

HoST Calculus – Advanced Software for Transformer Thermal Analysis



Implementation of Detailed Static and Dynamic Thermal-Hydraulic Network Model (THNM)

Introduction

- During power transformer operation, load variations cause changes in energy losses and heating power.
- The temperature of the external cooling fluid also fluctuates, leading to variations in internal transformer temperatures.
- These thermal changes can be managed by adjusting the cooling system, such as modifying the number of active fans.
- To prevent transformer failure and accelerated insulation aging, the temperature must remain within critical limits and rated values.
- A transformer's thermal characteristics are evaluated through a standard heat run test under steady-state conditions (IEC 60076-2).

Overview

- Static HoST Calculus is software designed tool for thermal analysis of liquid-immersed oil power transformers (PT).
- Dynamic HoST Calculus is a software for thermal monitoring and estimation of overload possibility.
- Key Benefits:
 - Accurate temperature predictions and hotspot identification.
 - Fast execution (Static HoST: max. 10–15 minutes for complex designs, Dynamic HoST: executable in real time for grid operating conditions).

Static HoST

- **Thermal Design:**
 - Predicts temperatures during a standard heat run test (IEC 60076-2).
 - Estimates the hotspot location and temperature rise.
- **Safety Margins:**
 - Recommended 5 K margin for hotspot, 3 K for top oil.
- **Performance:**
 - Based on analysis of 146 heat run tests [1], estimated 8.2% increase in profit.
- **Input Requirements:**
 - Detailed transformer construction data and material properties.
 - No calibration required.

Input GUI – Global Parameters

- Thermal Influences:
 - Oil flow and viscosity (dependent on oil type and temperature).
 - Altitude.
 - Ambient air temperature.
 - Losses at specified per unit load.
- Guaranteed values

The screenshot shows the 'Input' window for 'Global Parameters'. The left sidebar lists categories: Core, Winding, Tank, Cooling, and Model Parameters. The main area contains the following parameters:

- Project Name:** DemoProject
- Version:** 1
- Rated Power:** 175 MVA
- Oil type:** NYNAS_LIBRA
- Altitude:** 500 m
- Construction of inner cooling:** Non OD
- Inner cooling mode:** ON
- Outer cooling mode:** AF
- Air temperature:** 20 °C
- Per unit load:** 1 Recalculate winding losses to local temperature
- Consider polygonal shape:**
- Maximum allowed temperature rises (K):**
 - Winding Hot-Spot: 80
 - Average winding: 80
 - Top oil: 65
- Maximum allowed temperature rises in core (K):**
 - Surface: 90
 - Hot-Spot: 90

Database Integration

- Built-in databases with characteristics for various types from different manufacturers for:
 - Oil
 - Fans
 - Pumps
 - Radiators
 - Compact coolers

Oil type

NYNAS_LIBRA

Altitude

PETROCHINA_45X

SHELL_DIALA_D

SHELL_DIALA_DX

Constant

NYNAS_GEMINI_10XN

ERGON_HYVOLT_I

ERGON_HYVOLT_II

ERGON_HYVOLT_III

ERGON_HYVOLT_WEGBRA

Inner

NYNAS_TAURUS

ENVIROTEMP_FR3

LUMINOL_TRI

RAMOIL

Outer

NYNAS_ORION_II

IREQ

Fans in battery

Producer of the fan ZIEHL_ABEGG

Frequency

Diameter ZIEHL_ABEGG mm

Type of the fan

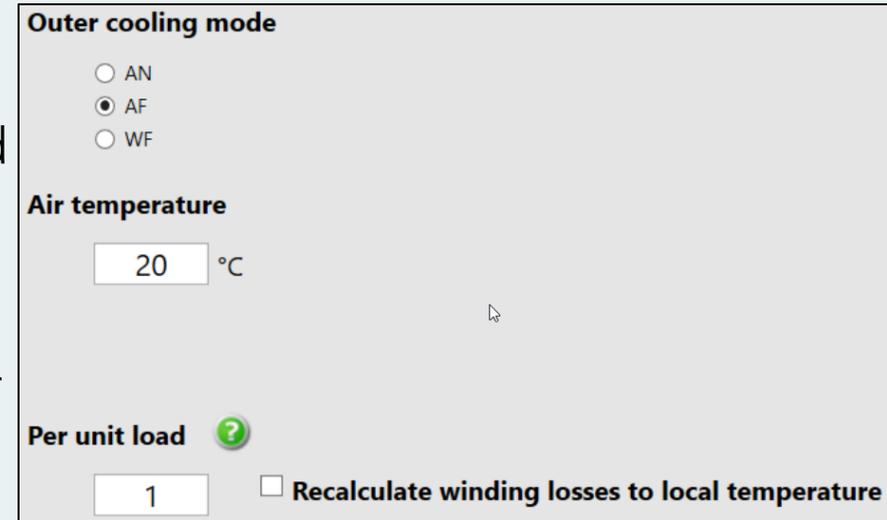
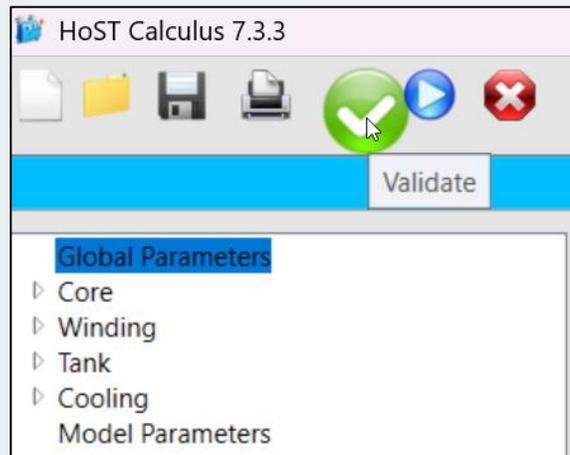
Protection network on inner side of the fan exists No

Protection network on outer side of the fan exists No

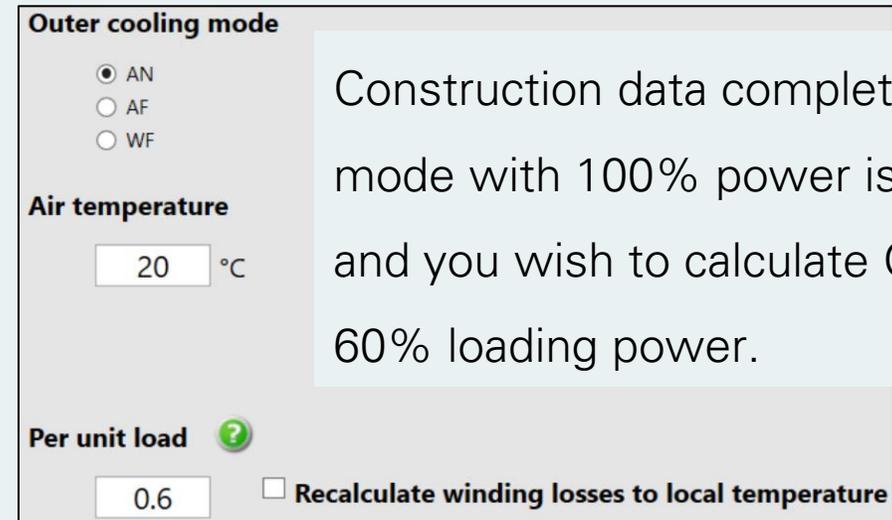
Type of draft FORCED

Integrated Data Entry & Validation

- Efficient Data Entry:
 - Integrated, smart interface for rapid input of transformer design data.
- Validation:
 - Automated warnings for missing or out-of-range data ensure correct input.



The screenshot shows the software interface for data entry. It features three main sections: 'Outer cooling mode' with radio buttons for AN, AF (selected), and WF; 'Air temperature' with a text input field containing '20' and a '°C' label; and 'Per unit load' with a text input field containing '1' and a green question mark icon. A checkbox labeled 'Recalculate winding losses to local temperature' is located to the right of the 'Per unit load' field.



The screenshot shows the software interface for data entry. It features three main sections: 'Outer cooling mode' with radio buttons for AN (selected), AF, and WF; 'Air temperature' with a text input field containing '20' and a '°C' label; and 'Per unit load' with a text input field containing '0.6' and a green question mark icon. A checkbox labeled 'Recalculate winding losses to local temperature' is located to the right of the 'Per unit load' field.

Construction data completed, ONAF mode with 100% power is calculated and you wish to calculate ONAN with 60% loading power.

Winding - Losses

- Import distributed losses from Excel or specify total losses.
- Distributed losses can be loaded for all tap positions, and for calculations the losses corresponding to specified tap are used.
- The losses can be recalculated to local conductor temperatures.

Total losses of the winding 

Distributed losses in the winding

.../LV DC.xlsx

.../LV E.xlsx

Tap changer exist Tap position

Recalculate winding losses to local temperature

Temperature at which the distribution of losses is specified °C

Winding - Handling

Option to handle complete windings to speed up repetitive design entries.

The screenshot shows a software interface with a tree view on the left and a main table on the right. The tree view includes 'Global Parameters', 'Core', 'Winding' (selected), 'LV', 'HV', 'RW', 'Radial insulation over the last winding', 'Winding Connection', 'Tank', 'Cooling', and 'Model Parameters'. The main table has columns for winding type, actions, and parameters. The parameters are: Rated Power (175 MVA), Rated Voltage (35 kV for LV, 330 kV for HV and RW), and Connection (Y). The actions are: Edit, Remove, Copy, Save, and Load.

