

Co-simulation between RTDS and TSAT as a validation method for InterSCADA solutions

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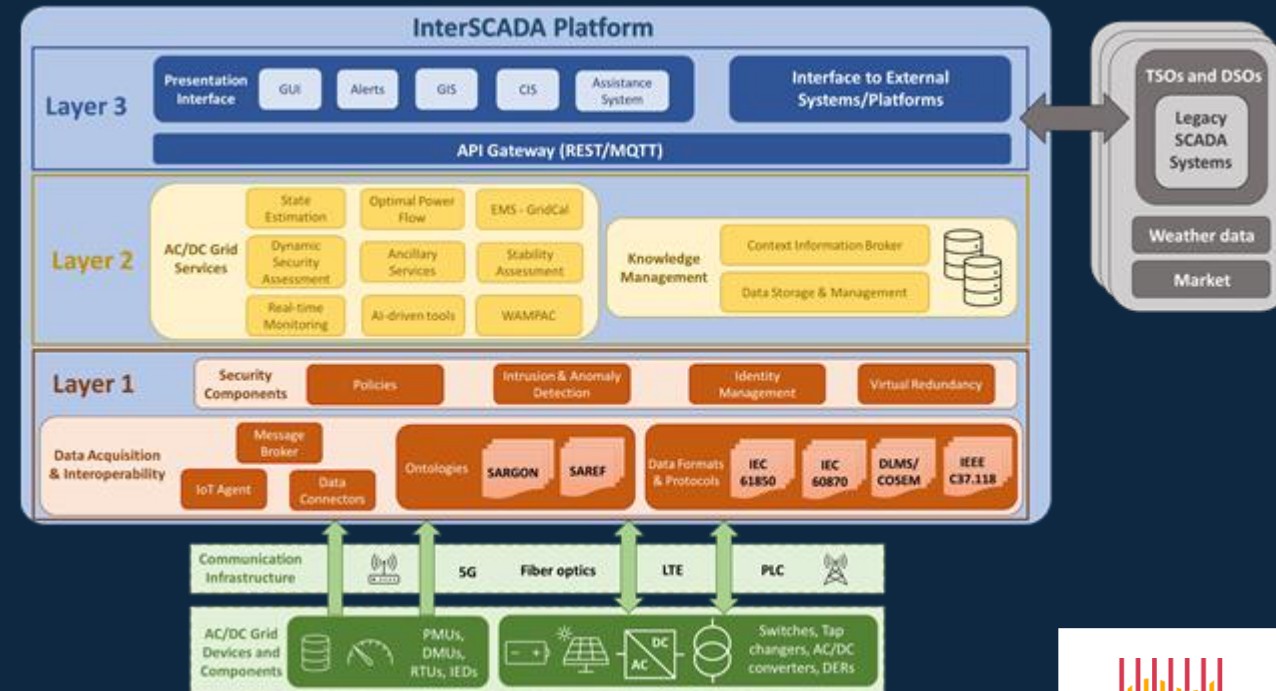
Agenda

1. Introduction
2. Model and laboratory setup description
3. Microservice testing
4. Summary

1. Introduction

RTDS as a development tool for InterSCADA EU project

- Scope of InterSCADA Project:
 - Develop a **flexible data-driven ICT infrastructure**
 - Develop **algorithms for real-time operation of hybrid AC/DC grids**
 - Validate solutions through real-world demonstrations (ES, FR, GR, IT)
 - Identify **gaps in the existing regulations and grid codes**

