6SigmaET

Alcatel Lucent Benchmark of 6SigmaET

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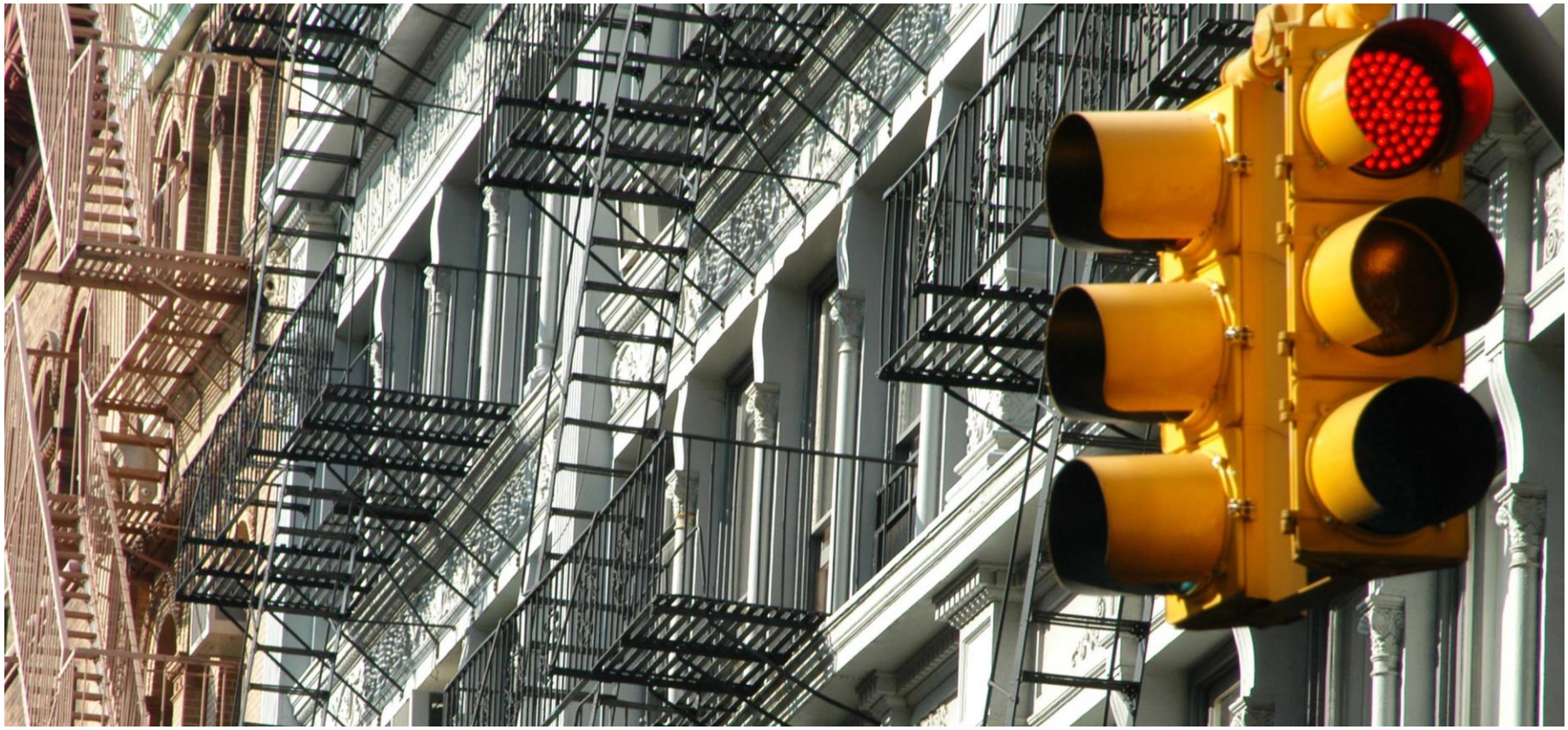
Introduction

Alcatel Lucent's wireless division in Stuttgart have been using 6SigmaET as their thermal simulation since soon after the launch of 6SigmaET in 2009. Alcatel Lucent are using 6SigmaET to simulate a variety of indoor and outdoor telecommunications equipment.

Pavel Valenta is an experienced thermal engineer who has used thermal simulation from the very early days of electronics thermal simulation.



Bench Mark
6SigmaET Thermal Simulation Software

August 19th, 2013

Alcatel·Lucent

OUTLINE

- SUMMARY AND RECOMMENDATIONS
- RELIABILITY OF RESULTS
- CONVERGENCE OF LARGE PROJECTS

Summary and Recommendations

- Four test cases were selected for the bench mark. The basis for the test cases was the thermal design of equipment built in Stuttgart during the last 3 years. ALU Stuttgart has 3 years experience with 6SigmaET on a large area of applications.
- Hardware used for the bench mark test:
  - HP Z800 with 12 cores Intel CPU (6SigmaET solver is licensed for 8 cores)
- Software used for the bench mark test:
  - 6SigmaET Rel. 7.1

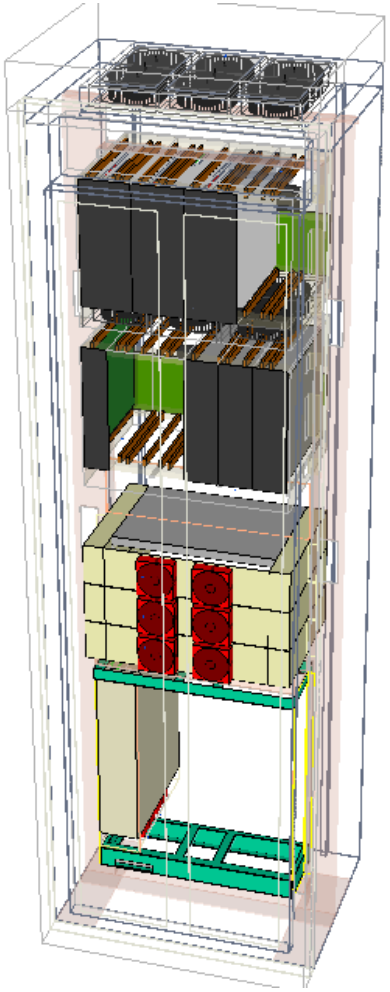
Summary and Recommendations

- Reliability of results
  - All test cases have a very good correspondence between the simulated and the measured temperatures. There are some small deviations – but all due only to modelling uncertainties, such as component heat dissipations or component thermal resistances. There is no systematical error of the 6SigmaET solver.
  - It was not possible to measure the supply currents on component level. But an analysis of the different voltages was made and the component dissipations were calculated with a good level of confidence.
- Gridding
  - Nearly no need for user interaction
- Solver
  - Fast and robust convergence, no projects with convergence problems
  - Easy handling of large models
  - Nearly no need for user to modify the solver parameters
- Pre-/ Post processing
  - Very fast and convenient
- Fully integrated in the ALU MCAD/ EDA tool chain
- Recommendation
  - 1 or 2 days training course together with
  - 1 month trial license

RELIABILITY OF RESULTS

- The comparison of simulated temperatures with the measured values was performed on three test cases:
  - Test case 1: Indoor cabinet (fan cooled)
  - Test case 2: RRH (Remote Radio Head) (natural convection)
  - Test case 3: TRDU (Transceiver and Receiver Unit) (fan cooled)
- Results
  - All test cases have a good correspondence between the simulated and the measured temperatures. The deviations are due to model simplifications and to parameter uncertainties and not to systematical solver errors.
  - All test cases show a good convergence behavior. The test cases have up to 19 millions grid cells, the solve time is between 3.7 h and 8.8 h.

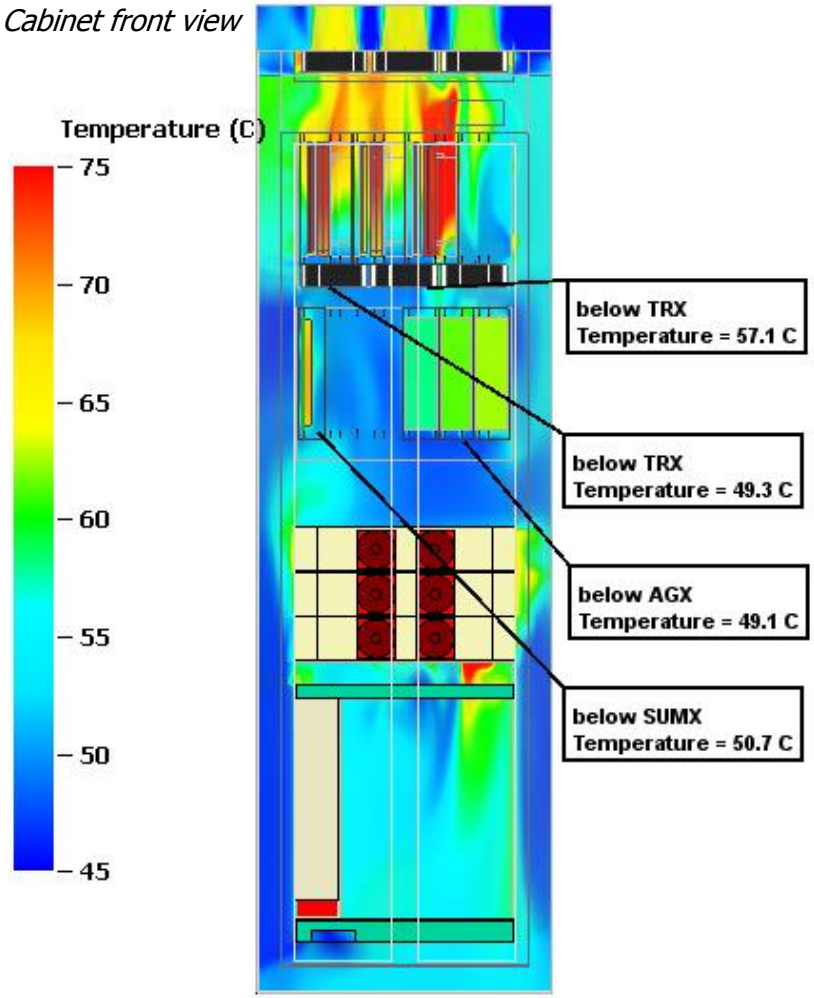
Test case 1: Indoor cabinet
Model set-up