					Rated Power ⁱ	Rated Voltage ⁱ	Connection ⁱ	
LV	Edit	Remove	Copy	Save	Load	175 MVA	35 kV	Y
HV	Edit	Remove	Copy	Save	Load	175 MVA	330 kV	Y
RW	Edit	Remove	Copy	Save	Load	175 MVA	330 kV	Y

Winding - Defining coils

Input

Global Parameters

- Core
- Winding
 - LV
 - Additional Pressure Drop
 - Structure
 - Part 1 1
 - Losses
 - Oil Entering Winding
 - Boundary Axial Ducts
 - Type of Coils
 - LV - TOP
 - LV - MIDDLE
 - LV - BOTTOM

LV - TOP Edit Remove Copy

LV - MIDDLE Edit Remove Copy

LV - BOTTOM Edit Remove Copy

Input

Global Parameters

- Core
- Winding
 - LV
 - Additional Pressure Drop
 - Structure
 - Part 1 1
 - Losses
 - Oil Entering Winding
 - Boundary Axial Ducts
 - Type of Coils
 - LV - TOP
 - Number of Conductors
 - Edge Protection
 - REMT
 - Wire
 - LV - MIDDLE
 - LV - BOTTOM

NT = 4
NAPC = 2
NRPC = 2

Layer winding

Axial: NT · NAPC
Radial: NRPC

Quantity of turns NT = 1

Number of parallel conductor in radial direction in one turn NRPC = 1

Number of parallel conductor in axial direction in one turn NAPC = 2 Refresh image

Set edge protection

Set REMT

Input

Global Parameters

- Core
- Winding
 - LV
 - Additional Pressure Drop
 - Structure
 - Part 1 1
 - Losses
 - Oil Entering Winding
 - Boundary Axial Ducts
 - Type of Coils
 - LV - TOP
 - Number of Conductors
 - Edge Protection
 - REMT
 - Wire
 - LV - MIDDLE
 - LV - BOTTOM

Material of the conductor CU

Radial dimension of conductor W = 1,5 mm

Axial dimension of conductor H = 3,7 mm

Double side enamel thickness 0,1 mm

Epoxy glue thickness 0 mm

Outer insulation thickness doi = 0 mm

Type of outer insulation NETTING

Shrinkage 10 %

Producer of the conductor p

Outer radial dimension WCond = 57,6 mm

Outer axial dimension HCond = 7,65 mm

Shrunk axial dimension HCondSh = 7,65 mm

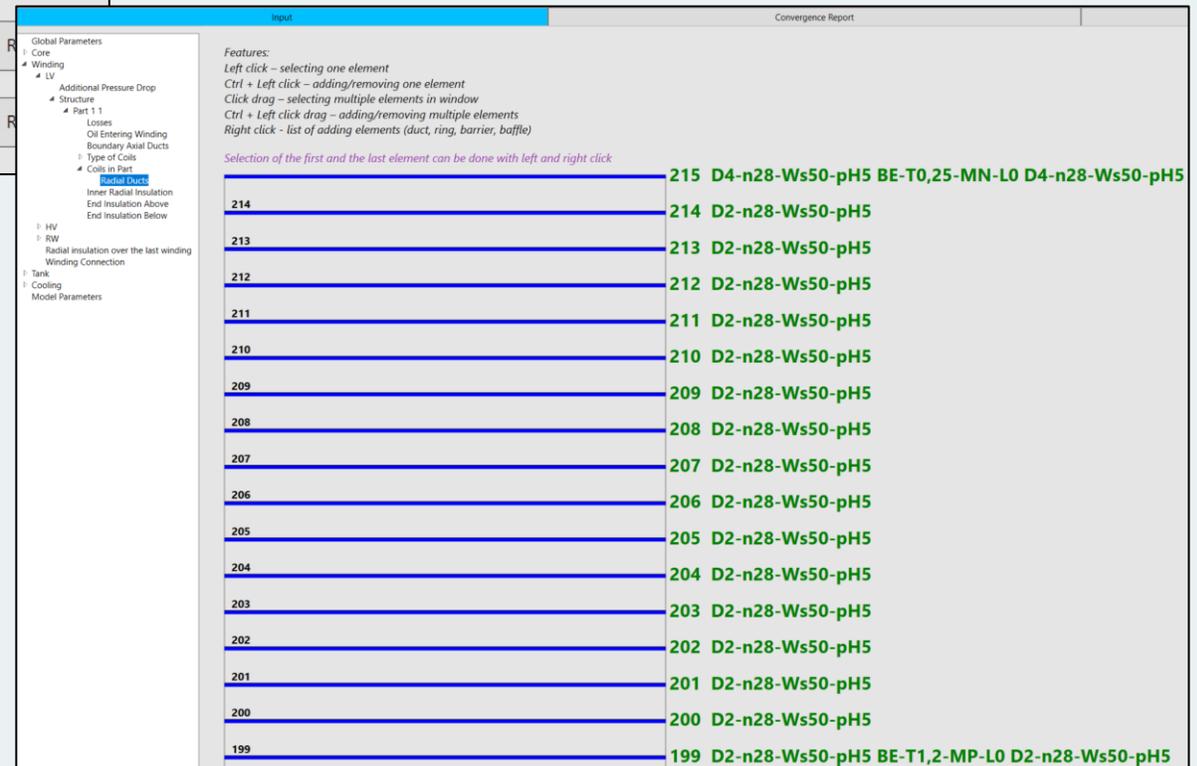
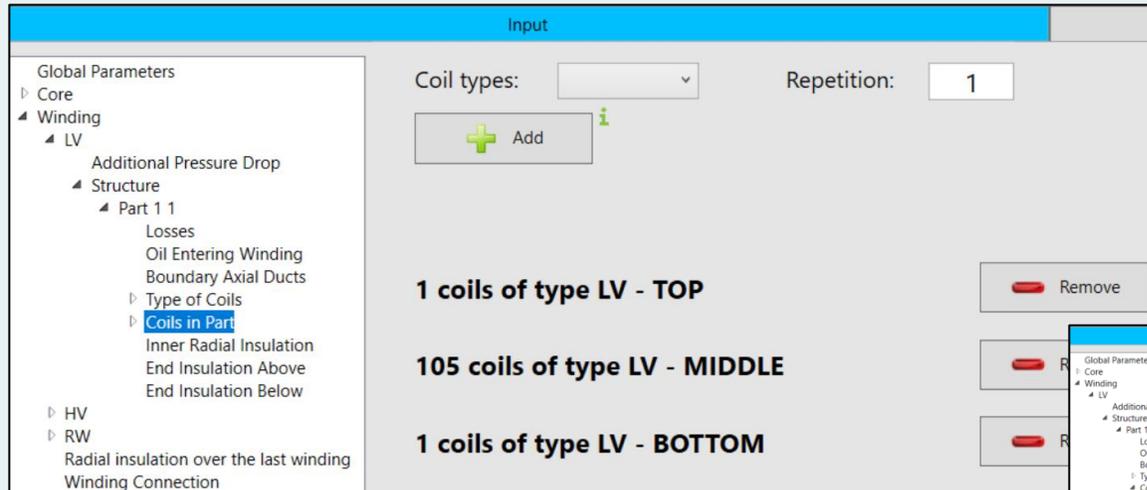
Number of conductors Nt = 71

Dimension Si = 0,05 mm

CTC cross section

2n+1 1+2n+1 2n

Coils & Radial ducts in winding part



A sample case with 107 coils (each with two axial parallel conductors) results in 107×2 radial ducts plus one extra top duct (totaling 215 ducts).

Winding – Inclusion of barriers for zig-zag oil flow between conductors

Input
Converge

Global Parameters

- Core
- Winding
 - LV
 - Additional Pressure Drop
 - Structure
 - Part 1.1
 - Losses
 - Oil Entering Winding
 - Boundary Axial Ducts
 - Type of Coils
 - Coils in Part
 - Radial Ducts**
 - Inner Radial Insulation
 - End Insulation Above
 - End Insulation Below
 - HV
 - RW
 - Radial insulation over the last winding
 - Winding Connection
 - Tank
 - Cooling
 - Model Parameters

Type: E

Thickness of barrier: T = 1,2 mm

Material: PRESSBOARD

Leakage: 0 %

Apply

Cancel

A, C (if covers the coil) i

B, D (if does not cover the coil) i

W = 2 mm n = 28

W = 2 mm n = 28

Ws = 50 mm Ph = 5 %

Ws = 50 mm Ph = 5 %

Height of spacer W [mm]

Number of spacers n

Width of spacers Ws [mm]

Shrinkage of spacer p_H [%]

$p_H = 100 \frac{W - W_s}{W}$

The insulation between top of HV winding and yoke of the core

Global Parameters

- Core
- Winding
 - LV
 - HV
 - Additional Pressure Drop
 - Structure
 - Part 1 1
 - Losses
 - Oil Entering Winding
 - Boundary Axial Ducts
 - Type of Coils
 - Coils in Part
 - Inner Radial Insulation
 - End Insulation Above**
 - End Insulation Below
- RW
 - Radial insulation over the last winding
 - Winding Connection
- Tank
- Cooling
- Model Parameters

Width of duct for oil exit = 20 mm

No oil mixture after exiting the part

Winding

Width = 144 mm

ws

Number of spacers: 28

Width of spacers: 55 mm

Global Parameters

- Core
- Winding
 - LV
 - HV
 - Additional Pressure Drop
 - Structure
 - Part 1 1
 - Losses
 - Oil Entering Winding
 - Boundary Axial Ducts
 - Type of Coils
 - Coils in Part
 - Inner Radial Insulation
 - End Insulation Above**
 - End Insulation Below
 - RW
 - Radial insulation over the last winding
 - Winding Connection
 - Tank
 - Cooling
 - Model Parameters

Type of insulation element: AR

Last element

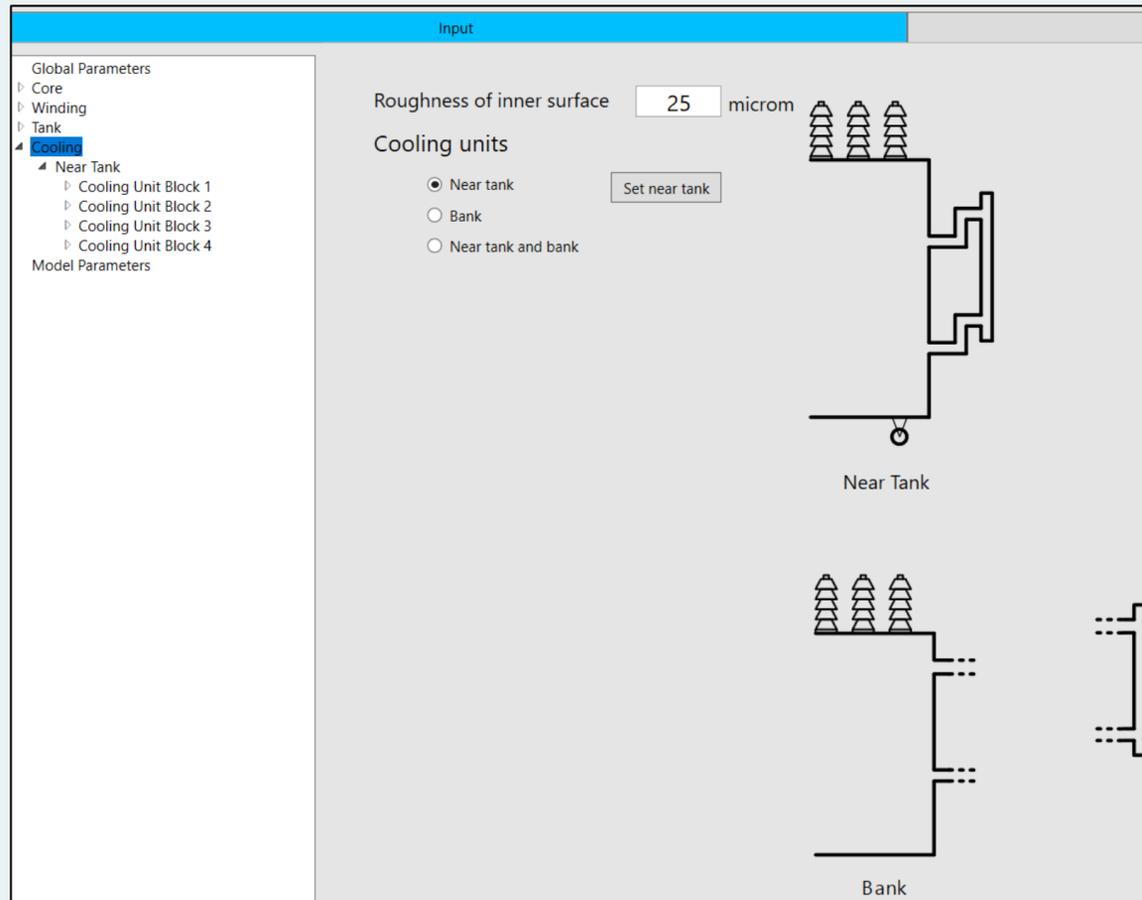
Duct length: [] mm

Thickness: 5 mm

Duct width: 20 mm

Apply Cancel

Outer cooling tab



Options:

- Near tank
- Bank – a piping system connects the bank of cooling units with the tank

Cooling unit block

The screenshot shows a software interface for configuring a cooling unit block. The interface is divided into several sections:

- Tree View (Left):** A hierarchical tree view showing the structure of the model. The selected path is: Global Parameters > Cooling > Near Tank > Cooling Unit Block 1 > Operational Cooling Units > Radiators.
- Input Fields (Center):**
 - Number of cooling units in block:** $N = 3$
 - Distance between cooling units:** $d = 600$ mm
 - Distance bottom tank - bottom cooling unit:** $H_{br} = 1940$ mm
- Type of coolers (Bottom):**
 - Radiators
 - Horizontally blowing fans
 - Compact coolers
 - Vertically blowing fans
- Buttons:** "Operational Cooling Units" (top), "Set radiators" (bottom).
- Schematic Diagram (Right):** A schematic diagram showing a cross-section of the cooling unit block. It illustrates three cooling units (represented by horizontal lines) arranged in a row, with a distance d between them. Below the units, a vertical dimension H_{br} is shown, representing the distance from the bottom tank to the bottom of the cooling unit block. The diagram also shows a tank with a pump at the bottom and a vertical pipe leading up to the cooling units.

Cooling Unit Composition:

- Consists of radiators or compact coolers.
- In the case of radiators, a cooling unit block is formed as the group of radiators cooled by the group of fans.

Operating cooling units / operating fans

Input

Global Parameters
Core
Winding
Tank
Cooling
Near Tank
Cooling Unit Block 1
Operational Cooling Units
Radiators
Horizontally Blowing Fans
Cooling Unit Block 2
Cooling Unit Block 3
Cooling Unit Block 4
Model Parameters

Cooling unit with green color is active, cooling unit with red color is disabled.

CU 1 CU 2 CU 3

All three radiators are operating

Input

Global Parameters
Core
Winding
Tank
Cooling
Near Tank
Cooling Unit Block 1
Operational Cooling Units
Radiators
Horizontally Blowing Fans
Cooling Unit Block 2
Cooling Unit Block 3
Cooling Unit Block 4
Model Parameters

Cooling unit with green color is active, cooling unit with red color is disabled.

CU 1 CU 2 CU 3

The middle radiator is inactive (the valves on it are closed)

Input

Global Parameters
Core
Winding
Tank
Cooling
Near Tank
Cooling Unit Block 1
Operational Cooling Units
Radiators
Horizontally Blowing Fans
Position Left
Cooling Unit Block 2
Cooling Unit Block 3
Cooling Unit Block 4
Model Parameters

(1,44, 2,6)

Add a fan Radius: 315 mm
X: mm
Y: mm
Remove last fan

(0,0) (0,38, 1,9) (1,1, 1,88) (0,38, 1,15) (1,1, 1,15) (0,38, 0,4) (1,1, 0,4)

State with 5 active fans

Input

Global Parameters
Core
Winding
Tank
Cooling
Near Tank
Cooling Unit Block 1
Operational Cooling Units
Radiators
Horizontally Blowing Fans
Position Left
Cooling Unit Block 2
Cooling Unit Block 3
Cooling Unit Block 4
Model Parameters

(1,44, 2,6)

Add a fan Radius: 315 mm
X: mm
Y: mm
Remove last fan

(0,0) (0,38, 1,9) (1,1, 1,88) (0,38, 1,15) (1,1, 1,15) (0,38, 0,4) (1,1, 0,4)

State with 3 active fans

Radiators / Fans

Input

Global Parameters

- Core
- Winding
- Tank
- Cooling
 - Near Tank
 - Cooling Unit Block 1
 - Operational Cooling Units
 - Radiators
 - Type of Radiator
 - Stamped plate
 - Tubular

Type of radiator: **Stamped plate**

Iron Thickness, Width, SOil, Circum, NGG = 7

Plate Distance

Type of radiator: MENK_1

Length of duct in radiator: A = 58 mm

Width of duct in radiator: B = 7,2 mm

Cross-section of oil in on duct: SOil = 417,6 mm²

Duct circumference: Duct Circum = 130,4 mm

Number of ducts in radiator: NGG = 7

Circumference of surface on air side: Circum = 1070 mm

Iron thickness: 1 mm

Width of radiator: Width = 520 mm

Distance between plates: Plate Distance = 45 mm

Height of plates: H = 2600 mm

Height of plates closer to tank in radiator with goose neck: 2100 mm

Number of plates per radiator: N = 33

Input

Global Parameters

- Core
- Winding
- Tank
- Cooling
 - Near Tank
 - Cooling Unit Block 1
 - Operational Cooling Units
 - Radiators
 - Horizontally Blowing Fans
 - Position Left
 - Cooling Unit Block 2
 - Cooling Unit Block 3
 - Cooling Unit Block 4

Fans in battery

Producer of the fan: ZIEHL_ABEGG

Frequency: 50

Diameter: 630 mm

Type of the fan: FE063-VD_6N.V7-400Y

Protection network on inlet of the fan exists: No

Protection network on outlet of the fan exists: No

Type of draft: FORCED

Position left

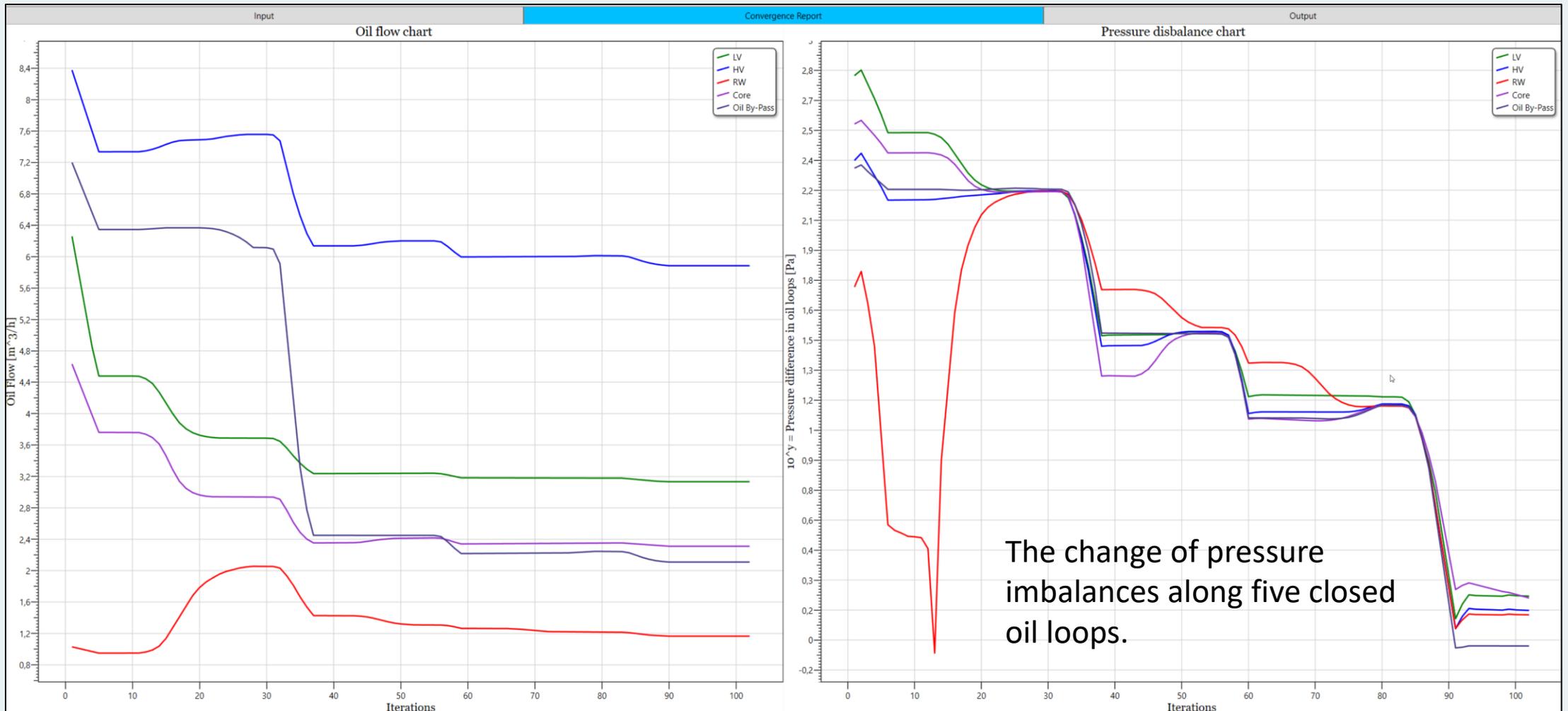
Position right

Remove position left

For the selected fan, retrieves characteristics (e.g., pressure–airflow curves). Determines air velocity based on pressure produced by fans vs. frictional pressure drop on the radiators.

Numerical iterative process

Oil flow through five branches inside the tank is changing to balance the pressure in each of the inner branches with the pressure in the outer cooling branch. The flow through the outer cooling is equal to the sum of the flows inside the tank.