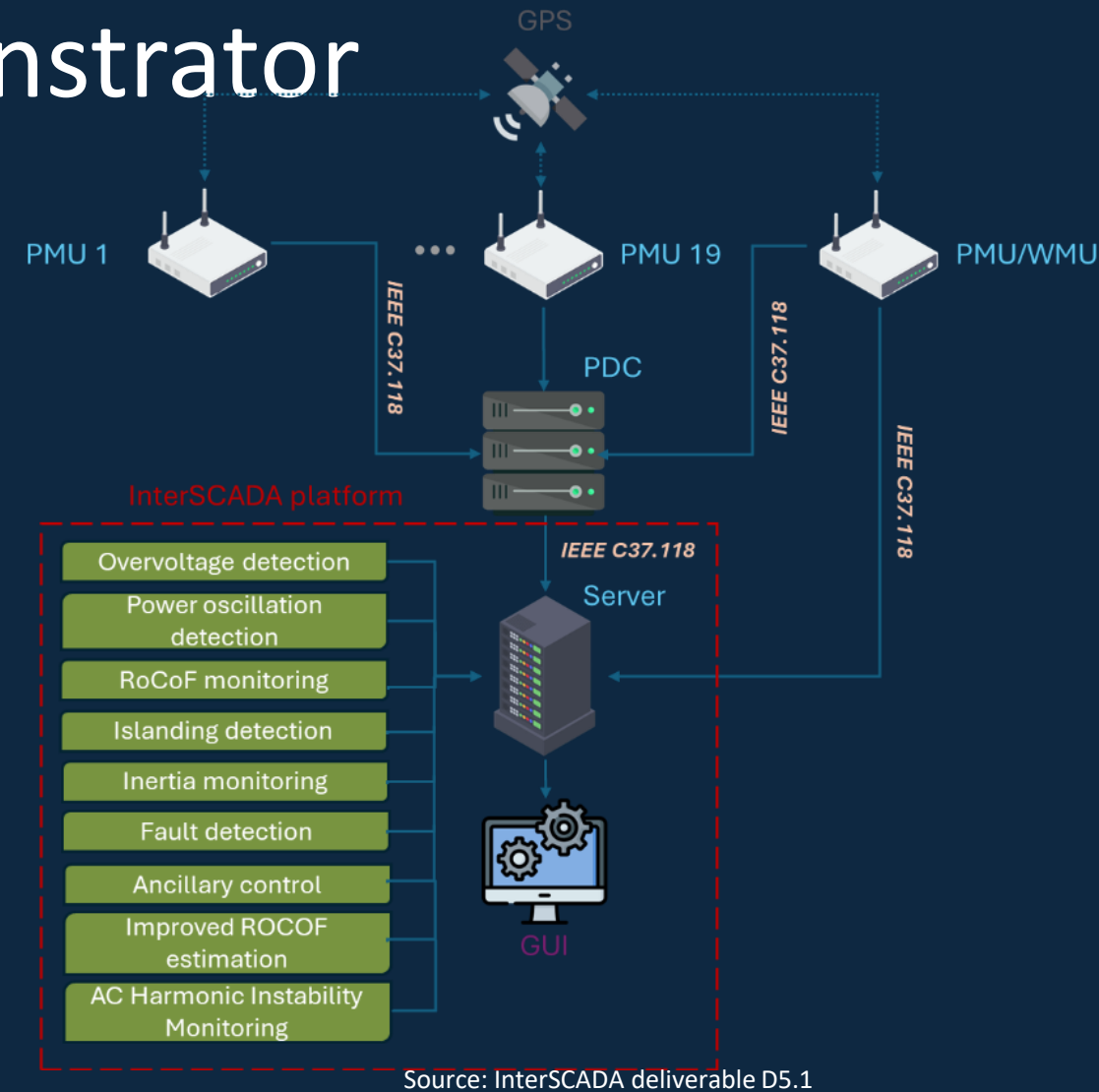


Source: InterSCADA deliverable D5.1



InterSCADA: Greek Demonstrator

- In the development phase RTDS was used in place of the dedicated server architecture
- Together with PMU capability of the GTNETx2 card allowed for development and testing of the microservices
- Other communication functions of the GTNETx2 card were also handy (UDP via SKT)
- Proper power system model was required



2. Model preparation

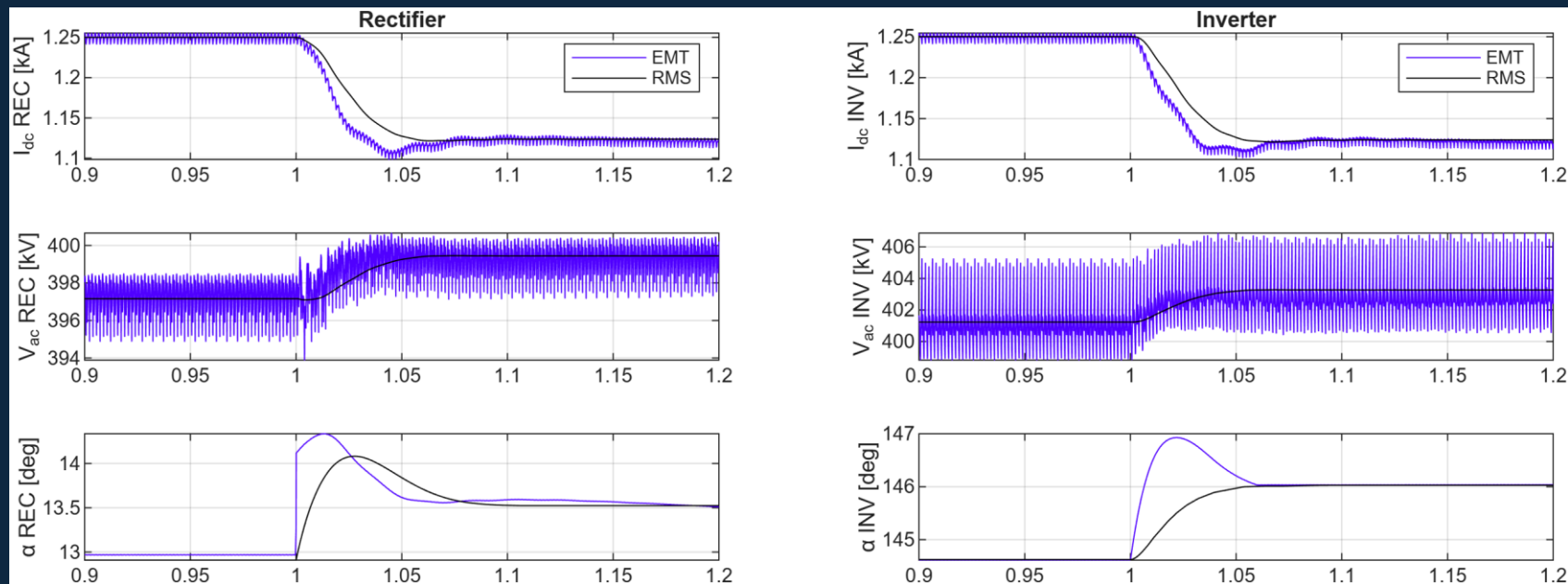
Model preparation for Greek demo

- The key element of Greek demonstrator is the GRITA HVDC link between Greece and Italy (LCC 500 MW, 400 kV)
 - This model was constructed based on common control structure (CHVDC2 model)
- IPTO provided RMS model of a large part of the Greek power system
- The goal was to use both of these models together in a co-simulation environment, gaining:
 - More accurate representation of DC link response to system disturbances (EMT part)
 - More accurate representation of the large power system response for disturbances in this system (RMS part)

