Reduced Order Modeling App

Modelon Innovate 2024 – Day 2

Presenter’s Info

From Jakarta, Indonesia

Located in Hamburg, Germany

Background in Mechatronics and Computational Mechanics

8 years experience in modeling and simulation

Simulation engineer at Modelon

- Development of Modelica libraries
- Customer projects
- Technical support

Nirmala

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But first..

Modelon Impact Web-App basic

Introductory session by Erik Durling available as recording

- ✓ Jupyter - Voila - Modelon Impact UX
- ✓ Custom user interface for various use-cases
- ✓ Framework and workflow for sharing web-app

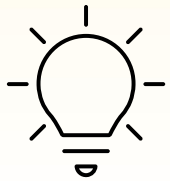
Why reduced order models (ROMs)?

physical modeling:

- Known correlations → implement equations
- High fidelity i.e., accuracy, multitude of parameters

however..

- Physical models → computationally expensive
- Use-case might not need detailed model
- Insufficient knowledge of the governing equations



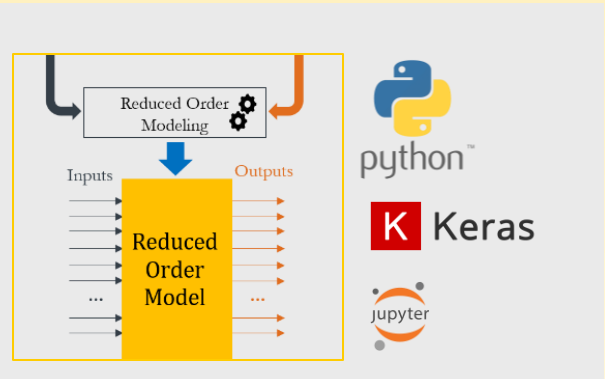
Generate reduced order models to be used in Modelica environment!

Reduced order modeling workflow

Modelon Impact Web-app to generate neural-network based ROMs

Overview

0



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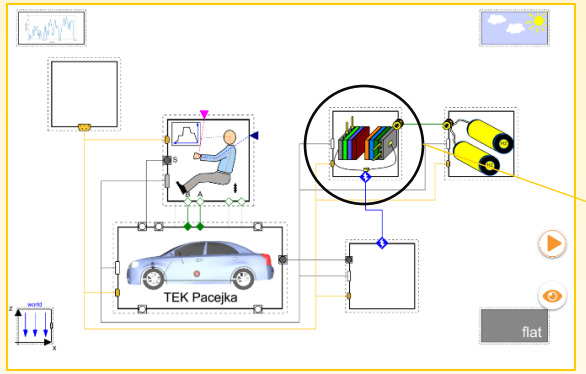
Modelon Impact



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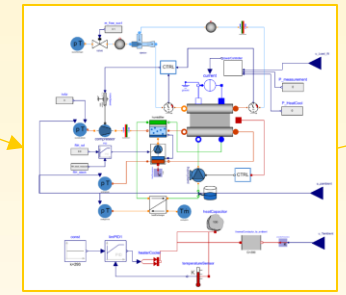

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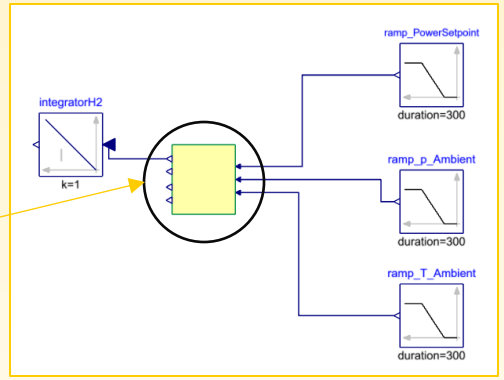

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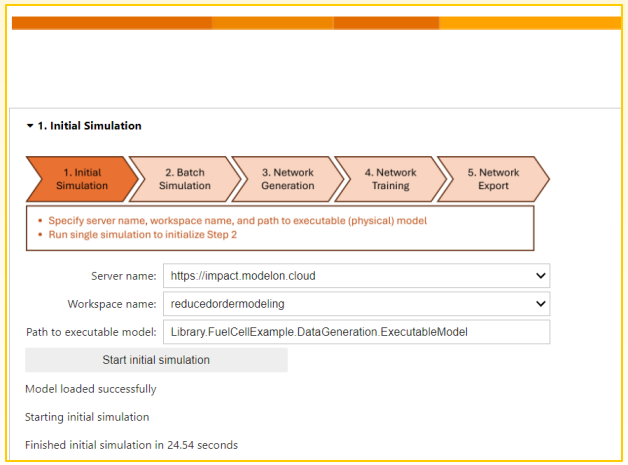
voilà



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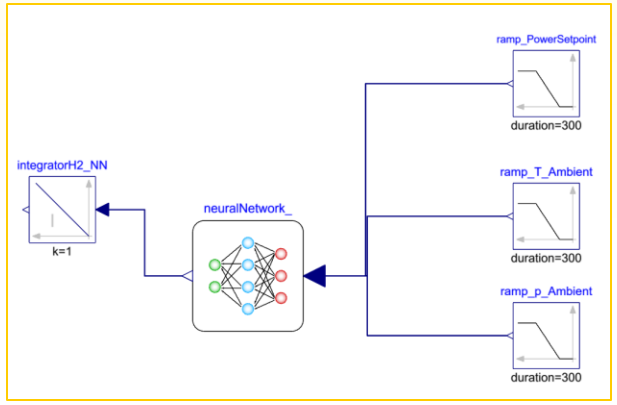
Modelon Impact