Main results – Guarantee values

OIL (COOLING SYSTEM)	Calculated	Limit
Top oil rise [K]	48.4	65
Average oil rise [K]	32.33	/
Bottom oil rise [K]	16.26	/
Gradient Top - Bottom [K]	32.15	/

WINDINGS	LV	HV	RW	Limit
Common Part				
Average winding rise [K]	43.58	43.05	34.32	80
Hot spot rise [K]	65.41	69.58	47.35	80

Calculated values for the core surface and the hot spot in the core

CORE	Calculated	Limit
Surface temperature rise [K]	70	90
Hot spot temperature rise [K]	84.52	90
Frictional pressure drop [Pa]	37	/
Bottom oil temperature rise over ambient [K]	16.94	/
Top oil temperature rise over ambient [K]	60.8	/
Oil flow [m3/h]	2.3115	/

Main results – Intermediate values

The hot spot factor is determined from calculated hot spot temperature (ϑ_{hs}), top oil temperature (ϑ_{to}), average winding temperature (ϑ_{av}), and average oil temperature (ϑ_{ao}).

$$H = \frac{\vartheta_{hs} - \vartheta_{to}}{\vartheta_{av} - \vartheta_{ao}}$$

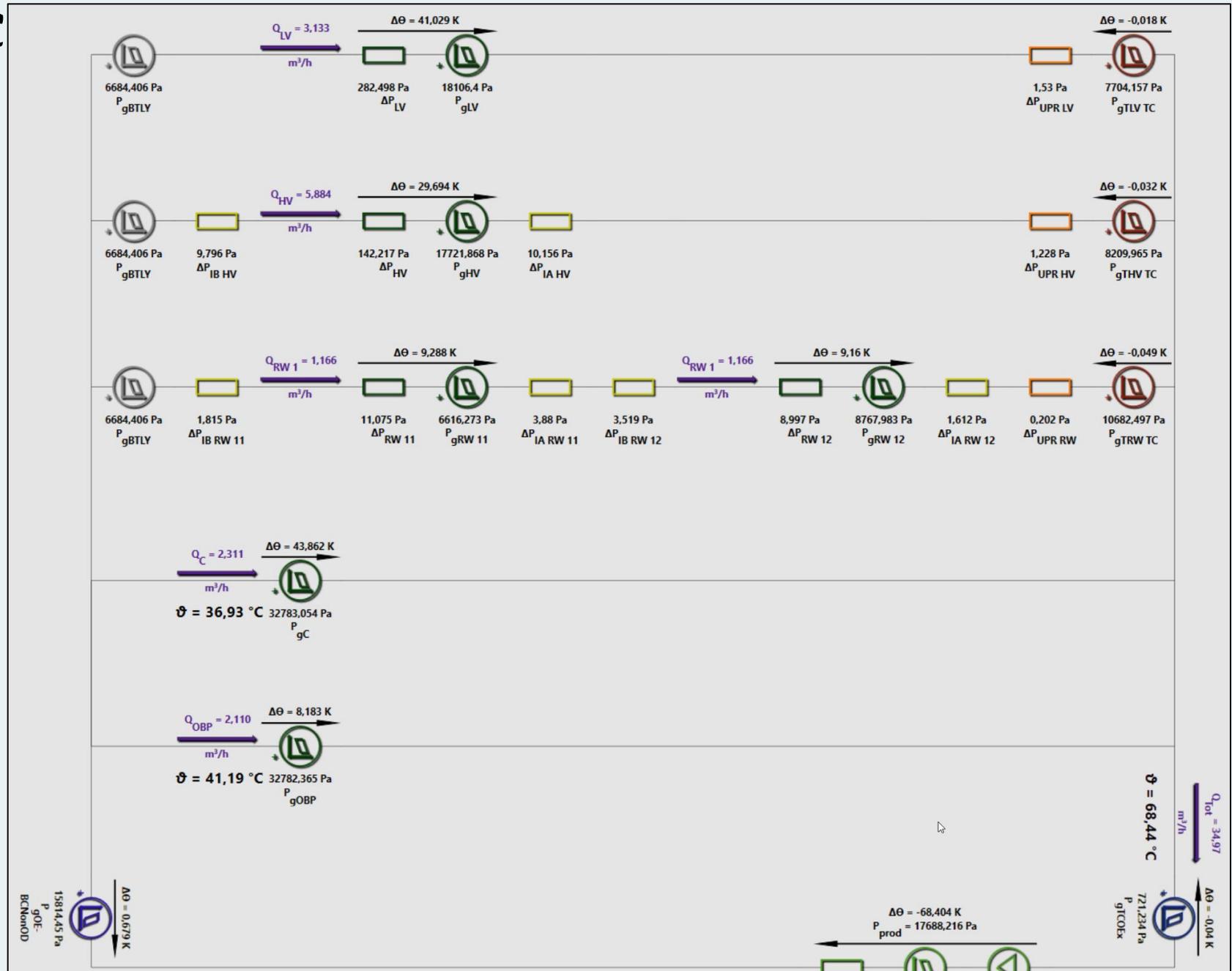
Two options for top oil:

- Oil entering the cooler
- Oil at the top of the winding

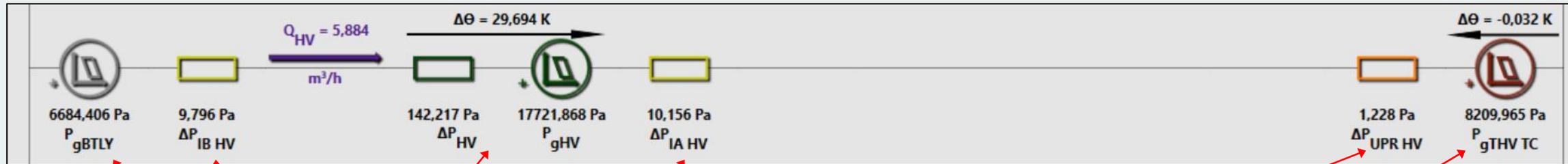
WINDINGS	LV	HV	RW	Limit
Common Part				
Average winding rise [K]	43.58	43.05	34.32	80
Hot spot rise [K]	65.41	69.58	47.35	80
Bottom oil temperature rise over ambient [K]	16.94	16.94	16.94	/
Average oil temperature rise over ambient [K]	37.45	31.78	26.16	/
Top oil temperature rise over ambient [K]	57.96	46.62	35.38	/
Oil flow per phase [m3/h]	3.1329	5.8841	1.166	/
Frictional pressure drop in winding [Pa]	282	142	20	/
Test-bay results (based on cooler oil temperatures)				
Test-bay gradient [K]	11.25	10.72	1.99	/
Test-bay hot-spot factor	1.51	1.98	-0.53	/
Calculated results (based on winding oil temperatures)				
Calculated gradient [K]	6.13	11.27	8.16	/
Calculated hot-spot factor	1.22	2.04	1.47	/
Other Parameters				
Oil flow / heat loss parameter	2.4326	3.4138	5.5025	/
Average oil - Average cooling system oil [K]	5.12	-0.55	-6.17	/
Average radial oil velocity [cm/s]	1.6	0.7	0.3	10 - 50
Min radial oil velocity [cm/s]	1.1	0.2	0.1	1
Max radial oil velocity [cm/s]	4.4	1.3	0.7	50
Max axial oil velocity [cm/s]	5.6	6.4	1.2	75
Pressure drop top end insulation [Pa]	0	10.2	5.5	/
Pressure drop bottom end insulation [Pa]	0	9.8	5.3	/

Hydraulic Scheme

Oil flows and characteristic oil temperatures for all five inner branches and the outer cooling branch.



The pressure drops on the elements of the branches



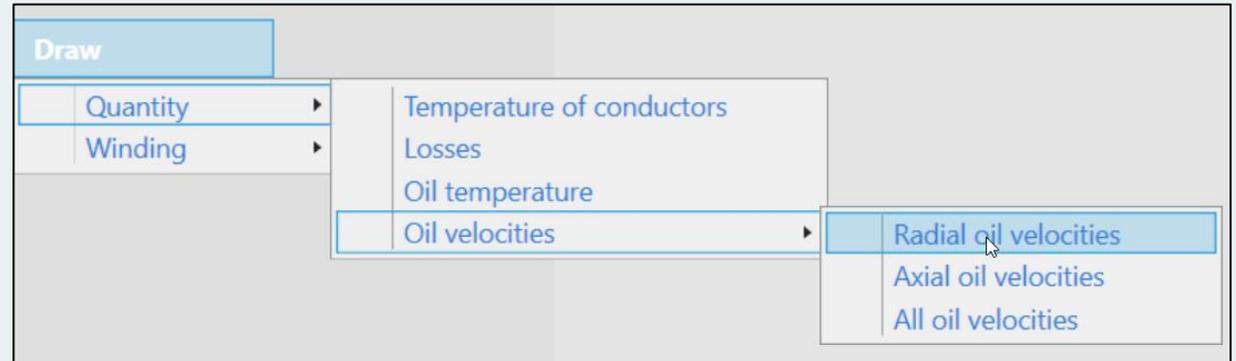
An example for the high voltage winding, consisting of:

- Between the bottom tank and the top of the yoke (gravitation)
- Insulation below the winding
- Winding itself
- Insulation above the winding
- Path of oil under the pressing ring
- Between the winding top and the top of the core (gravitation)

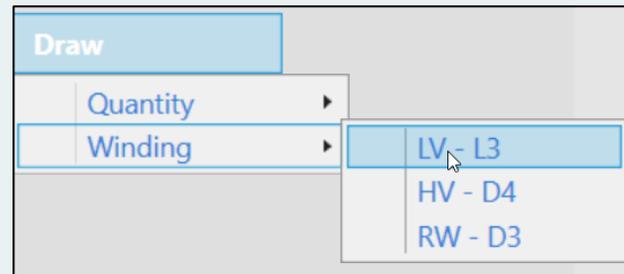
Winding calculation results

Drawing options:

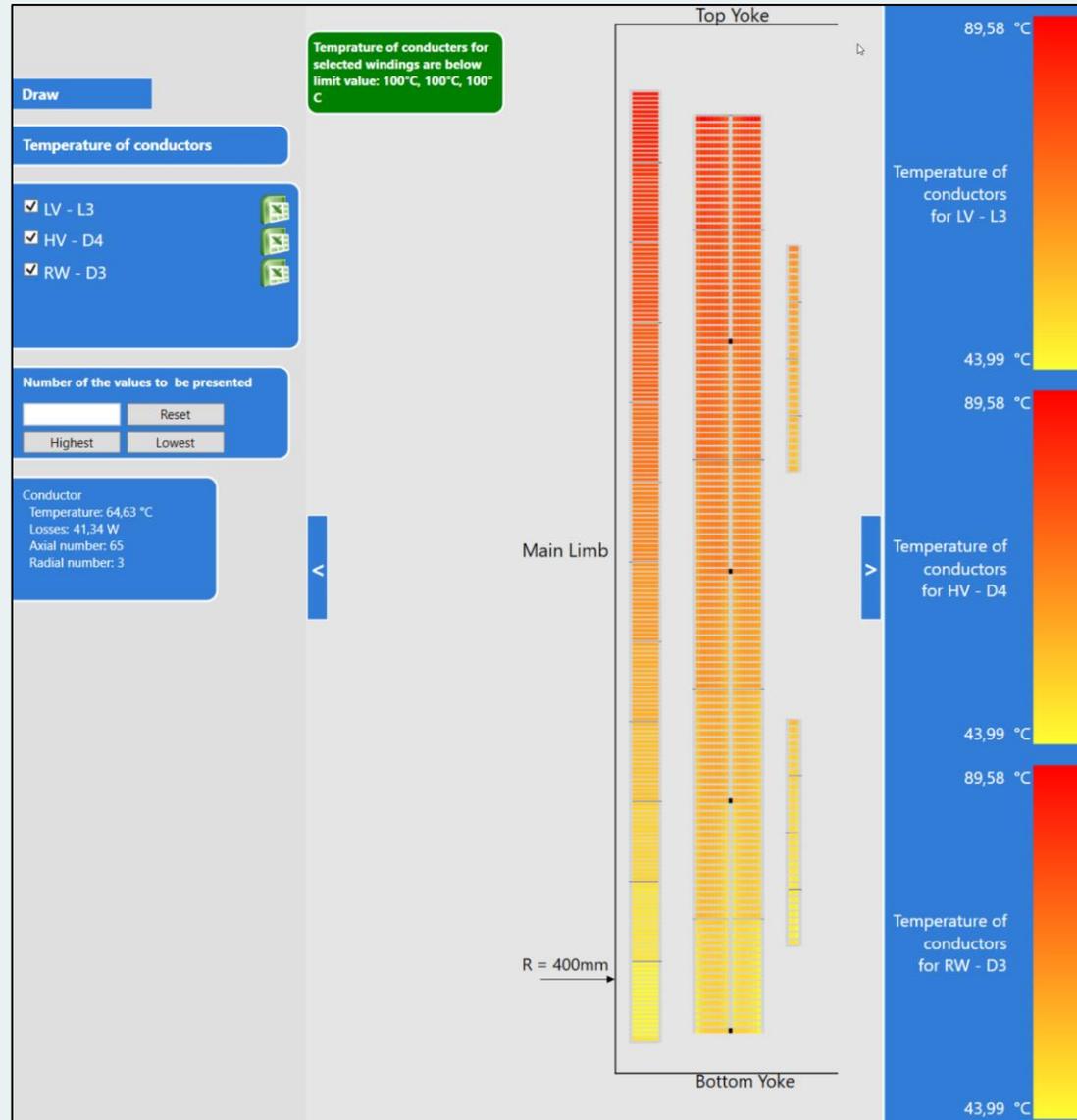
- One quantity (temperature of conductors, losses, oil temperatures, and oil velocities) for all the windings