Response to -0.1 step change in I_{dc} reference

Modeling of LCC HVDC

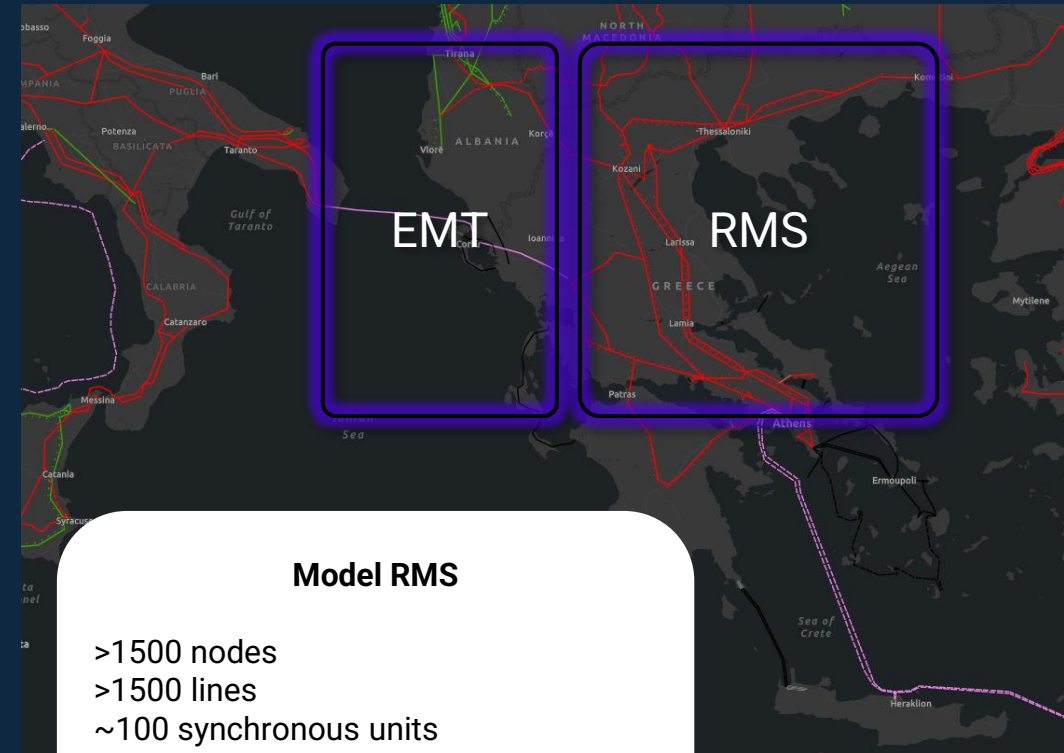
- CHVDC2 model was used for LCC HVDC link representation in RMS domain
- The same control structure was represented in RTDS



Response to -0.1 step change in I_{dc} reference

Co-simulation model

- Once the DC model was verified, one AC system was substituted with a large model of the AC power system in RMS domain
- To do this, co-simulation environment has been set up



Model RMS

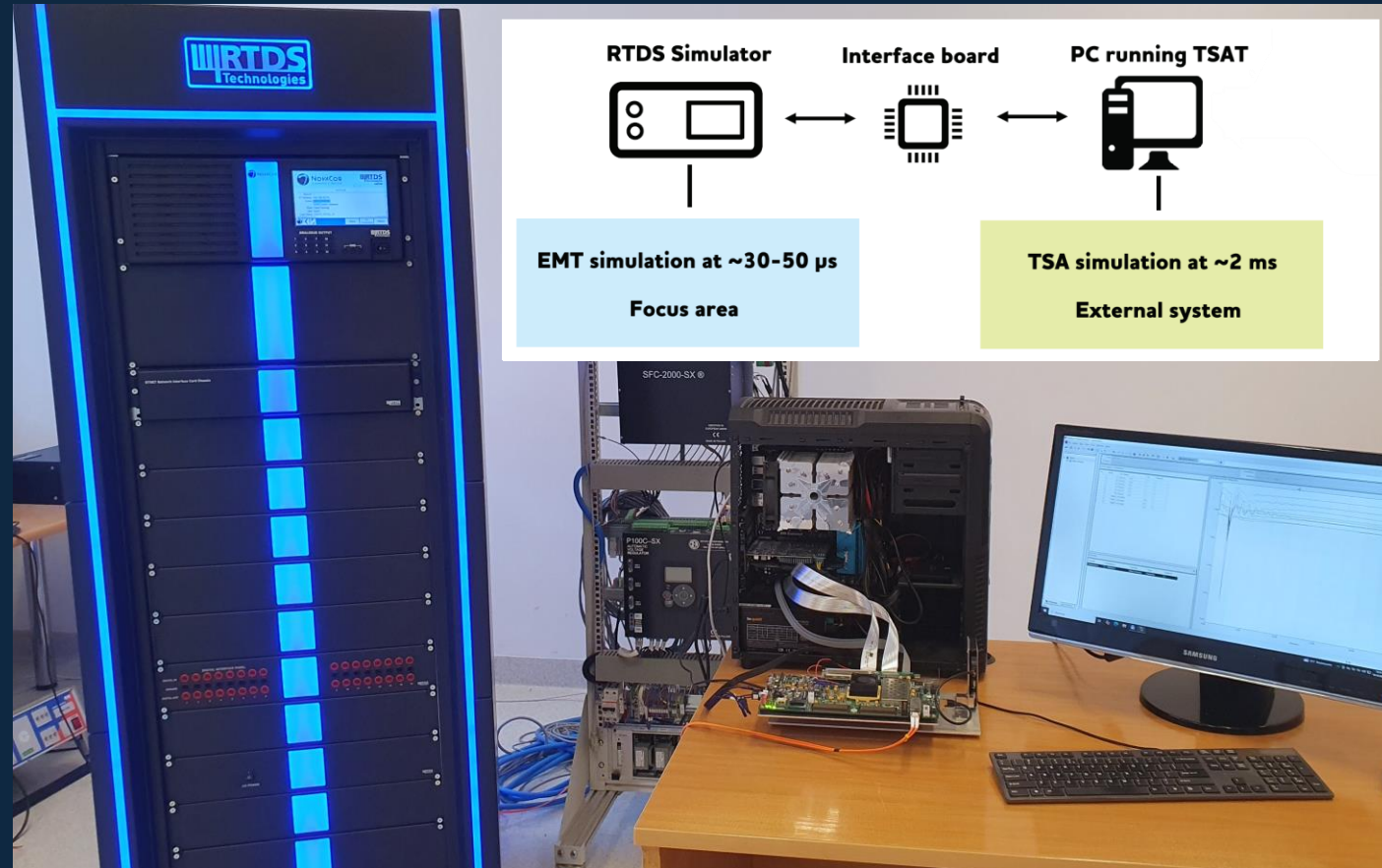
>1500 nodes
>1500 lines
~100 synchronous units

