Steady-State Thermal Analysis of CLIC module T0#2

Case: Two-beam module 50Hz vs. 100Hz

Antti J. Moilanen

Introduction

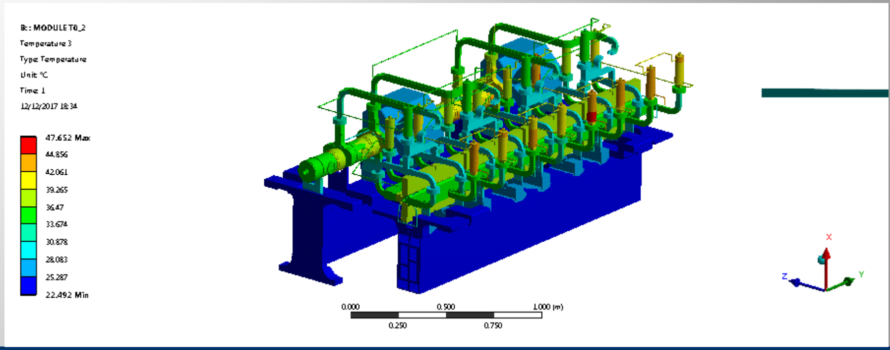
Thermal analysis of CLIC module

Aim of the Finite Element Method (FEM) simulation is to study heat distribution and dissipation in CLIC module T0#2.

Thermal gradients originate from several sources: RF structures produce heat, components are cooled by water and air flow, ambient temperature varies

The modelling is done using ANSYS 17.2 Workbench. The FEM simulation of includes:

- 3D CAD geometry
- Steady-state thermal analysis (followed by Static structural analysis)
- Isotropic materials: OFE copper, aluminium, stainless steel, SiC
- Thermal loads
- Ambient temperature
- Thermal fluid (water)
- Convection, radiation, conduction



Heat-to-air simulation

Finite element model and boundary conditions

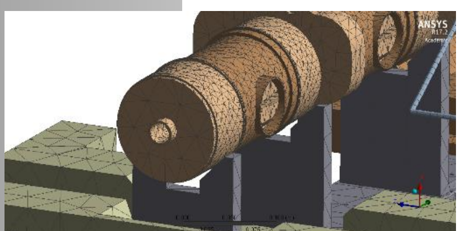
Geometry: After deleting, suppressing, and simplifying; 360 parts

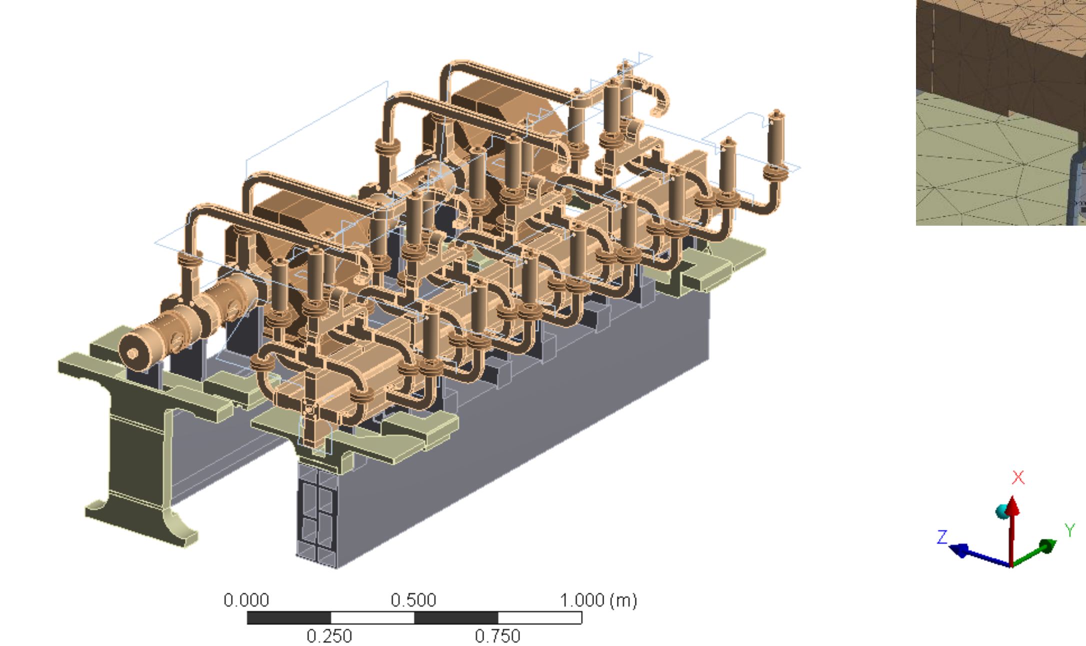
Contacts: Around 600 (bonded) contacts between parts

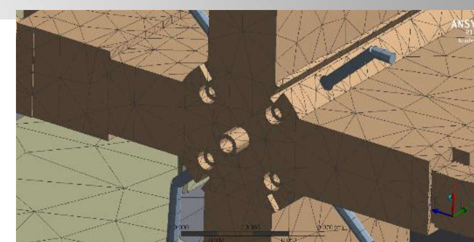
Mesh: 1.3 million nodes, 0.7 million elements

→ Computation time with ANSYS remote solver (MECH-016c-128GB):

