



Forward. For all.

Enhancements and future directions in
the development of KULI

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Speakers



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Agenda

- 01** New user interface
- 02** KULI fmu pro
- 03** HVAC, transient and UI improvements
- 04** Under Development - Air side Representation
- 05** Under Development - Better modelling support

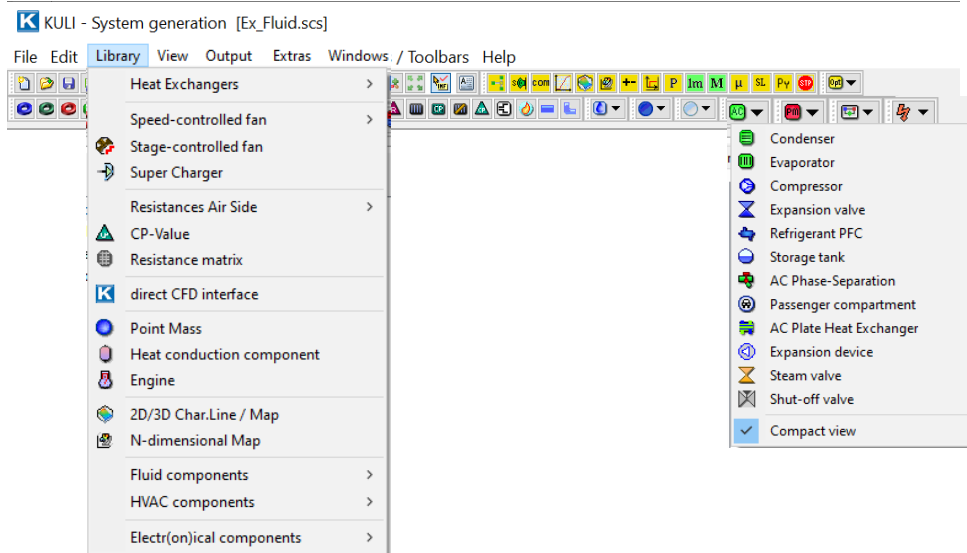


01

New user interface

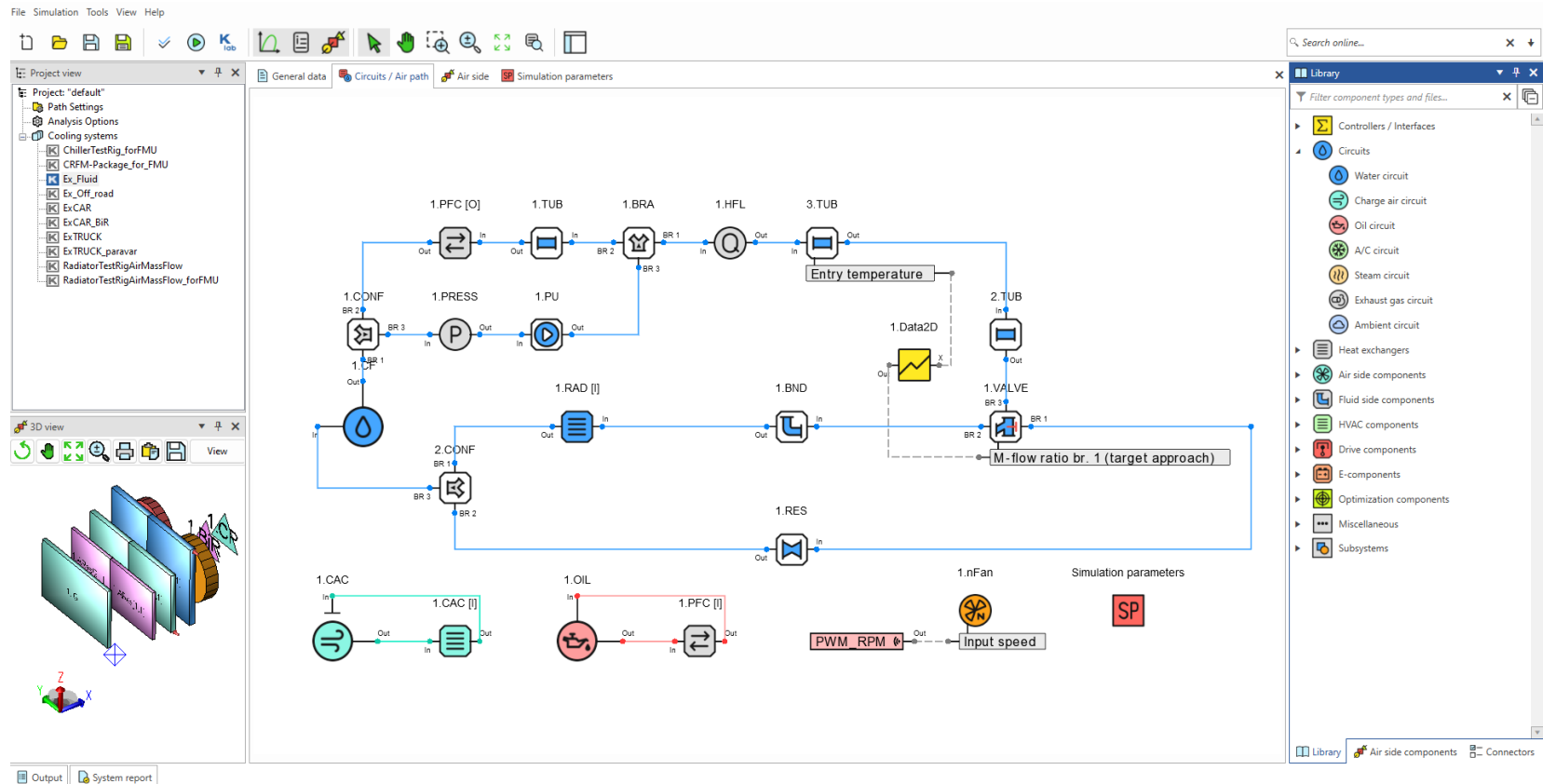
Released with KULI 18

Challenge...



- More and more component types and functions have been added
- Effect on UI and workflow

New UI released with KULI 18





02

KULI fmu pro

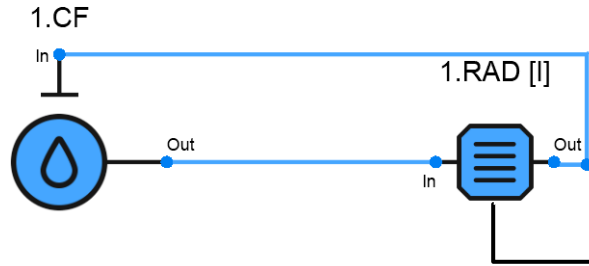
Released with KULI 18.1

KULI fmu pro



Suppliers

- Know a lot about their components
- Want the OEMs to use their components
- Want to keep design know-how privately
- Use **KULI** software

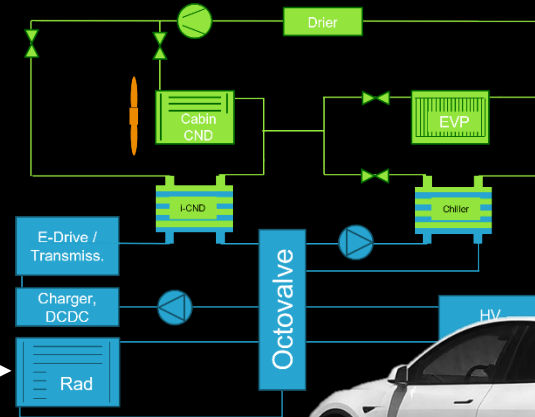


KULI Software

Simple component testbench model

OEMs

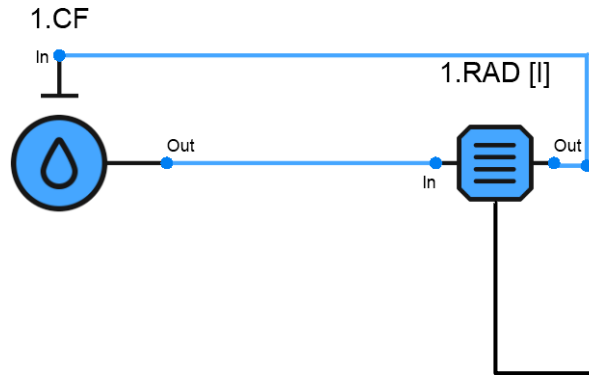
- Know a lot about systems and have data
- Need components from suppliers
- Want to use these components in their system simulations
- Use **ANY** simulation tool



