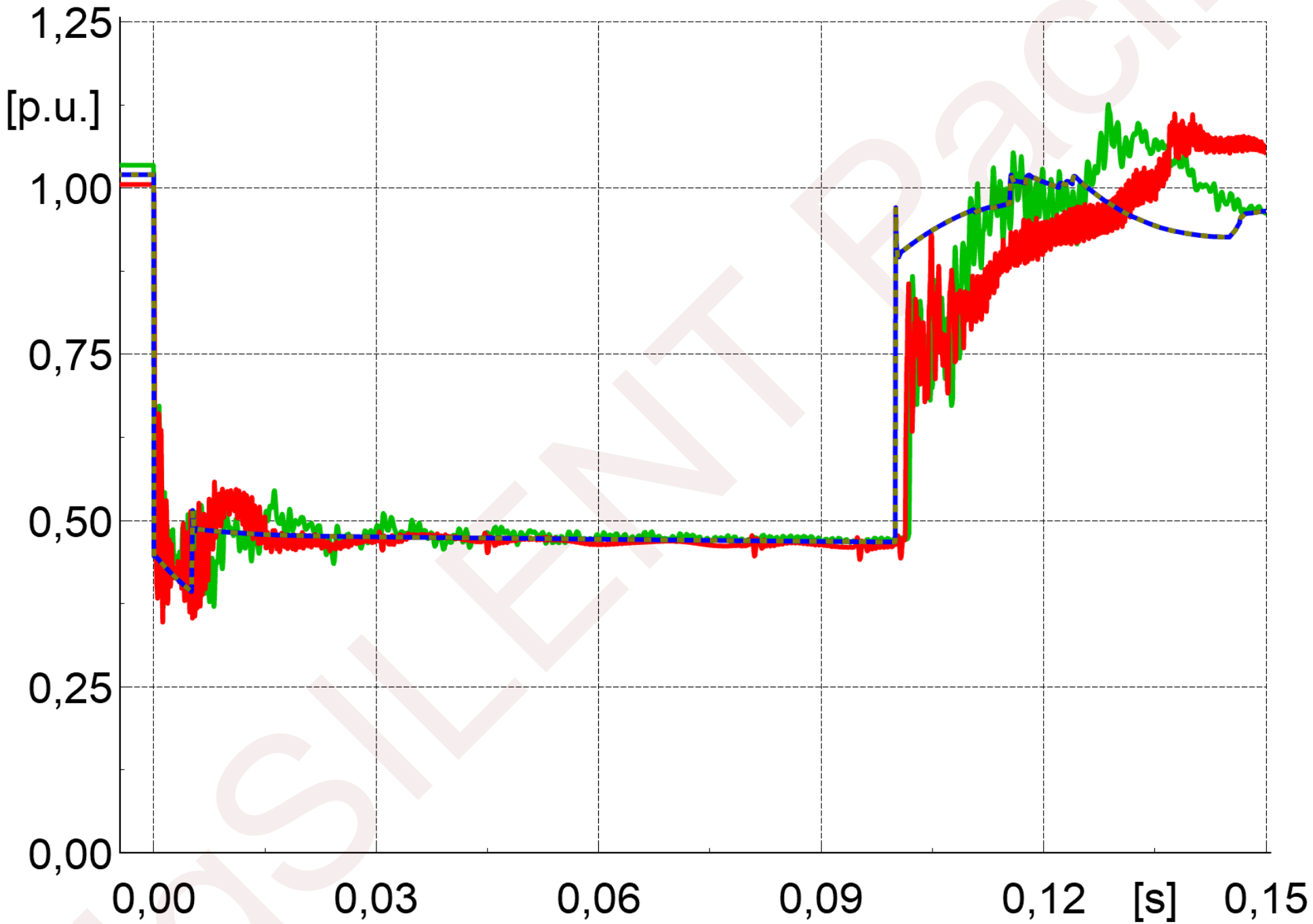
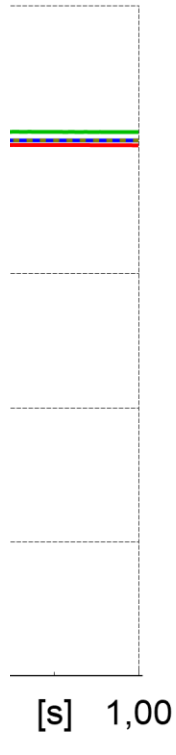
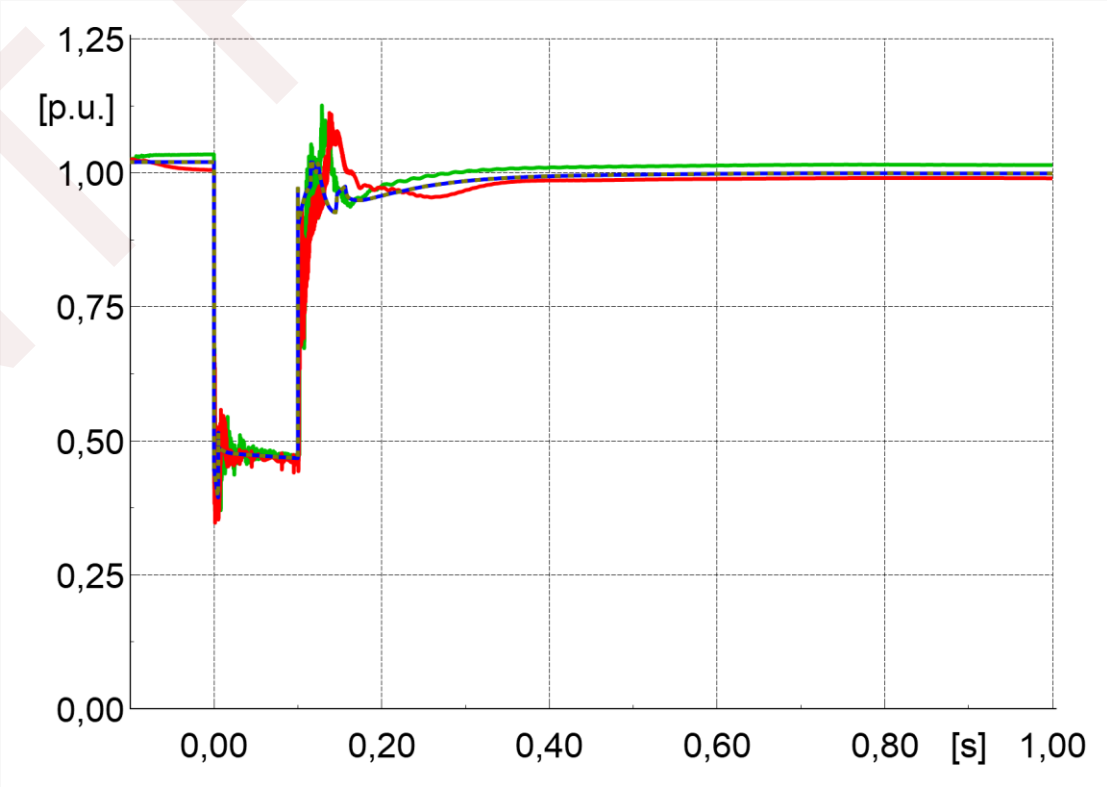