Thermal analysis – 20 min





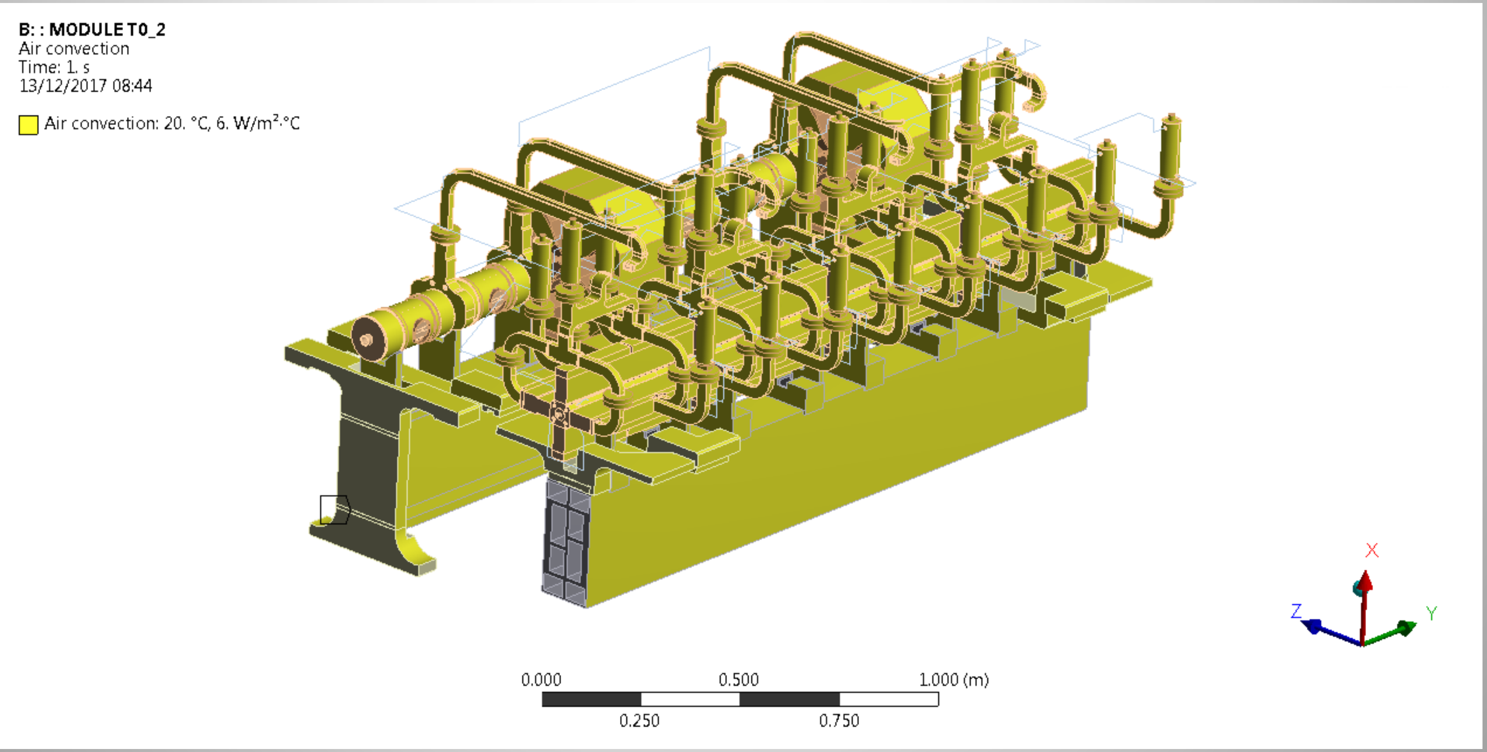


Heat-to-air simulation

Air convection

Convection to air

- Constant heat transfer coefficient 6 W/(m^2 °C), total area 11.32 m^2
- This has been estimated based on horizontal air flow of 0.4 m/s (CFD simulations, E. Lam)

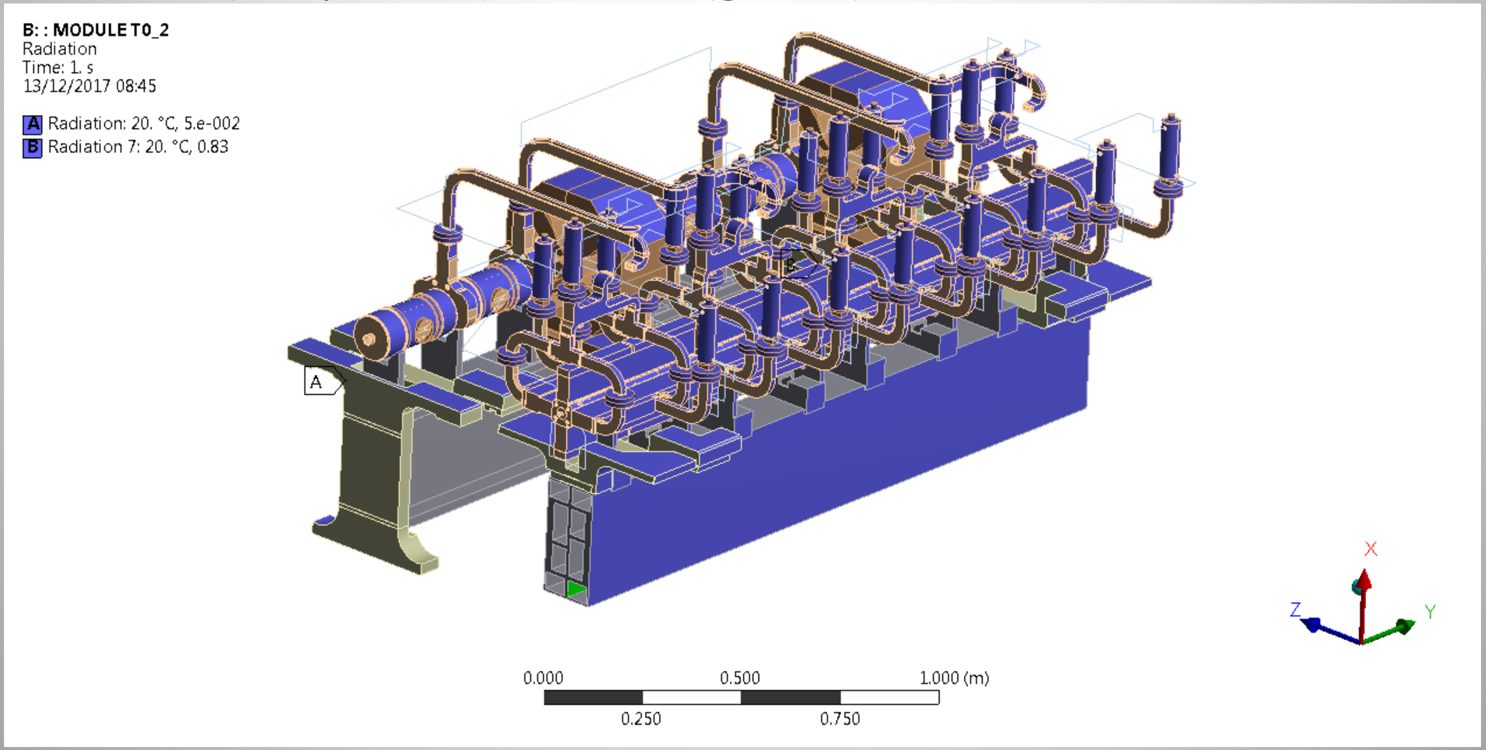


Heat-to-air simulation

Thermal radiation

Radiation to surrounding space (ambient temperature):