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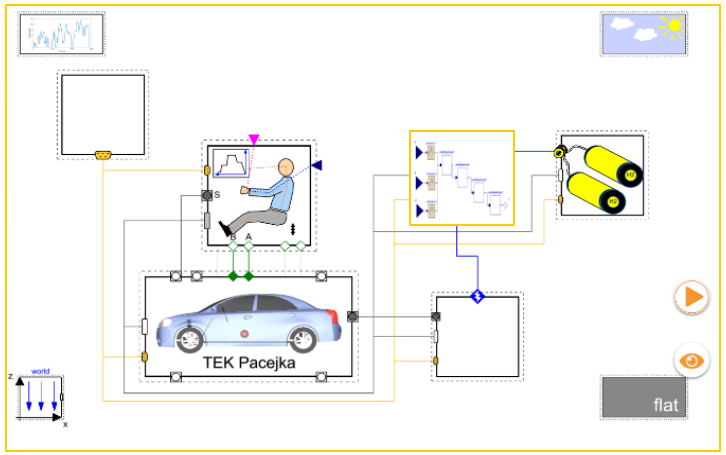
Modelon Impact



Modelon

(in words)

1. Which part of the system I would like to replace?
   - Select subcomponent or subsystem
2. Create wrapper: select input and output, add interfaces
3. Create test bench to generate training data

[Setup Modelica dependencies incl. *NeuralNetwork* open-source library]

4. Deploy web-app*
5. Validate ROM against physical model
6. Use ROM in system

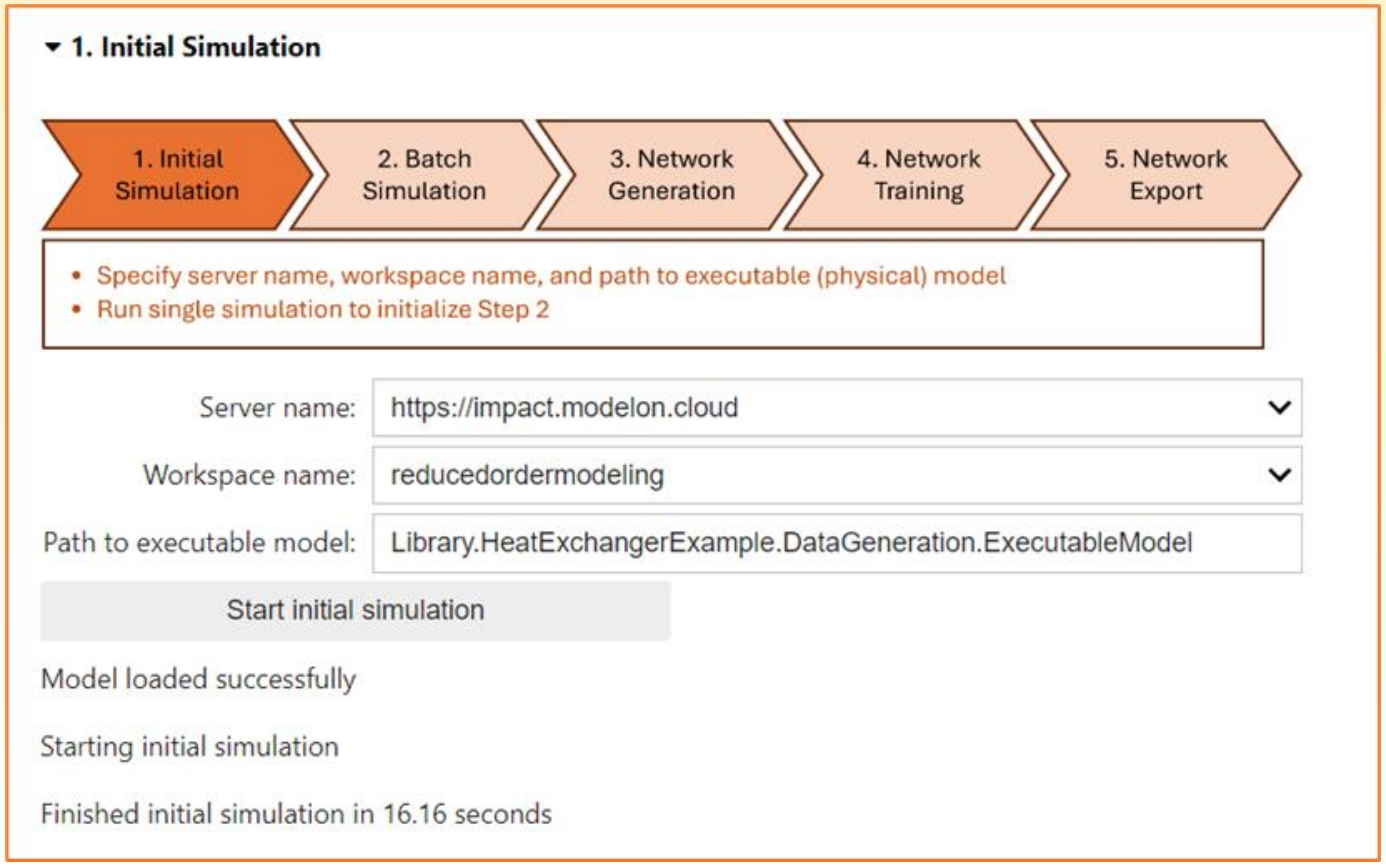
***0 – Web-app setup**

Install with bash script

- Open JupyterLab
- Open terminal from within the project
- Type *bash install.sh*