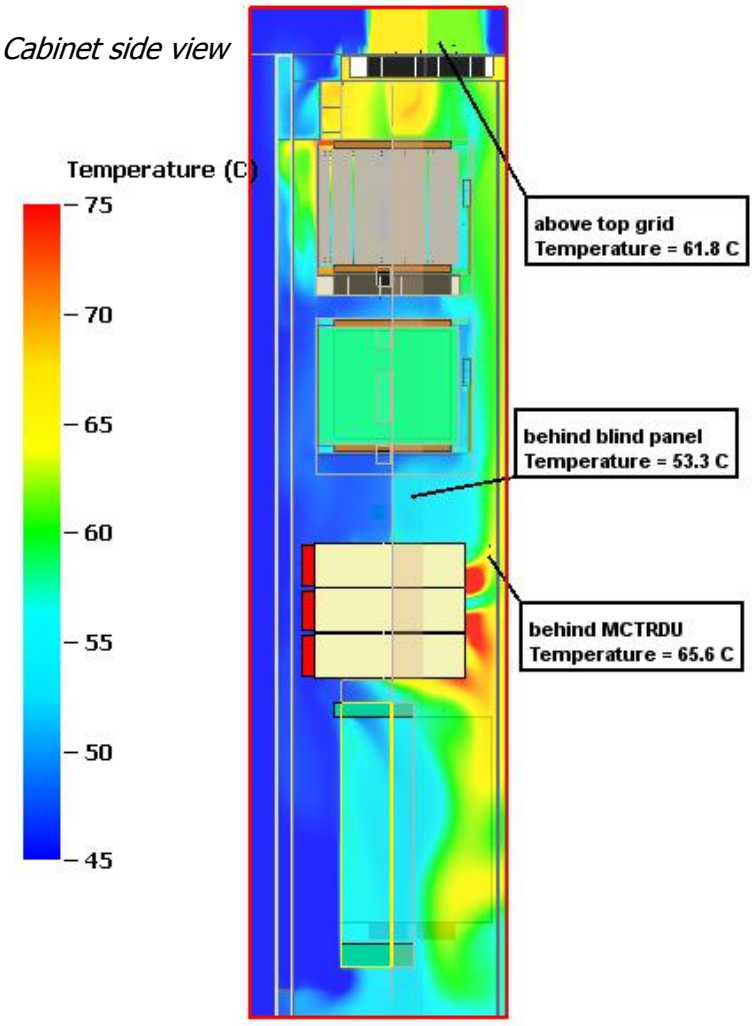
- Indoor cabinet was simulated with 6SigmaET
  - Ambient 45 °C
  - Standard KE turbulence model
  - 19.564.803 grid cells
  - Solve time 5h:32m
- Cabinet equipment
  - 3x TMXA: fan cooled bottom-to-top
  - 3x TRDU: fan cooled front-to-back
  - 1x d2U: fan cooled right-to-left
  - Top fan unit in the cabinet
  - Detailed fan models

Test case 1: Indoor cabinet
Simulation results

Cabinet front view



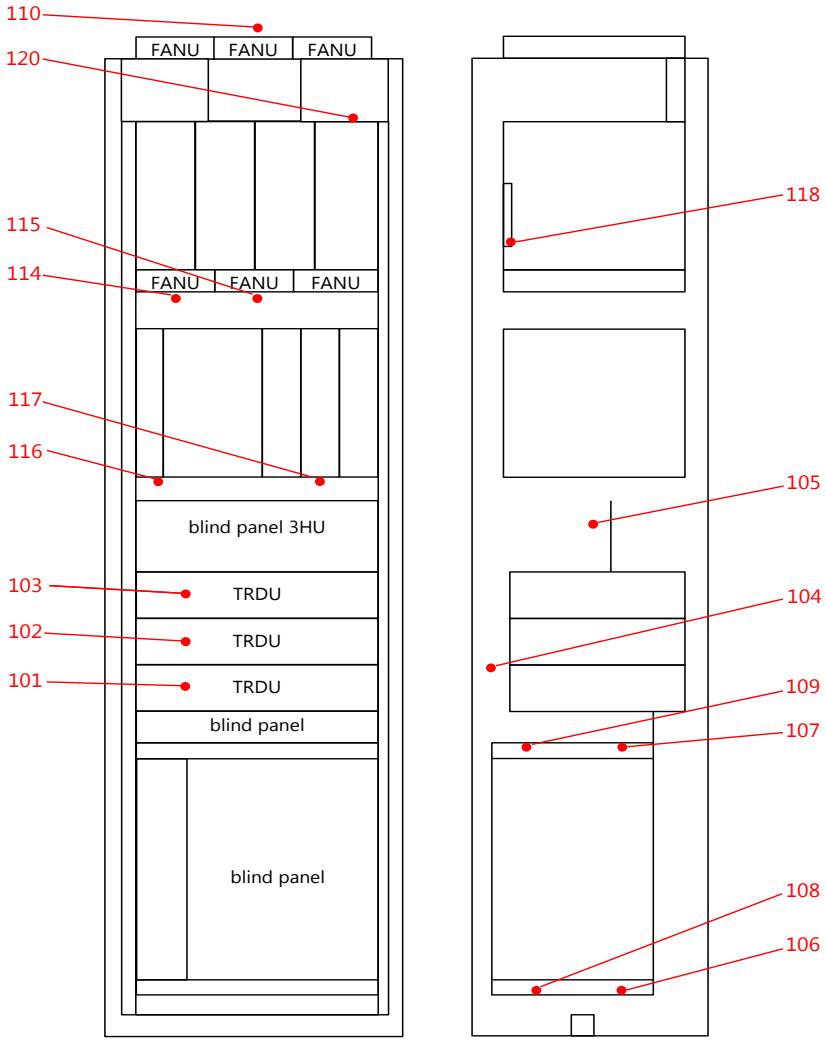
Cabinet side view



Test case 1: Indoor cabinet
Measurements in the climatic chamber

- Indoor cabinet tested in the climatic chamber at +45°C
- Air temperatures measured with thermocouples
- Module output power and supply current controlled during the test

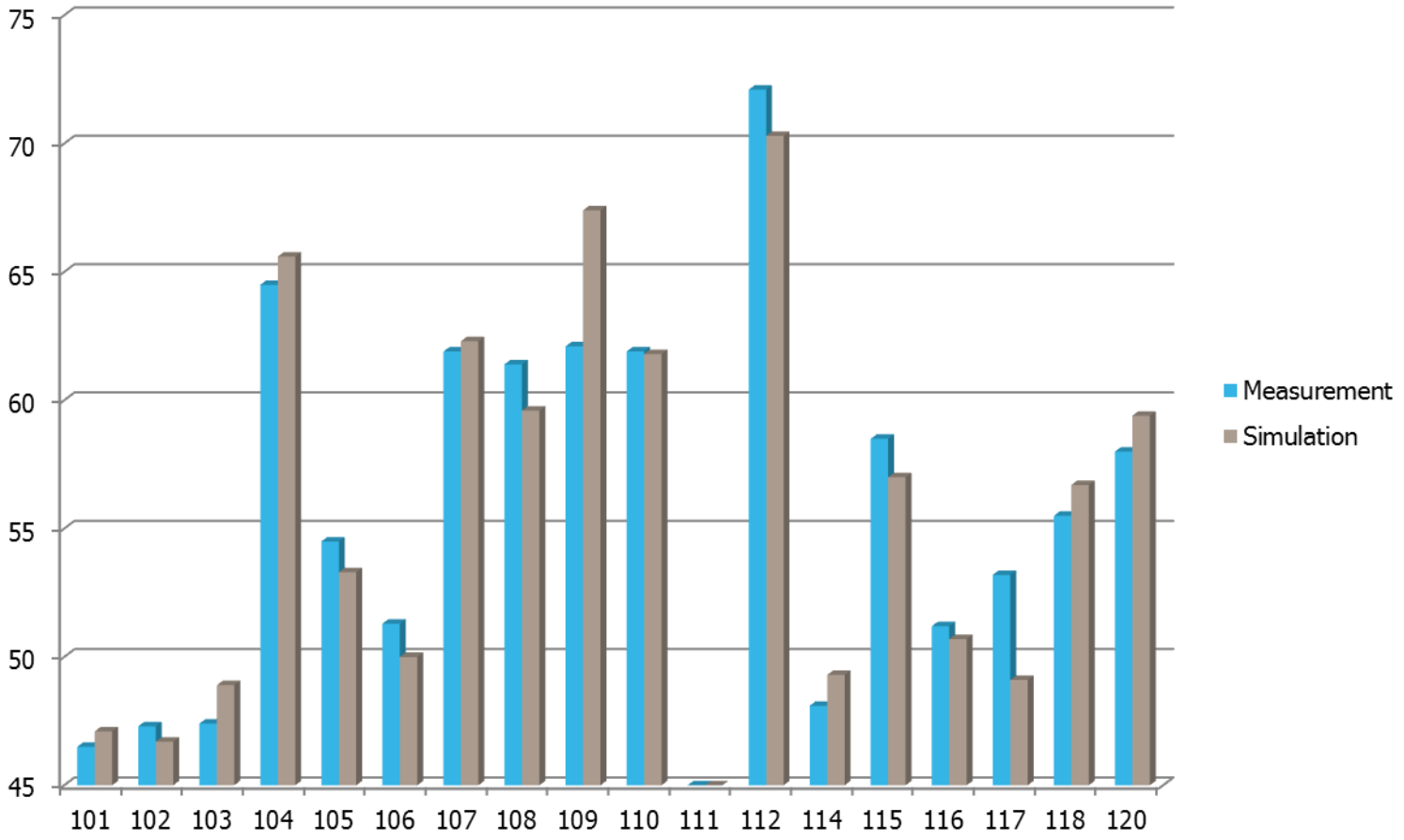
Test case 1: Indoor cabinet
Location of thermocouples