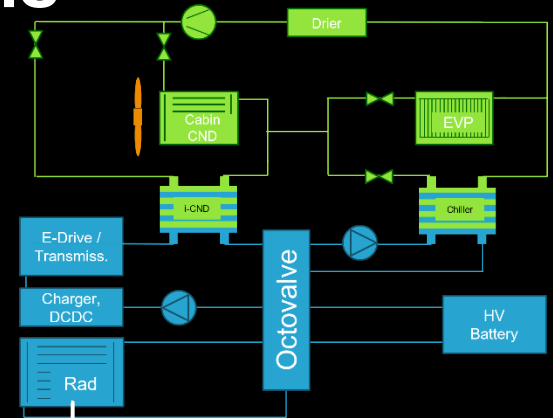
System model in any simulation tool

KULI fmu pro

Suppliers



OEMs



- The KULI component is exported as an FMU (Functional Mock-Up Unit)
- The FMU is an encrypted black box that keeps the design details hidden
- The FMU can be used for simulation in any tool supporting the FMI standard

- OEMs can use their existing simulation tools without workflow changes
- The FMU performs according to supplier specifications
- Accidental model changes are prevented, providing safe and accurate results

KULI fmu pro

Case study

Supplier - OEM

- **You are a cooling components supplier:**

- You have received an **RFQ for a cooling package** (CRFM = Condenser-Radiator-Fan-Module) from an OEM partner
- Based on the provided requirements and boundary conditions you have assembled a **cooling package that matches the RFQ**
- You have **validated** this **by simulation** with your development tool **KULI**

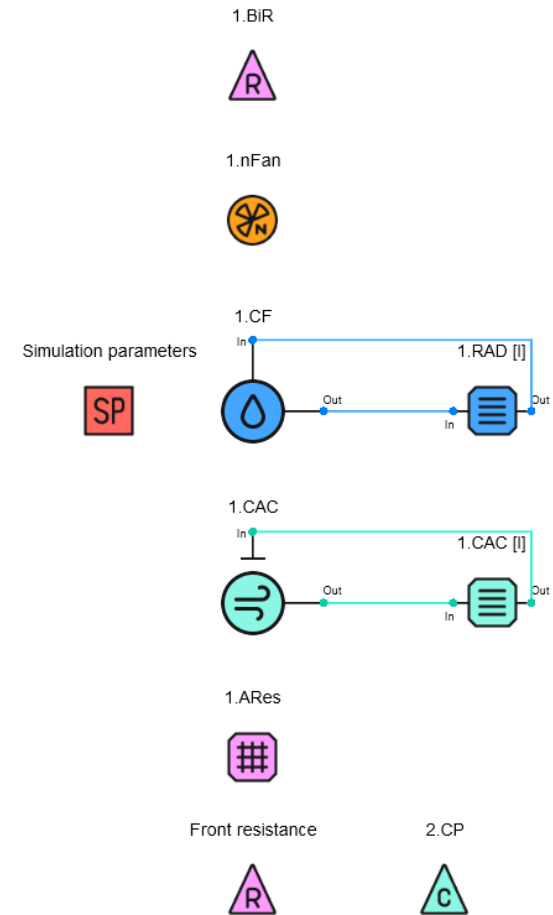
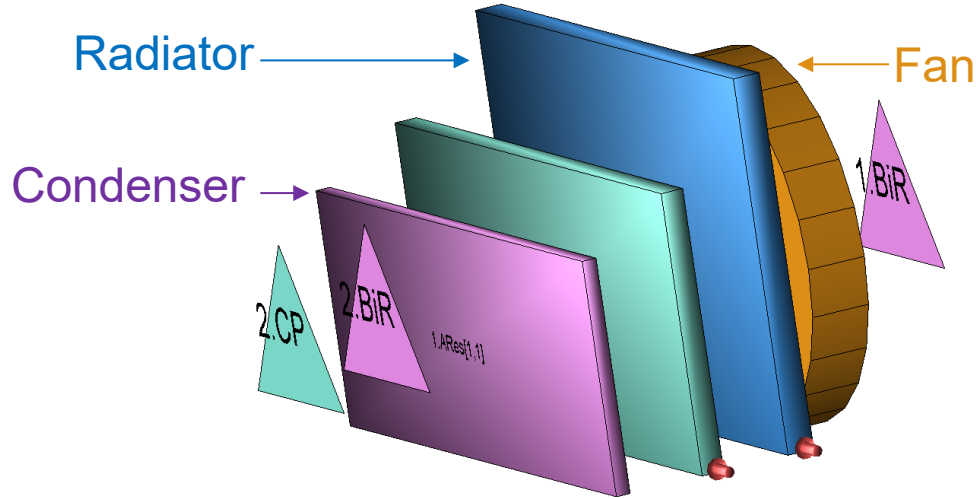
- **Your customer is an OEM:**

- He has a **complete vehicle simulation model** covering all scenarios needed for his specific development workflows
- This is set up in **any simulation tool... not necessarily KULI**
- Now your customer wants you to provide all the information that is needed to **test your virtual cooling package within his vehicle simulation model...**