How to use the web-app

Step 1 – setup and initial simulation

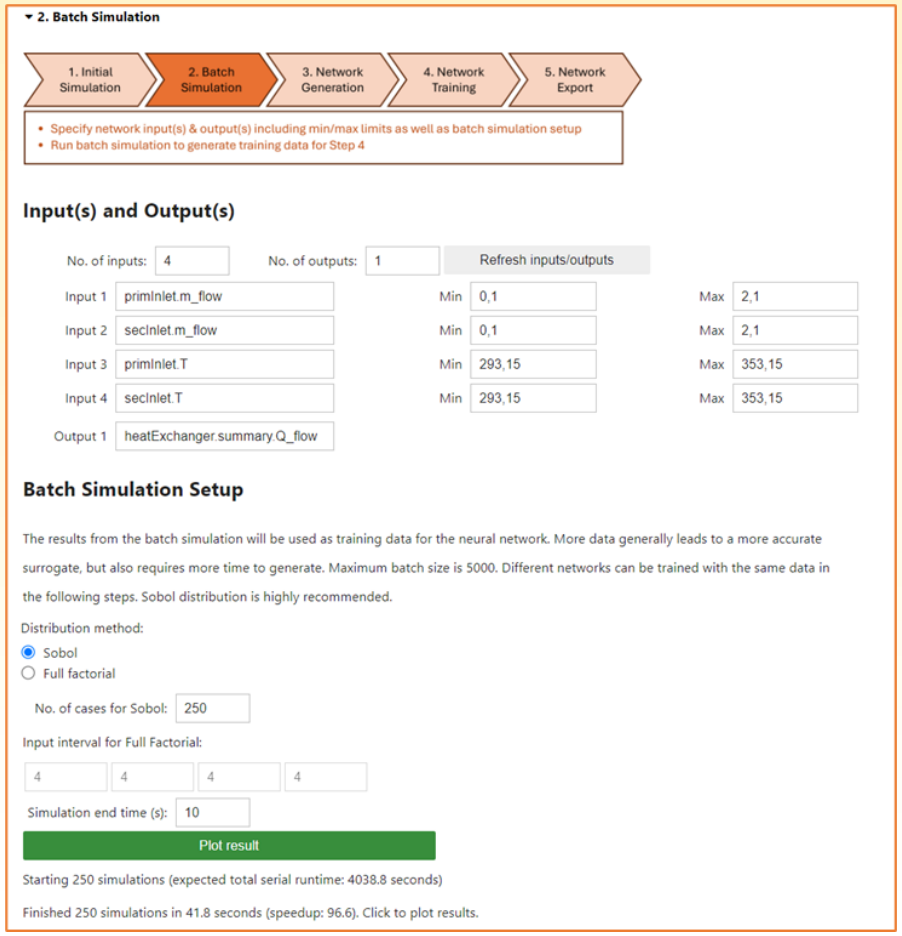


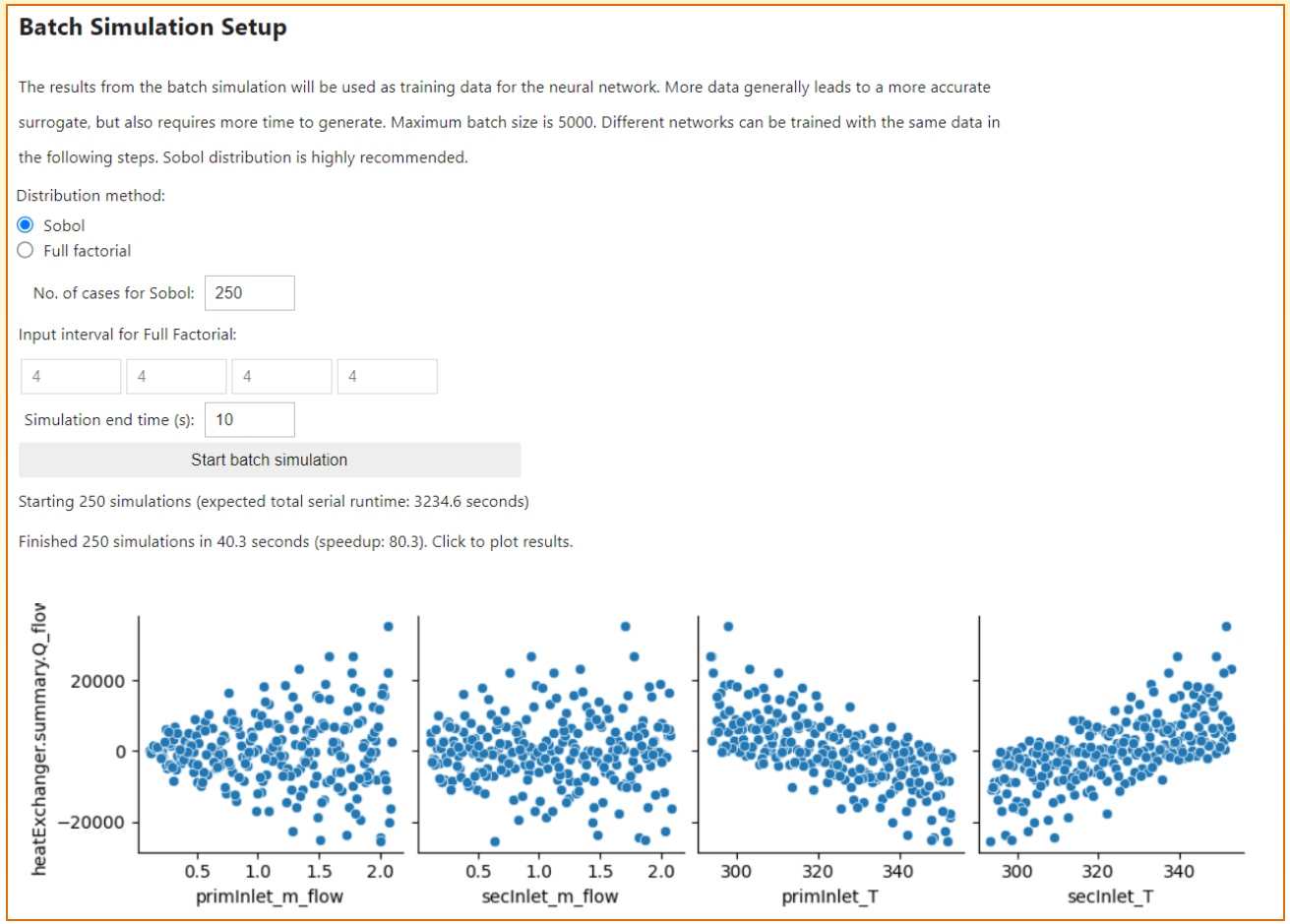
NOTE:

requires that test bench can be compiled and simulated as it is

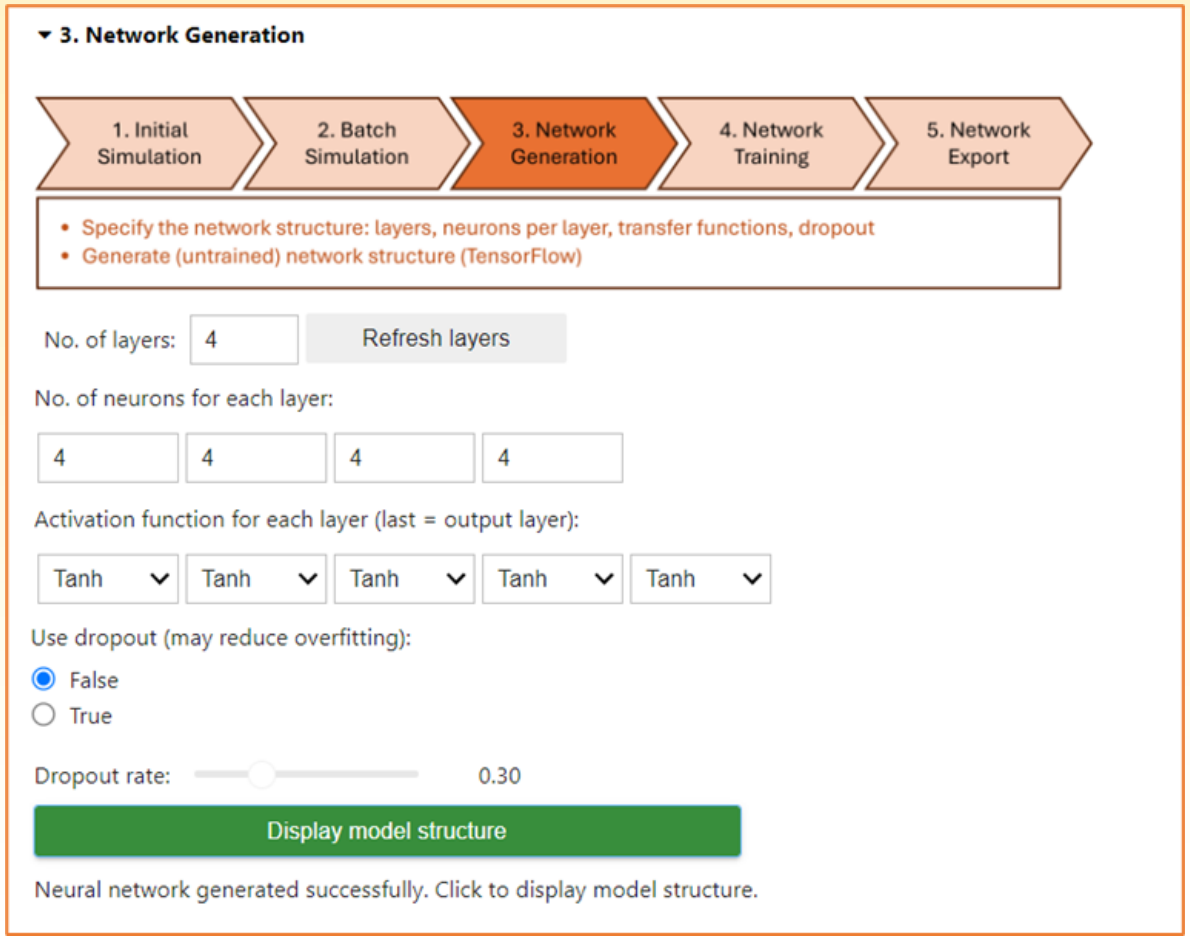
Web-app is not meant to debug failing model