Model EMT

HVDC 500 MW Greece – Italy (GRITA)

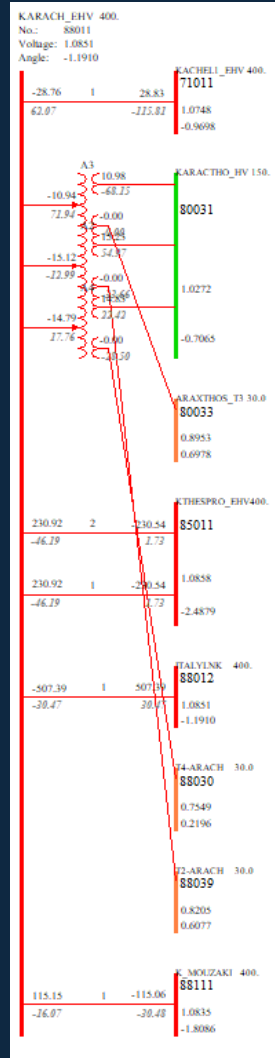
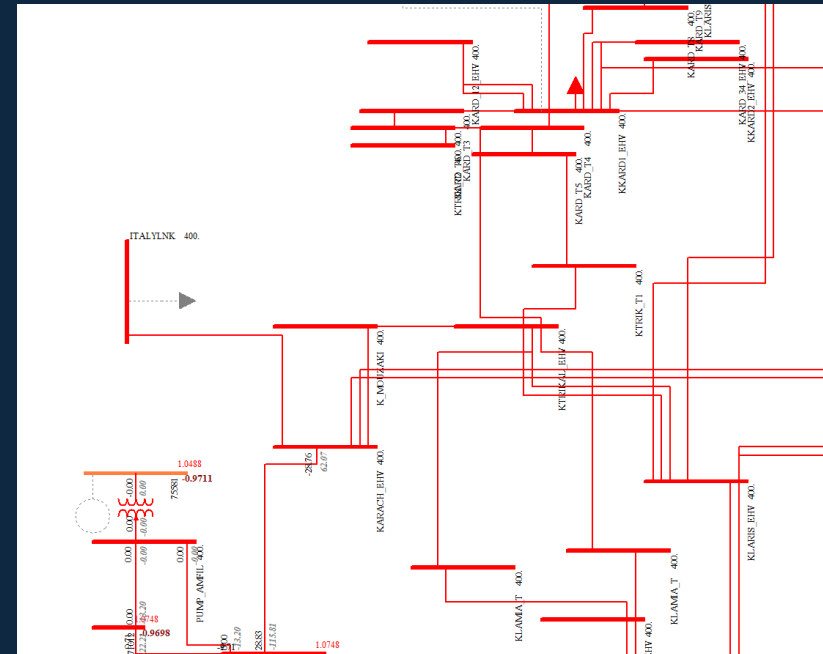
Co-simulation setup

