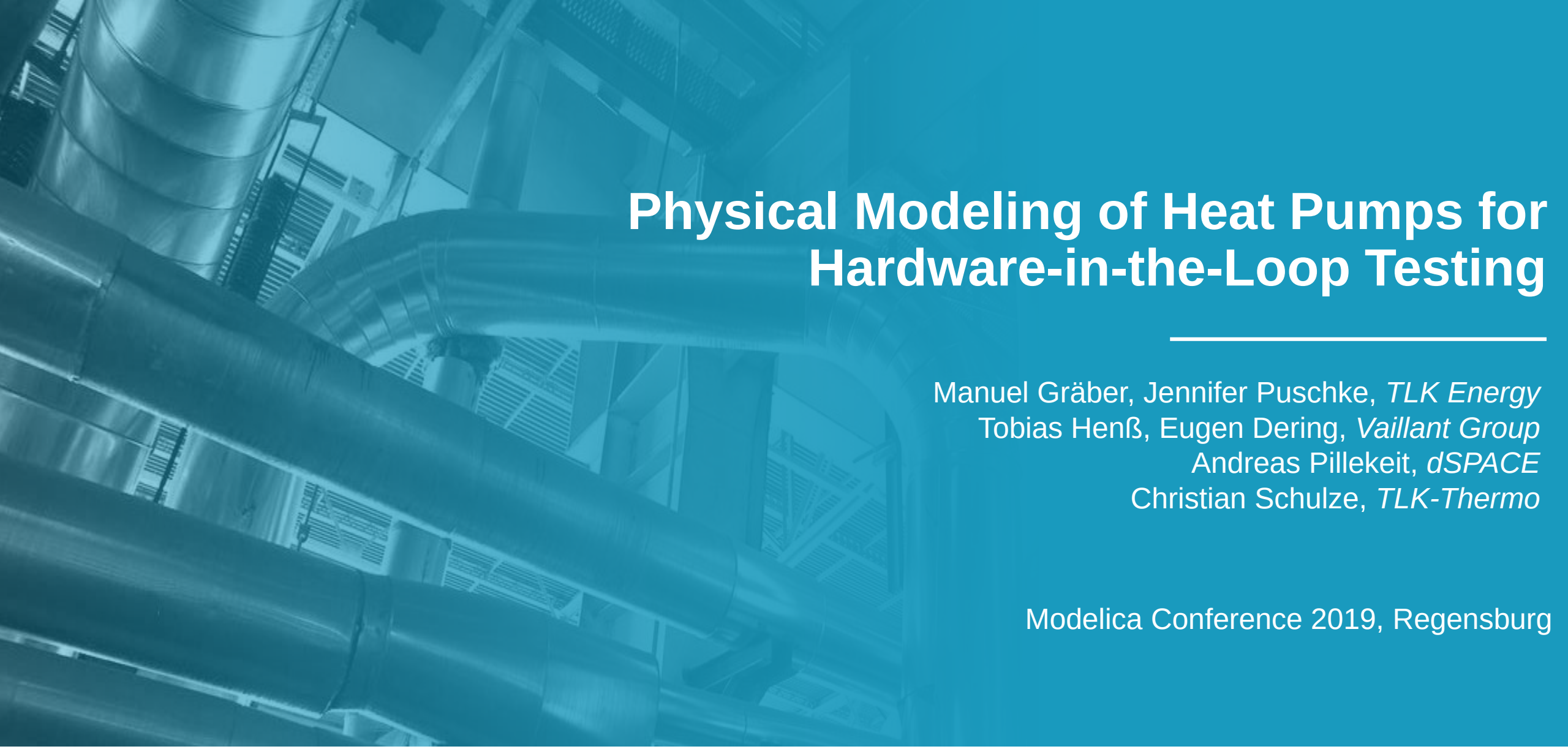


Physical Modeling of Heat Pumps for Hardware-in-the-Loop Testing

Manuel Gräber, Jennifer Puschke, *TLK Energy*
Tobias Henß, Eugen Dering, *Vaillant Group*
Andreas Pillekeit, *dSPACE*
Christian Schulze, *TLK-Thermo*