This is a perfect application for **KULI fmu pro**

CRFM package for FMU



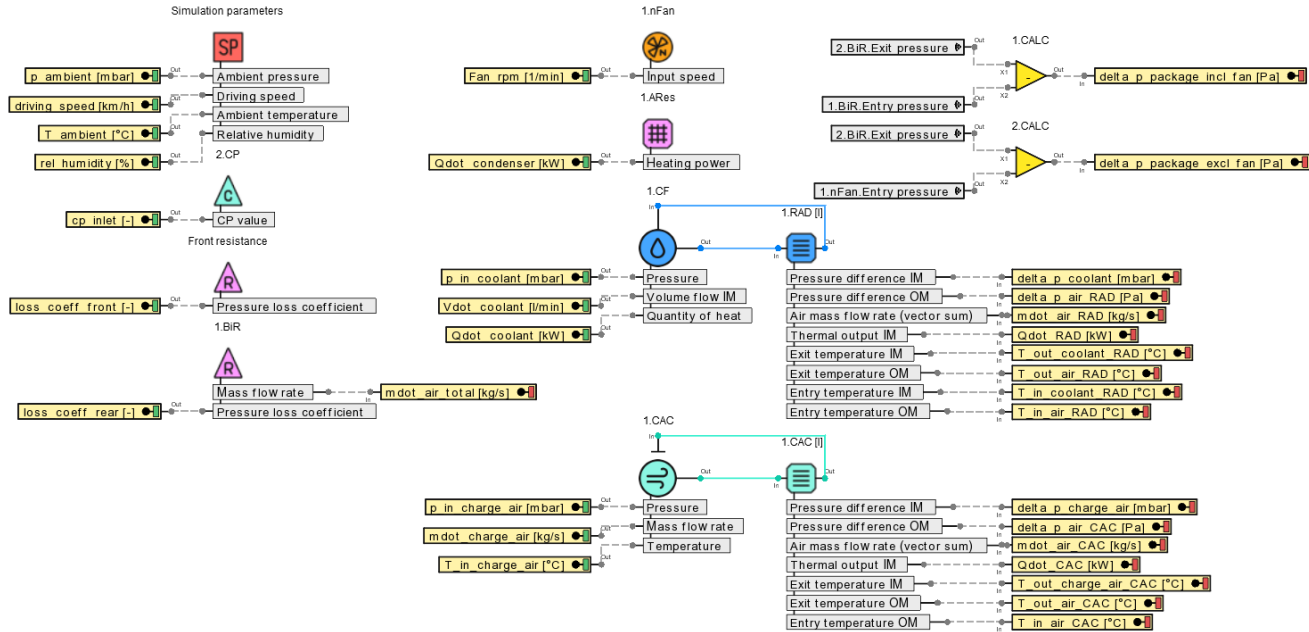
CRFM package for FMU



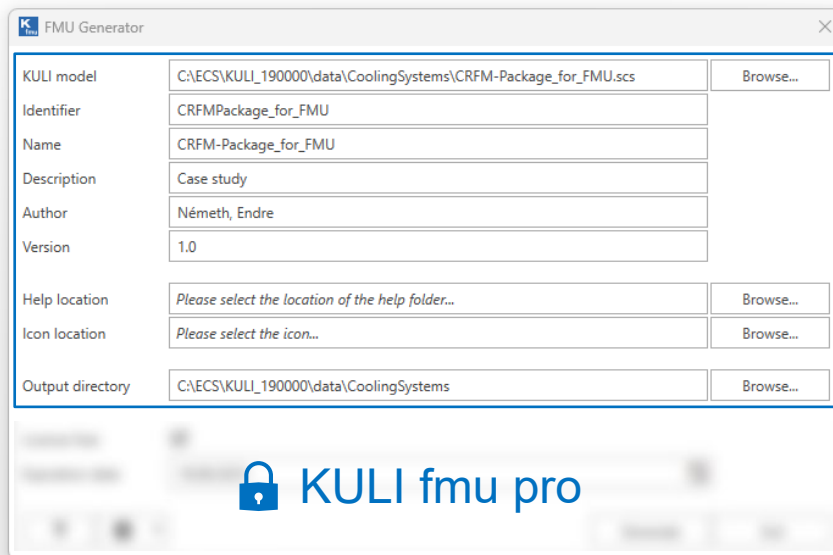
- Decide what the user can control and see from the sim. results,
- and define inputs and outputs accordingly,
- with the combination of COM objects, sensors and actuators.



CRFM package for FMU



CRFM package for FMU



The screenshot shows the 'FMU Generator' application window. It contains several input fields for defining an FMU package. The fields are as follows:

Field	Value	Action
KULI model	C:\ECS\KULI_190000\data\CoolingSystems\CRFM-Package_for_FMU.scs	Browse...
Identifier	CRFMPackage_for_FMU	
Name	CRFM-Package_for_FMU	
Description	Case study	
Author	Németh, Endre	
Version	1.0	
Help location	Please select the location of the help folder...	Browse...
Icon location	Please select the icon...	Browse...
Output directory	C:\ECS\KULI_190000\data\CoolingSystems	Browse...

Below the input fields, there is a blurred section containing the 'KULI fmu pro' logo, which consists of a blue padlock icon followed by the text 'KULI fmu pro'.



CRFM package for FMU

FMU Generator

KULI model: C:\ECS\KULI_190000\data\CoolingSystems\CRFM-Package_for_FMU.scs [Browse...]

Identifier: CRFMPackage_for_FMU

Name: CRFM-Package_for_FMU

Description: Case study

Author: Németh, Endre

Version: 1.0

Help location: Please select the location of the help folder... [Browse...]

Icon location: Please select the icon... [Browse...]

Output directory: C:\ECS\KULI_190000\data\CoolingSystems [Browse...]

License free: ☒

Expiration date: 18.08.2025 [Calendar icon]

[?] [Settings icon] [Generate] [Exit]





03

HVAC, transient and UI improvements Released with KULI 19

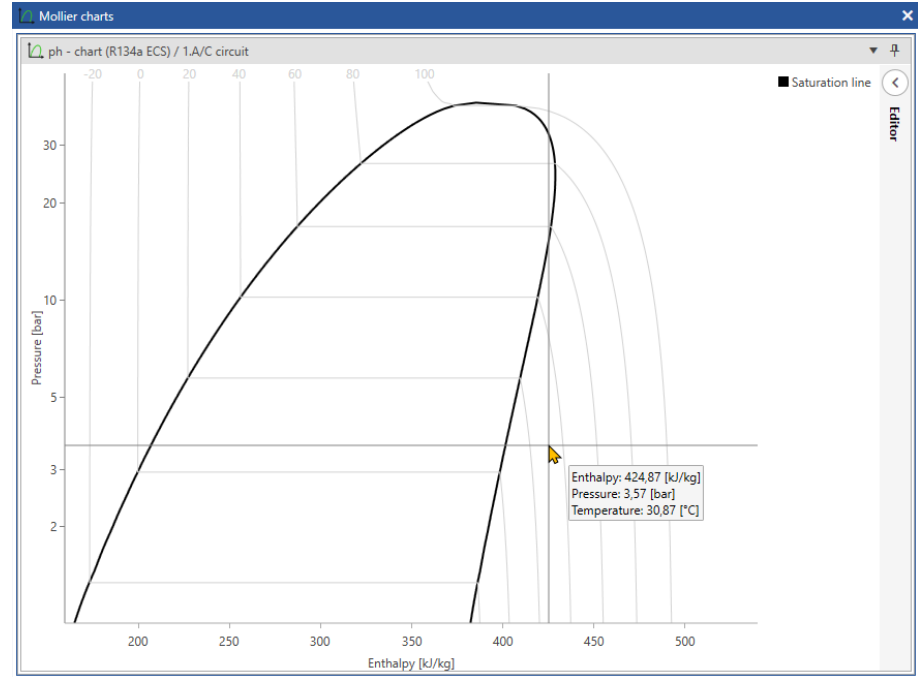
KULI 19

Improved Mollier-Chart

Mollier Charts in KULI

As soon as there is a refrigerant/ steam circuit available in the simulation model the chosen medium is depicted in the Mollier charts window:

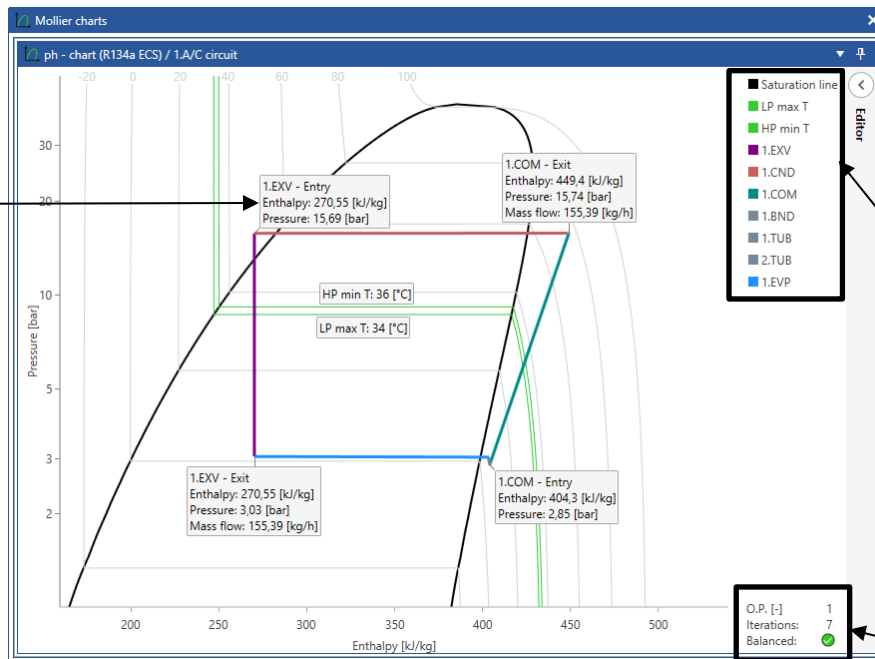
- In such a Mollier chart the saturation line of the refrigerant (in this case R134a as written at the top) and some isothermal lines are drawn
- Additionally, the mouse can be used as cursor to visualize enthalpy, pressure and temperature at a specific point
- This is a nice addition to the already available refrigerant properties calculator (Tools – Refrigerant properties)