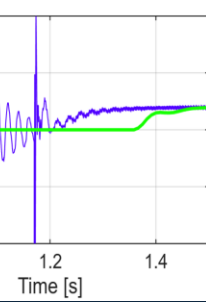
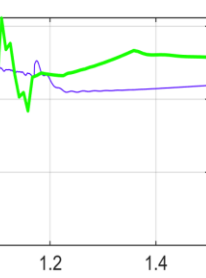
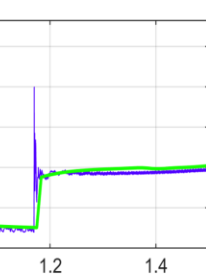
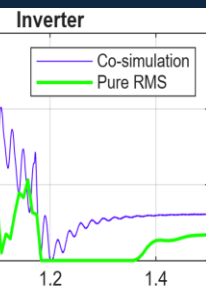
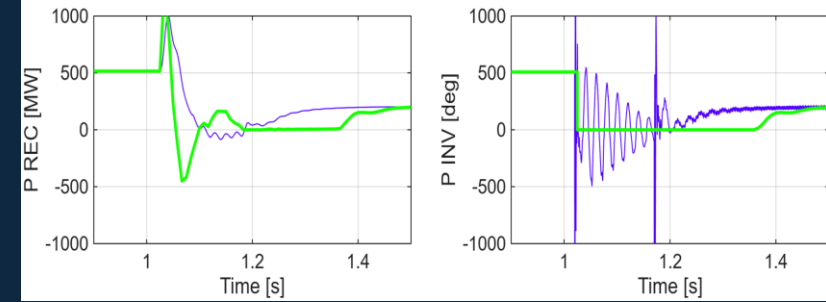
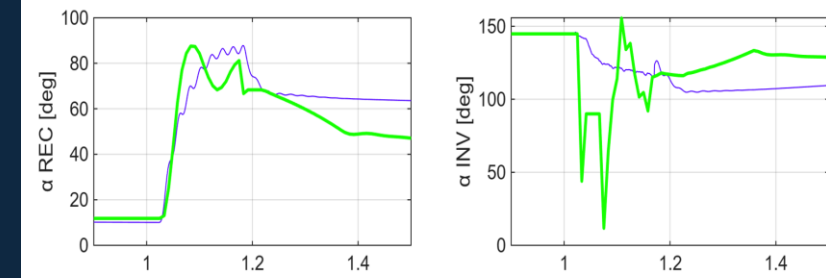
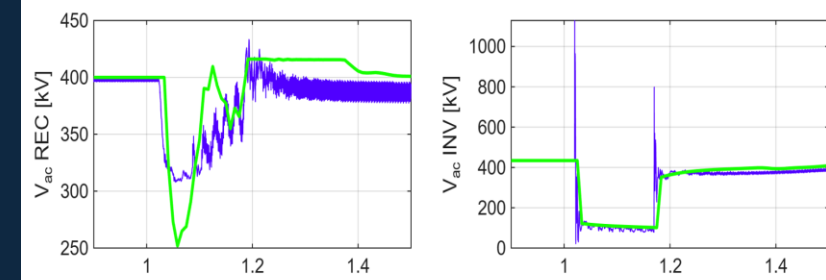
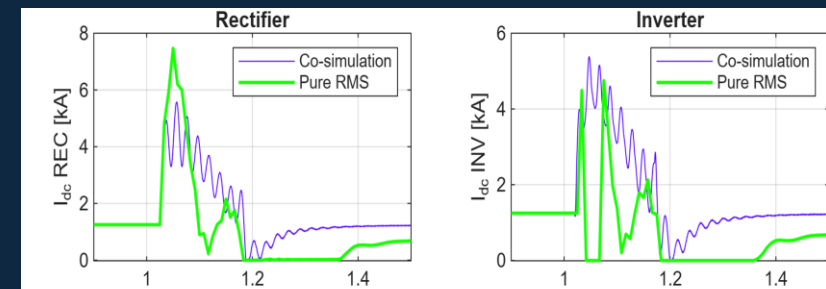
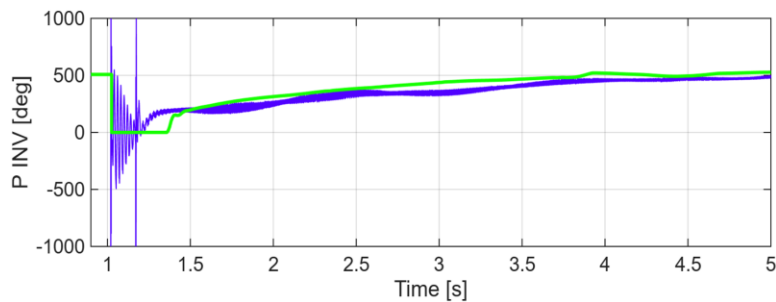
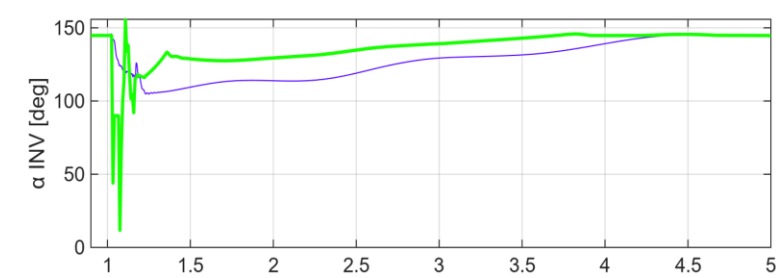
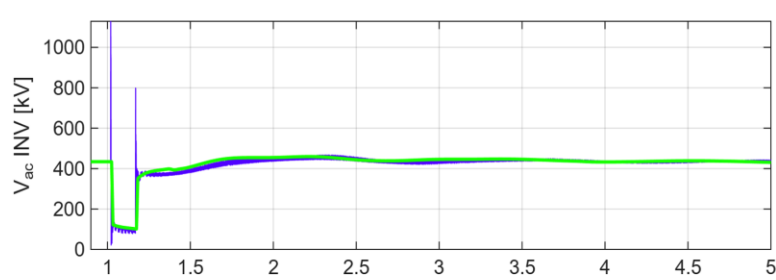
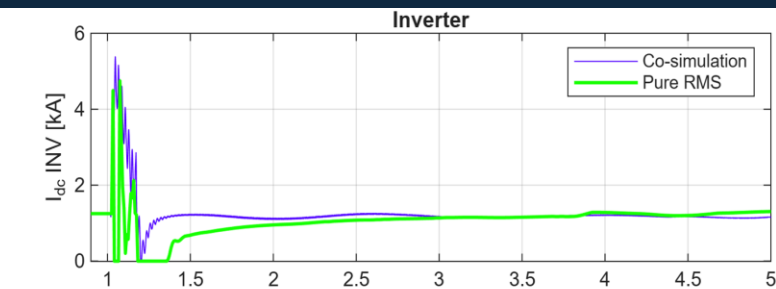
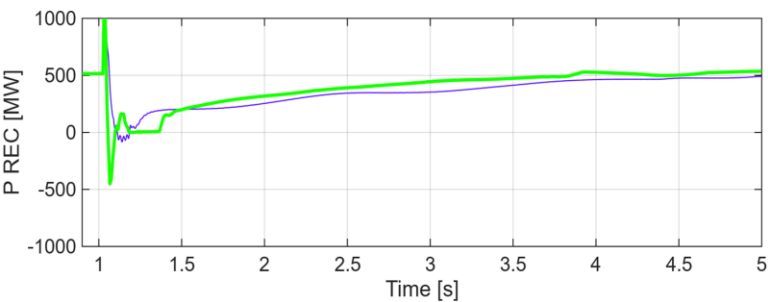
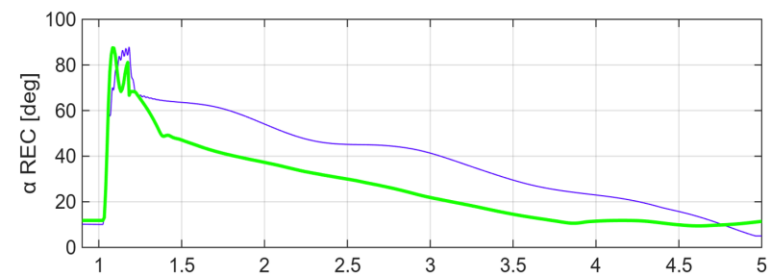
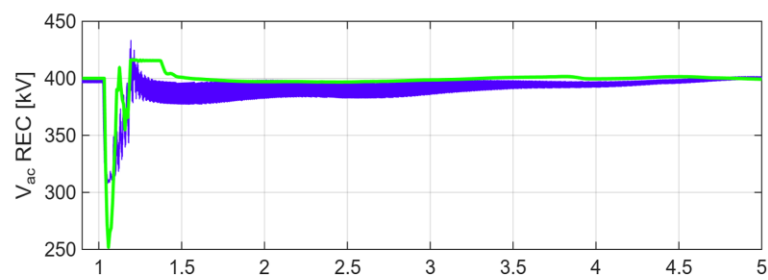
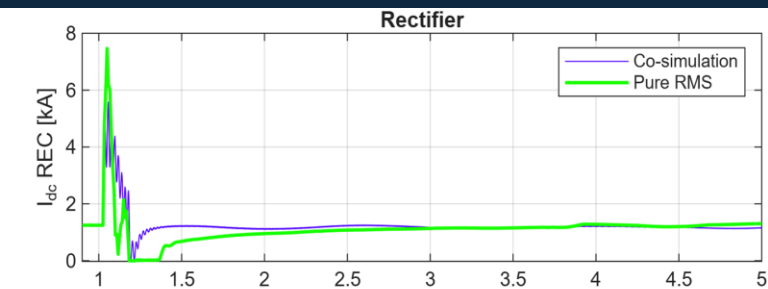
- What is needed?
 - RTDS rack
 - PC with decent CPU
 - Interface card (AMD Virtex7 FPGA card)
 - DSA Tools TSAT with TRI license
- Seamless installation process in RTDS (it is just detected as a regular FPGA card!)