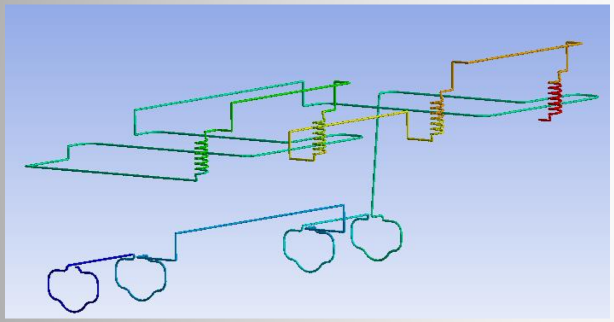
- Emissivity for copper, aluminium and stainless steel (0.05) and SiC (0.83)
- No surface-to-surface effects
- Area 4.87 m² (components) + 1.47 m² (girders) = 6.34 m²



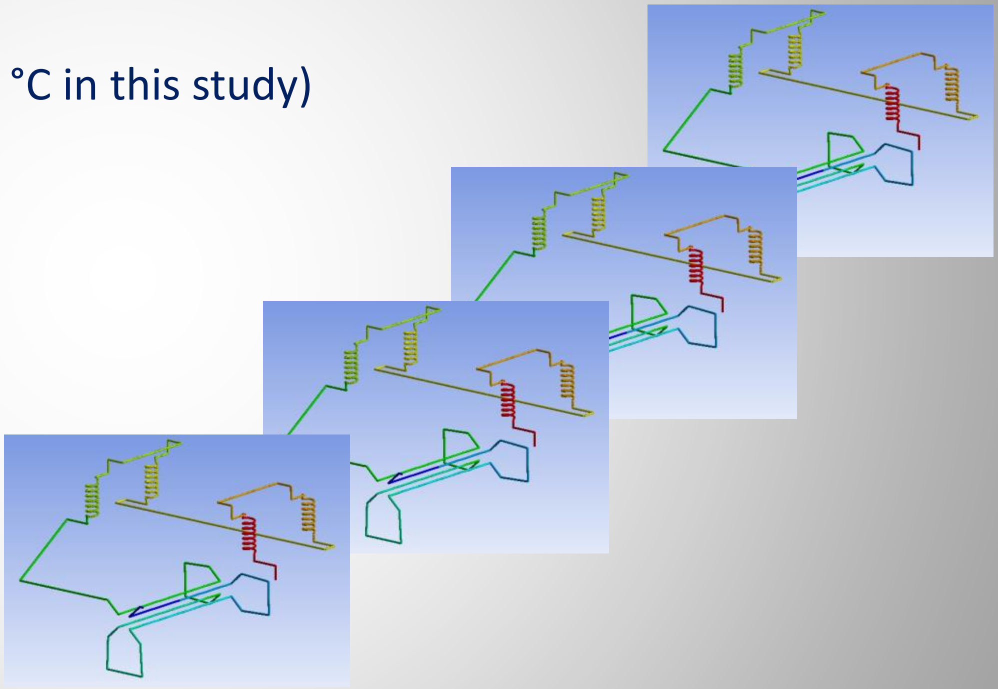
2. Heat-to-air simulation

Water cooling

5 separate cooling circuits
- Water heat transfer coefficient is calculated similarly as in Refs. [1-4]
- Flow can be varied
- Inlet temperature can be varied (27 °C in this study)



2 double PETS and 4 RF loads in series
(these RF loads are not active
in this study)