Modelica Conference 2019, Regensburg

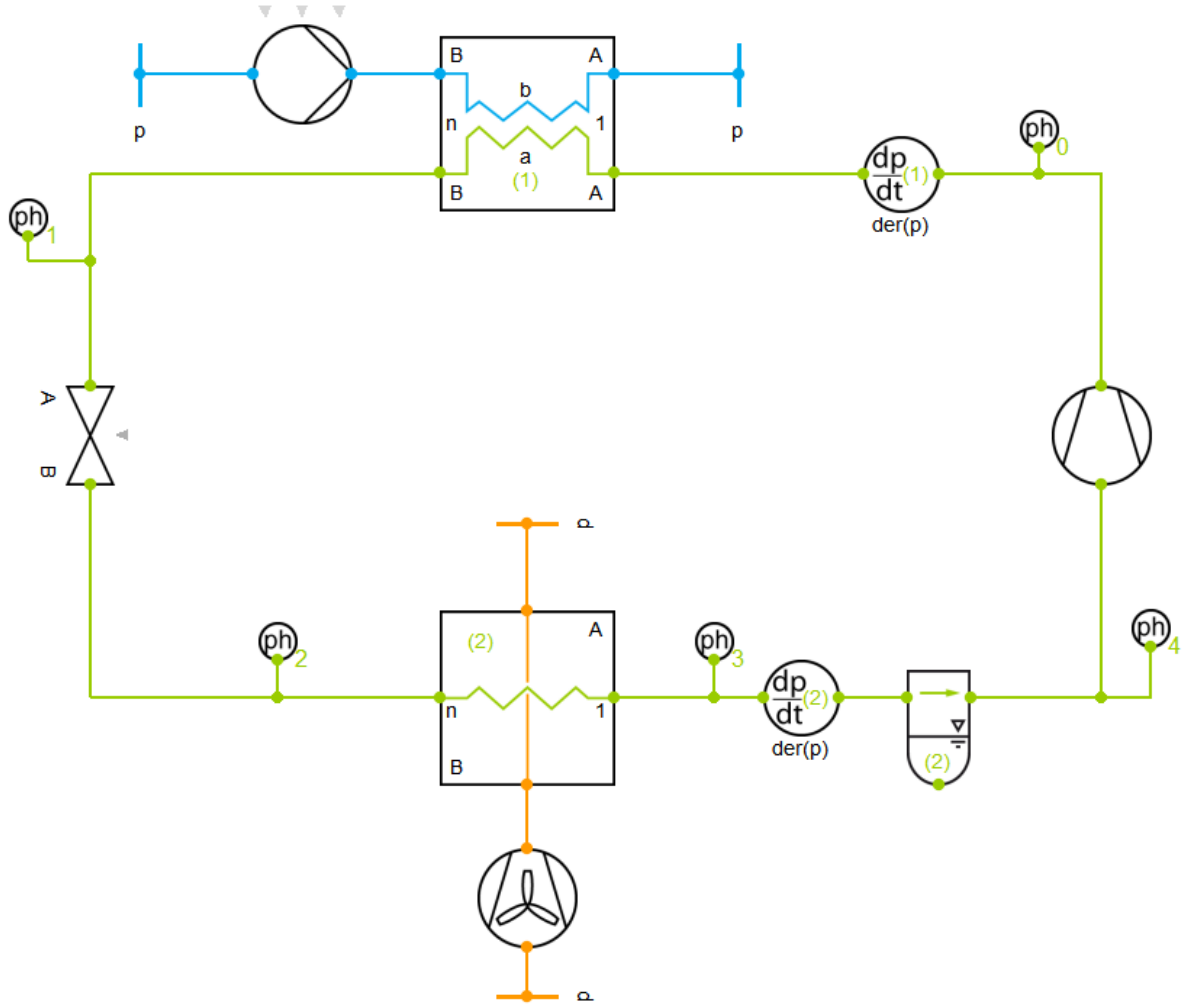
TLK ENERGY

Heat Pumps

TLK ENERGY

Vapor Compression Cycle

- Modelica Library TIL
- Two phase fluid
- Moist air as two component mixture
- 1D discretization of heat exchangers
- Moisture condensation and frost formation



