Development of BTMS control algorithm using KULI / MATLAB co-simulation

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Tomasz Turek
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SEMS'23

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DESIGN

- Support in design space for cooling
- Calculation of selected solution
- CFD Simulation of cover grills / airducting
- Control algorythms

PROTOTYPING

- Quick prototype delivery
- Support in installation
- Installation check (approval)
- Quick response

VALIDATION

- Support in validation planning
- Measurements
- Analysis and reporting

PRODUCTION

- Series deliveries
- Flexible planning

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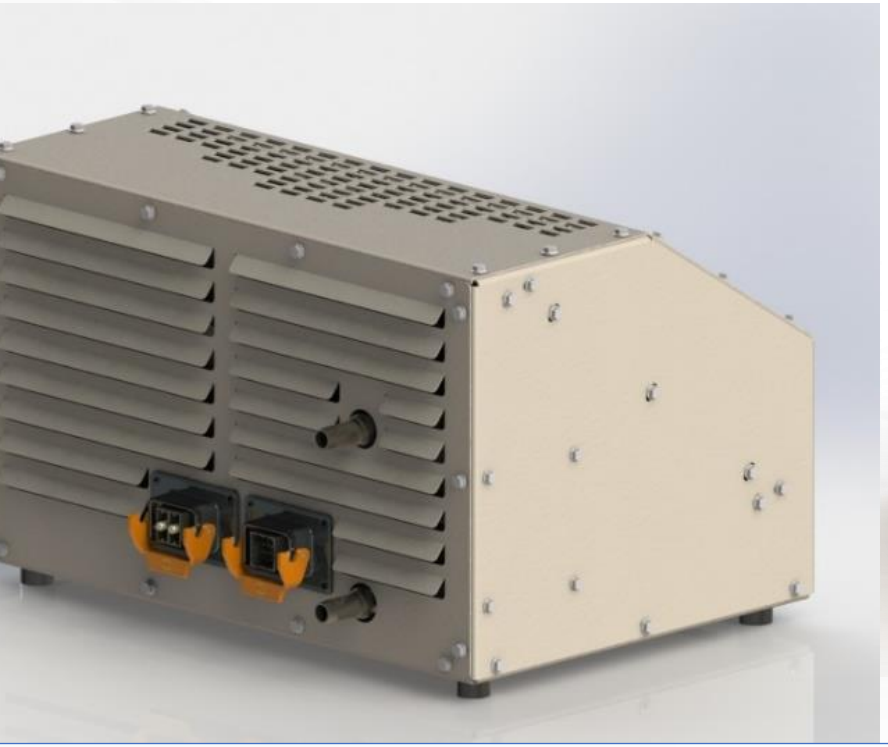
BSPL battery thermal comfort products



AG01 series – Off-highway

AC07 series – On-highway

AG02 series – Off-highway

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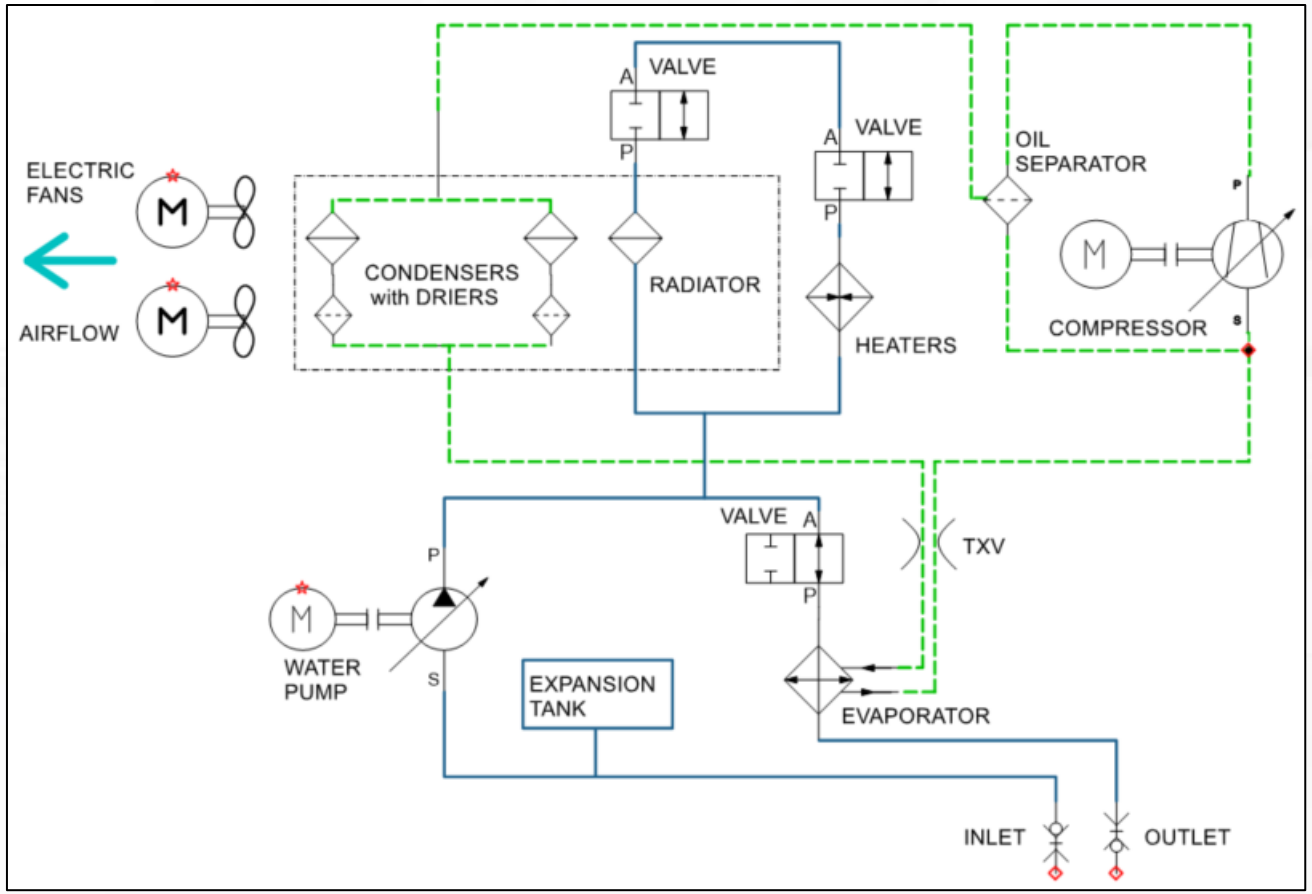
KULI