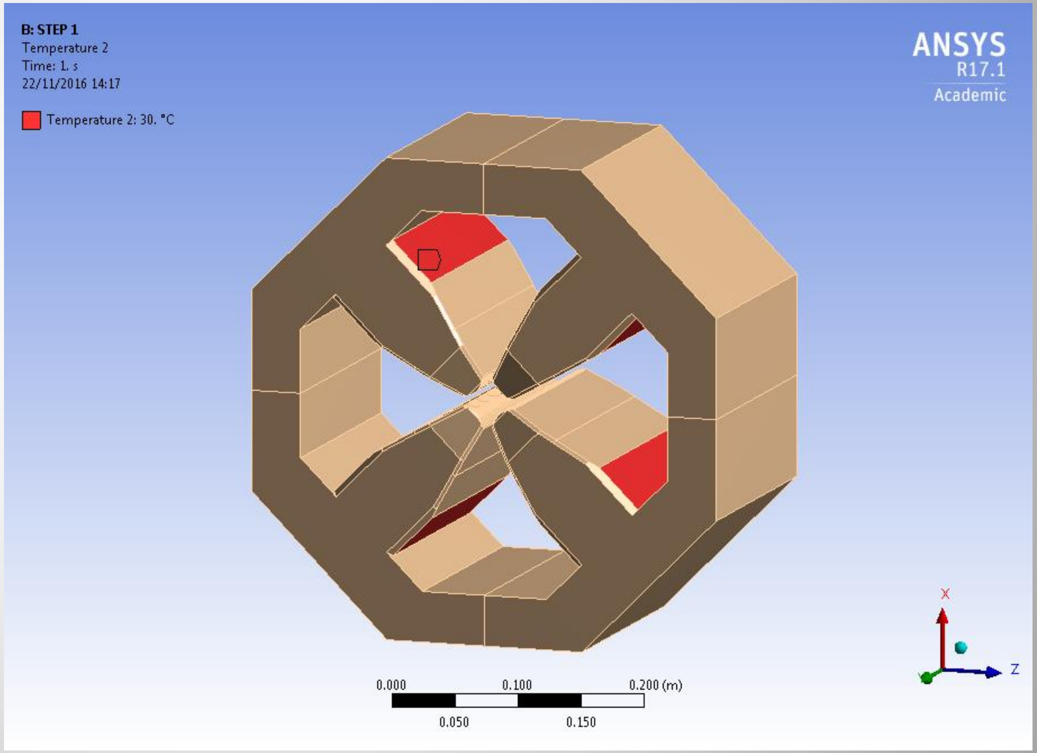


SAS and 4CLs in series

Heat-to-air simulation

Heat loads

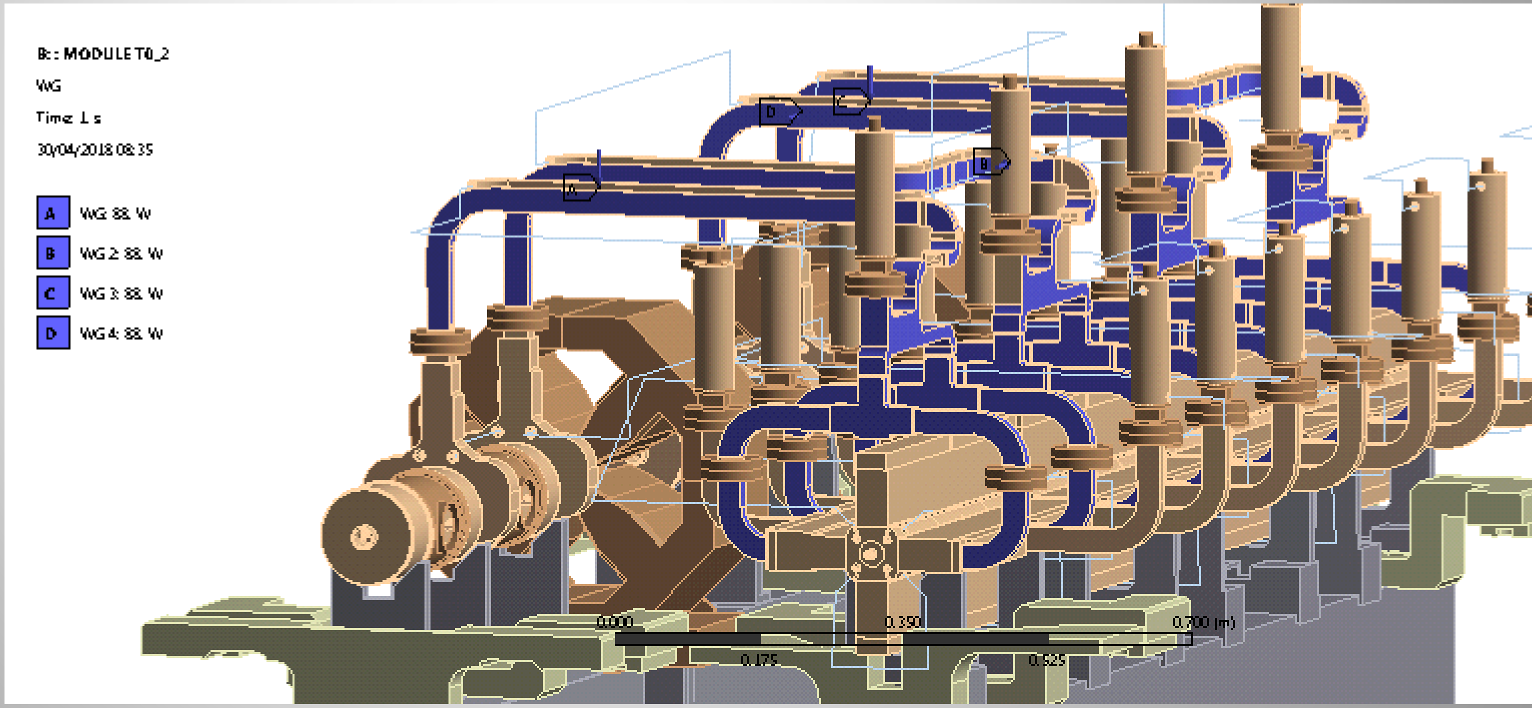
DBQ:
- Coils are excluded
- Cooling of the coils is assumed very effective:
- Convection with HTC = 5000 (around the same magnitude than water cooling in SAS and PETS) is set to the surfaces where coils should be
- Heat load 171 W



Heat-to-air simulation

Heat loads

Waveguides:
- WG network connecting DB and MB is cooled from the top
- Heat 88 W per network (@50Hz)



Heat-to-air simulation

Heat loads

Components are heated with heat elements.

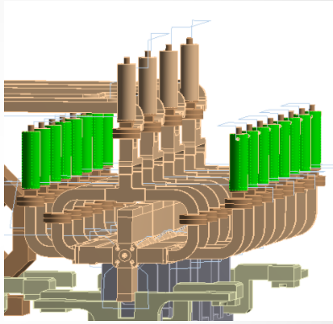
Assume: increasing 50Hz to 100Hz doubles the heat generation in RF components

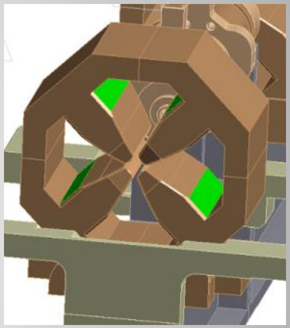
Two cases studied here:

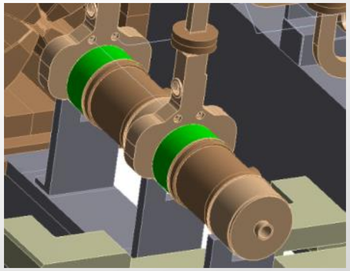
RF@50Hz, Unloaded

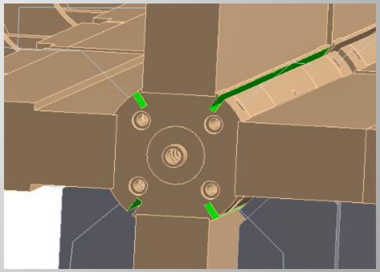
		Heating power (W)	
CL	16x	168	2688
PETS	4x	11	44
SAS	4x	780	3120
DBQ	2x	171	342
WG	4x	88	352
Total			**6546**