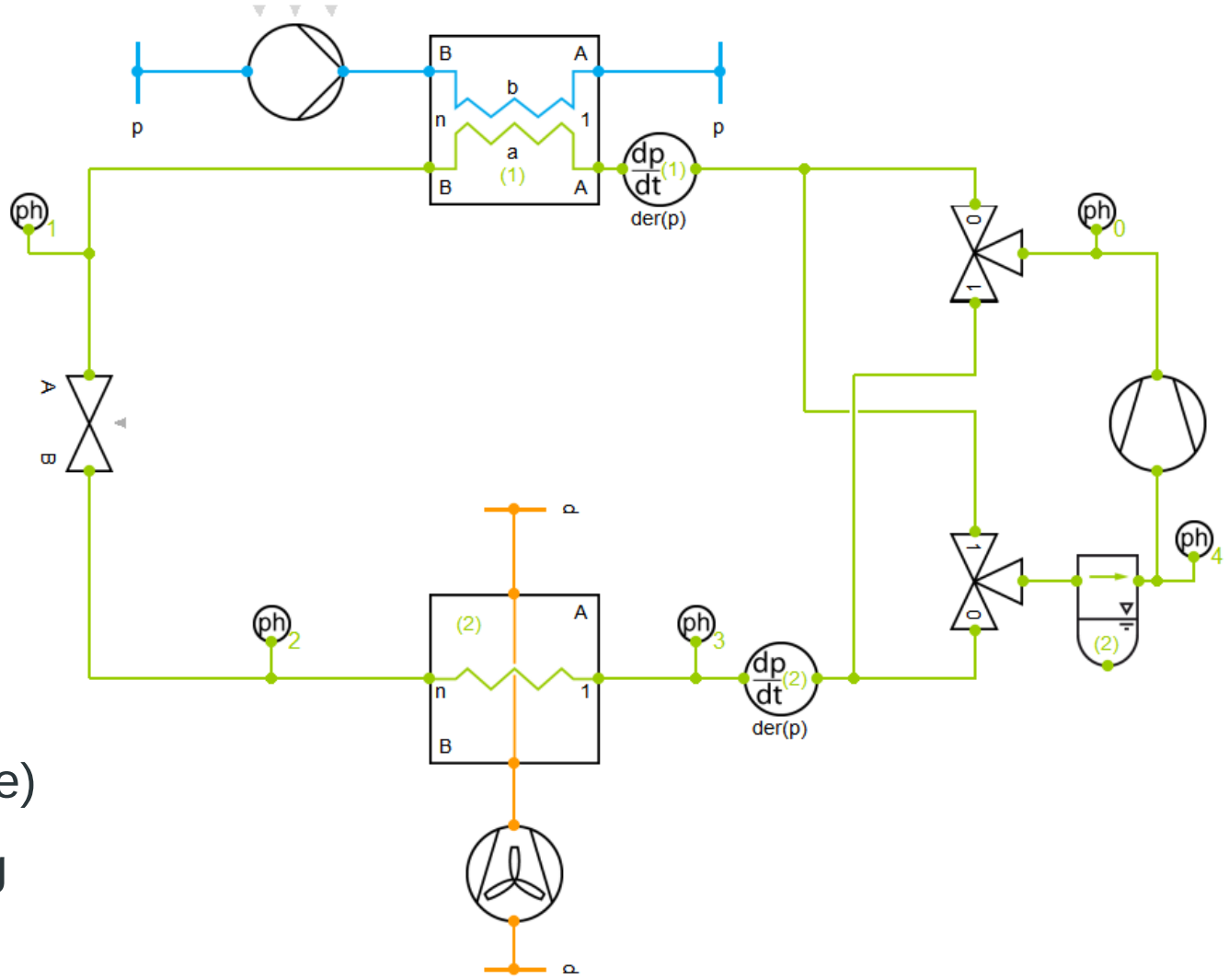
Control

System inputs:

- Expansion valve opening
- Compressor speed
- Pump speed
- Fan speed
- Switching valves

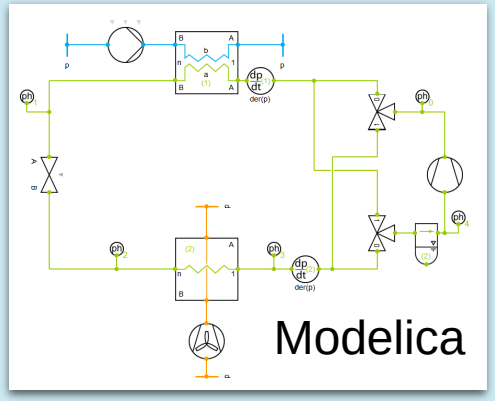
Control targets:

- Energy efficient working point
- Compressor limits (pressure, temperature)
- Switching modes: defrost/heating/cooling

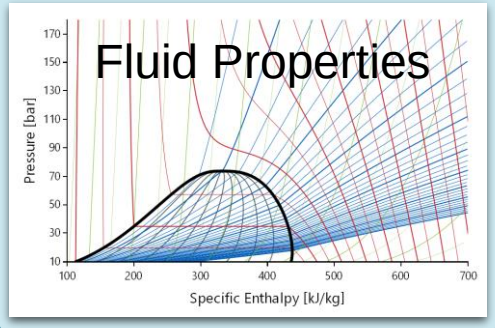


Model-in-the-Loop (MiL) Tests

Modelling



External
C Code



Export

Exchange

FUNCTIONAL MOCK-UP UNIT

FMI for Co-Simulation
(source code)

Import

Integration

VEOS®

Download

Simulation

ControlDesk

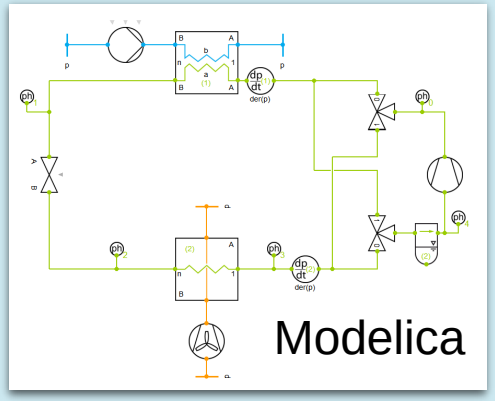
Access

VEOS®

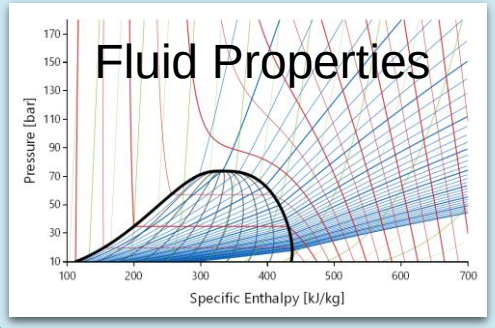
TLK ENERGY

Hardware-in-the-Loop (HiL) Tests

Modelling



External
C Code



Export

Exchange

FUNCTIONAL MOCK-UP UNIT

FMI for Co-Simulation
(source code)