Mollier Charts in KULI

During the simulation, the window as usual shows the process of balancing either in the operating point under investigation or the whole transient simulation over time

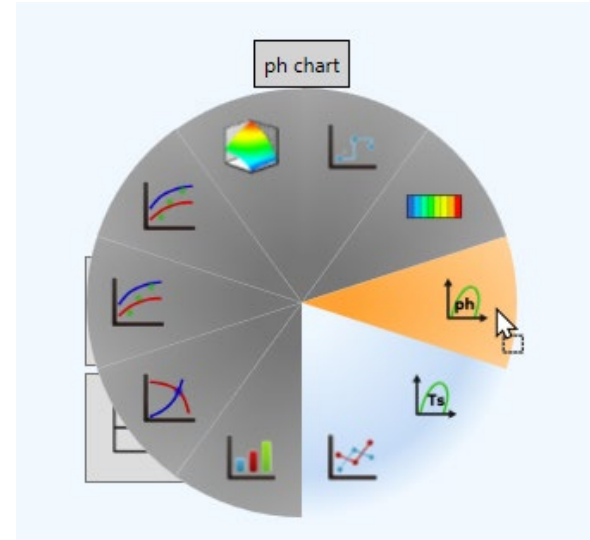
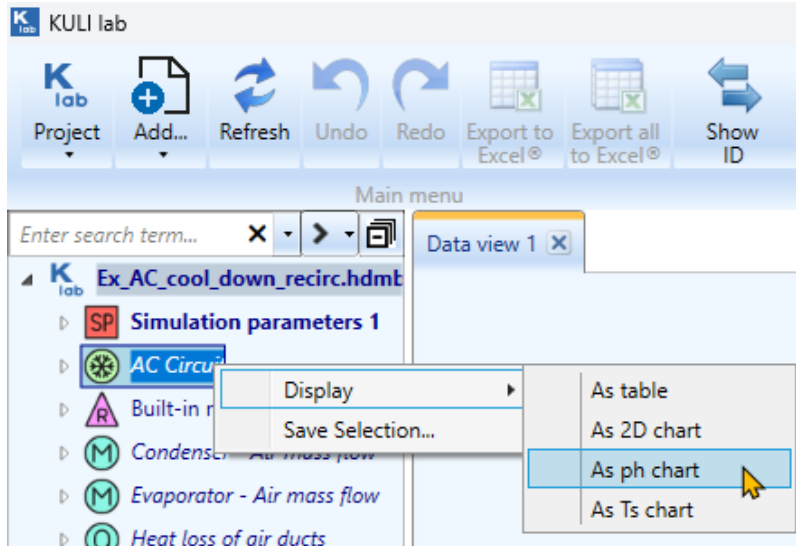
Labels at important points of the circuit (entry and exit of compressor and all active expansion valves)



Legend that lists all active components and other drawn lines that are important (either the ID or the inserted comment, depending on what is shown on the tab *Circuits/Air Path*)

Information regarding the simulation process

Mollier Chart in KULI lab

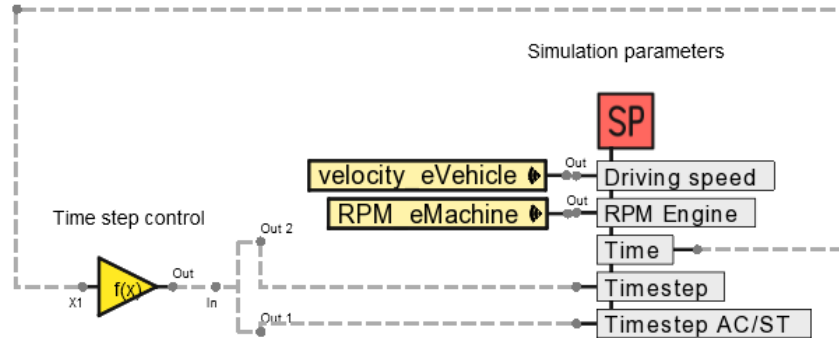


KULI 19

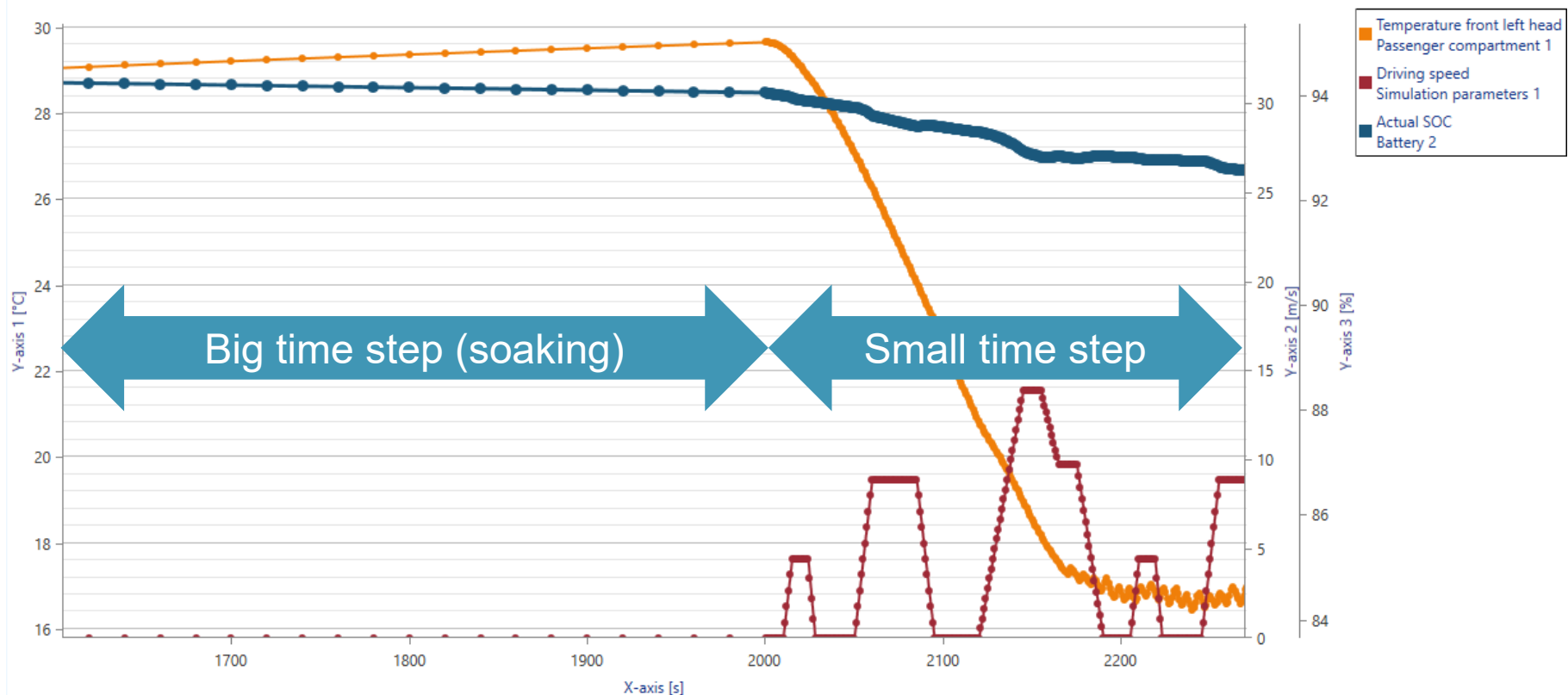
Variable transient time steps

Variable Time Steps

- KULI now fully supports variable time steps
- Variable time steps can be set using the *Timestep* and *Timestep AC/ST* actuators
- Ideal for setting different time steps e.g. in soaking phase and in driving cycle phase