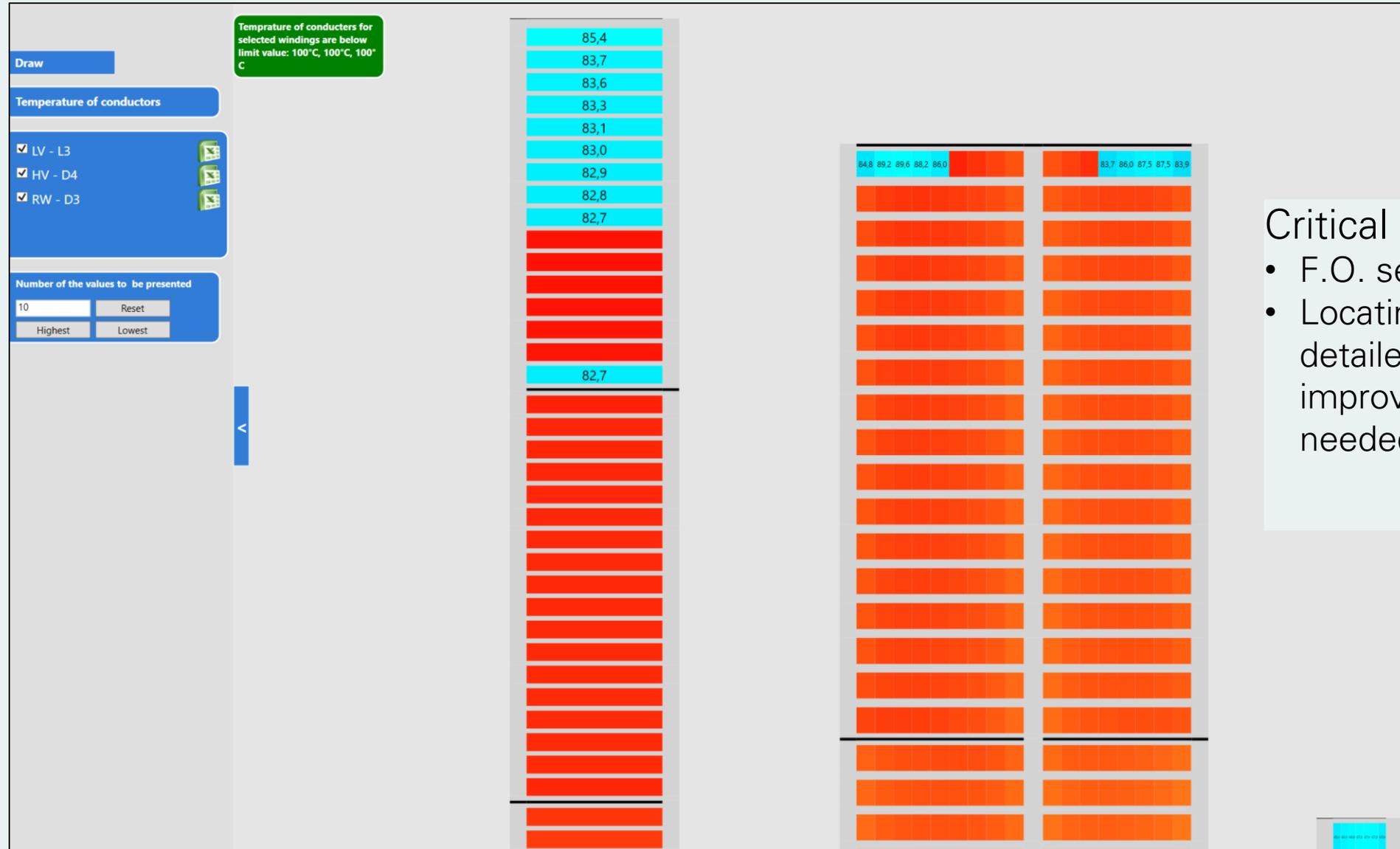
- One of the windings and observe selected quantities for it



Temperatures for conductors for all windings



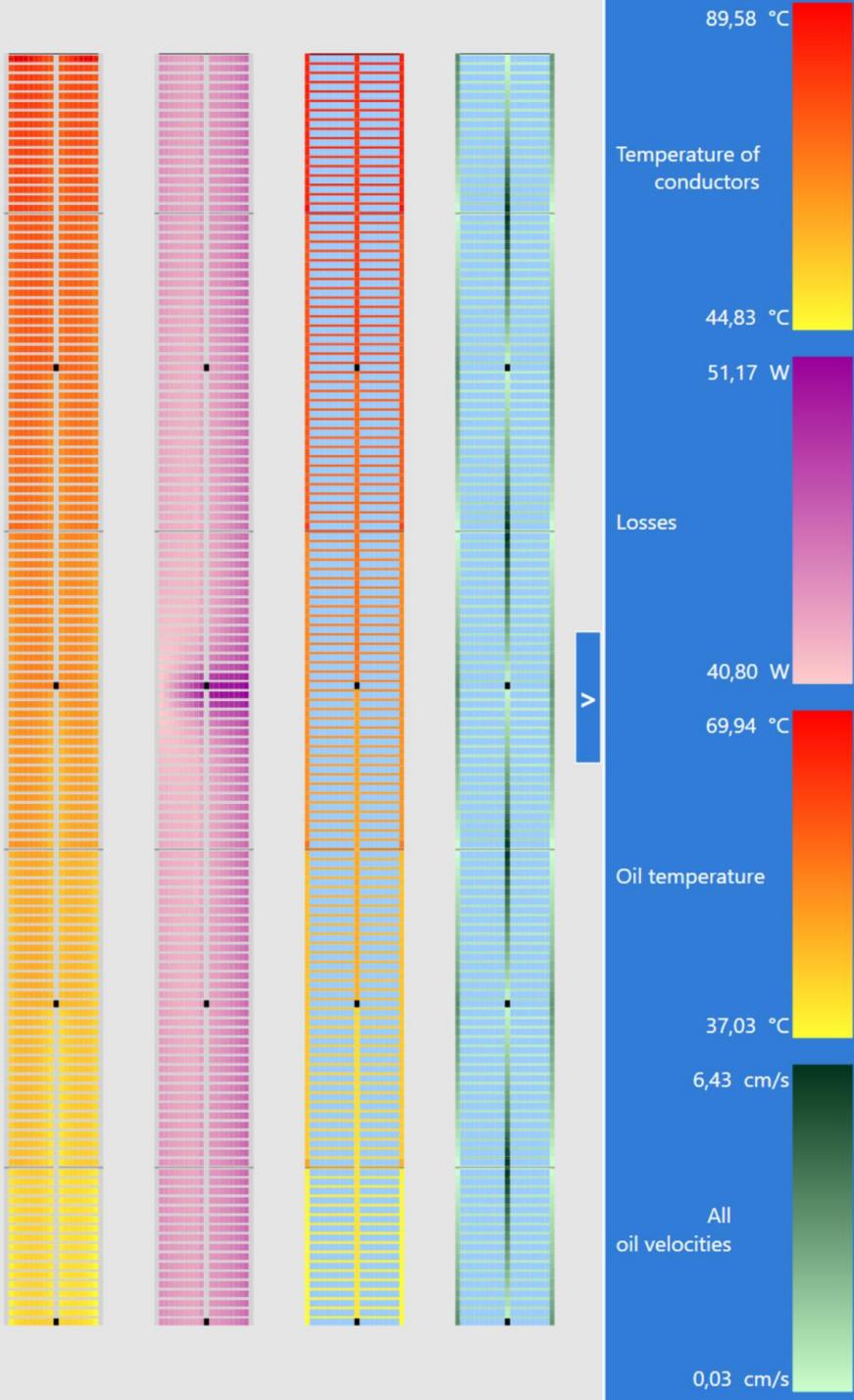
The hottest conductors



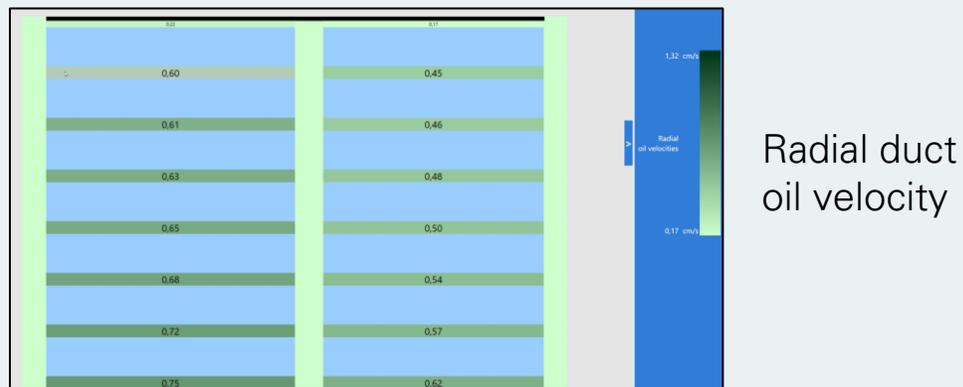
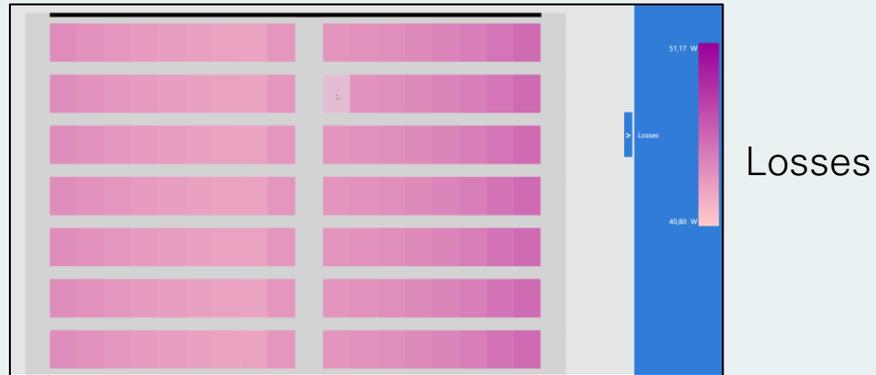
Critical insights:

- F.O. sensor positioning
- Locating zones for detailed analyses to improve design if needed

Drawing all quantities for the HV winding



Exploring the zone with the highest temperature in HV winding

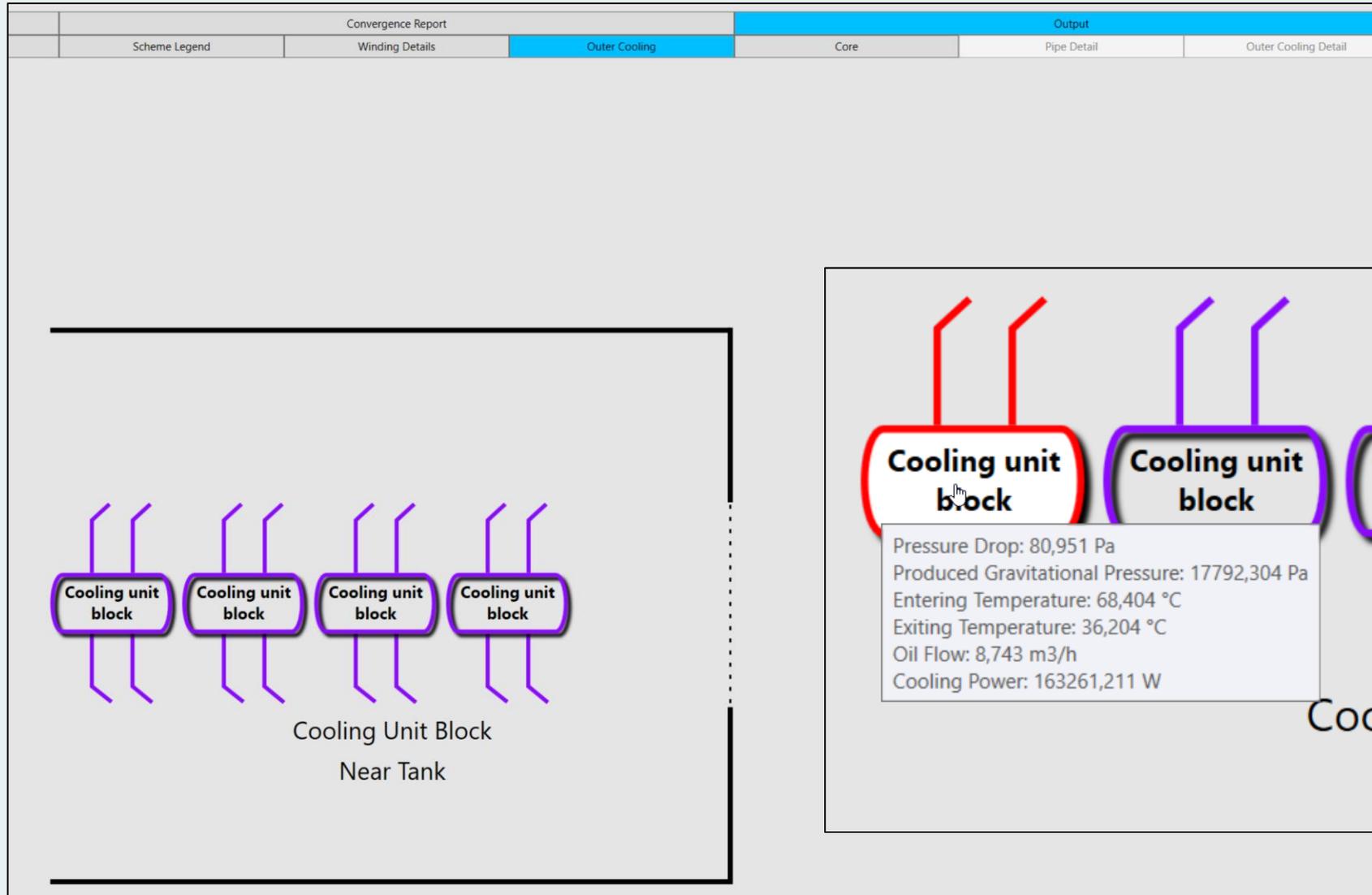


In this sample case, the highest temperatures appear in the inner part of the top coil.

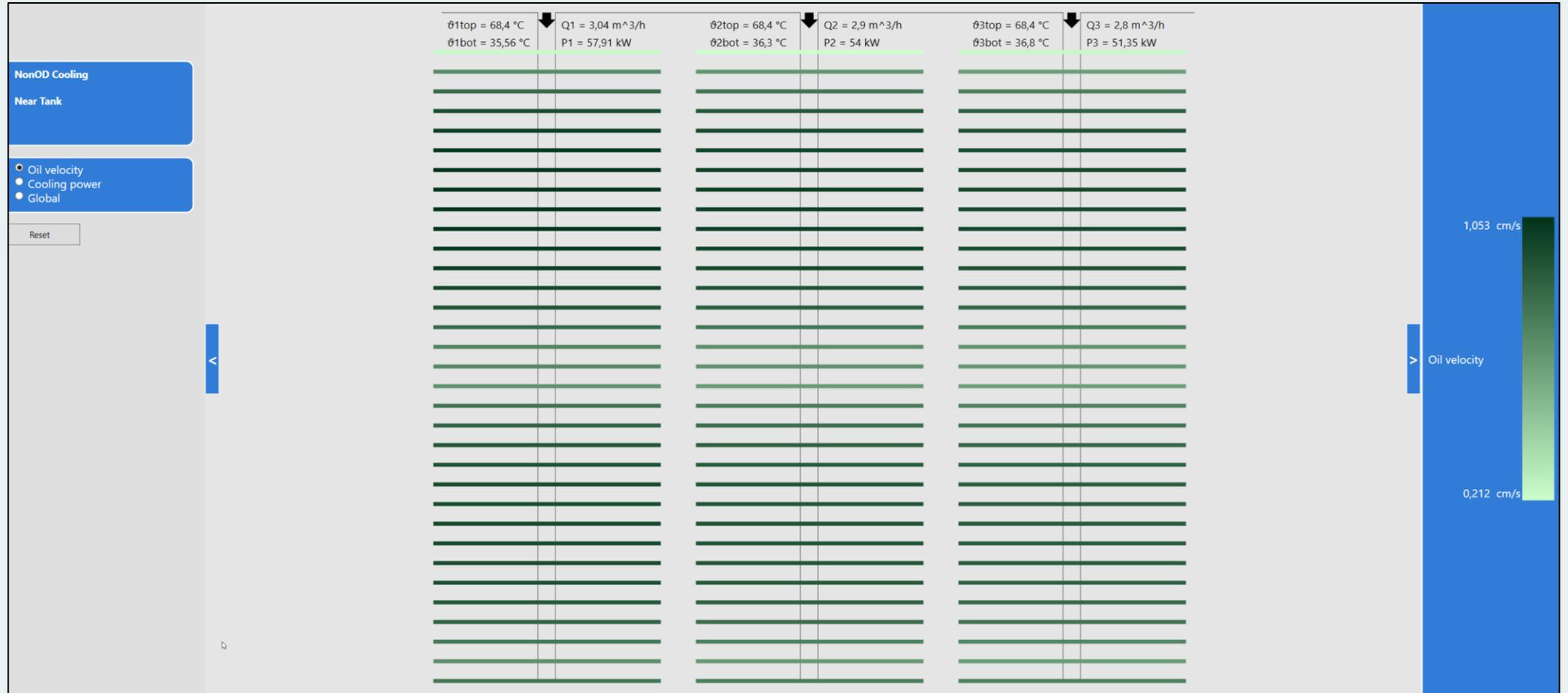
The following factors influence the temperature distribution:

- The duct above the coil is smaller than other ducts, influencing the flow through this duct to be small. The velocity in this radial duct is 0.22 cm/s, while in the others you can see the values 0.61, 0.62 cm/s and so on.
- This low oil flow caused a lower heat transfer coefficient, and consequently, higher temperatures in this coil.
- The oil flows from the inlet to the radial duct to the outlet, increasing its temperature.
- The conductor near the inner axial duct is cooled on the axial surface near the axial duct.

