Developing a co-simulation platform to evaluate impacts of grid faults in NPPs

Results from the COSI project

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Agenda

- Motivations
- Developing a co-simulation platform
- Models and testing the platform
- Fault-based studies
- Conclusions and future work

Why create a co-simulation platform?

Motivations behind the COSI project

- Nuclear power plants (NPP) are usually treated as black boxes in power system studies
  - Studies performed in electrical simulation software

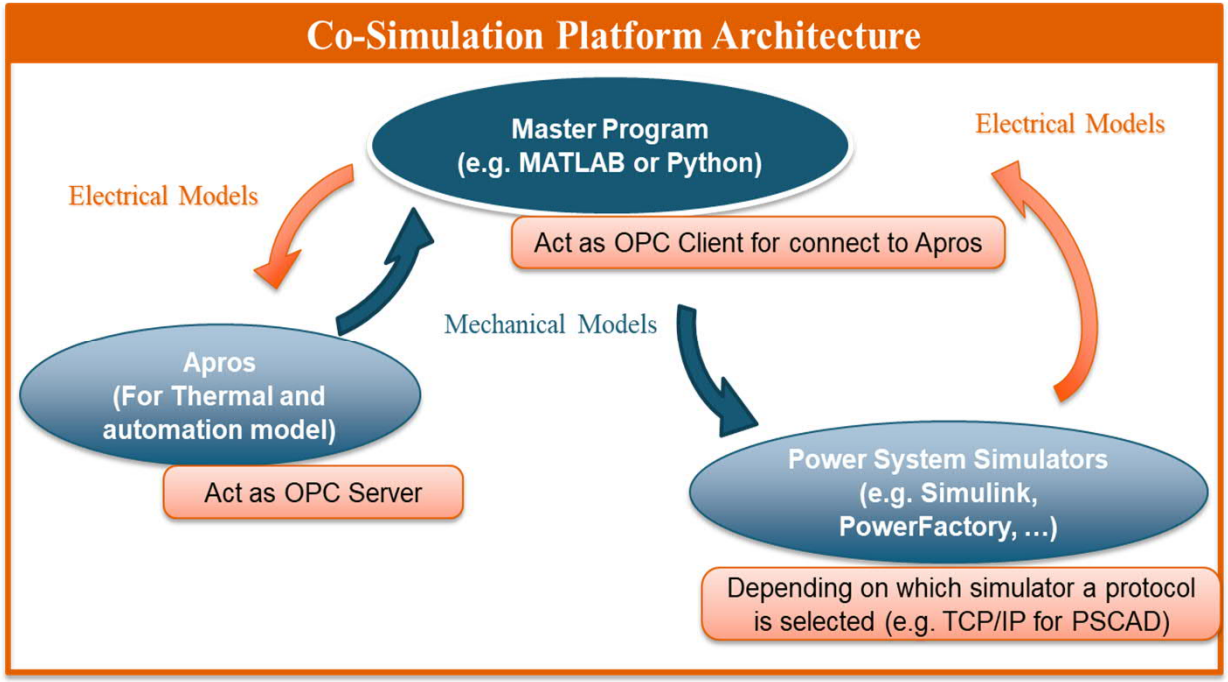
- Safety assessment and simulations for NPPs typically refrain from the off-site grid
  - Thermomechanical and reactor-physical systems are the focus of these studies

COSI idea overview

- COSI develops a detailed simulation tool for integrating on-site electric power system, off-site high voltage power system, and thermomechanical, reactor-physical and automation models.
- The simulation tool can be used for evaluating
  - Adequacy of safety requirements of the electrical systems in NPP
  - Impacts of grid disturbances on NPP behaviour
  - Impacts of NPP operating modes on the grid
  - We focus on the power grids that support the NPP (on- and off-site)
- SAFIR2022 project funding and support from Energiforsk, Fingrid and our Steering Group members

Developing the COSI platform

Combining thermomechanical simulation models with electrical simulation models



- Establish a communication and data exchange between the simulation of NPP models in Apros and electrical models in Simulink