Variable Time Steps in KULI lab



KULI 19

ACPHE Improvements

Calibration & (Quick) Calculation

The screenshot displays the 'A/C plate heat exchanger [chiller_ac_12_water.kuliacphe]' software window. The interface is divided into several sections:

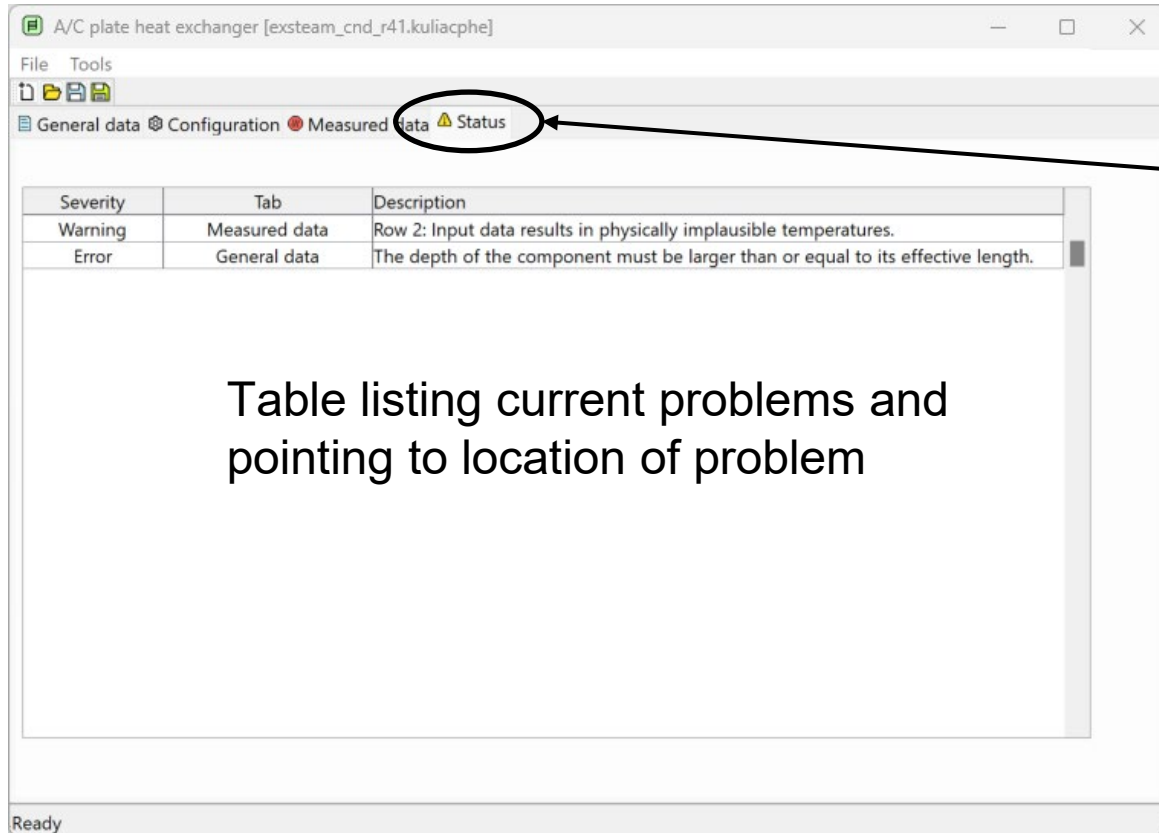
- User Information:** Fields for User, Date (0= current), Title, Memo, Type, No., Manufacturer, Series, and Measrd. data file.
- Geometric data:** Fields for Depth [mm], Width [mm], Height [mm], Effective length [mm], and Metal thickness [mm]. Below these are radio buttons for 'Channel height' (User defined or Both channels are equal) and input fields for Inner flow [mm] and Outer flow [mm]. At the bottom are checkboxes for 'Tanks volume inside [cm³]' and 'Tanks volume outside [cm³]'.
- Parameter Calculation:** A section with three rows of data:
 - Error inner pressure drop [%]: Min -5.96362, Mean value 4.08422, Max 9.43809
 - Error outer pressure drop [%]: Min -7.09054, Mean value 2.50163, Max 4.54768
 - Error heat transfer [%]: Min -4.98495, Mean value 1.22644, Max 1.80305
- Separation of off length:** A field set to 20.
- Calibration Options:** A checked checkbox 'Use quick calculation' and a 'Calibrate' button with a warning icon.
- Diagram:** A 3D perspective view of a plate heat exchanger with red arrows indicating 'Effective length', 'Height', 'Width', and 'Depth'.

The status bar at the bottom left shows 'Ready'.