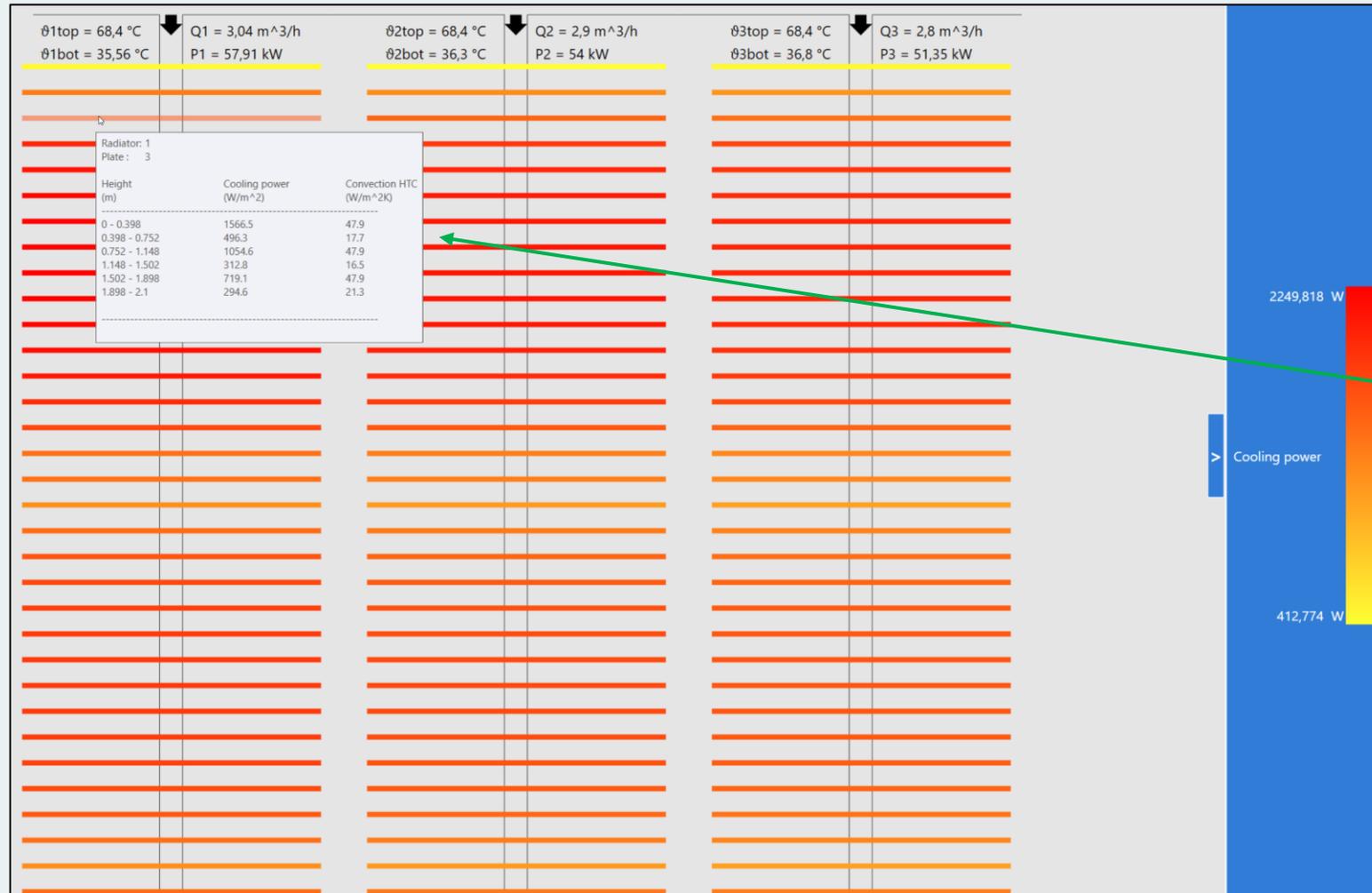
Outer cooling results



Cooling unit block 1 – Oil velocity distribution

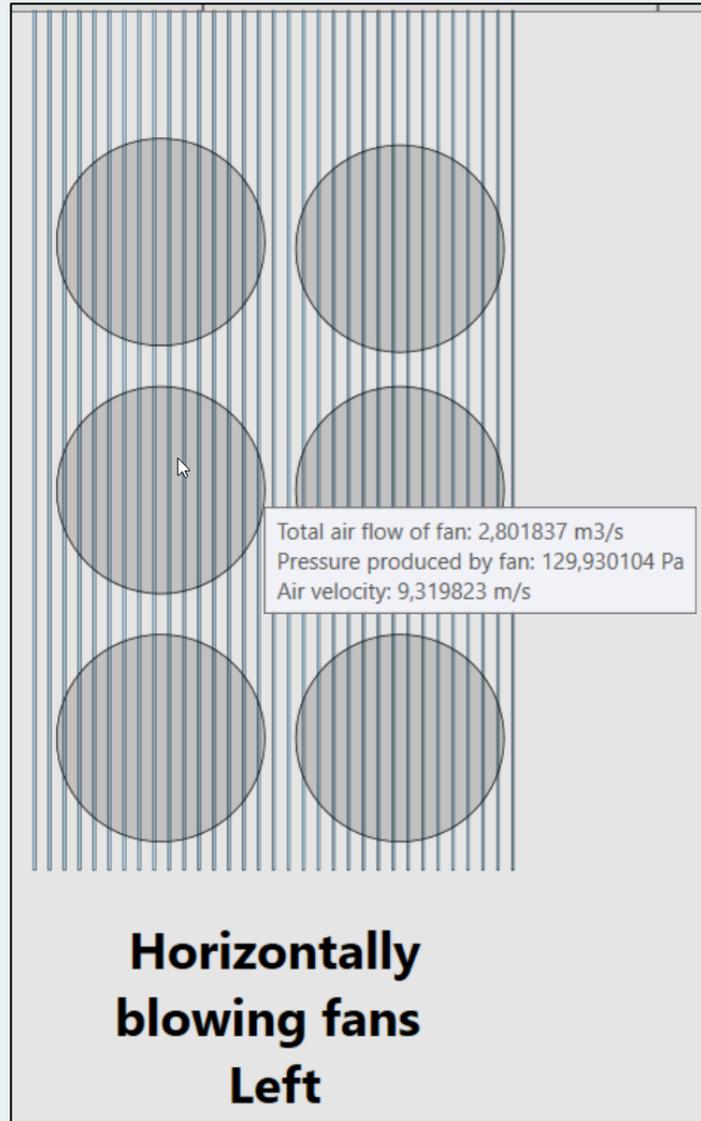


Cooling unit block 1 – Cooling power distribution



Details of the cooling power in AF and AN zones in each of the plates can be observed.

Values calculated for the fan



End of the text related to Static HoST

Transition from Static to Dynamic HoST

- Intensive work on dynamic THNM began in 2022, requiring major changes in the thermal model.
- Incorporates distributed heat accumulation modeling via a 1D convective-diffusive partial differential equation:

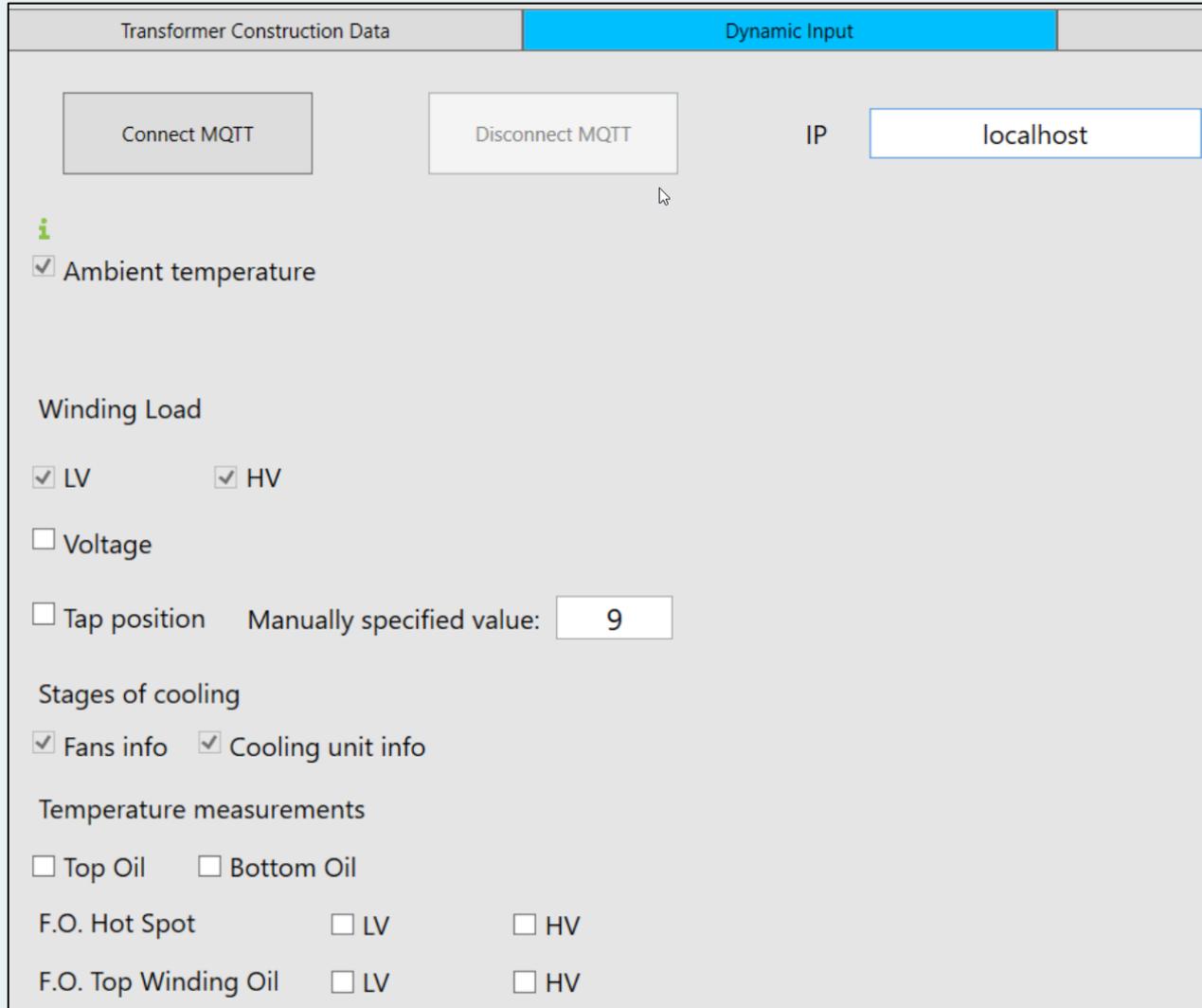
$$c_p \frac{\partial(t, X)}{\partial t} + \rho c_p u(t, X) \cdot \nabla(t, X) + \nabla(-k \nabla(t, X)) = q_v$$

- Hydraulic calculations in dynamic THNM remain similar as those in the static THNM. A component for dynamic pressure drop due to changes in oil flow velocity over time is added.
- We published the basics of the model, for example in [6] and [7]

Input data for dynamic THNM

- The same set of data as for Static HoST
(detailed transformer construction data and material properties)
- The main Dynamic HoST application mode is to calculate the temperatures in the transformer's on-line grid operating mode
- The data from the operation are needed (Dynamic HoST contains a module for collecting data via internet communication using the MQTT protocol)
- The program collects data from PT for a period of 1 minute, and temperatures and flows are calculated for 1 minute into the future

Data from transformer grid operation



Transformer Construction Data Dynamic Input

Connect MQTT Disconnect MQTT IP: localhost

Ambient temperature

Winding Load

LV HV

Voltage

Tap position Manually specified value: 9

Stages of cooling

Fans info Cooling unit info

Temperature measurements

Top Oil Bottom Oil

F.O. Hot Spot LV HV

F.O. Top Winding Oil LV HV

Necessary data:

- ambient temperature
- load for each winding
- tap position
- fan information
- cooling unit information

The remaining data is optional.

The data set is transmitted via MQTT messages.

The software receives and processes MQTT messages, performs range validation of the values, and resolves situations when information about a specific operational variable is interrupted.