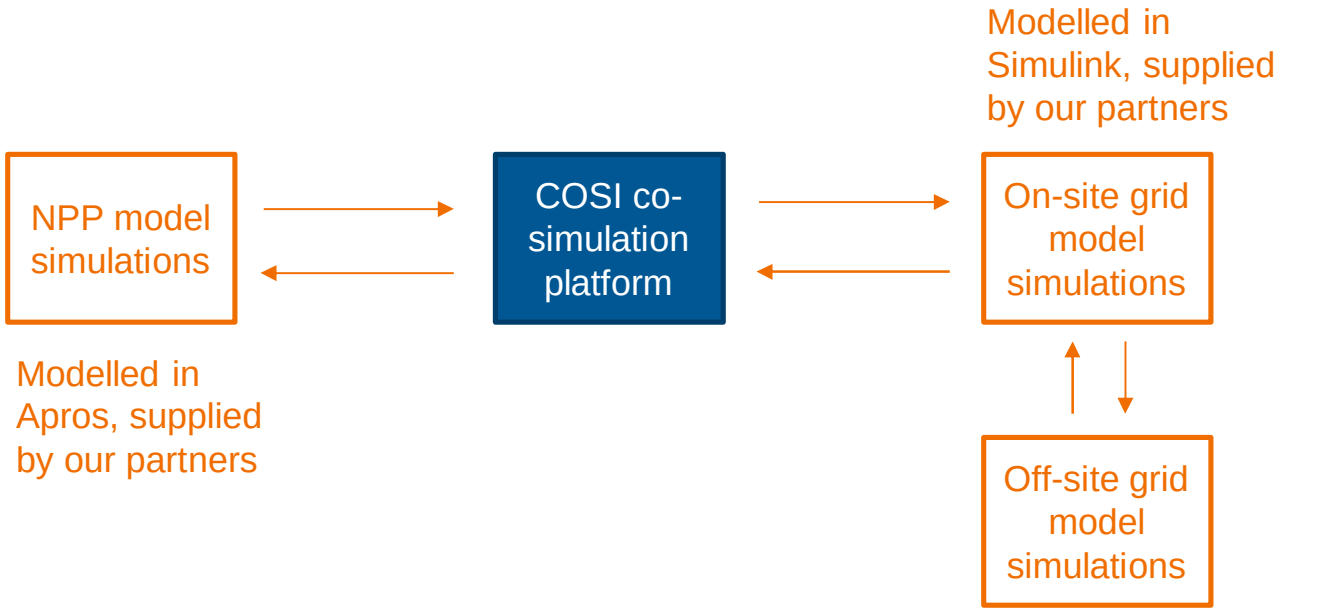
- Master file developed in MATLAB, future plans to take it to open access (2022?)

- Plans for support different electrical simulation tools (2022?)

Linking two simulations for a more complete overview of NPP operations and safety assessment