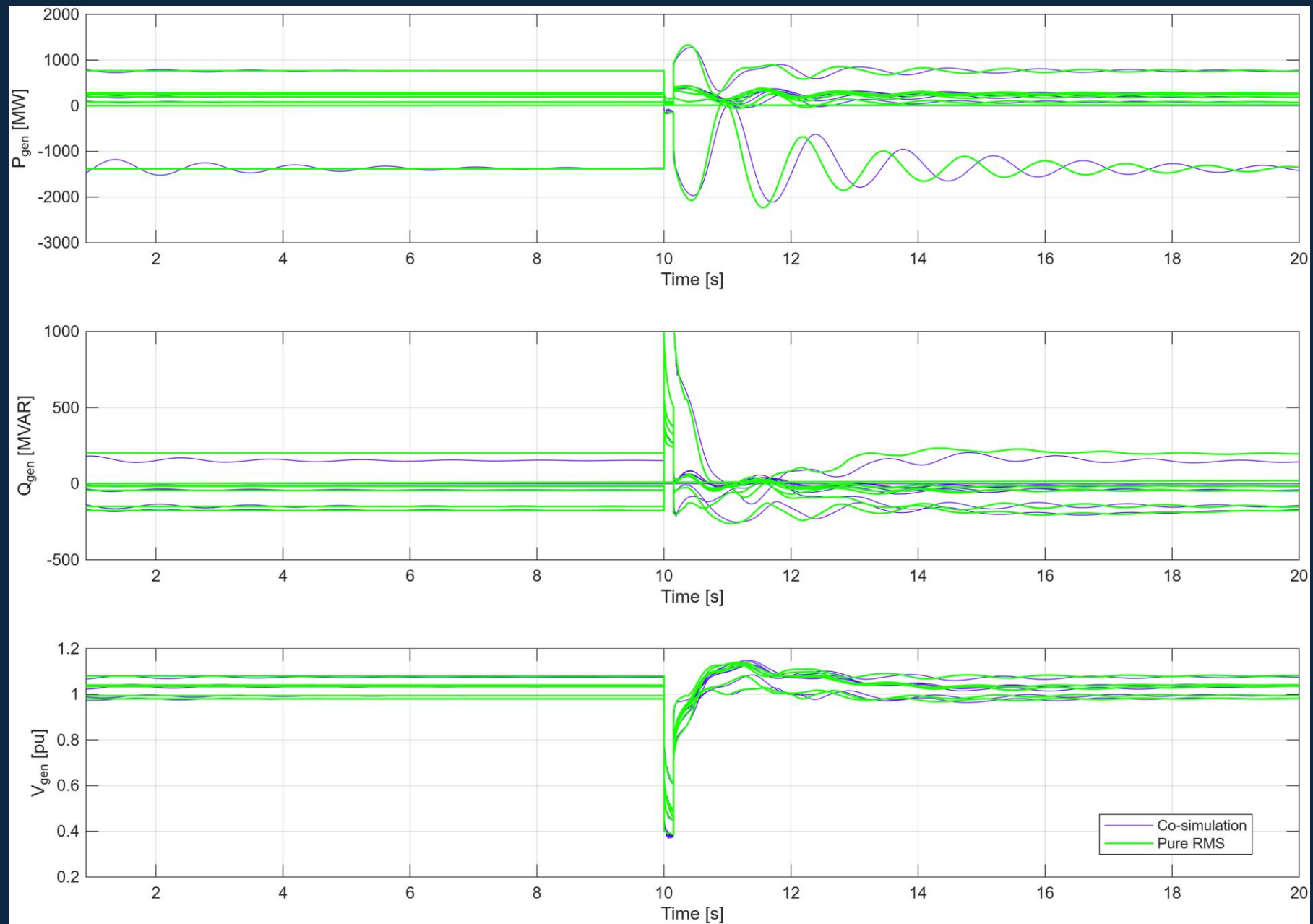


Boundary definition

- Key element of the co-simulation model is the boundary between the two parts
- It should not be located where the faults are to be simulated
- The DC is connected to a strong node with a lot of connections
- TSAT facilitates complex boundaries and multiple boundaries via a special tool