Improved handling of quick calculation mode

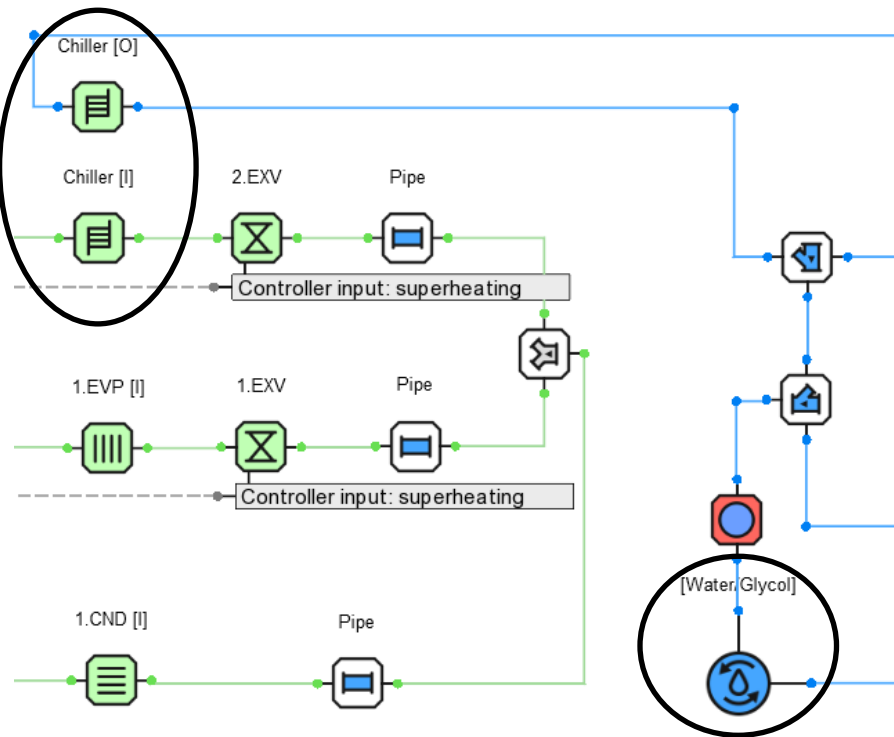
Improved calibration & calculation

New Status Tab



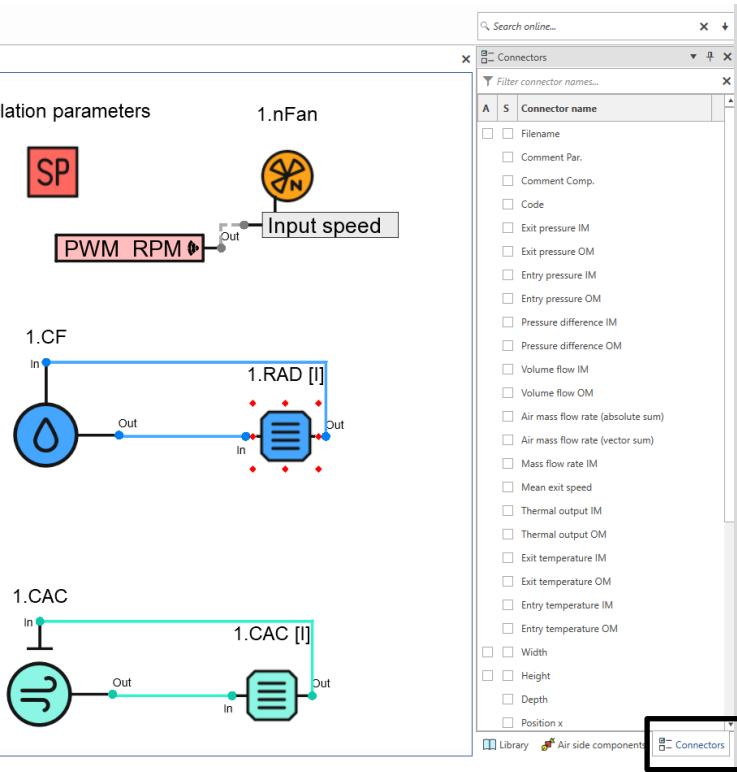
New Status tab

ACPHE and Dynamic Solver



- ACPHE can now be used in coolant circuits being simulated by the dynamic solver
- Initial temperature for coolant inside the component can be set
- Initial temperature and fluid volumes can be viewed in KULI lab

UI Improvements



Improved “**Add/remove connectors**”:

- Easier and quicker user interaction
- Manage sensors and actuators for multiple components at once
- Dock-able window



04

Under Development - Air side Representation

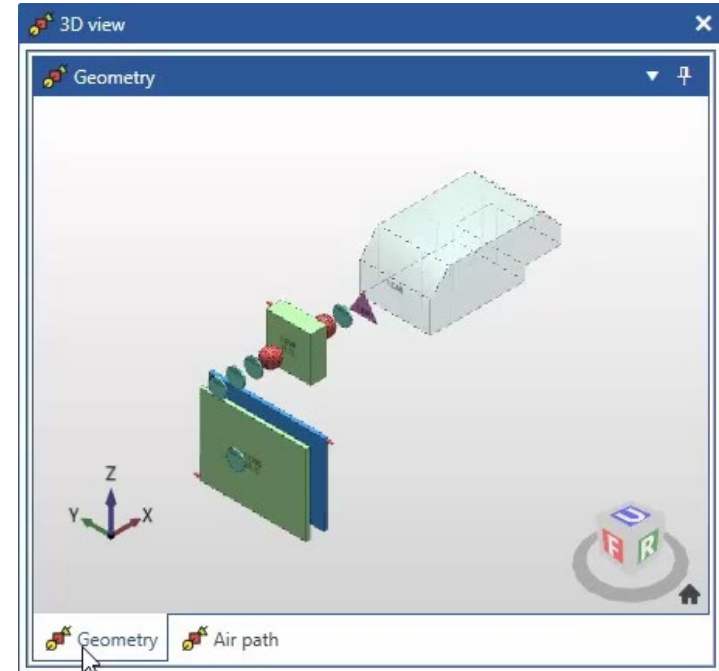
Targets in the Development

- Support of modelling with simplified workflows and user interface
- Reduce effort and time for setting up simulation models and make variants
- Make it easy for the users to setup components in a good quality
- Get a clear understanding in which quality the component data are used in the simulation

Air side Representation

3D view

- Split into two windows: Geometry and Air Path
- Fully integrated into the existing KULI framework
- Improved user experience for rotating, shifting, and standard views
- Detailed information available for each component
- Passenger compartment
 - Clearer representation
 - Geometry variants
 - Different numbers of seat rows
 - Additional information at every inlet and outlet



Air side Representation

3D view

- Enhanced Air Path Setup Workflow
 - Improved setup using mouse interactions
 - Simplified component connections
 - Easy definition of blocks
- Clearer information about the air path (Ambient)