Import

Integration

ConfigurationDesk

Configure

ECU
Loads
I/O CFG

Download

Simulation

ControlDesk

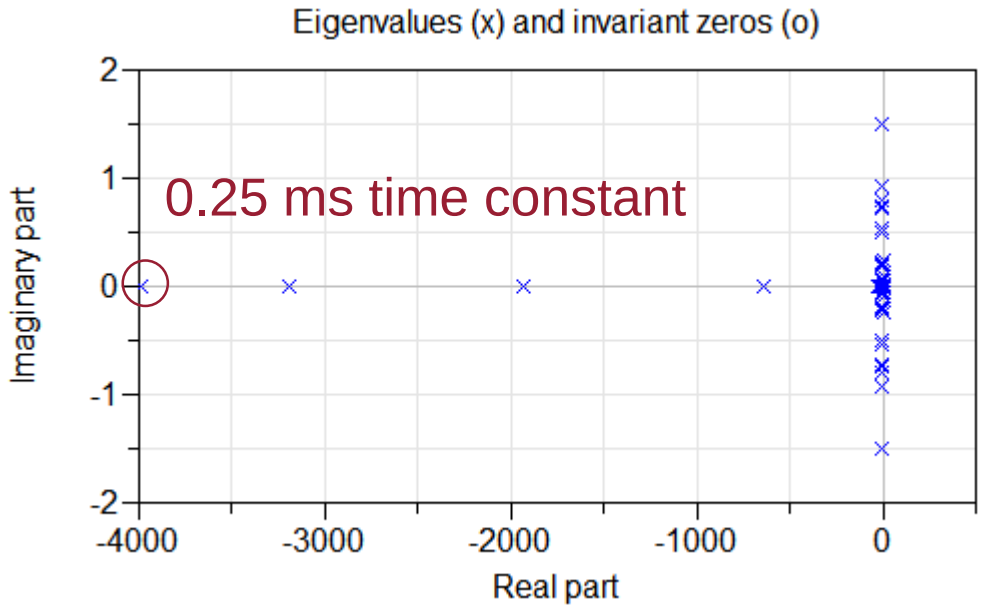
Access

Connect

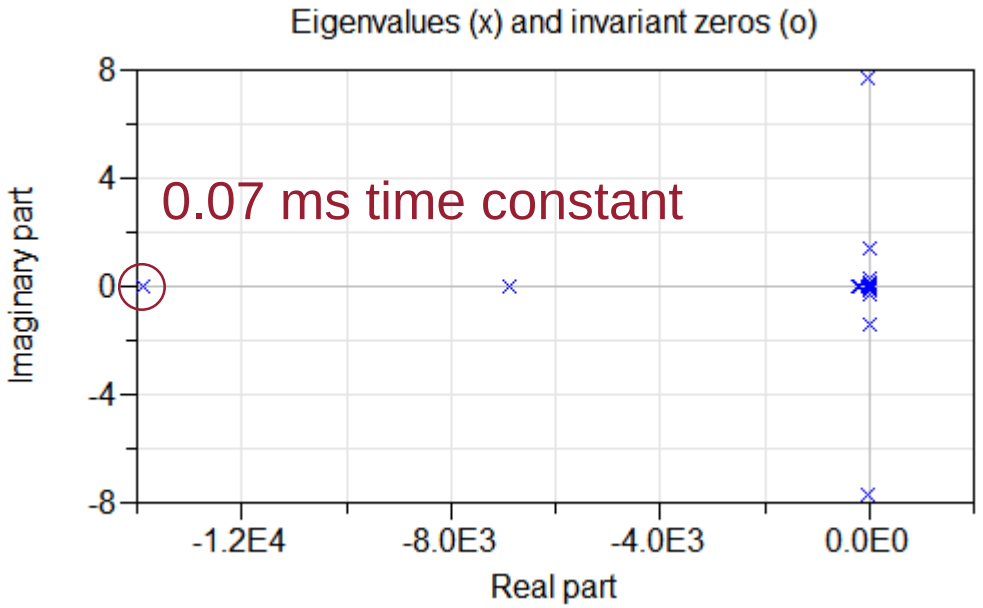
TLK ENERGY

Nonlinearity and Stiffness