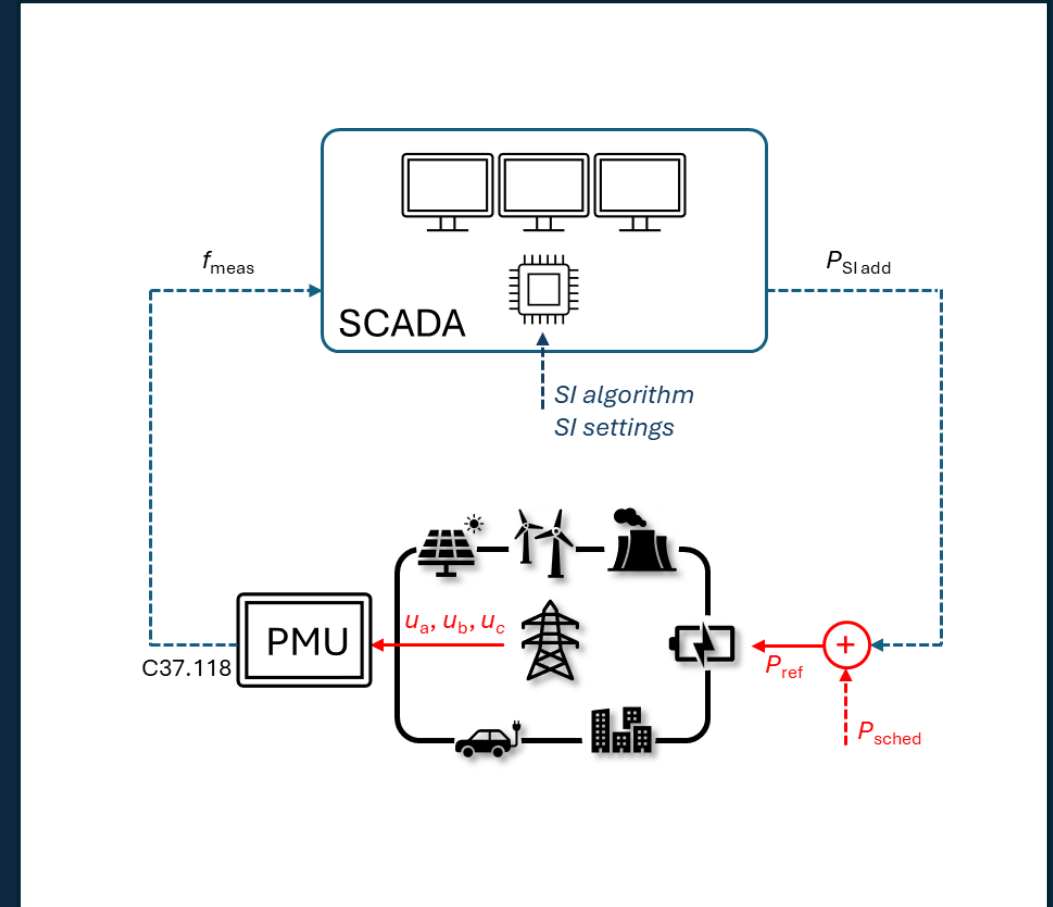




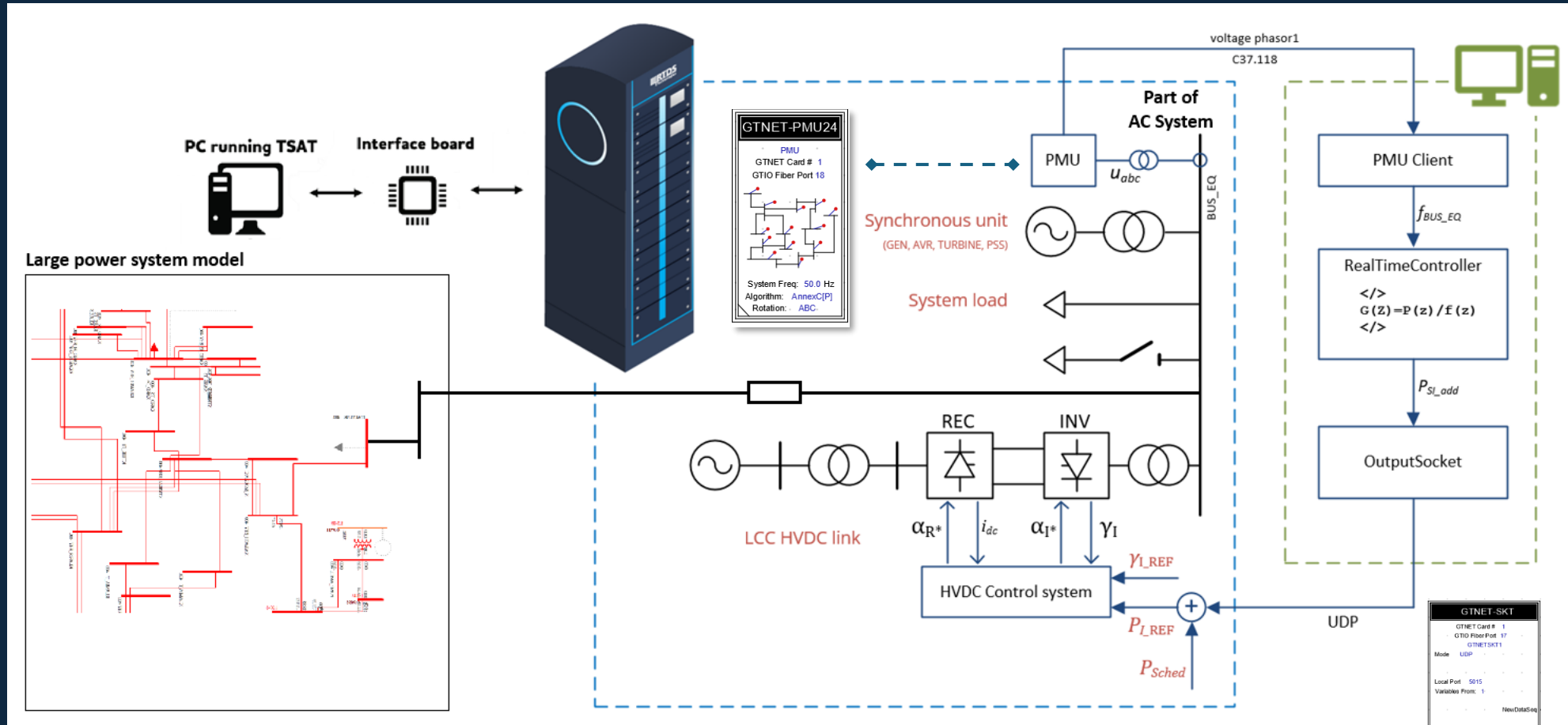
3. Microservice testing

Inertial response from non-inertial resources

- Microservice enables inertial response from GFL devices
- Both frequency measurements and auxiliary control signal are external to the device, i.e.
- Central control offers more flexibility, quick re-tuning, etc. which might be beneficial from inertia market perspective
- The goal of this demonstration is to show that remote frequency measurement and centralized control can be used to obtain synthetic inertia from a line commutated HVDC link.