≈ 2.8 kW/m









RF@100Hz, Unloaded

		Heating power (W)	
CL	16x	336	5376
PETS	4x	22	88
SAS	4x	1560	6240
DBQ	2x	171	342
WG	4x	176	704
Total			**12750**

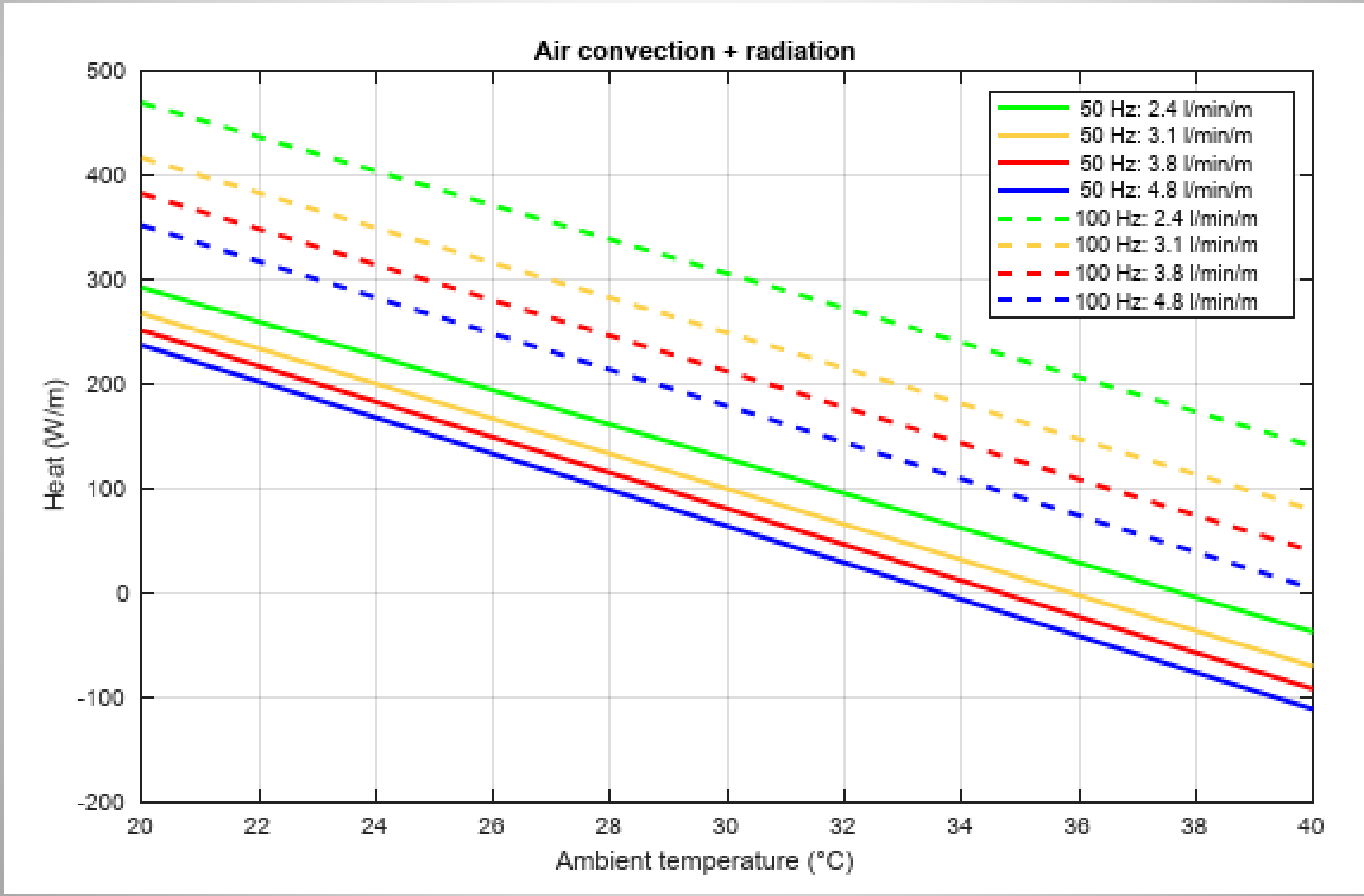
≈ 5.4 kW/m

*simulation is done with 2m long model but results divided by 2.35m