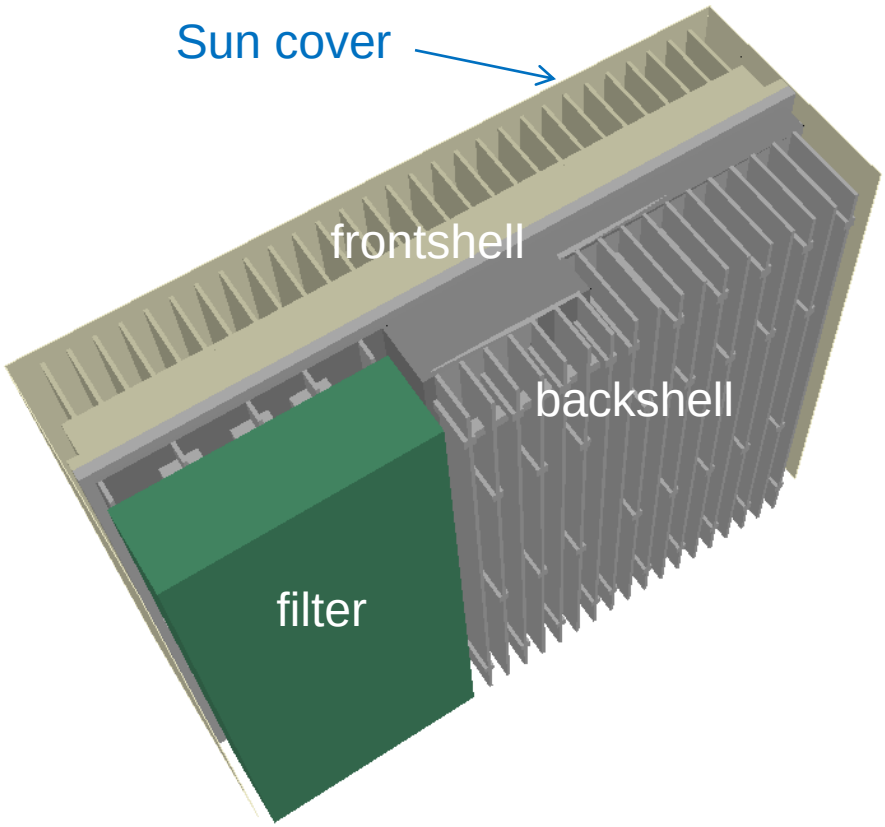
Test case 1: Indoor cabinet
Comparison of measurements and simulations

Temperature sensor		Temperature °C		
		Measurement	Simulation	Deviation
101	lower TRDU, air in front of the fan	46.5	47.1	0.6
102	central TRDU, air in front of the fan	47.3	46.7	-0.6
103	upper TRDU, air in front of the fan	47.4	48.9	1.5
104	air behind TRDU	64.5	65.6	1.1
105	air behind the blind panel 3HU	54.5	53.3	-1.2
106	air inlet of the front fan	51.3	50.0	-1.3
107	air outlet at the front	61.9	62.3	0.4
108	air inlet of the rear fan	61.4	59.6	-1.8
109	air outlet at the rear	62.1	67.4	5.3
110	air above the top grid	61.9	61.8	-0.1
111	air in front of the cabinet, 1.5 m height	45.0	45.0	0.0
112	upper TRDU glued on power supply heat sink	72.1	70.3	-1.8
114	upper subrack, air below the left TRX	48.1	49.3	1.2
115	upper subrack, air below the right TRX	58.5	57.0	-1.5
116	air below	51.2	50.7	-0.5
117	air below the middle	53.2	49.1	-4.1
118	upper subrack, air in front	55.5	56.7	1.2
120	air below the fuses	58.0	59.4	1.4

Test case 1: Indoor cabinet
Comparison of measurements and simulations



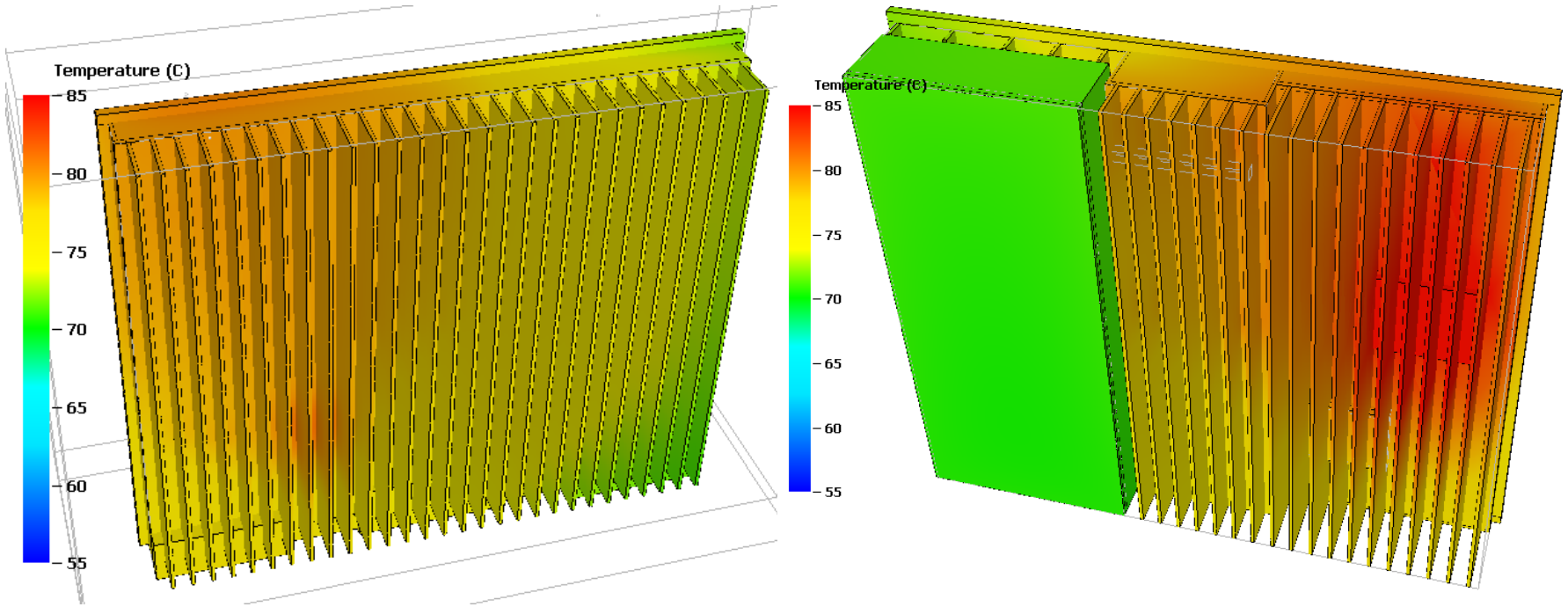
Test case 2: RRH
Model set-up



6Sigma ET simulation model

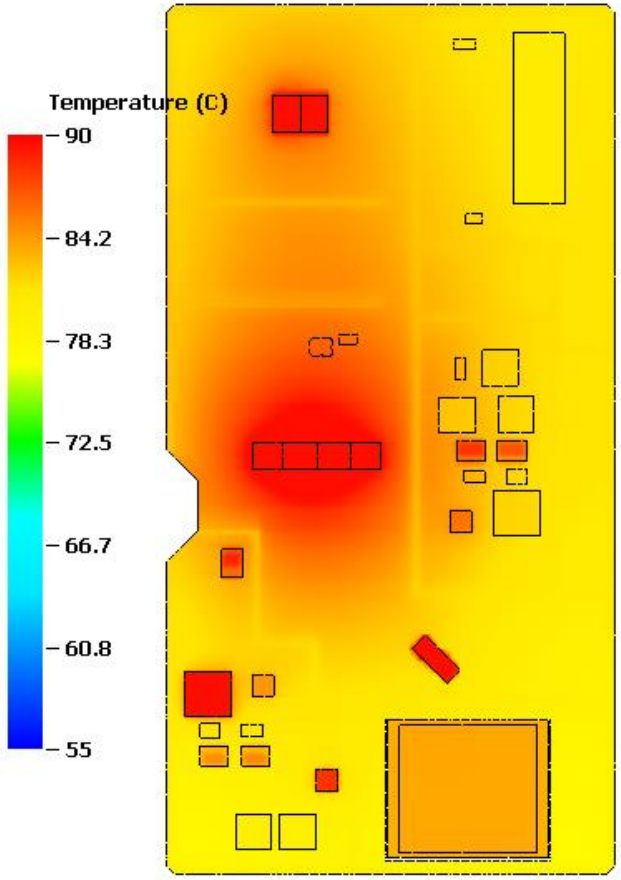
- RRH was simulated with 6SigmaET
  - 55°C ambient
  - Laminar flow
  - Heat radiation
  - 19.064.448 grid cells
  - Solve time 8h:44m