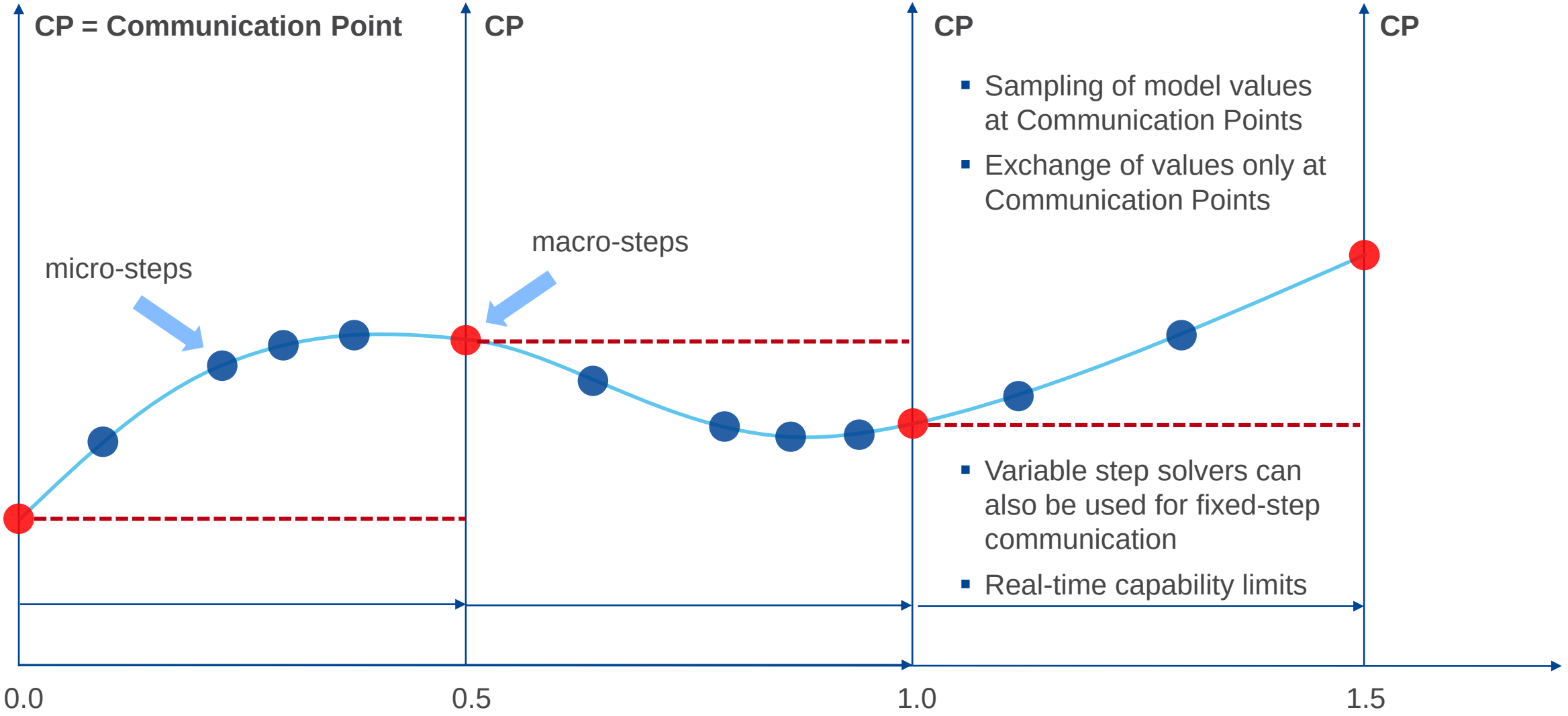
Steady state at high compressor speed



After switching to low compressor speed



FMI for Co-Simulation: Communication Point Concept

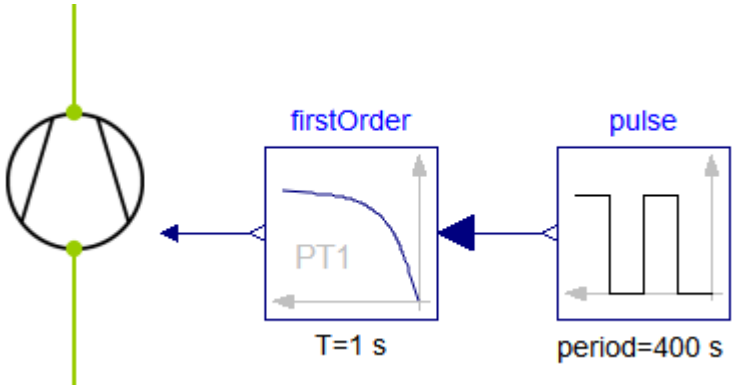