Heat-to-air simulation

Results: 50Hz vs 100Hz

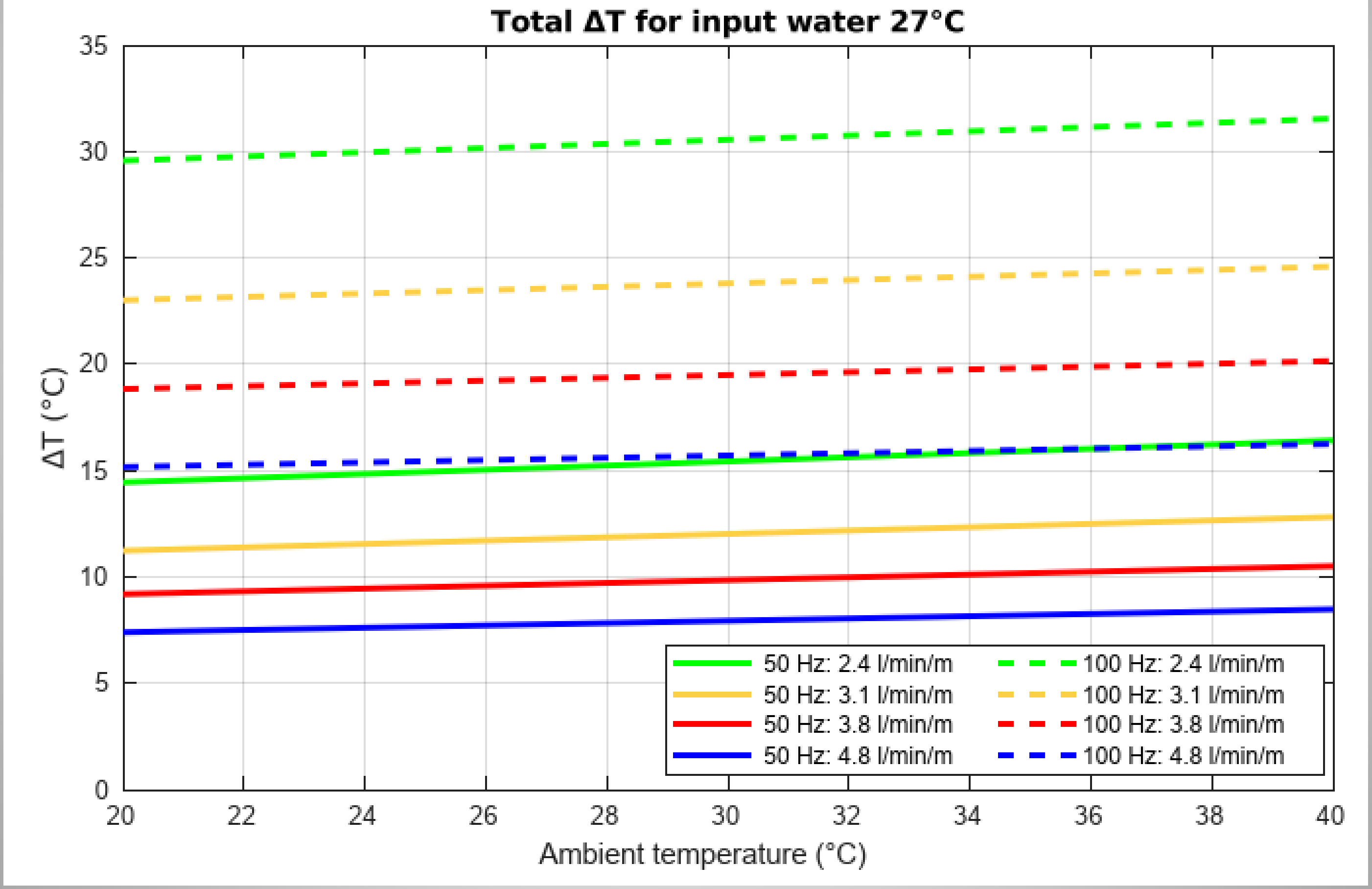
Heat to air: for different water flows



Heat-to-air simulation

Results: 50Hz vs 100Hz

Delta T: for different water flows



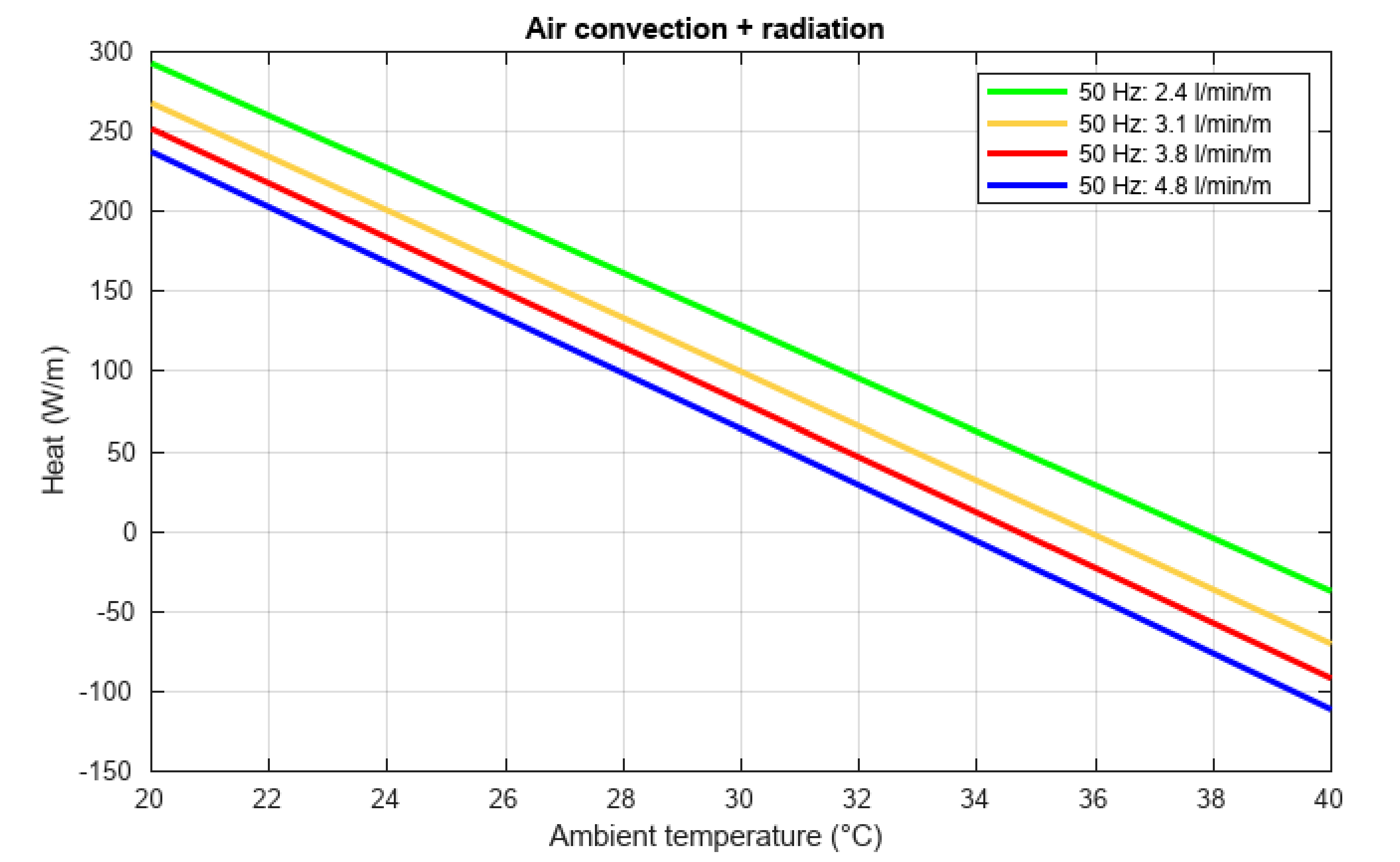