Step 2 – data generation





Step 3 – neural network structure

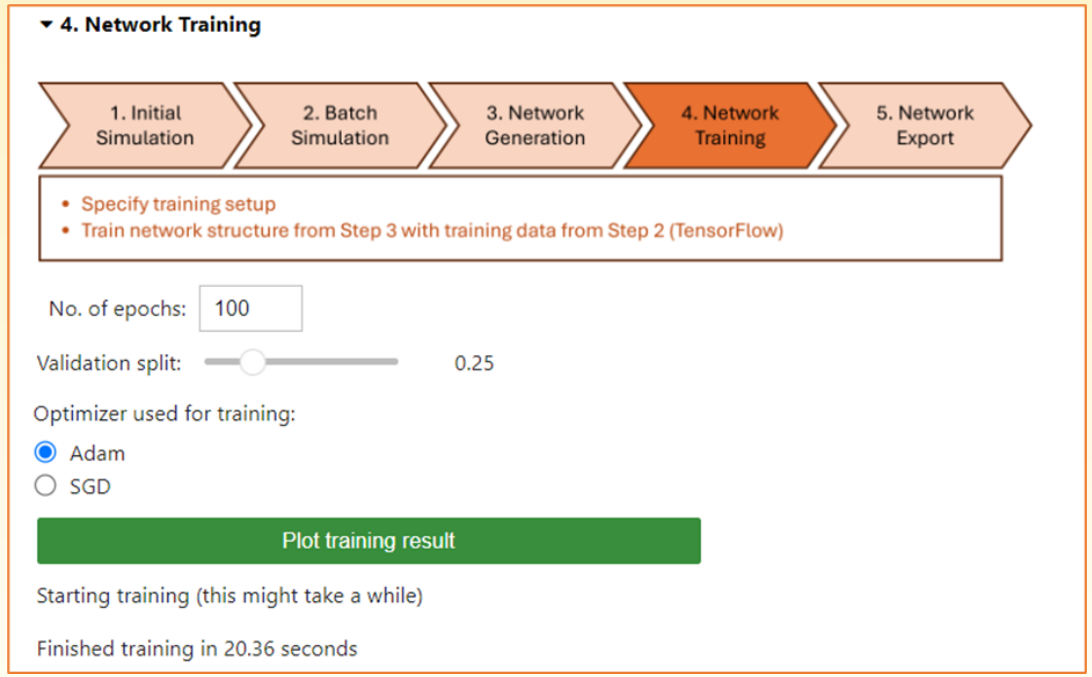


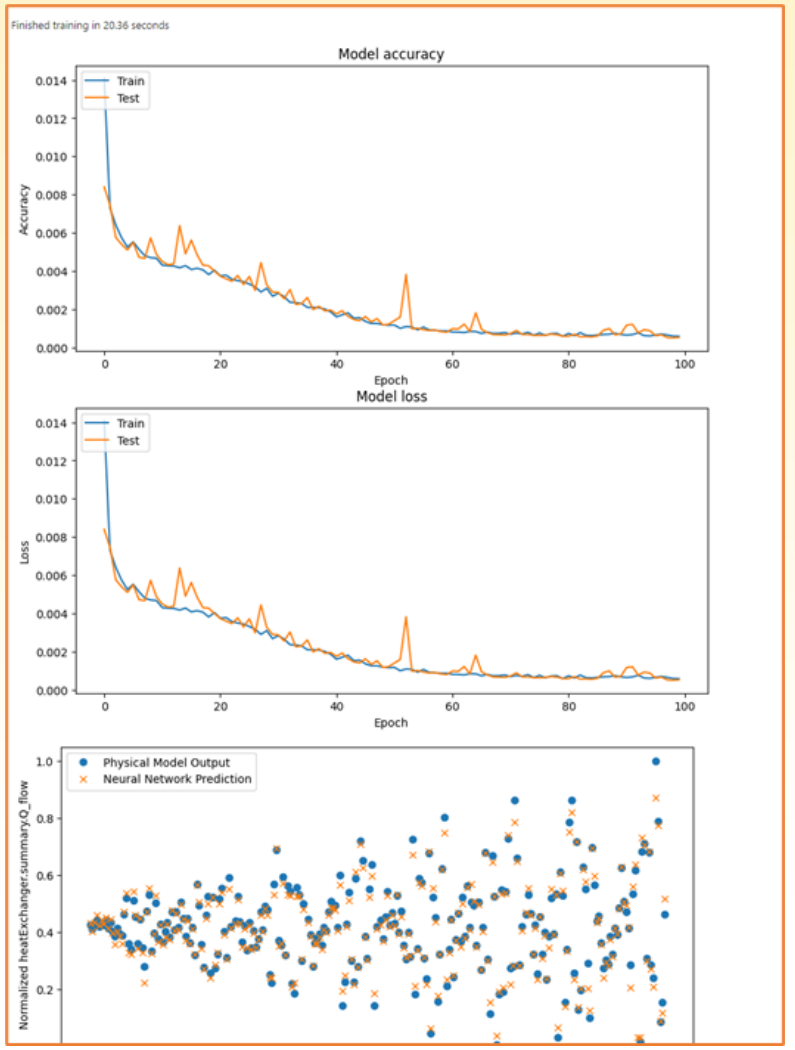
NOTE:

Feedforward neural network (FNN) is employed

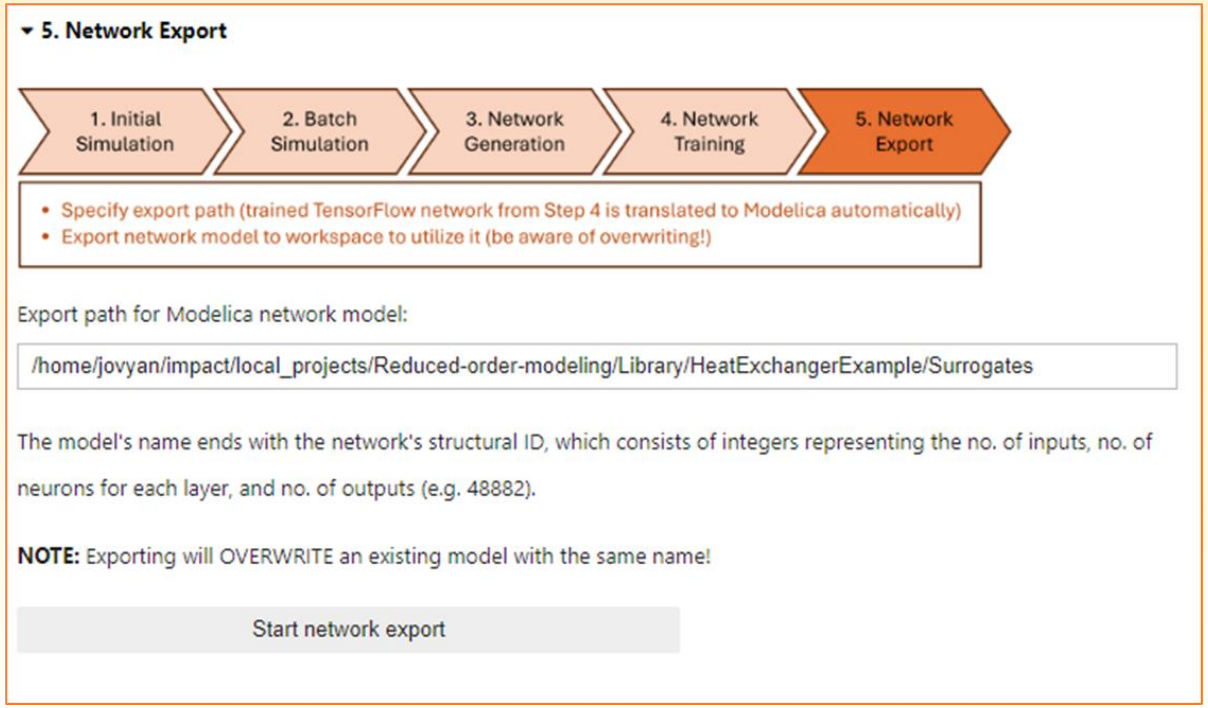
```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense (Dense)               (None, 4)                 20

 dense_1 (Dense)             (None, 4)                 20

 dense_2 (Dense)             (None, 4)                 20

 dense_3 (Dense)             (None, 4)                 20

 dense_4 (Dense)             (None, 1)                 5

=================================================================
Total params: 85 (340.00 Byte)
Trainable params: 85 (340.00 Byte)
Non-trainable params: 0 (0.00 Byte)
```