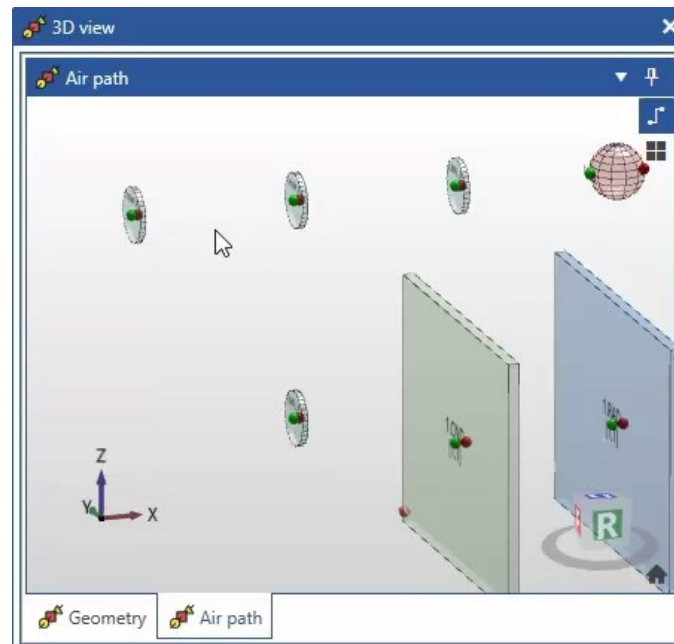
Nodes





☐ Use only 1. element

Nodes	Previous	Next
Ambient	From ambient	1.MFL_A;1.TEMP_A
1	1.MFL_A	1.CND[1,1]
2	1.TEMP_A	1.HUM_A
3	1.HUM_A	2.MFL_A
4	2.MFL_A	1.PMA
5	1.CAB[Recirc];1.PMA	1.EVP[1,1]
6	1.EVP[1,1]	2.PMA
7	2.PMA	1.HFL_A
8	1.HFL_A	1.BiR
9	1.BiR	1.CAB[1,1];1.CAB[1,2];1.CAB[1,3];1.CAB[1,4];1.CAB[1,5];1.CAB[1,6];1.CAB[1,7];1.CAB[1,8];1.CAB[1,9];1.CAB[1,10];1.CAB[1,11];1.CAB[1,12];1.CAB[1,13];1.CAB[1,14];1.CAB[1,15];1.CAB[1,16];1.CAB[1,17];1.CAB[1,18];1.CAB[1,19];1.CAB[1,20];1.CAB[1,21];1.CAB[1,22];1.CAB[1,23];1.CAB[1,24];1.CAB[1,25];1.CAB[1,26];1.CAB[1,27];1.CAB[1,28];1.CAB[1,29];1.CAB[1,30];1.CAB[1,31];1.CAB[1,32];1.CAB[1,33];1.CAB[1,34];1.CAB[1,35];1.CAB[1,36];1.CAB[1,37];1.CAB[1,38];1.CAB[1,39];1.CAB[1,40];1.CAB[1,41];1.CAB[1,42];1.CAB[1,43];1.CAB[1,44];1.CAB[1,45];1.CAB[1,46];1.CAB[1,47];1.CAB[1,48];1.CAB[1,49];1.CAB[1,50];1.CAB[1,51];1.CAB[1,52];1.CAB[1,53];1.CAB[1,54];1.CAB[1,55];1.CAB[1,56];1.CAB[1,57];1.CAB[1,58];1.CAB[1,59];1.CAB[1,60];1.CAB[1,61];1.CAB[1,62];1.CAB[1,63];1.CAB[1,64];1.CAB[1,65];1.CAB[1,66];1.CAB[1,67];1.CAB[1,68];1.CAB[1,69];1.CAB[1,70];1.CAB[1,71];1.CAB[1,72];1.CAB[1,73];1.CAB[1,74];1.CAB[1,75];1.CAB[1,76];1.CAB[1,77];1.CAB[1,78];1.CAB[1,79];1.CAB[1,80];1.CAB[1,81];1.CAB[1,82];1.CAB[1,83];1.CAB[1,84];1.CAB[1,85];1.CAB[1,86];1.CAB[1,87];1.CAB[1,88];1.CAB[1,89];1.CAB[1,90];1.CAB[1,91];1.CAB[1,92];1.CAB[1,93];1.CAB[1,94];1.CAB[1,95];1.CAB[1,96];1.CAB[1,97];1.CAB[1,98];1.CAB[1,99];1.CAB[1,100];1.CAB[1,101];1.CAB[1,102];1.CAB[1,103];1.CAB[1,104];1.CAB[1,105];1.CAB[1,106];1.CAB[1,107];1.CAB[1,108];1.CAB[1,109];1.CAB[1,110];1.CAB[1,111];1.CAB[1,112];1.CAB[1,113];1.CAB[1,114];1.CAB[1,115];1.CAB[1,116];1.CAB[1,117];1.CAB[1,118];1.CAB[1,119];1.CAB[1,120];1.CAB[1,121];1.CAB[1,122];1.CAB[1,123];1.CAB[1,124];1.CAB[1,125];1.CAB[1,126];1.CAB[1,127];1.CAB[1,128];1.CAB[1,129];1.CAB[1,130];1.CAB[1,131];1.CAB[1,132];1.CAB[1,133];1.CAB[1,134];1.CAB[1,135];1.CAB[1,136];1.CAB[1,137];1.CAB[1,138];1.CAB[1,139];1.CAB[1,140];1.CAB[1,141];1.CAB[1,142];1.CAB[1,143];1.CAB[1,144];1.CAB[1,145];1.CAB[1,146];1.CAB[1,147];1.CAB[1,148];1.CAB[1,149];1.CAB[1,150];1.CAB[1,151];1.CAB[1,152];1.CAB[1,153];1.CAB[1,154];1.CAB[1,155];1.CAB[1,156];1.CAB[1,157];1.CAB[1,158];1.CAB[1,159];1.CAB[1,160];1.CAB[1,161];1.CAB[1,162];1.CAB[1,163];1.CAB[1,164];1.CAB[1,165];1.CAB[1,166];1.CAB[1,167];1.CAB[1,168];1.CAB[1,169];1.CAB[1,170];1.CAB[1,171];1.CAB[1,172];1.CAB[1,173];1.CAB[1,174];1.CAB[1,175];1.CAB[1,176];1.CAB[1,177];1.CAB[1,178];1.CAB[1,179];1.CAB[1,180];1.CAB[1,181];1.CAB[1,182];1.CAB[1,183];1.CAB[1,184];1.CAB[1,185];1.CAB[1,186];1.CAB[1,187];1.CAB[1,188];1.CAB[1,189];1.CAB[1,190];1.CAB[1,191];1.CAB[1,192];1.CAB[1,193];1.CAB[1,194];1.CAB[1,195];1.CAB[1,196];1.CAB[1,197];1.CAB[1,198];1.CAB[1,199];1.CAB[1,200];1.CAB[1,201];1.CAB[1,202];1.CAB[1,203];1.CAB[1,204];1.CAB[1,205];1.CAB[1,206];1.CAB[1,207];1.CAB[1,208];1.CAB[1,209];1.CAB[1,210];1.CAB[1,211];1.CAB[1,212];1.CAB[1,213];1.CAB[1,214];1.CAB[1,215];1.CAB[1,216];1.CAB[1,217];1.CAB[1,218];1.CAB[1,219];1.CAB[1,220];1.CAB[1,221];1.CAB[1,222];1.CAB[1,223];1.CAB[1,224];1.CAB[1,225];1.CAB[1,226];1.CAB[1,227];1.CAB[1,228];1.CAB[1,229];1.CAB[1,230];1.CAB[1,231];1.CAB[1,232];1.CAB[1,233];1.CAB[1,234];1.CAB[1,235];1.CAB[1,236];1.CAB[1,237];1.CAB[1,238];1.CAB[1,239];1.CAB[1,240];1.CAB[1,241];1.CAB[1,242];1.CAB[1,243];1.CAB[1,244];1.CAB[1,245];1.CAB[1,246];1.CAB[1,247];1.CAB[1,248];1.CAB[1,249];1.CAB[1,250];1.CAB[1,251];1.CAB[1,252];1.CAB[1,253];1.CAB[1,254];1.CAB[1,255];1.CAB[1,256];1.CAB[1,257];1.CAB[1,258];1.CAB[1,259];1.CAB[1,260];1.CAB[1,261];1.CAB[1,262];1.CAB[1,263];1.CAB[1,264];1.CAB[1,265];1.CAB[1,266];1.CAB[1,267];1.CAB[1,268];1.CAB[1,269];1.CAB[1,270];1.CAB[1,271];1.CAB[1,272];1.CAB[1,273];1.CAB[1,274];1.CAB[1,275];1.CAB[1,276];1.CAB[1,277];1.CAB[1,278];1.CAB[1,279];1.CAB[1,280];1.CAB[1,281];1.CAB[1,282];1.CAB[1,283];1.CAB[1,284];1.CAB[1,285];1.CAB[1,286];1.CAB[1,287];1.CAB[1,288];1.CAB[1,289];1.CAB[1,290];1.CAB[1,291];1.CAB[1,292];1.CAB[1,293];1.CAB[1,294];1.CAB[1,295];1.CAB[1,296];1.CAB[1,297];1.CAB[1,298];1.CAB[1,299];1.CAB[1,300];1.CAB[1,301];1.CAB[1,302];1.CAB[1,303];1.CAB[1,304];1.CAB[1,305];1.CAB[1,306];1.CAB[1,307];1.CAB[1,308];1.CAB[1,309];1.CAB[1,310];1.CAB[1,311];1.CAB[1,312];1.CAB[1,313];1.CAB[1,314];1.CAB[1,315];1.CAB[1,316];1.CAB[1,317];1.CAB[1,318];1.CAB[1,319];1.CAB[1,320];1.CAB[1,321];1.CAB[1,322];1.CAB[1,323];1.CAB[1,324];1.CAB[1,325];1.CAB[1,326];1.CAB[1,327];1.CAB[1,328];1.CAB[1,329];1.CAB[1,330];1.CAB[1,331];1.CAB[1,332];1.CAB[1,333];1.CAB[1,334];1.CAB[1,335];1.CAB[1,336];1.CAB[1,337];1.CAB[1,338];1.CAB[1,339];1.CAB[1,340];1.CAB[1,341];1.CAB[1,342];1.CAB[1,343];1.CAB[1,344];1.CAB[1,345];1.CAB[1,346];1.CAB[1,347];1.CAB[1,348];1.CAB[1,349];1.CAB[1,350];1.CAB[1,351];1.CAB[1,352];1.CAB[1,353];1.CAB[1,354];1.CAB[1,355];1.CAB[1,356];1.CAB[1,357];1.CAB[1,358];1.CAB[1,359];1.CAB[1,360];1.CAB[1,361];1.CAB[1,362];1.CAB[1,363];1.CAB[1,364];1.CAB[1,365];1.CAB[1,366];1.CAB[1,367];1.CAB[1,368];





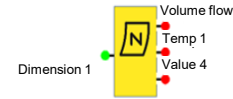
05

Under Development - Better modelling support

Better modelling support

N-maps

- Multiple outlets in the simulation model
 - Reduction of modelling effort
 - Simplifying of model
 - Makes it easy to set up model variants with different boundary condition (e.g. different driving cycles)
- Parameter naming in the component data and reusing in the simulation model leads to a clear understanding of data dependencies



Circuits / Air path

Parameter window for an N-dimensional map component. It shows input and output parameters.