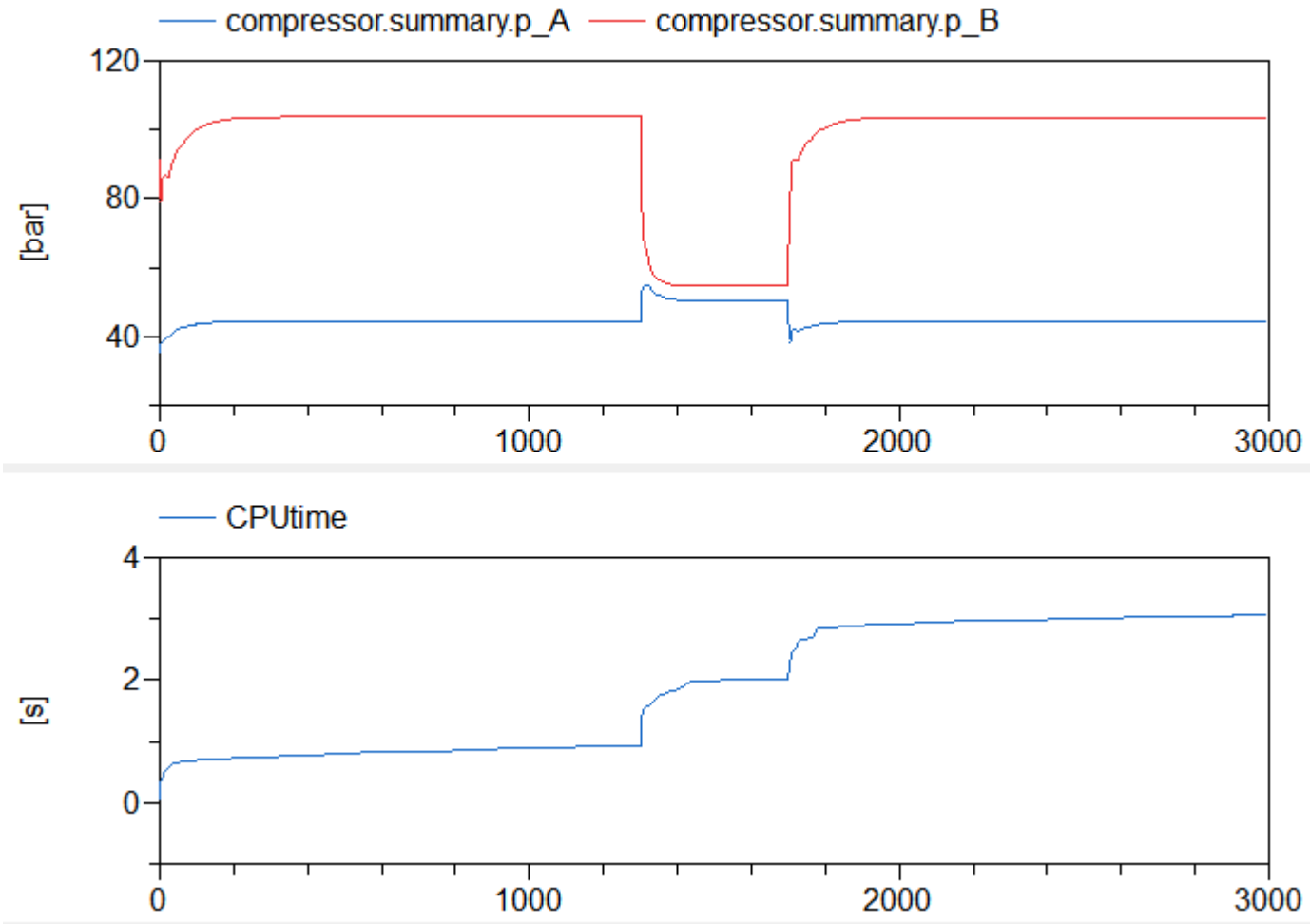
- Sampling of model values at Communication Points
- Exchange of values only at Communication Points
- Variable step solvers can also be used for fixed-step communication
- Real-time capability limits