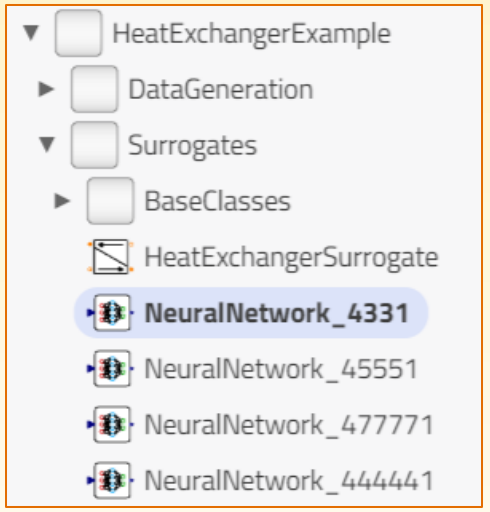
Step 4 – training





Step 5 – export to workspace



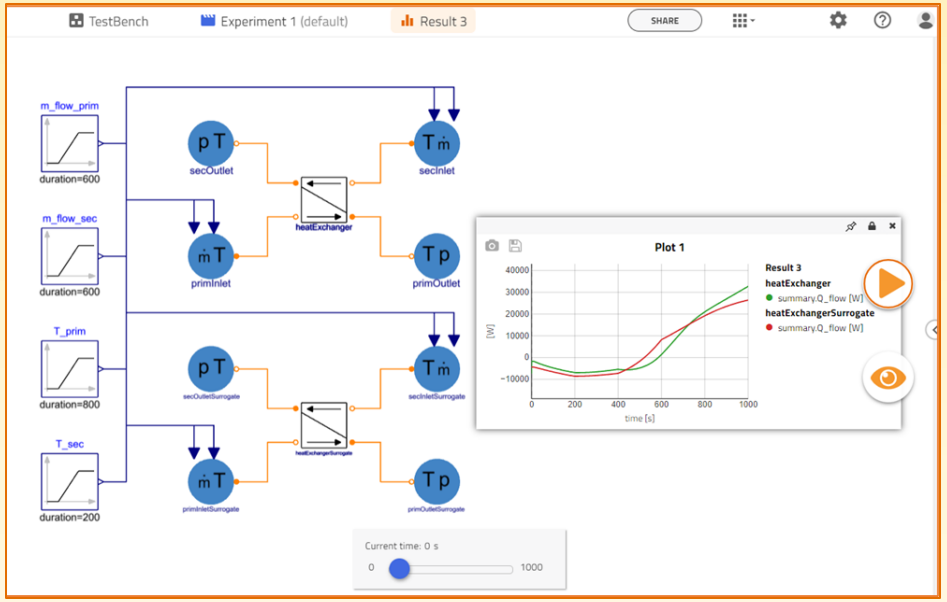


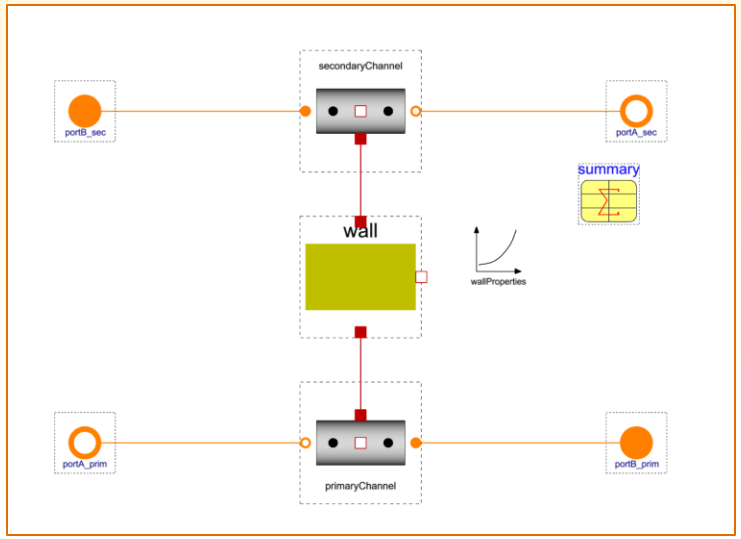
Reduced order model examples

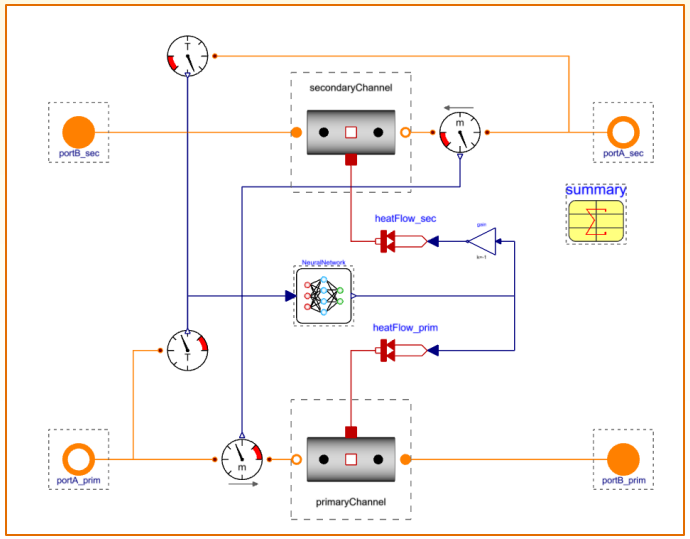
Modelon

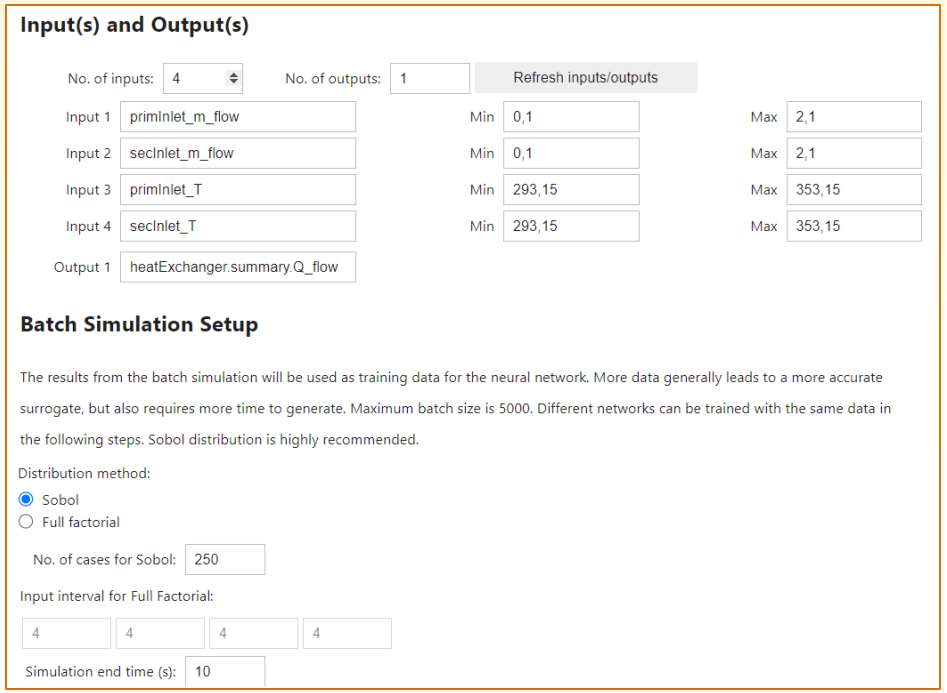
Heat Exchanger

- replacing heat exchanger
- input: mass flow rate and temperature for primary and secondary
- output: heat flow rate
- wrapper for reduced order HX:
  - conversion to fluid ports



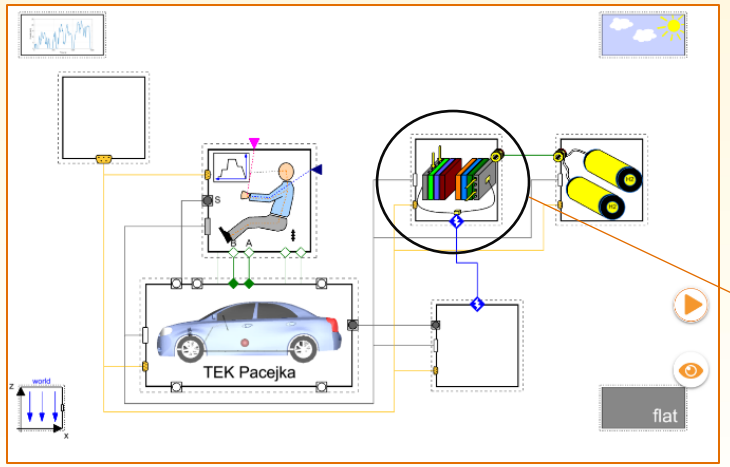


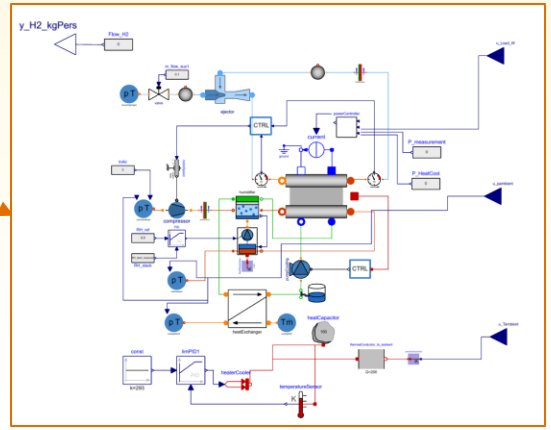




Fuel Cell Hybrid Vehicle

- replacing the fuel cell subsystem
- input: power setpoint, ambient pressure and temperature
- output: H2 consumption
- wrapper for fuel cell subsystem
  - scalar input and output connectors





Input(s) and Output(s)

No. of inputs:	3	No. of outputs:	1	Refresh inputs/outputs	
Input 1	targetPower	Min	100e3	Max	150e3
Input 2	T_ambient	Min	293	Max	303
Input 3	p_ambient	Min	1e5	Max	1.1e5
Output 1	fuelFlow				

Batch Simulation Setup

The results from the batch simulation will be used as training data for the neural network. More data generally leads to a more accurate surrogate, but also requires more time to generate. Maximum batch size is 5000. Different networks can be trained with the same data in the following steps. Sobol distribution is highly recommended.