Heat-to-air simulation

Extras: plots for 50Hz and 100Hz separately

Heat-to-air simulation

Results: 50Hz

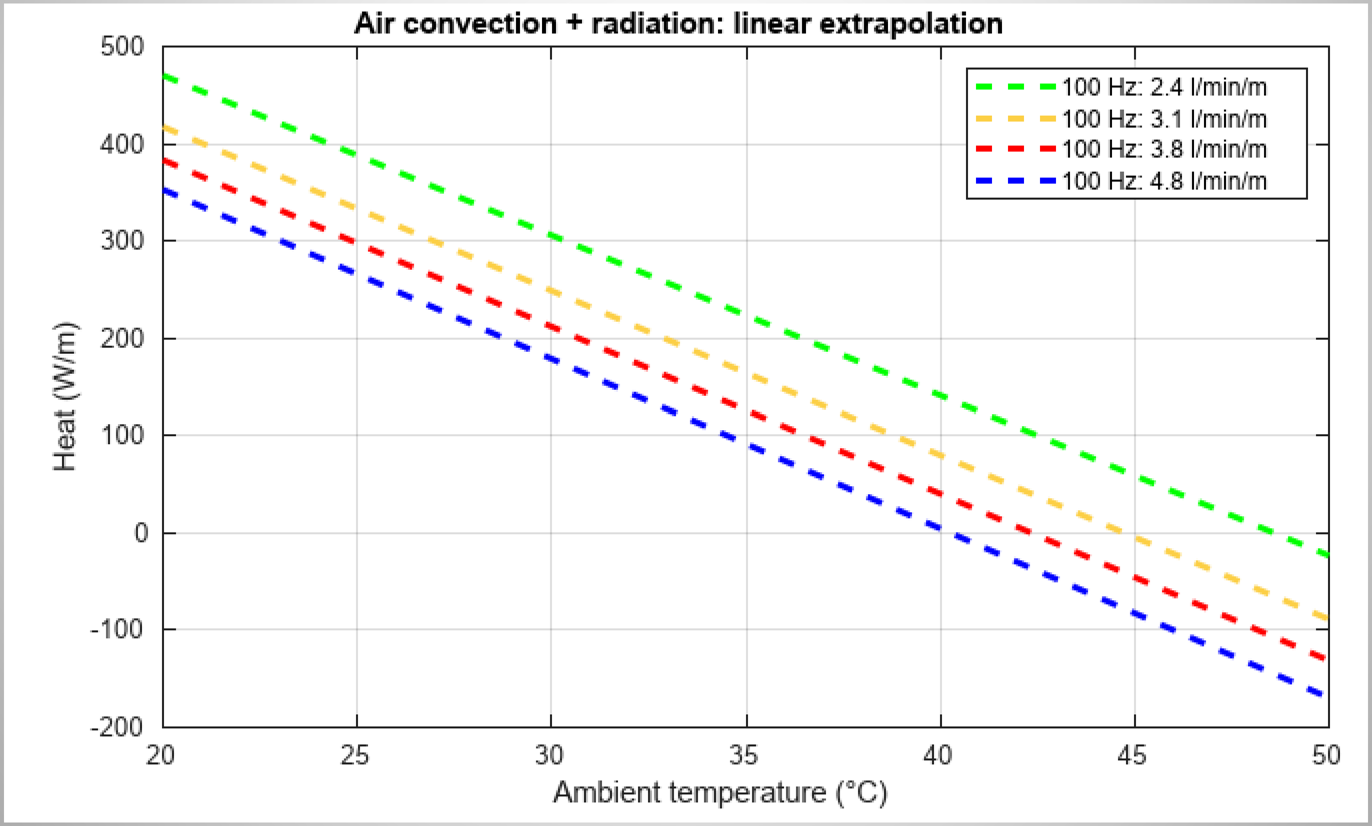
Heat to air: for different water flows



Heat-to-air simulation

Results: 100Hz (linear extrapolation 40…50°C)