Test case 2: RRH
Simulation results: frontshell and backshell

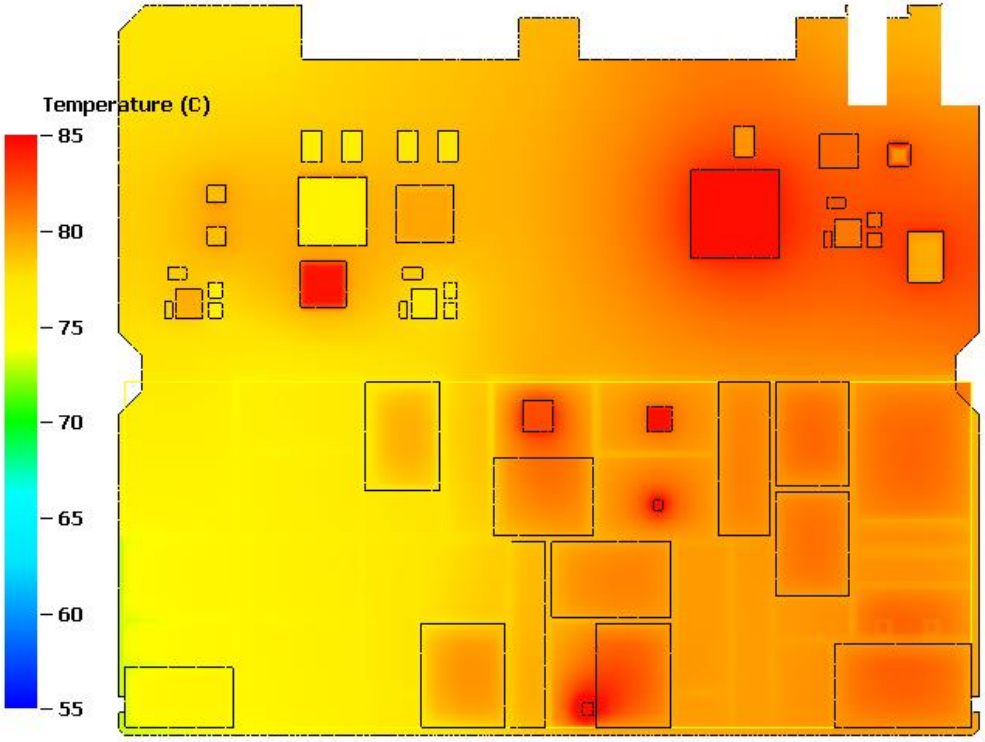


Test case 2: RRH
Simulation results: PCB temperatures

Board surface temperatures



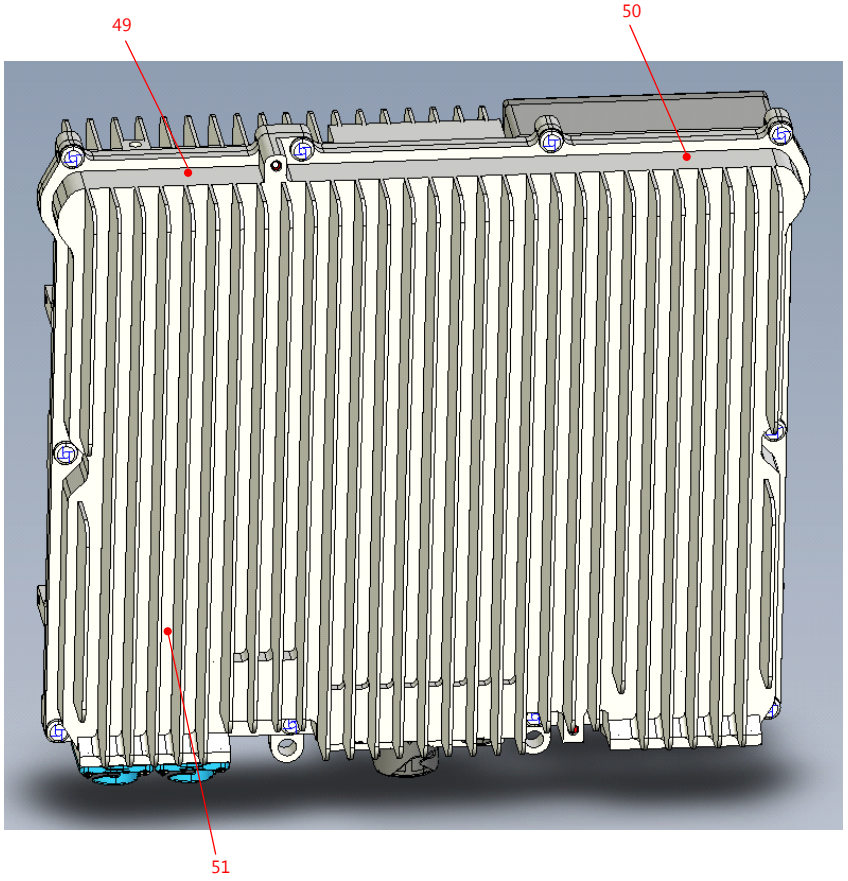
Board surface temperatures

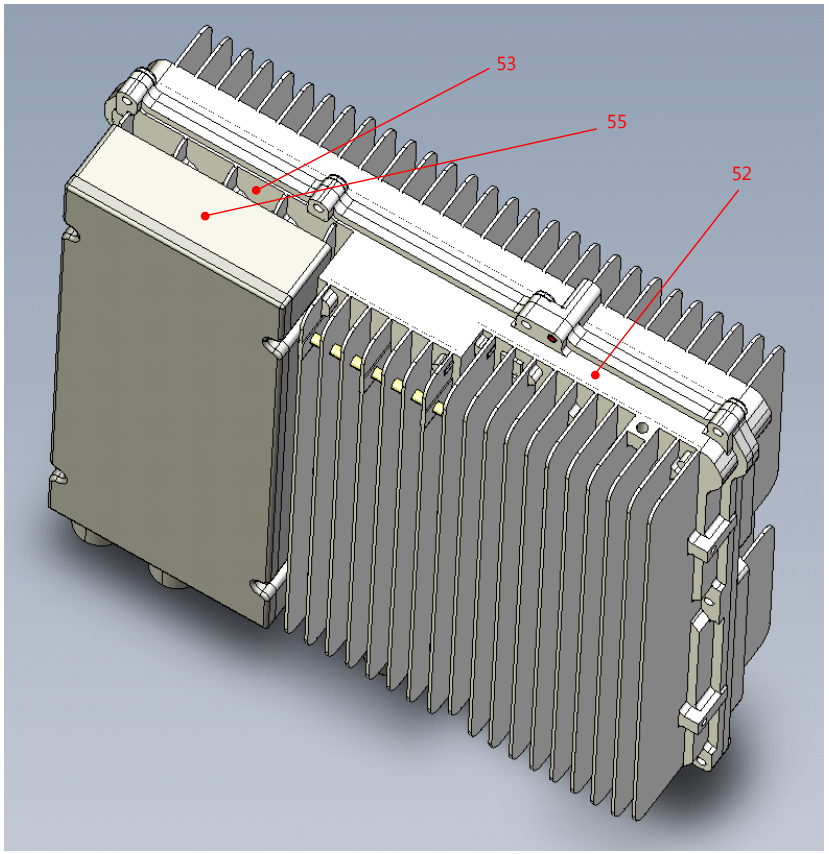


Test case 2: RRH
Measurements in the climatic chamber

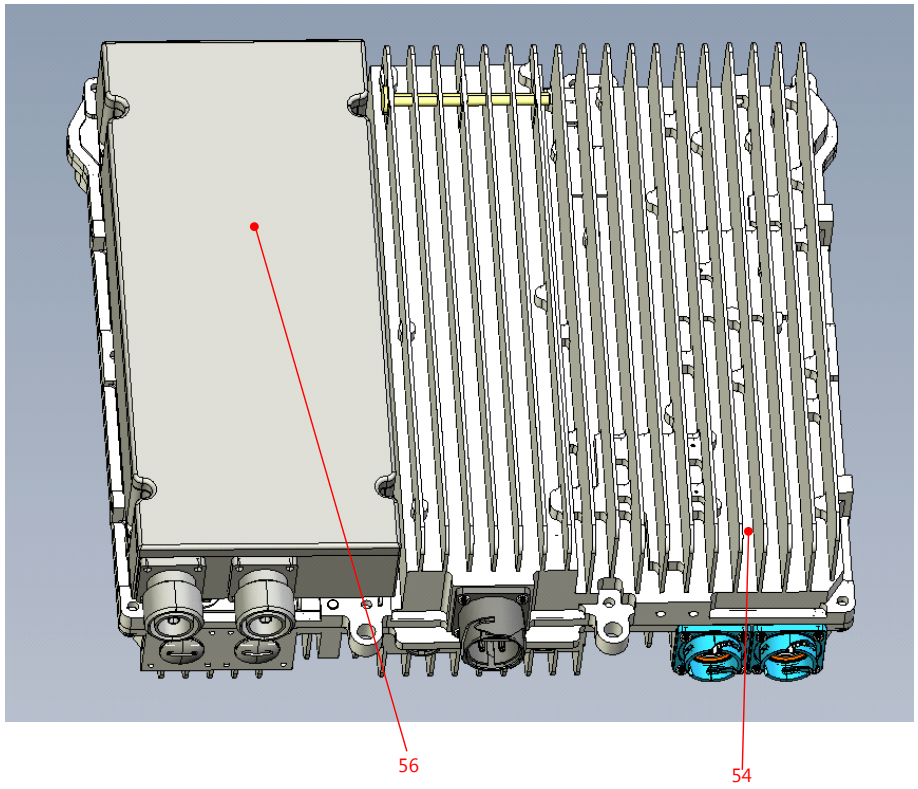
- RRH was tested at 55°C in the climatic chamber
- Housing temperatures and temperatures of selected components were measured with thermocouples
- Module power consumption and the RF output power was controlled during the test
  - Power consumption 158.7 W
  - RF output 42.9 dBm
- Still air conditions (velocities < 0.1 m/s)

Test case 2: RRH
Location of thermocouples





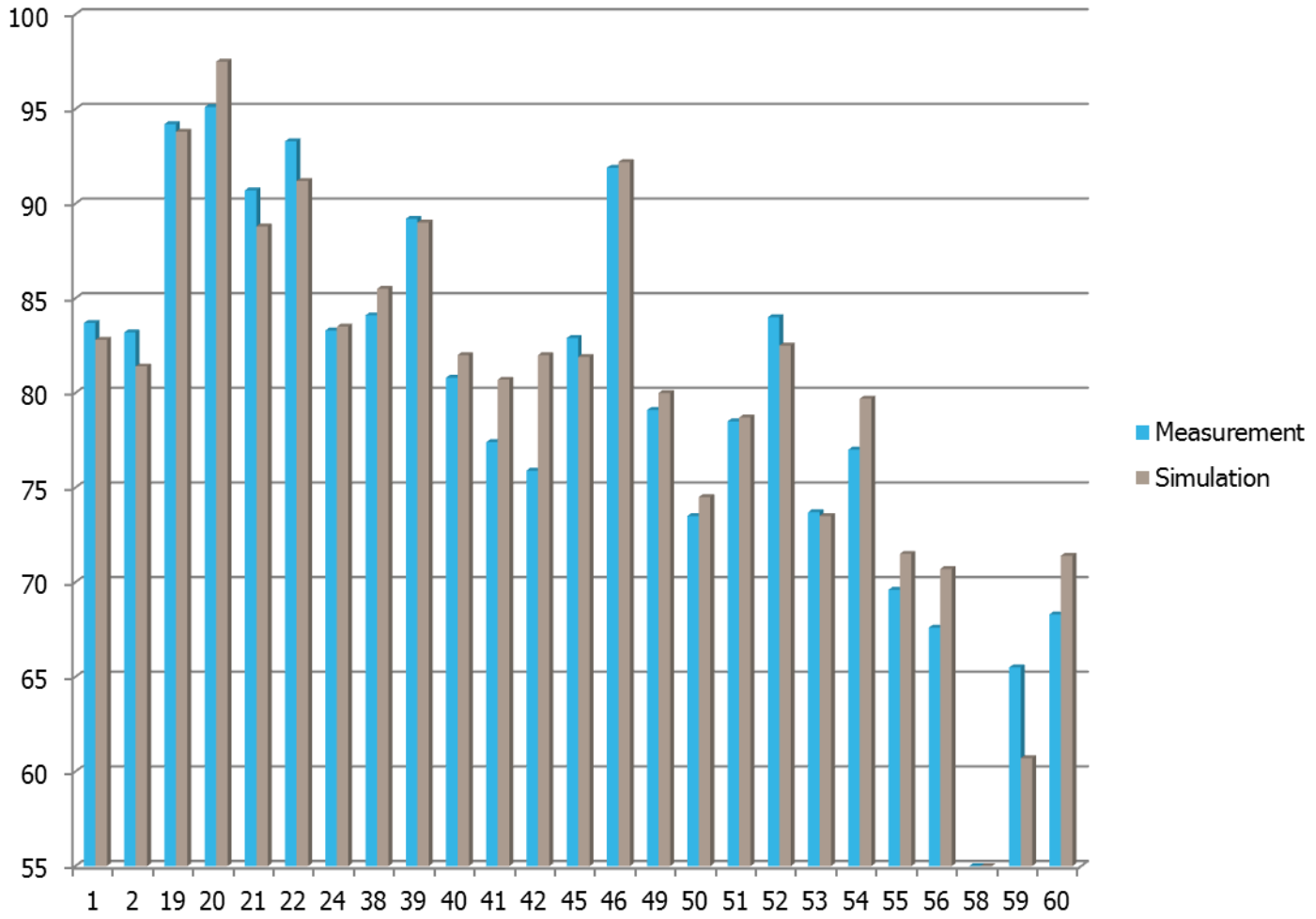
Test case 2: RRH
Location of thermocouples



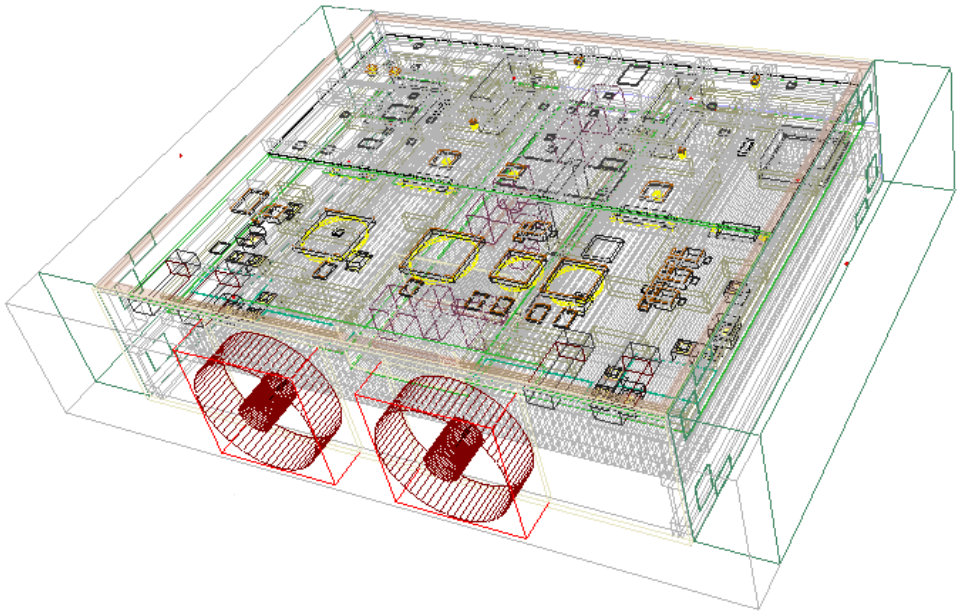
Test case 2: RRH
Comparison of Measurements and Simulations

		Temperature Sensor		Temperature, °C		
MP	MP location		TC mounting	Measurement	Simulation	Deviation