Distribution method:

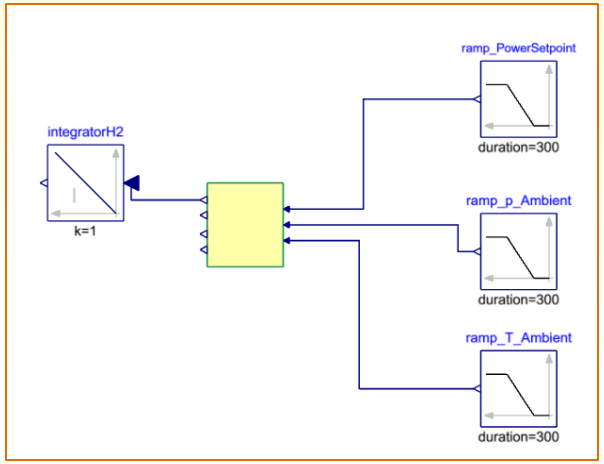
- (•) Sobol
- ( ) Full factorial

No. of cases for Sobol: 12

Input interval for Full Factorial:

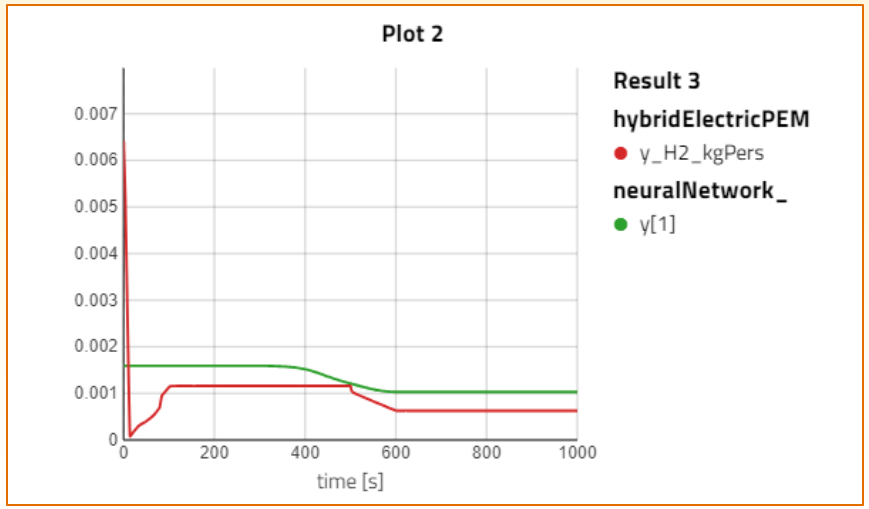
4 | 4 | 4

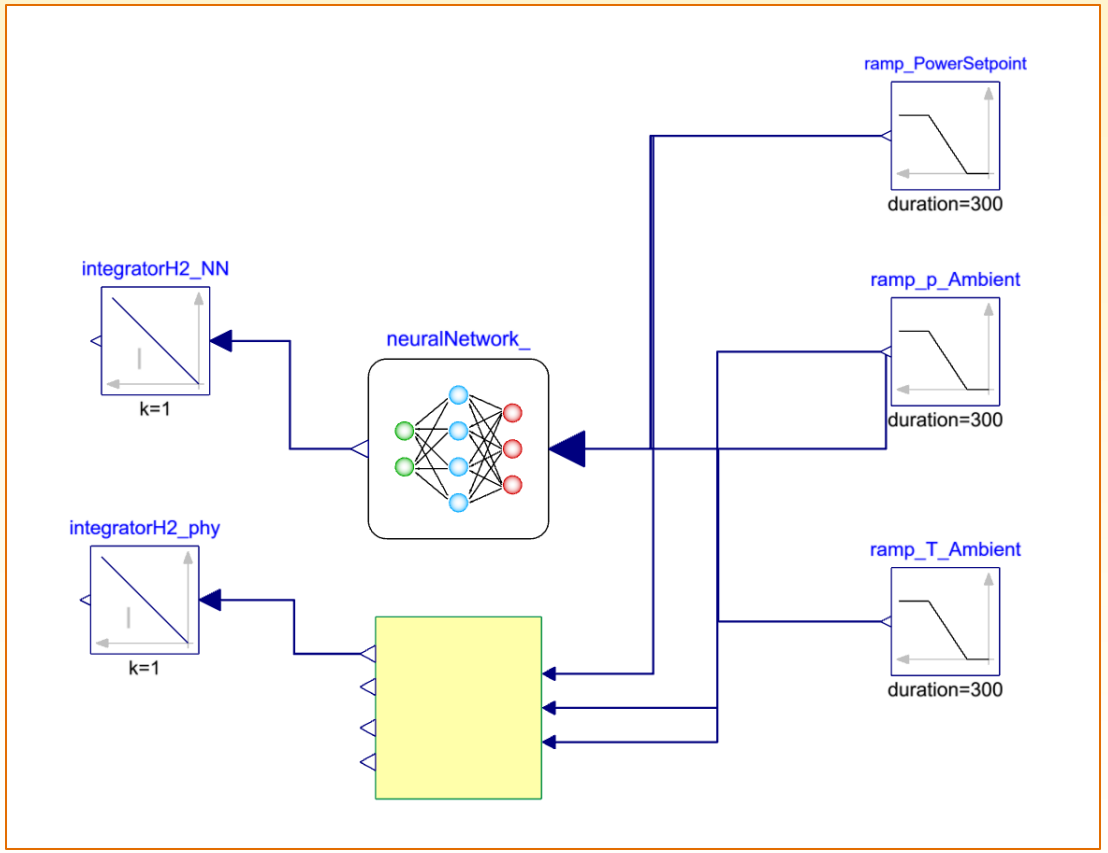
Simulation end time (s): 750



Performance

- Speed-up x5 – x500
- error 1-5%





Demo

Generating reduced order model for heat exchanger

Questions?

References:

PHyMoS project - https://phymos.de

NeuralNetwork Modelica library - https://github.com/AMIT-HSBI/NeuralNetwork

Modelon Impact client - https://modelon-impact-client.readthedocs.io/en/latest/

TensorFlow - https://www.tensorflow.org/

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