Results of the line fault 1) - Interpretation

- All simulations show a stable behavior after fault clearing
- The spikes shown in the EMT-based simulation might be relevant for a detailed analysis
- The need for an EMT-based simulation is limited
- **Co-simulation shows a good representation of the observed busbar**



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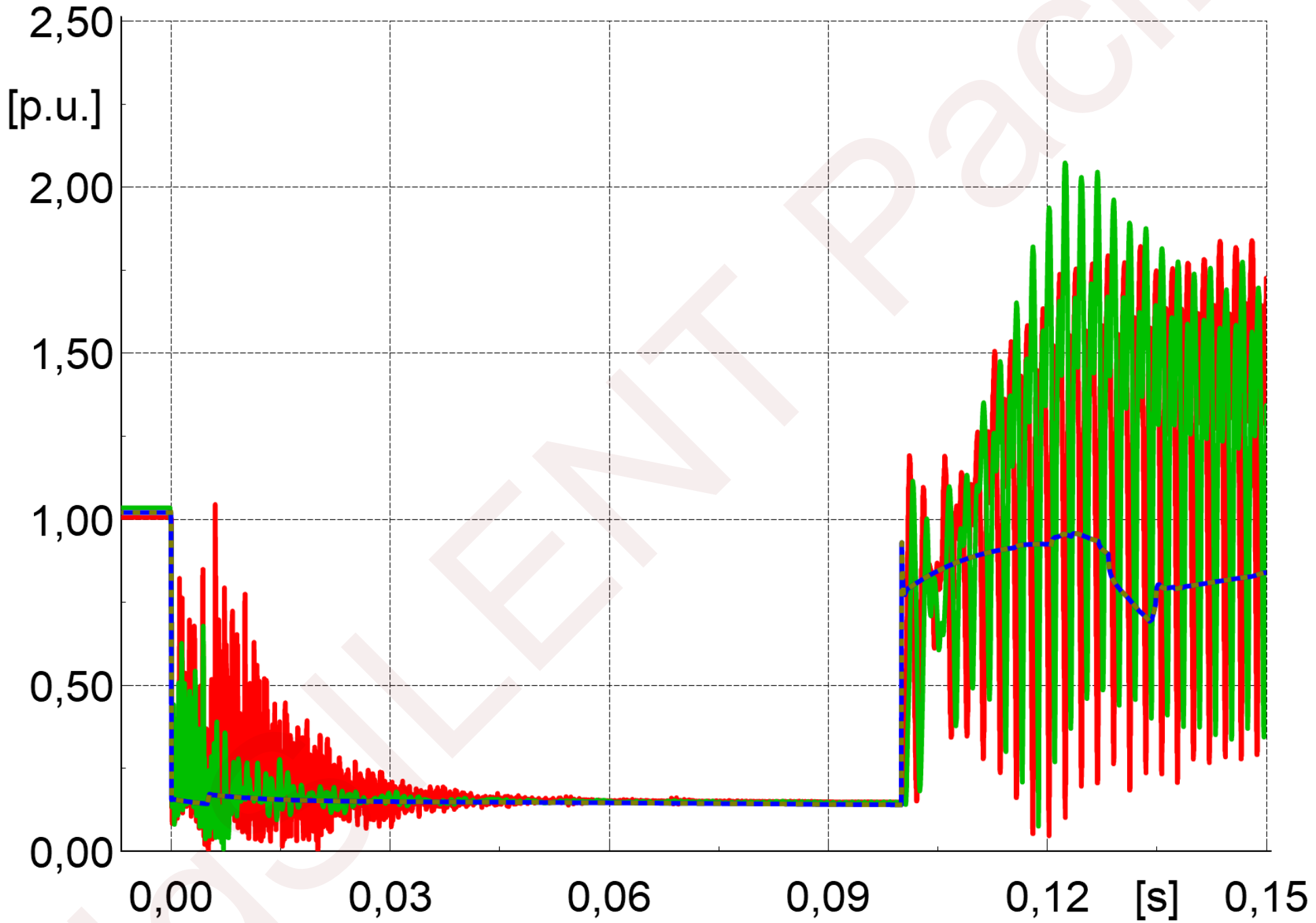
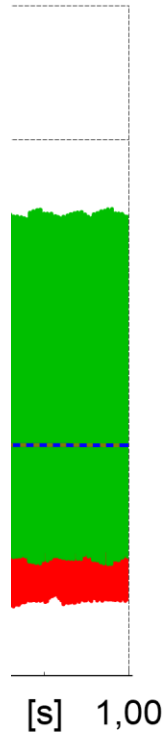
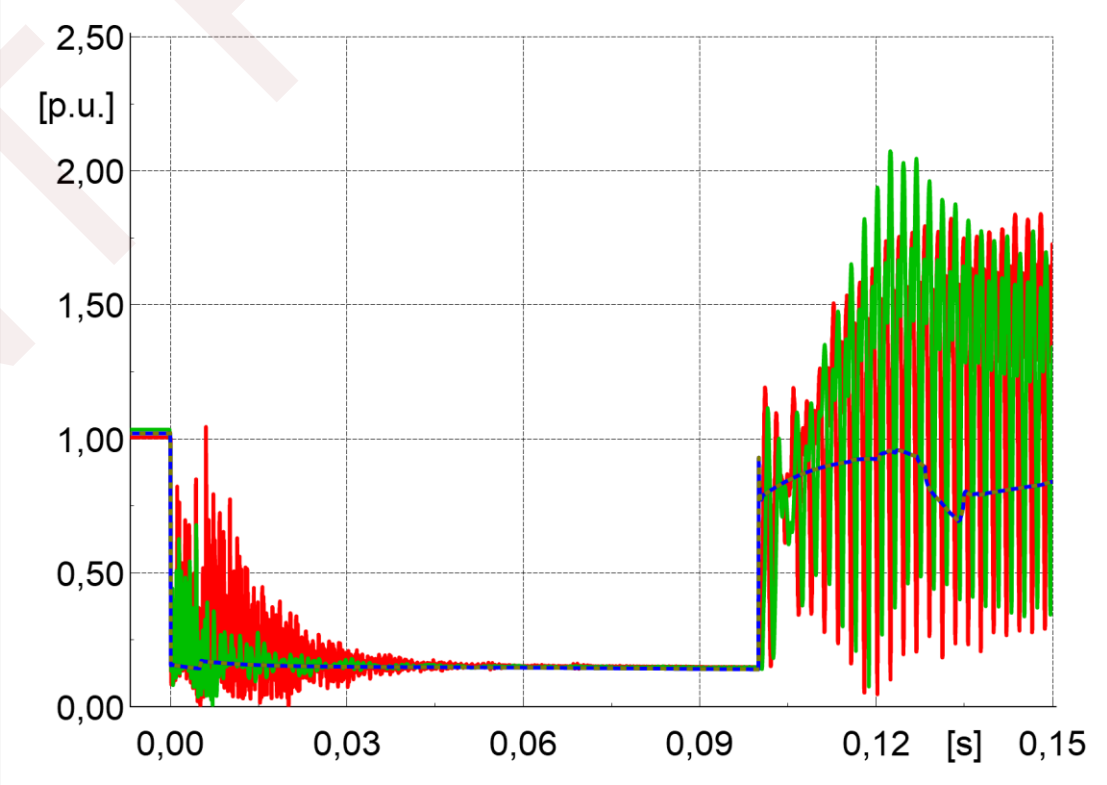