Variable Step Size Solver

CVODE, tolerance=1e-5

Only two time events when switching compressor speed

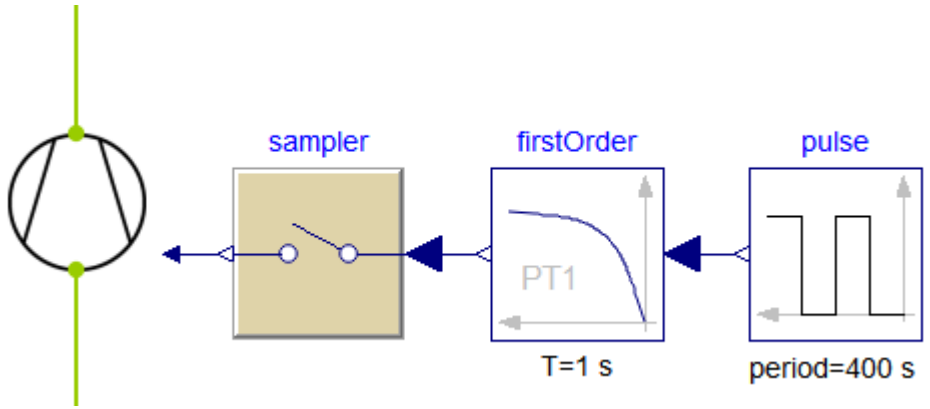


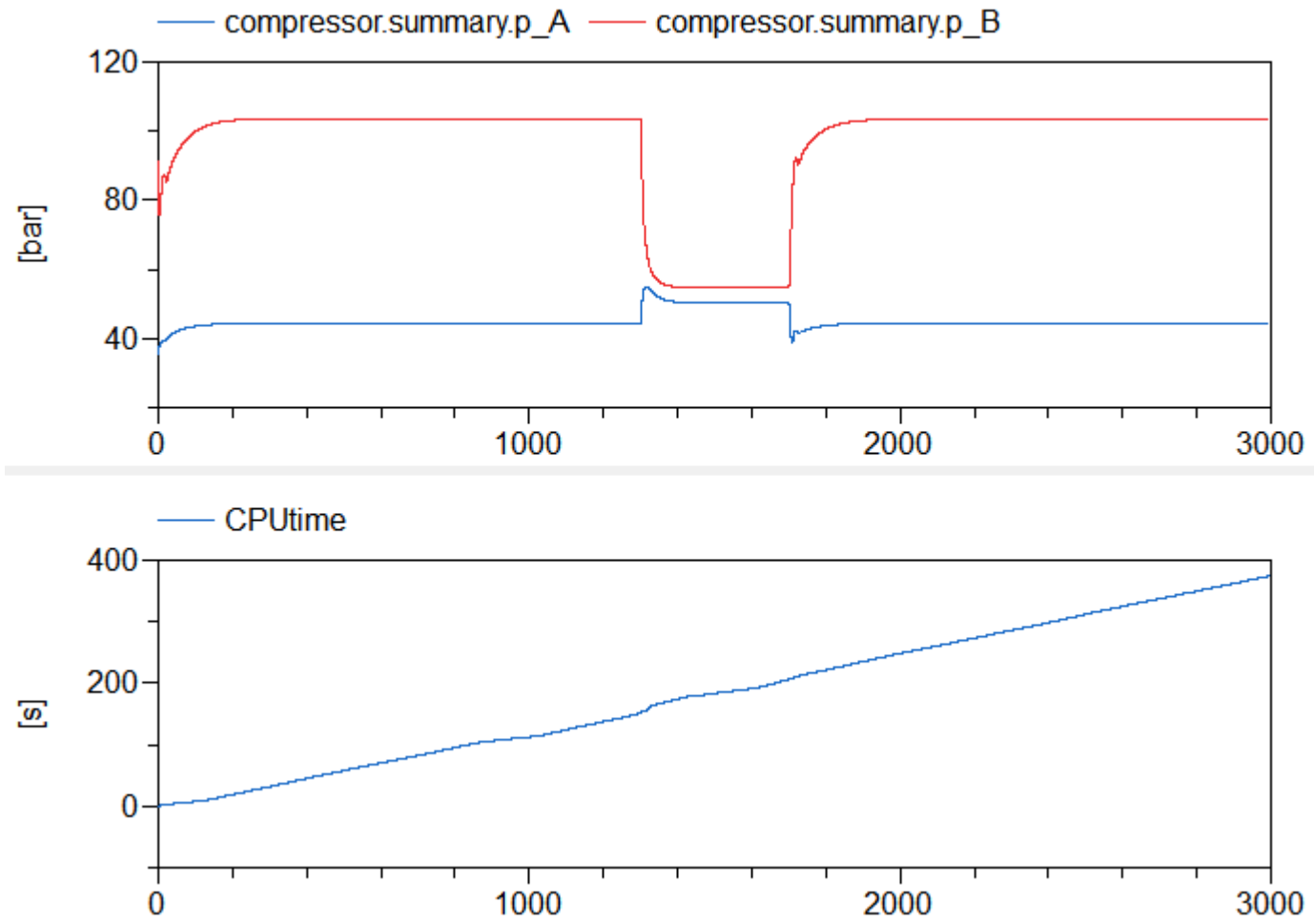


Variable Step Size Solver

CVODE, tolerance=1e-5

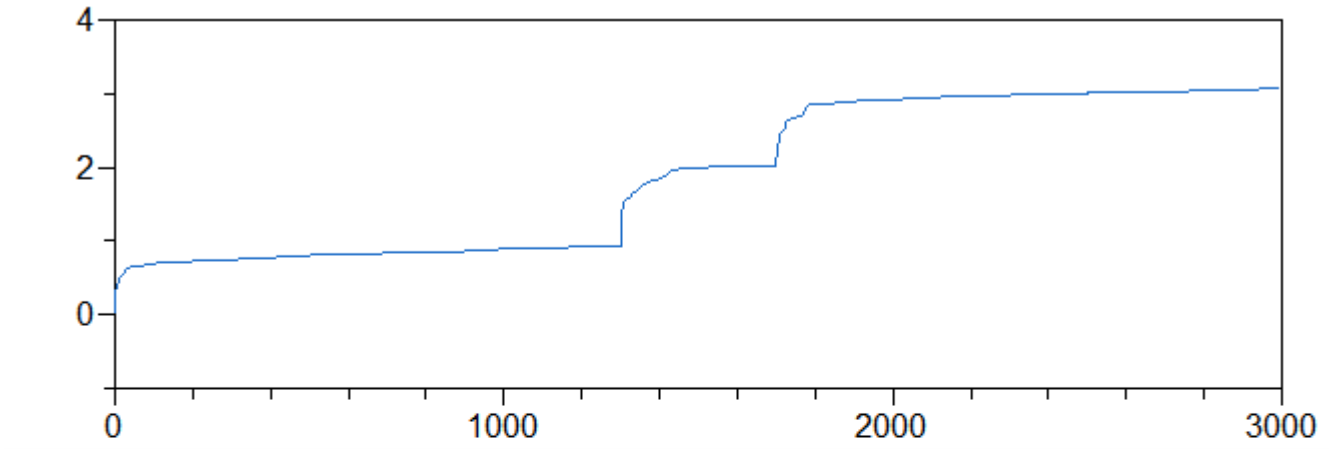
Sampling rate 0.1 s (macro steps)