Generating charts of values change over time

Configuring charts

The 'Add Chart' dialog box contains the following settings:

- Chart position on the grid:
 - Column: 1 (range 1 through 2)
 - Row: 1 (range 1 through 2)
- Chart title: Output
- Time axis grid line step: 5 min
- Visible minutes: 60
- Max. number of points on chart: 600
- Primary vertical axis:
 - Title: Temperatures
 - More vertical axes

Selecting the data presented on the charts

The 'Input data' panel shows a list of data sources with checkboxes:

- All
- Ambient temperature
- LV load
- HV load
- Tap position
- Fans in operation
- Cooling units in operation
- Top oil temperature
- Bottom oil temperature
- LV winding hot-spot temperature
- HV winding hot-spot temperature

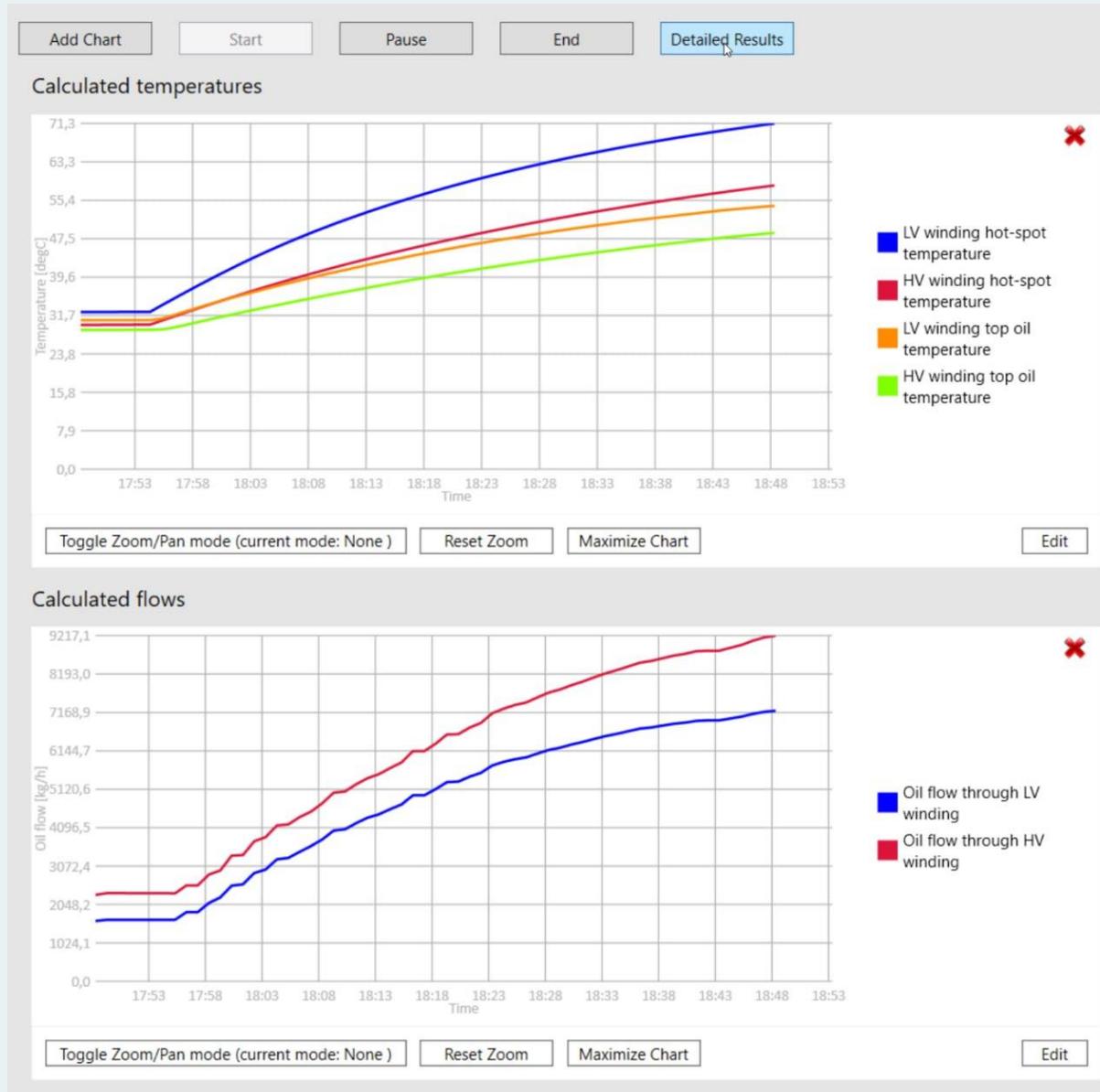
The 'Output data temperatures' panel shows a list of temperature data points with checkboxes:

- All
- Top oil temperature
- Bottom oil temperature
- LV winding hot-spot temperature
- HV winding hot-spot temperature
- LV winding top oil temperature
- HV winding top oil temperature
- LV winding average temperature
- HV winding average temperature

The 'Output data other' panel shows a list of other data points with checkboxes:

- All
- Oil flow through LV winding
- Oil flow through HV winding
- Oil flow through core
- Oil by-pass flow
- Oil flow through cooling system

Live charts



All values available in Static HoST output GUI can be seen in Dynamic HoST at a frozen moment, by clicking on the Detailed Results button.

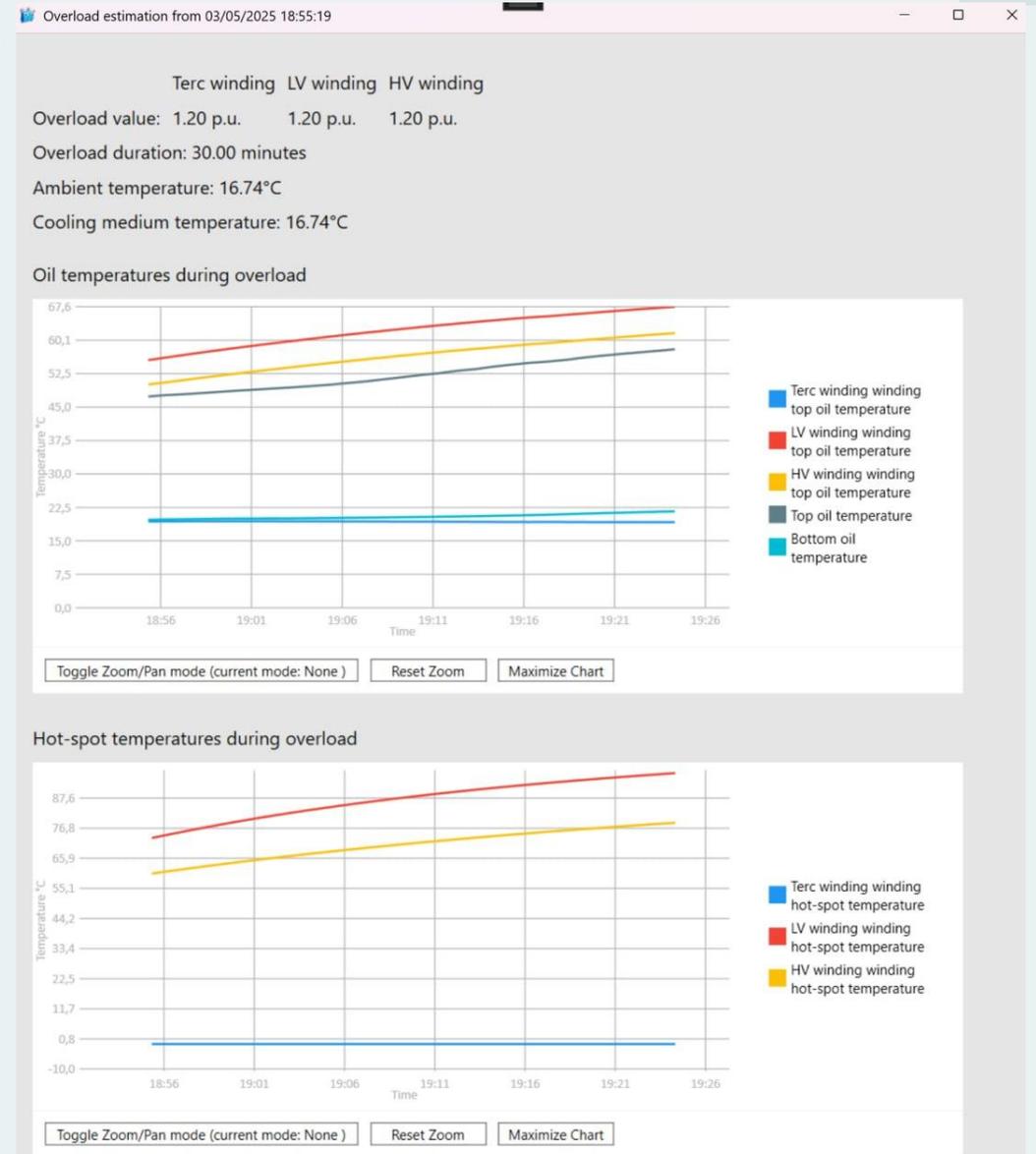
Assessment of the overload possibility

This can be done at any moment during grid operation.

Specifying overload

OVERLOAD DATA
Overload duration min
Load values for each winding (p.u.)
LV
HV

After clicking on the Start overload button, a separate parallel thread is created, and calculation for the specified overload is performed.



Since terc winding is not loaded, its hot-spot is not calculated.

Key Features & Capabilities of Dynamic HoST

- **Cold Start Simulation:**
 - Accurately predicts the highest insulation temperature during cold start.
- **Real-Time Adaptability:**
 - Considers changes in load, ambient temperature, fan operation, cooling unit status, and tap position.
- **Advanced Applications:**
 - Can be used for training Reduced Order Models (ROM), machine learning (ML), or neural network models (NN), or for parametrization of simple models.

History & Evolution of HoST Calculus

- We published the paper about the basics of static THNM in 2010 in IEEE Trans. on Power Delivery (Reference [2]) and kept working on further development.
- Applications of the model are presented in [3], [4] and [5].
- Meantime static THNM and its software implementation reached a high level of technological readiness.
- Static HoST is now used in design departments in several factories.
- We continuously provide thermal calculations and consulting services for checking and improving the design.
- We began intensively working on dynamic THNM in 2022.
- The results of first validation of dynamic THNM are published in [7].

Conclusion and Key Benefits

- **Accurate Thermal Modeling:**
 - Achieve precise predictions to ensure transformer reliability and safety.
- **Design Optimization:**
 - Integrate comprehensive data analysis to optimize transformer design and performance.
- **Efficient Calculations:**
 - Fast processing enables quick decision-making during design and operation.
- **Real-Time Monitoring:**
 - Dynamic HoST's real-time capabilities support predictive maintenance and investment planning.

Illustrative publications since the first paper in 2008

1. Radakovic, Z., Sorgic, M. (2008): Wirtschaftliche Betrachtung der thermischen Auslegung von ölgekühlten Leistungstransformatoren, *Elektrizitätswirtschaft*, Jg 107, Heft 15, 32-38
2. Radakovic, Z., Sorgic, M. (2010): Basics of Detailed Thermal-Hydraulic Model for Thermal Design of Oil Power Transformers, *IEEE Trans. on Power Delivery*, Vol. 25, No. 2, 790-802
3. M. Sorgic, Z. Radakovic. (2010): Oil-Forced Versus Oil-Directed Cooling of Power Transformers, *IEEE Trans. on Power Delivery*, Vol. 25, No. 4, 2590-2598
4. Radakovic, Z., Sorgic, M., Van der Veken, W., Claessens, G. (2012): Ratings of Oil Power Transformer in different Cooling Modes, *IEEE Trans. on Power Delivery*, Vol. 27, No. 2, 618-625
5. Radakovic, Z., Radoman, U., Kostić, P. (2015): Decomposition of the Hot-Spot Factor, *IEEE Trans. on Power Delivery*, Vol. 30, No. 1, 403-411 (DOI: 10.1109/TPWRD.2014.2352039)
6. Novkovic, M., Radakovic, Z., Torriano, F., Picher, P. (2023), Proof of the Concept of Detailed Dynamic Thermal-Hydraulic Network Model of Liquid Immersed Power Transformers, *Energies*, 28. April, 2023, Volume 16, No. 9, 3808 (DOI: 10.3390/en16093808)
7. Novkovic, M., Torriano, F., Picher, P., Radakovic, Z. (2024): Application of Dynamic Detailed Thermal Hydraulic Model on a Transformer with zig-zag winding scale model, *IEEE Trans. on Power Delivery*, Vol. 39, No. 6, pp. 3338 - 3346. (DOI: 10.1109/TPWRD.2024.3466297)