1		base plate top	on surface	83.7	82.8	-0.9
2		base plate center	on surface	83.2	81.4	-1.8
19		Final stage (peak)	pcb top, near screw	94.2	93.8	-0.4
20		Final stage (main)	pcb top, near screw	95.1	97.5	2.4
21		transistor	component top	90.7	88.8	-1.9
22		power coil	component top	93.3	91.2	-2.1
24		isolator	component top	83.3	83.5	0.2
38		Ethernet PHY	component top	84.1	85.5	1.4
39		FPGA	component top	89.2	89.0	-0.2
40		SDRAM	component top	80.8	82.0	1.2
41		DSP	component top	77.4	80.7	3.3
42		Controller	component top	75.9	82.0	6.0
45		inductor	component top	82.9	81.9	-0.9
46			component top	91.9	92.2	0.3
49		Front Shell top		79.1	80.0	0.8
50		Front Shell top		73.5	74.5	1.0
51		Front Shell bottom		78.5	78.7	0.2
52		Back Shell top		84.0	82.5	-1.5
53		Back Shell top		73.7	73.5	-0.1
54		Back Shell bottom		77.0	79.7	2.7
55		Antenna Module top		69.6	71.5	1.9
56		Antenna Module front		67.6	70.7	3.1
58		air below RRH		54.7	55.0	0.3
59		air above RRH right		65.5	60.7	-4.8
60		air above RRH left		68.3	71.4	3.1