Closed-loop control with centralized controller



Centralized inertia control

- Central inertia controller
$$G_{SI}(s) = \frac{K_{SI} \cdot s}{(T_{m1}s + 1)(T_{m2}s + 1)(T_{SI}s + 1)}$$
- The algorithm implemented in Python is executed in real-time on a PC, thus the controller needs to be discretized ($T_s = 20$ ms)

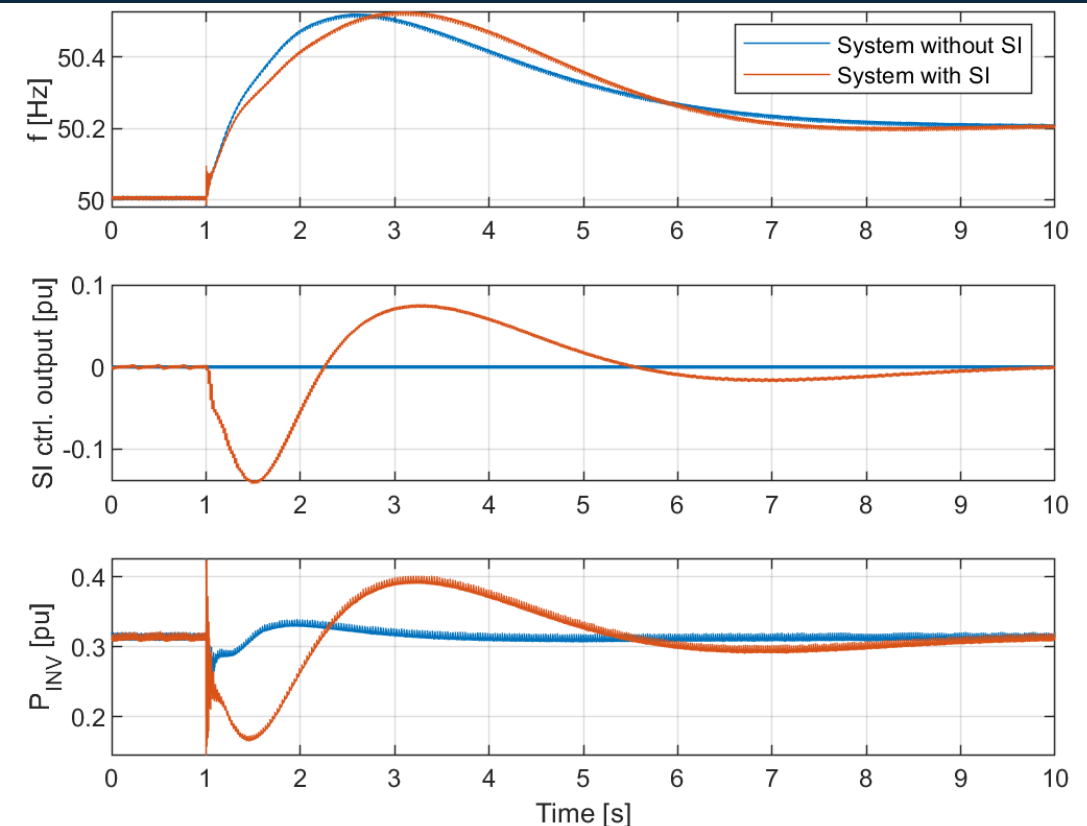
$$G_{SI}(z) = \frac{b_4 \cdot z^4 + b_3 \cdot z^3 + b_2 \cdot z^2 + b_1 \cdot z^1 + b_0}{a_4 \cdot z^4 + a_3 \cdot z^3 + a_2 \cdot z^2 + a_1 \cdot z + a_0}$$

- The microservice is:
 - listening to PMU stream at a specified port and IP address,
 - calculating the command signal for auxiliary input of active power reference of the resource (here LCC HVDC link) based on difference equations of the filter,
 - providing the command signal back to the RTDS via UDP protocol and.

Sample results

- 5000 MVA system with inertia constant $H=2.5$ s is being simulated. HVDC rating is 500 MW.
- At time $t=1.0$ s load is tripped and total demand of 400 MW is lost.
- Contribution from HVDC help to slow down frequency rise (**orange curves**) as compared with a case where synthetic inertia controller was off (**blue curves**)

```
#Connection to PMU: 192.168.20.72:4716 ID:2
FRAME SIZE: 94
ID CODE: 2
FRAC SEC: 31749
CHK: 170B
TIME BASE: 1000000
NUM PMU: 1
***** Station 1 *****
DATARATE: 50
Connection to PMU: OK!!
Executing control loop...
Freq: 49.9990 Hz -> U: -0.0044
Freq: 49.9990 Hz -> U: -0.0168
```



Conclusions

1. Although usually EMT domain is not necessary for simulation of phenomena related to frequency excursions and insufficient system inertia, it can be used if models are available.
 - In particular with real controllers in HIL setup
2. Co-simulation with RMS domain enables a very accurate representation of the power system, with all of its various devices reacting to frequency changes differently
 - Large models can handle thousands of such devices, each with different settings

Conclusions

3. While TSAT extends model range extensively, it also brings in limitations to time simulation (i.e. long simulation time is discouraged). Both TSAT and RTDS handle the interface really well.
4. RTDS proved to offer excellent testing capabilities.
GTNETx2 card with PMU C37.118 protocol and UDP via SKT protocol enable to close the loop even for time-requiring controllers (i.e. not really SCADA-like)