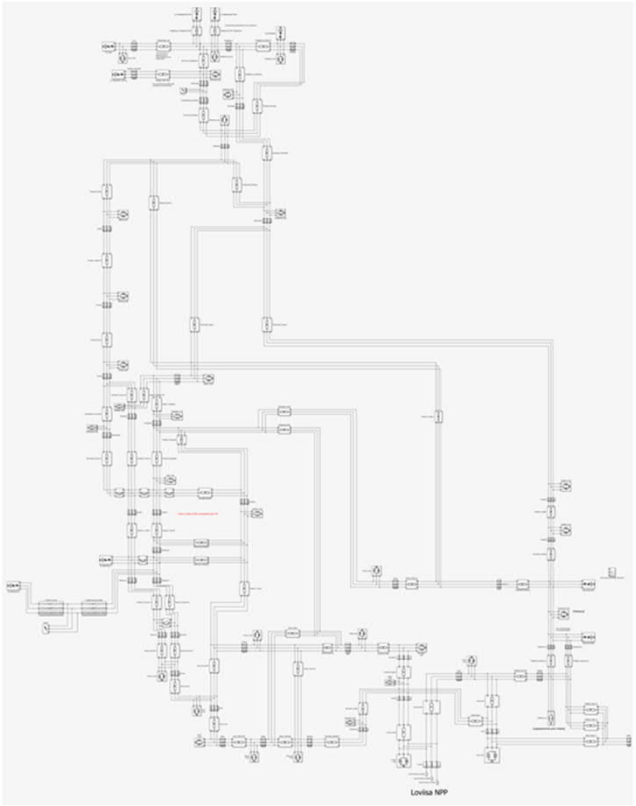
Plugging in the models

Plugging in simulation models



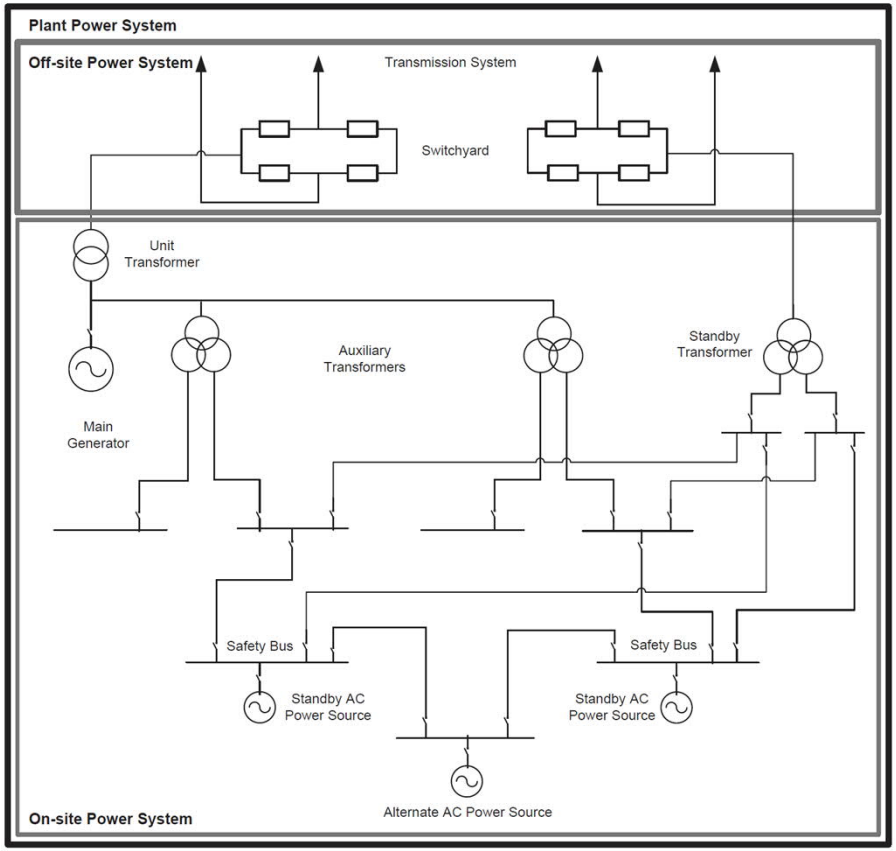
Off-site (Transmission system) model

- 8-node and later 50-node model for the Finnish transmission grid developed in Simulink by Aalto University
- Very useful by-product of the COSI project