Test case 2: RRH
Comparison of Measurements and Simulations



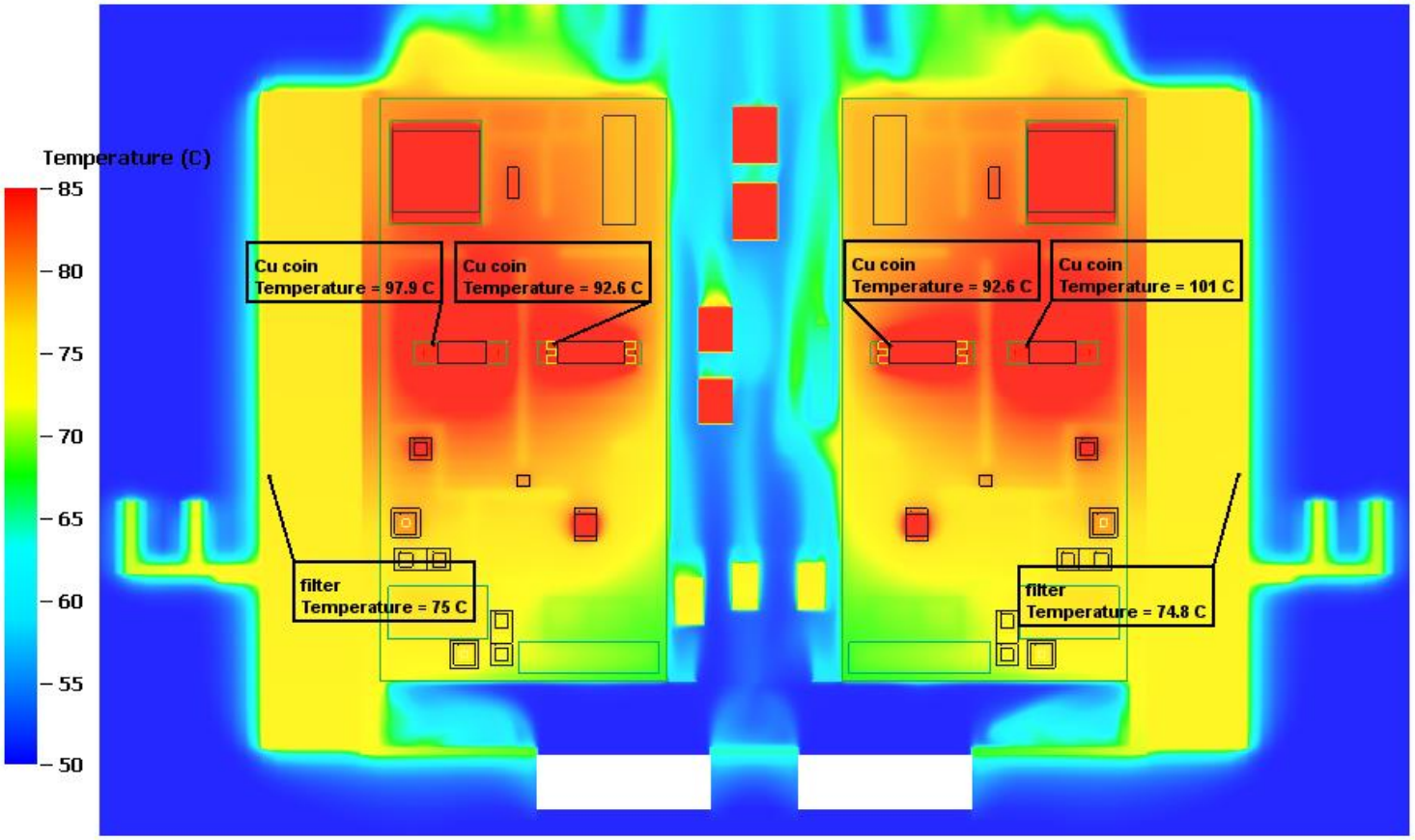
Test case 3: TRDU
Model Set-up



6Sigma ET simulation model

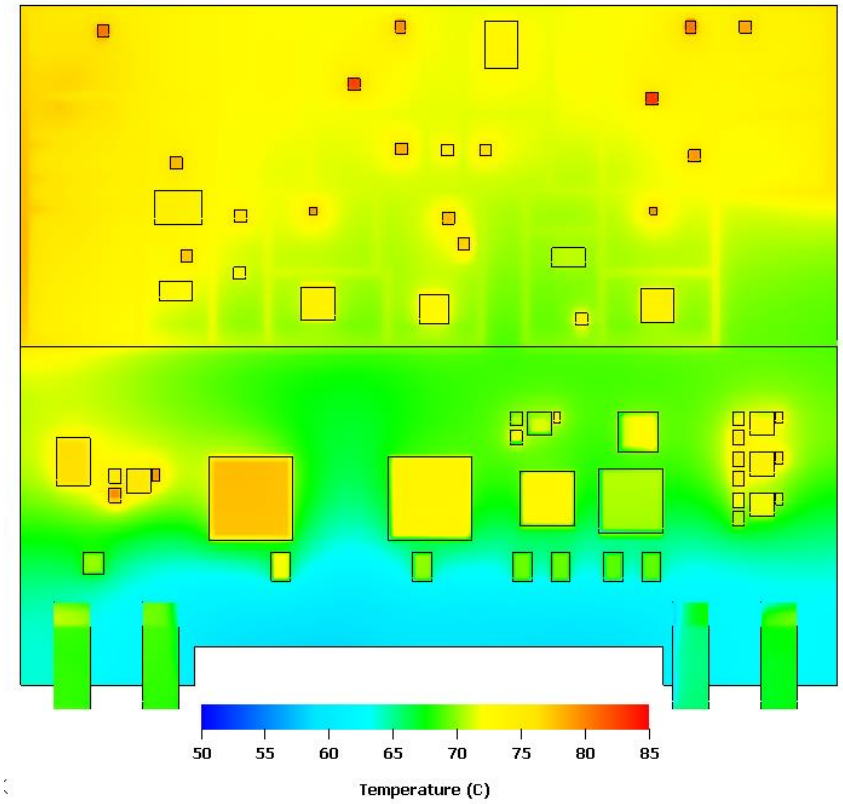
- TRDU was simulated with 6SigmaET
  - 50°C ambient
  - Standard KE turbulence model
  - Heat radiation
  - 17.680.294 grid cells
  - Solve time 3h:48m