Input		Output	
Dimension 1	[s]	Volume flow	[l/min] Yes
		Temp 1	[°C] Yes
		Volume flow 2	[l/min] No
		Torque	[Nm] Yes

Parameter window

Component file window showing N-dimensional map data. It includes a table with 6 columns: Dimension 1, Volume flow, Temp 1, Volume flow 2, Torque, and Value 5.

Dimension 1 [s]...	Volume flow [l/min]...	Temp 1 [°C]...	Volume flow 2 [l/min]...	Torque [Nm]...	Value 5 [°C]...
1	7.3	33.2	5	110	100.2
2	7.5	33.7	4	115	100.9
3	8	34	5	121	102
4	7.6	35	6	125	103

Component file

Better modelling support

Media file generator

- Easy generation of oils in KULI based on Ubbelohde-Walther Transformation with only few information

PROPERTIES		
Color	Visual	Red
Density at 20°C (68°F)	ASTM D1298	0.865
Viscosity at 40°C (104°F)	ASTM D445	38.5 mm²/s
Viscosity at 100°C (212°F)	ASTM D445	7.8 mm²/s
Viscosity Index	ASTM D2270	179.0
Flash point	ASTM D92	224.0 °C / 435.0 °F
Pour point	ASTM D97	-36.0 °C / -33.0 °F

Motul DEXRON IID

https://motul.incony.de/media/motulData/DO/base/dexron_iid_en.pdf



Oil data file generator

×

Density	850	kg/m³	at	15	°C
Kinematic Viscosity	98	mm²/s	at	40	°C
Kinematic Viscosity	10	mm²/s	at	100	°C
Description					
Open file after creation	☒				
Generate...					



Ubbelohde-Walther Transformation

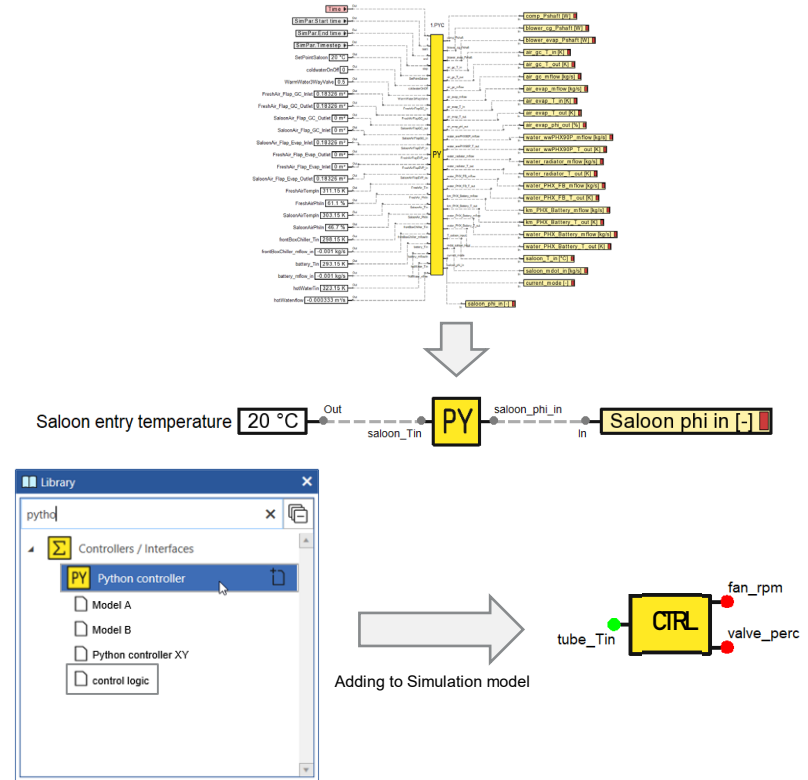
$$\lg \lg(\nu + z) = K - m \cdot \lg T \leftrightarrow \nu = 10^{10^{K-m \cdot \lg T} - z}$$

Oil_media_file.dat

Better modelling support

From Python controller to Python controller component

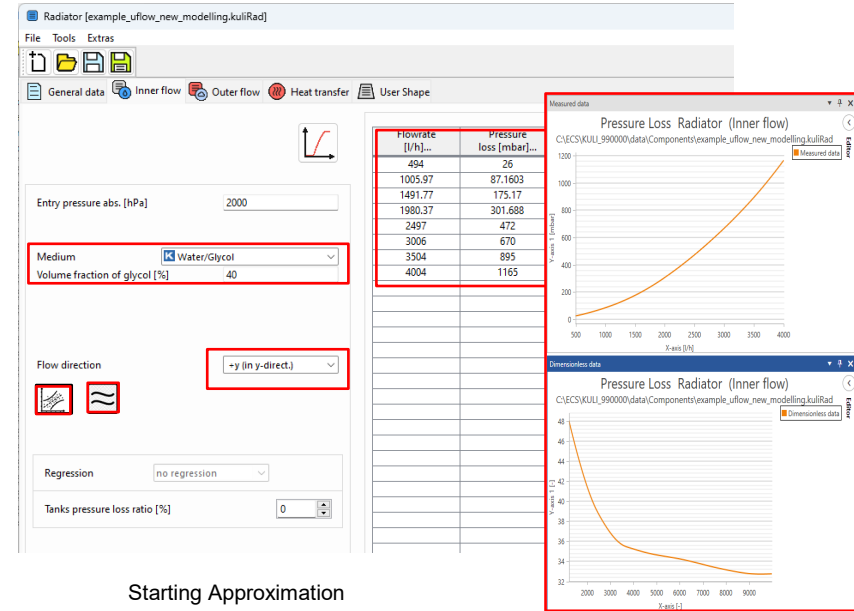
- Reusability of interface data in different simulation models
- Easier transfer of interface data to other simulation models
- Sharing existing interface
- Reduction of necessary in- and outlets
 - User defined outlet parameter in the simulation model
 - Specification of constant values directly in the component



Better modelling support

Component data

- Simplification of workflows
 - Regression of pressure loss and heat transfer
 - Display of maximum theoretical limits (for Heat transfer)
 - Approximation of data based on other component performances
- Visualization of input data
 - Ability to open multiple 2D charts simultaneously
-> That makes it possible to see changes in the provided data immediately
- Clear interpretation of data usage
 - Inter- and extrapolation method specification for simulation only in the component data
- Improved UI handling of 2D charts for better user experience



Starting Approximation

Starting Regression

Changing of component properties updates the opened charts

A long-exposure photograph of a highway at night. The road is dark, and the sky is dark with some clouds. On the left side of the road, there is a concrete barrier. On the right side, there are multiple lanes of traffic. The lights from the cars are blurred into long, horizontal streaks of red, yellow, and white, indicating motion. The text "Forward. For all." is overlaid on the left side of the image in a white, sans-serif font.

Forward.
For all.