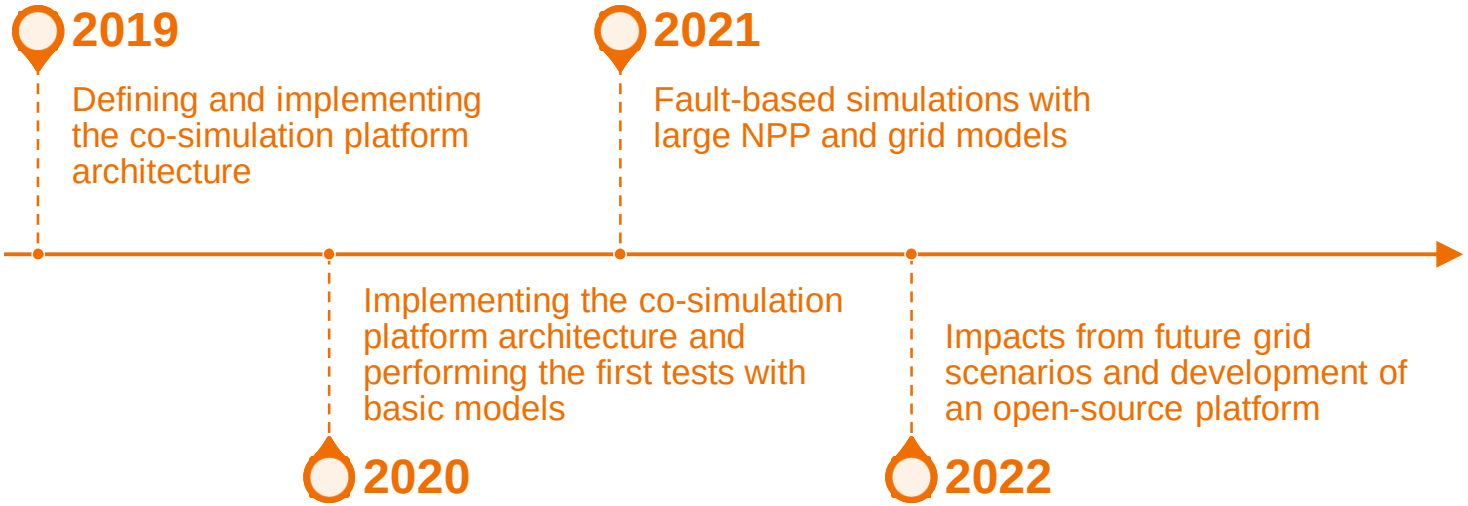


Testing the platform through Fault-based studies

COSI tests and simulations focus on the on-site and off-site electric grids



COSI platform development



Fault-based studies in 2021

Defined 6 priority locations on the on- and off-site grids

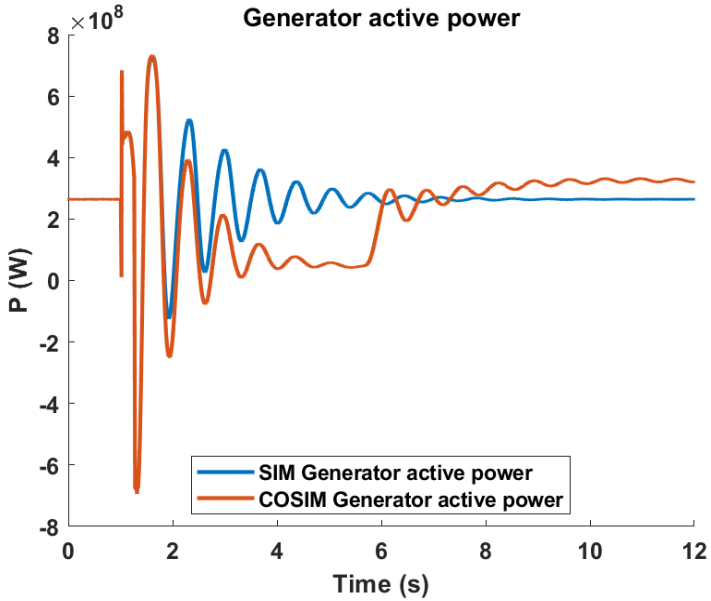
Defined fault types and parameters to evaluate

Selected different scenarios for the comparison between a co-simulation (including thermomechanical models) and a purely electrical simulation

Fault scenario 1

- Evaluating the main generator active power output at the event of a short circuit lasting 250 ms at the low voltage side of the unit transformer (15 kV)

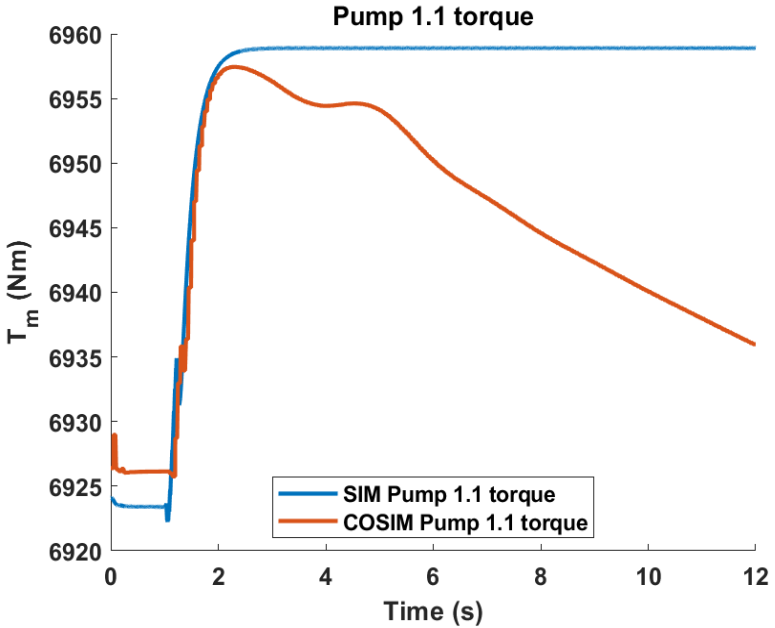
- Electrical simulation shows a much quicker recovery of the generating unit
- Co-simulation considers the instability in the automation control and thermomechanical processes



Benefit from the co-simulation platform: suitability to analyse border cases when the protection does not clear the fault at designated limits

Fault scenario 2

- Behaviour of a pump after a 200 ms open phase condition at the main generator output
- Torque stabilises after fault in the electrical simulation
- Co-simulation shows this torque remains falling way after the fault
- Inclusion of constant updates on mechanical parameters from the Apros model gives a different behaviour



SIM - utilising only static values to model the thermomechanical behaviour
COSIM - constant updates in control variables at the NPP based on the automation responses.

Many other possibilities

- The COSI platform was developed so that we can analyse the behaviour of many different entities in the NPP, on-site grid and off-site grid
- Different fault scenarios implemented in the Simulink models produce impacts in the behaviour of Apros components
- In-depth analysis of the NPP behaviour is out of our scope and expertise, but we count with the great feedback of our Steering Group

Conclusions and next steps

Main takeaways

- The better and more detailed models we have, more trustworthy are the results we obtain from a co-simulation

- Co-simulation platform an interesting resource for designing and modelling protection and back-up systems at the on-site grid

- Fast faults may not be the main use case for the co-simulation platform: interesting to look at slow and systematic changes (e.g. low inertia transmission system)
  → proposed continuation in 2022

Main takeaways

- Still a long way from a complete and final tool, but results show promise
- Communication between simulation software working as expected
  - Inputs from the thermomechanical side are considered in the electrical side and vice-versa
- Possibility to add new electrical simulation software and open-source platform to reach more experts
- We greatly welcome feedback and interaction with industry experts

VTT

beyond

the obvious

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