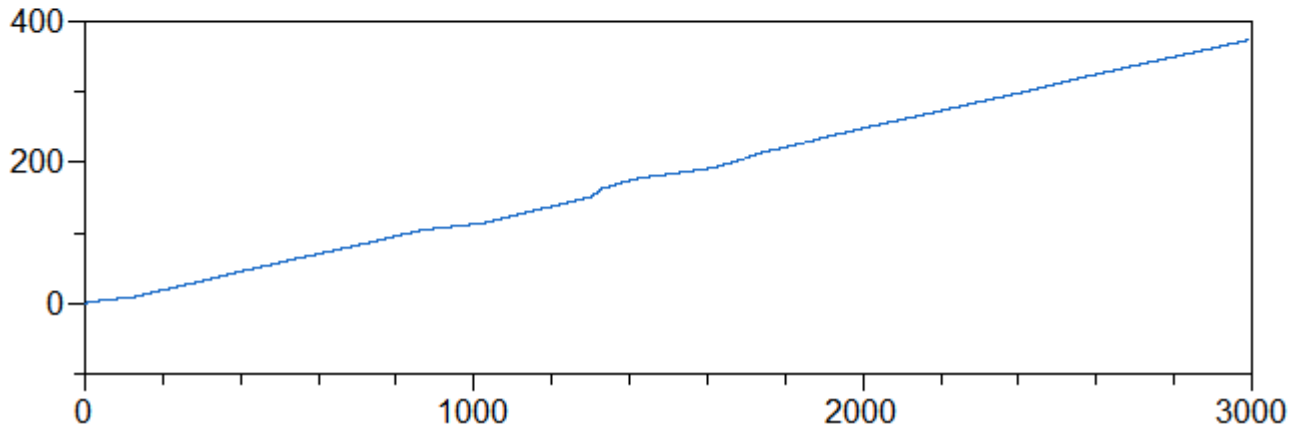


Variable Step Size Solver

CPU Time (s)
continuous

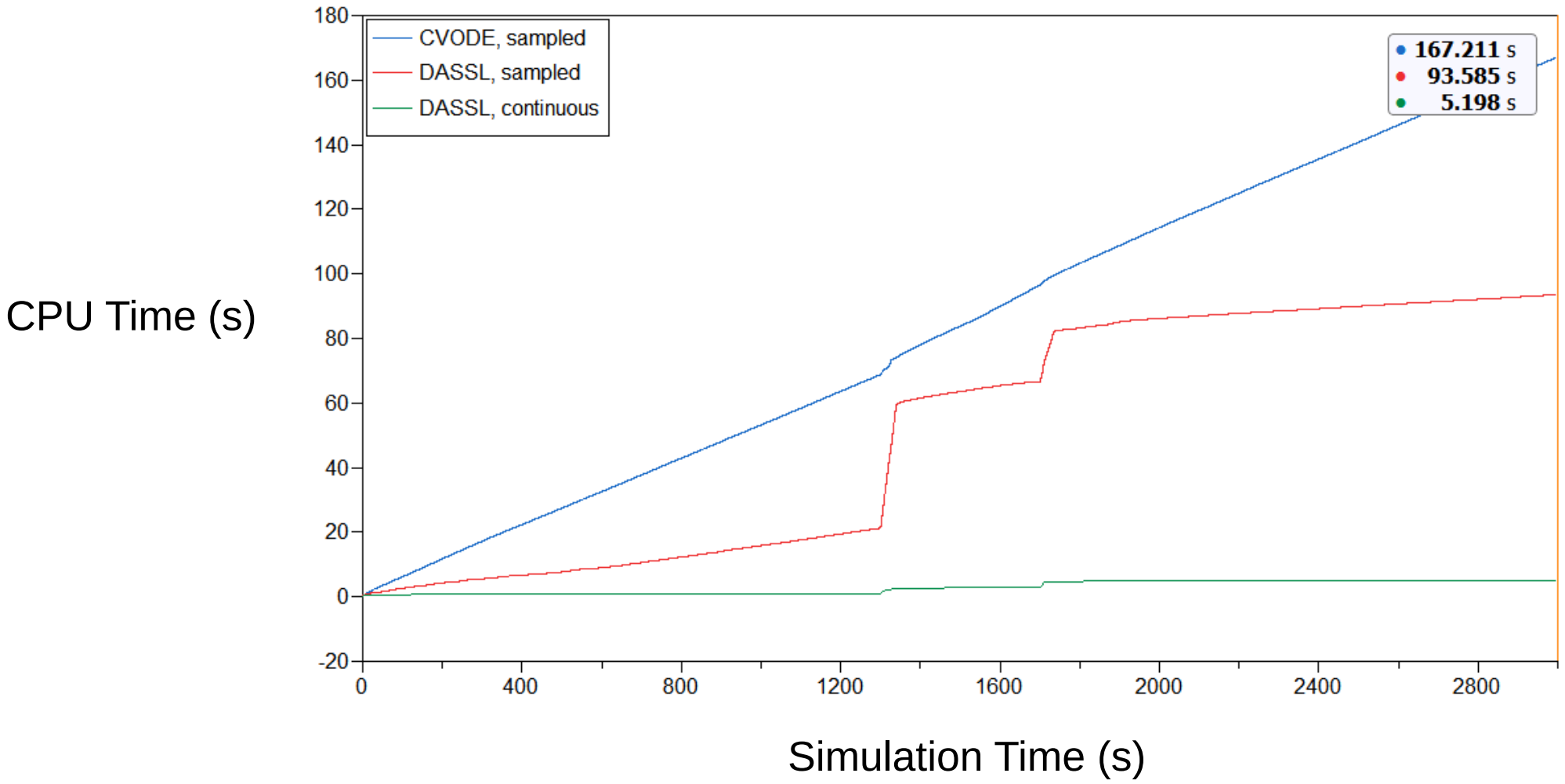


CPU Time (s)
0.1s sampled



Simulation Time (s)

Variable Step Size Solver



Embedding External C Code

```
function f2
    input Real u;
    output Real y;
     external "C"     y=f2(u) annotation(Include="#include \"func.c\"");
end f2;

model Test
    // Needed to include C file in exported source code FMUs
    parameter String file1 = Modelica.Utilities.Files.loadResource(
                    "modelica://TestSourceCodeExport/Resources/Include/func.c");

    Real y = TestSourceCodeExport.f2(time);
end Test;
```

Conclusion

Variable step size solvers:

- Improve performance for (time) sampled simulation
- Is it really needed to completly reset solvers at every sampling point?

External C Code in source code FMUs:

- Modelica tools should add complete Include directory

Thank you
for your attention!

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