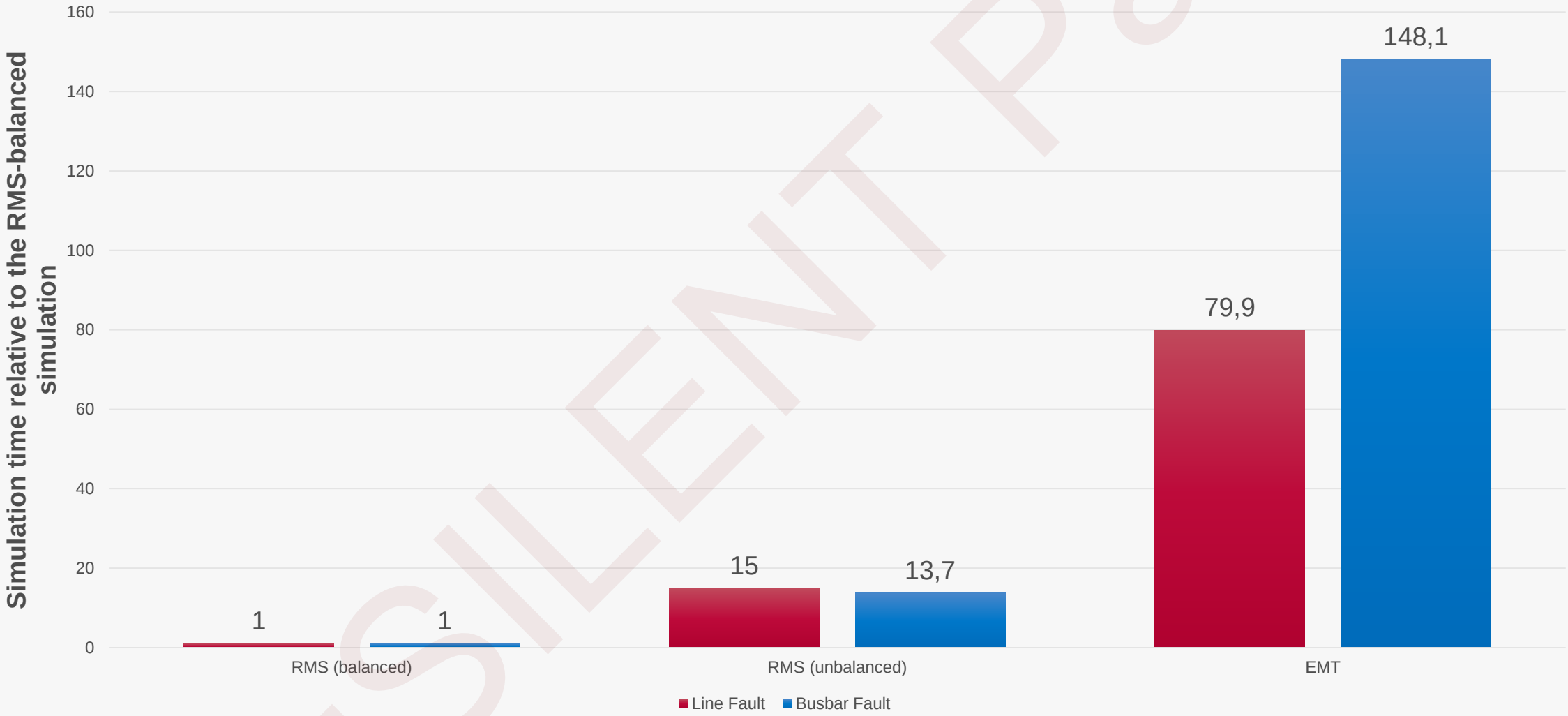


Results of the busbar 2) - Interpretation

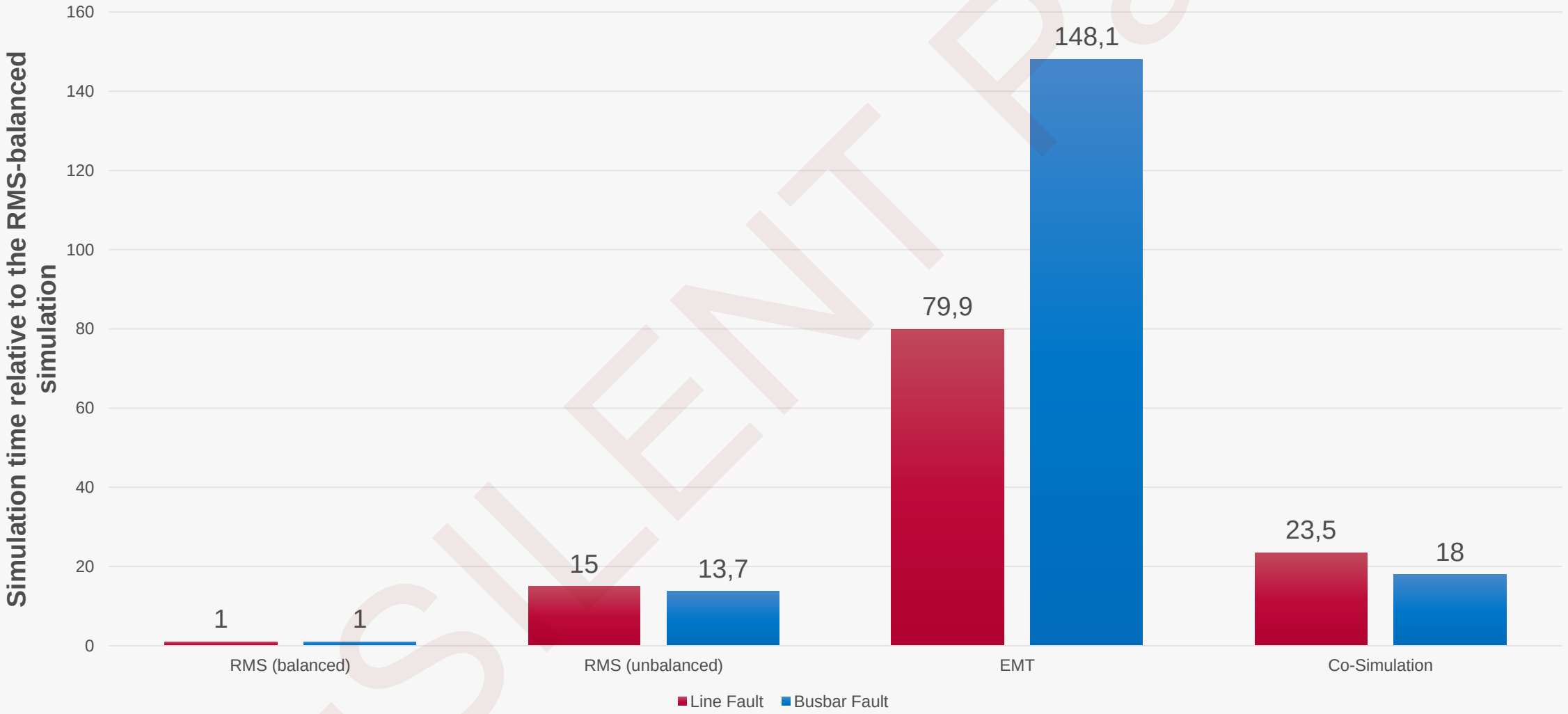
- The EMT-based simulation show an unstable oscillation above 1 kHz due to controller interactions
- The need for an EMT-based simulation is shown in this example
- **The unstable behavior can be represented using the co-simulation within PowerFactory**



Comparison of relative simulation performance



Comparison of relative simulation performance



Conclusion

- The used test case shows that in some cases of PE-based simulations, an EMT-simulation might be required to observe certain phenomena
- Co-simulation within PowerFactory can be used to observe such phenomena without the need to run a full model on EMT-basis
- The co-simulation however, can reduce the time required for a detailed EMT-simulation for certain study regions
- Co-simulation techniques can further be used for cross-platform simulations

Thank you!