Test case 3: TRDU
Simulation results

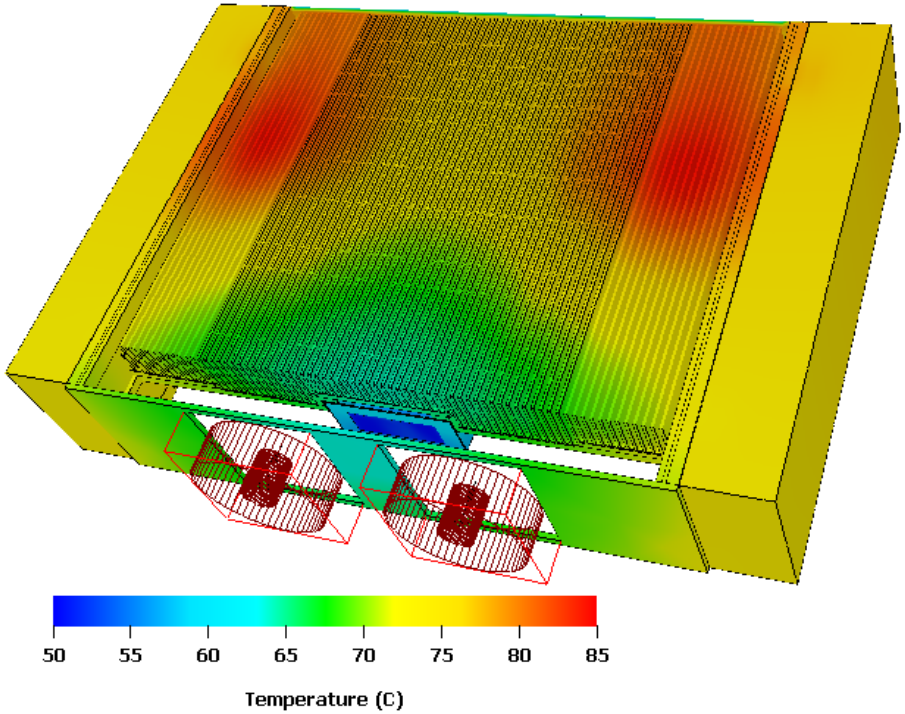


Test case 3: TRDU
Simulation results

Board surface temperatures



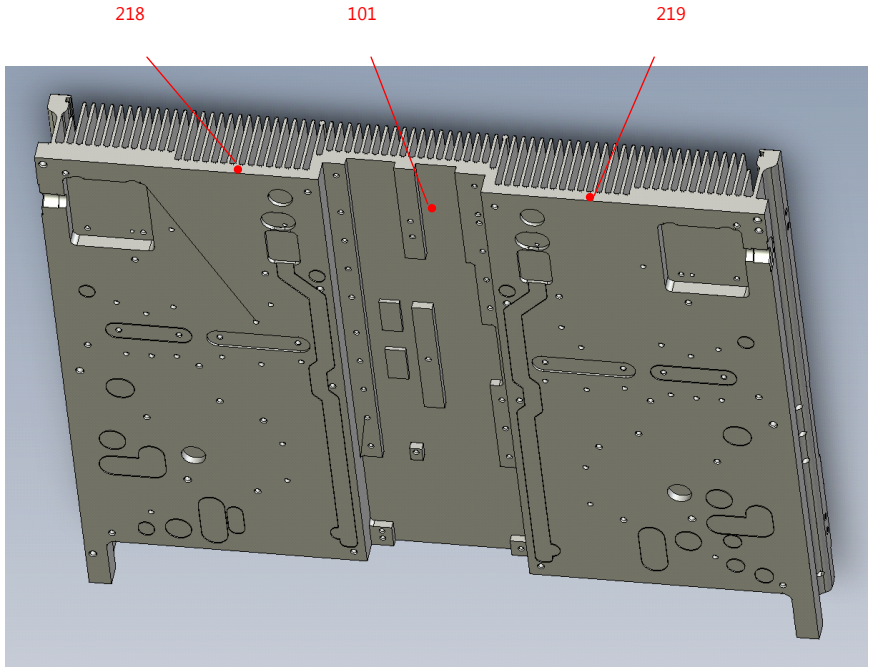
Backshell surface temperatures

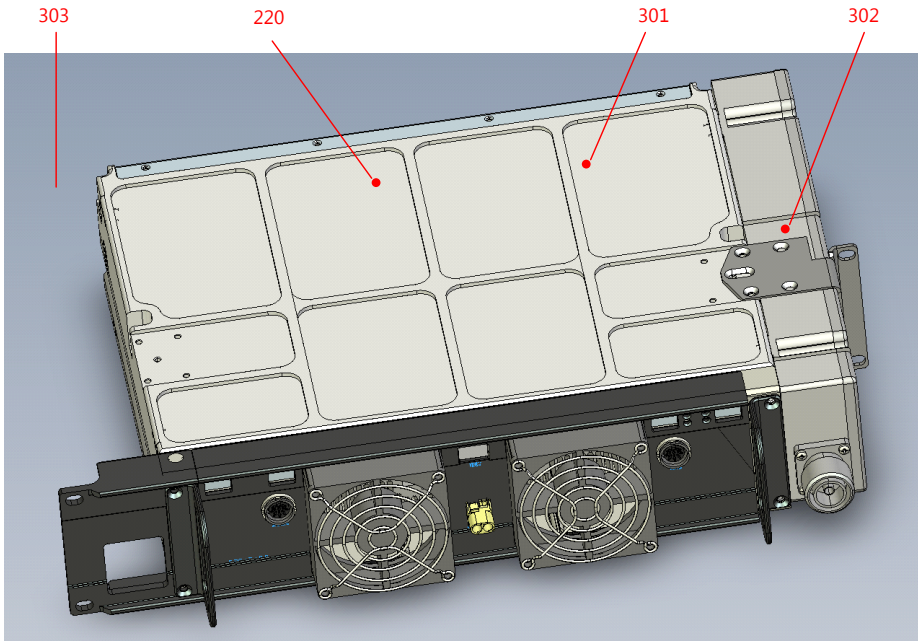


Test case 3: TRDU
Measurements in the climatic chamber

- TRDU was tested at 50°C in the climatic chamber
- Housing temperatures and temperatures of selected components were measured with thermocouples
- Module power consumption and the RF output power was controlled during the test
  - Power consumption 727.5 W
  - RF output
    - PA1: 47.8 dBm
    - PA2: 47.8 dBm

Test case 3: TRDU
Location of thermocouples

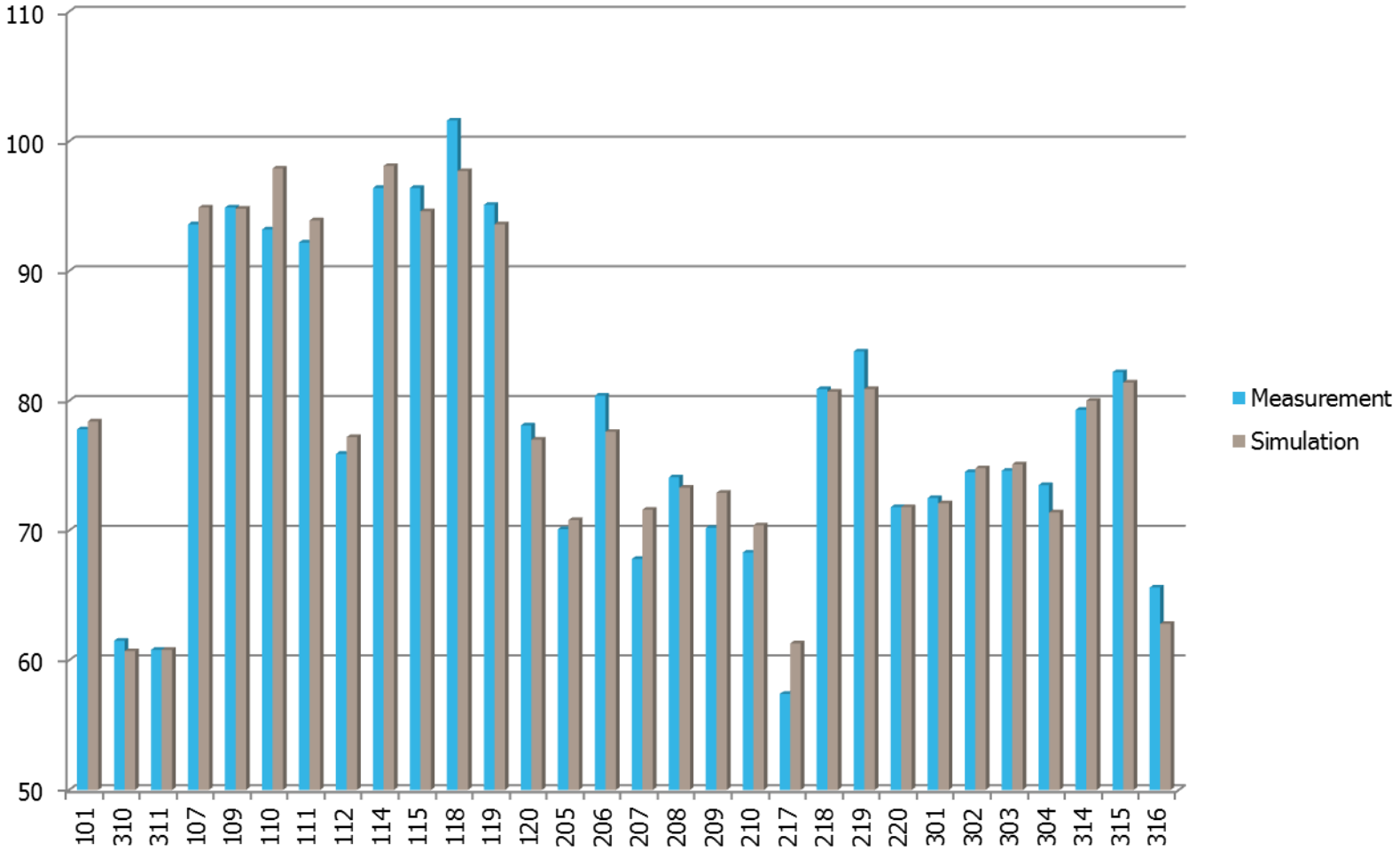




Test case 3: TRDU
Comparison of Measurements and Simulations

		Temperature Sensor		Temperature, °C		
MP	**MP location**		**TC mounting**	**Measurement**	**Simulation**	**Deviation**
101		main PS heat sink		77.8	78.4	0.7
310		inside PS rear		61.5	60.7	-0.8
311		inside PS front		60.8	60.8	-0.1
107		Isolator	component base	93.6	94.9	1.3
109		PCB near main stage	on PCB	94.9	94.8	0.0
110		transistor	component top	93.2	97.9	4.6
111		power inductor	component top	92.2	93.9	1.7
112		transistor	component top	75.9	77.2	1.3
114		main stage	Cu base	96.4	98.1	1.7
115		Isolator	component base	96.4	94.6	-1.8
118		transistor	component top	101.6	97.7	-3.9
119		power inductor	component top	95.1	93.6	-1.5
120		transistor	component top	78.1	77.0	-1.1
205		Ethernet PHY	component top	70.1	70.8	0.7
206		FPGA	component top	80.4	77.6	-2.8
207		SDRAM	component top	67.8	71.6	3.8
208		FPGA	component top	74.1	73.3	-0.8
209		DSP	component top	70.2	72.9	2.7
210		Controller	component top	68.3	70.4	2.0
217		SFP	PCB below component	57.4	61.3	3.9
218	backshell, PA heat sink base			80.9	80.7	-0.3
219	backshell, PB heat sink base			83.8	80.9	-2.9
220	frontshell rear			71.8	71.8	0.0
301	frontshell rear			72.5	72.1	-0.4
302	right filter, top surface			74.5	74.8	0.3
303	left filter, top surface			74.6	75.1	0.4
304	TMX cover			73.5	71.4	-2.0
314	air outlet, behind PA heat sink			79.3	80.0	0.7
315	air outlet, behind PB heat sink			82.2	81.4	-0.7
316	air outlet			65.6	62.8	-2.8

Test case 3: TRDU
Comparison of Measurements and Simulations

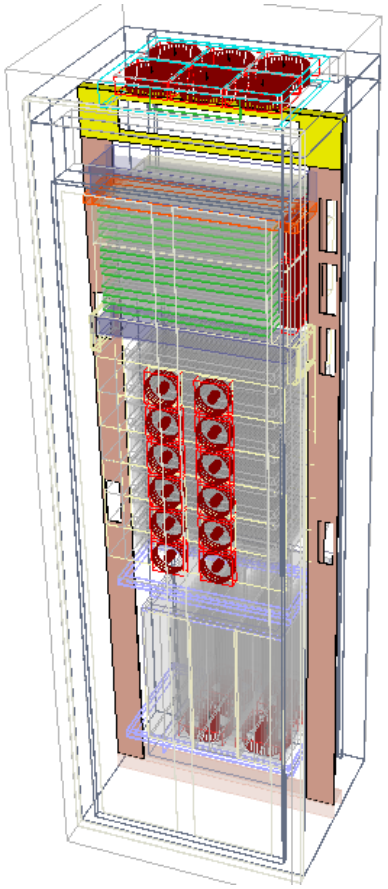


CONVERGENCE OF LARGE PROJECTS

- A large project with 60 millions nodes was created to test the convergence behavior
  - Test case 4: Fully equipped Indoor Cabinet, with detailed models of the modules inside, in total with 28 fans
- Result
  - 6Sigma ET solver can easily cope with large models. The 60 millions grid cells project was solved after 14h, 600 iteration steps.