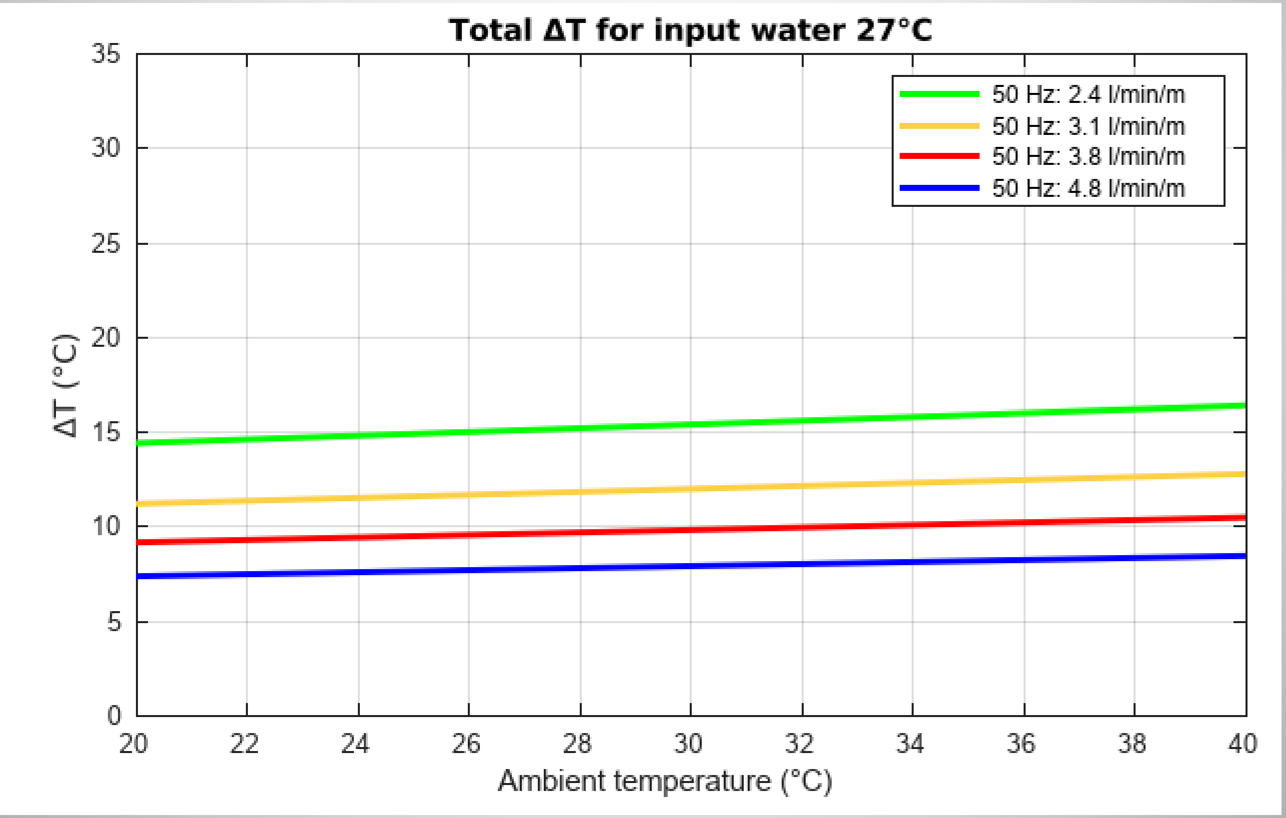
Heat to air: for different water flows



Heat-to-air simulation

Results: 50Hz

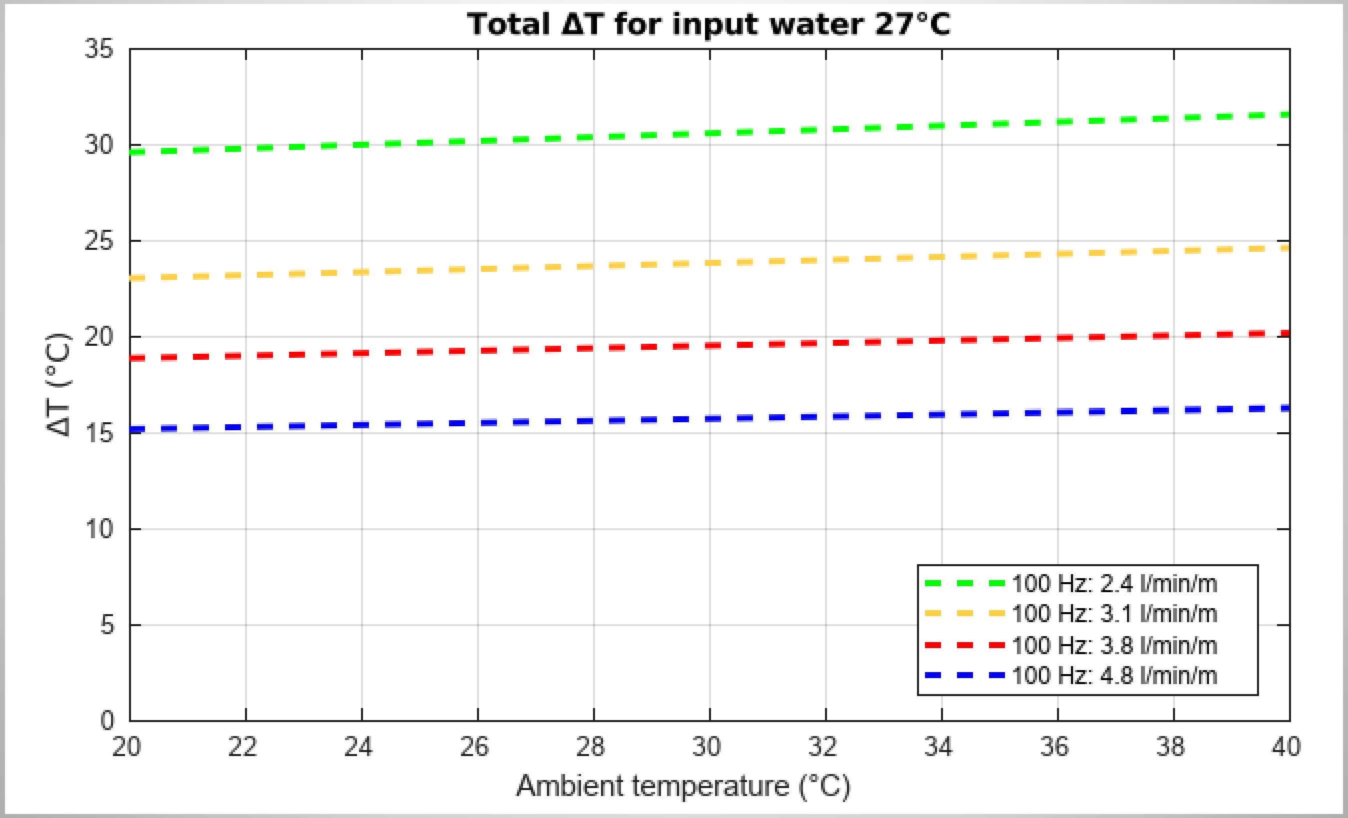
Delta T: for different water flows



Heat-to-air simulation

Results: 100Hz

Delta T: for different water flows



References:

[1] Kortelainen, L., Thermo-mechanical modelling and experimental validation of CLIC prototype module type 0, Master's thesis, Department of Mechanical Engineering, University of Oulu, Finland, 2013

[2] Nousiainen, R. *et al.*, Studies on the Thermo-Mechanical behaviour of the CLIC Two-Beam Module. Linear Accelerator Conference 2010, Tsukuba, Japan, 2010

[3] Raatikainen, R., Modelling of the thermo-mechanical behavior of the two-beam module for the compact linear collider, Master's thesis, Department of Mechanics and Design, Tampere University of Technology, Finland, 2011

[4] Moilanen, A., Aicheler, M. , Vamvakas, A., Vainola, J., Doebert, S., Finite Element Model for Thermal-Structural analysis of CLIC Lab Module type 0#2, CERN-ACC-2017-0016, CLIC-Note-1073, 2017