Test case 4: Indoor cabinet
Model Set-up

- Model Set-up:
  - Indoor Cabinet with top fans
- Cabinet equipment
  - 3x d2U: fan cooled right-to-left
  - 6x TRDU fan cooled front-to-back
  - 3x TRDU: fan cooled bottom-to-top
  - Totally 28 fans in the cabinet, fans with the characteristics
- Standard KE turbulence model
- 60.782.700 grid cells
- Good convergence
  - Solve time 13h:53m, 600 iterations

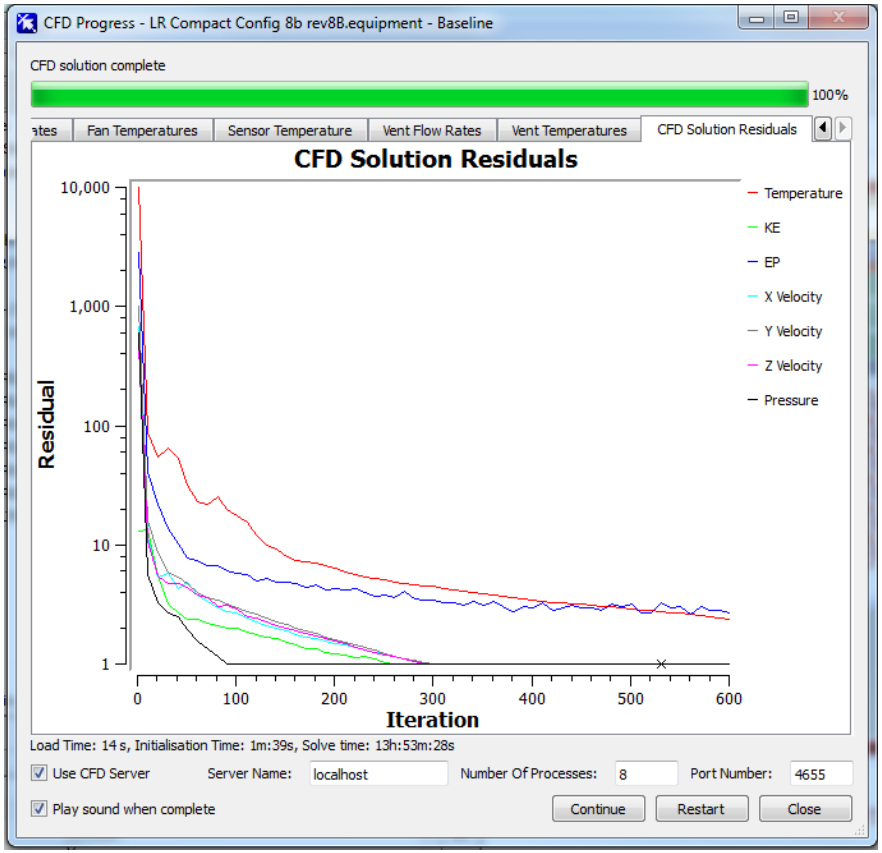


6Sigma ET simulation model

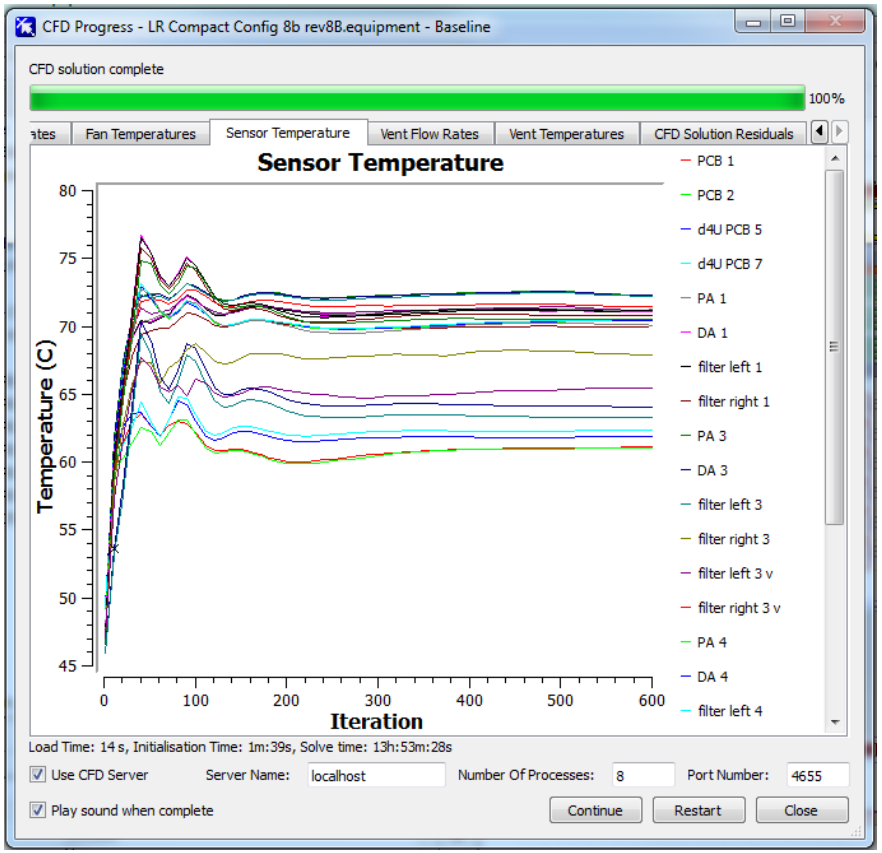
Test case 4: Indoor Cabinet
Model Convergence

- Solve time 13h:53m, after 600 iterations

CFD Solution Residuals

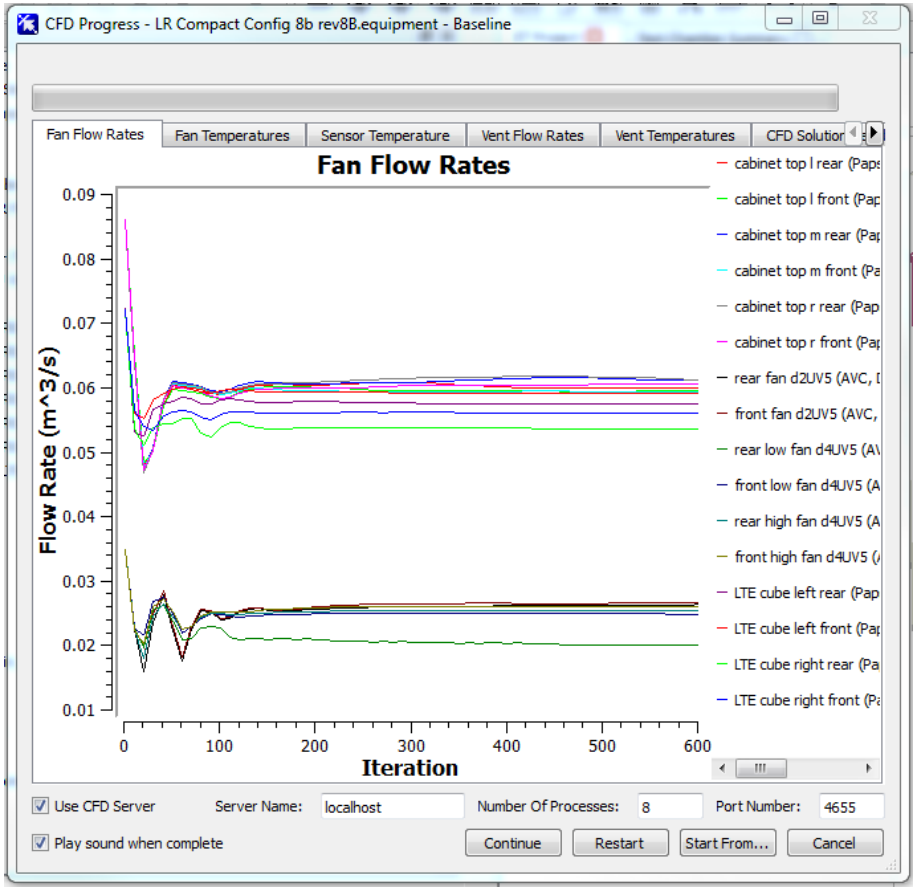


Sensor Temperatures



Test case 4: Indoor Cabinet
Model Convergence

Fan Flow Rates



For more information about 6SigmaET please visit:

www.6SigmaET.info