AC07 configuration

- Active cooling based on refrigerant cycle
- Passive cooling based on coolant to air heat exchanger
- Heating based on electric heater



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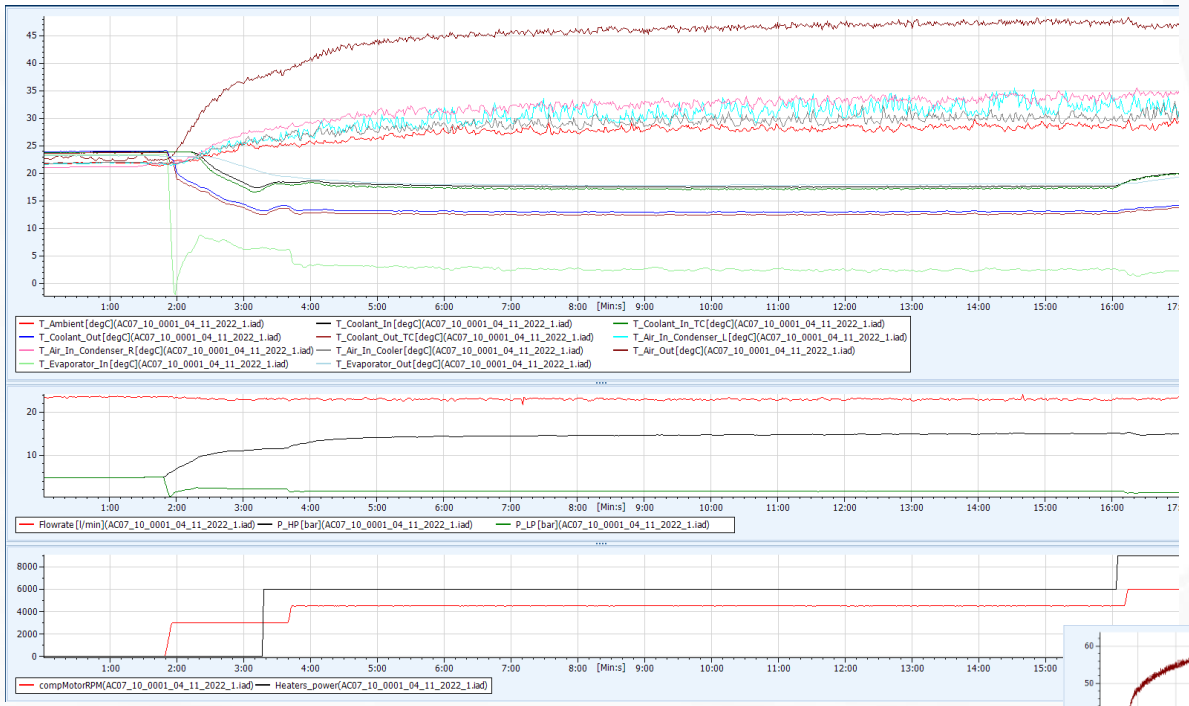
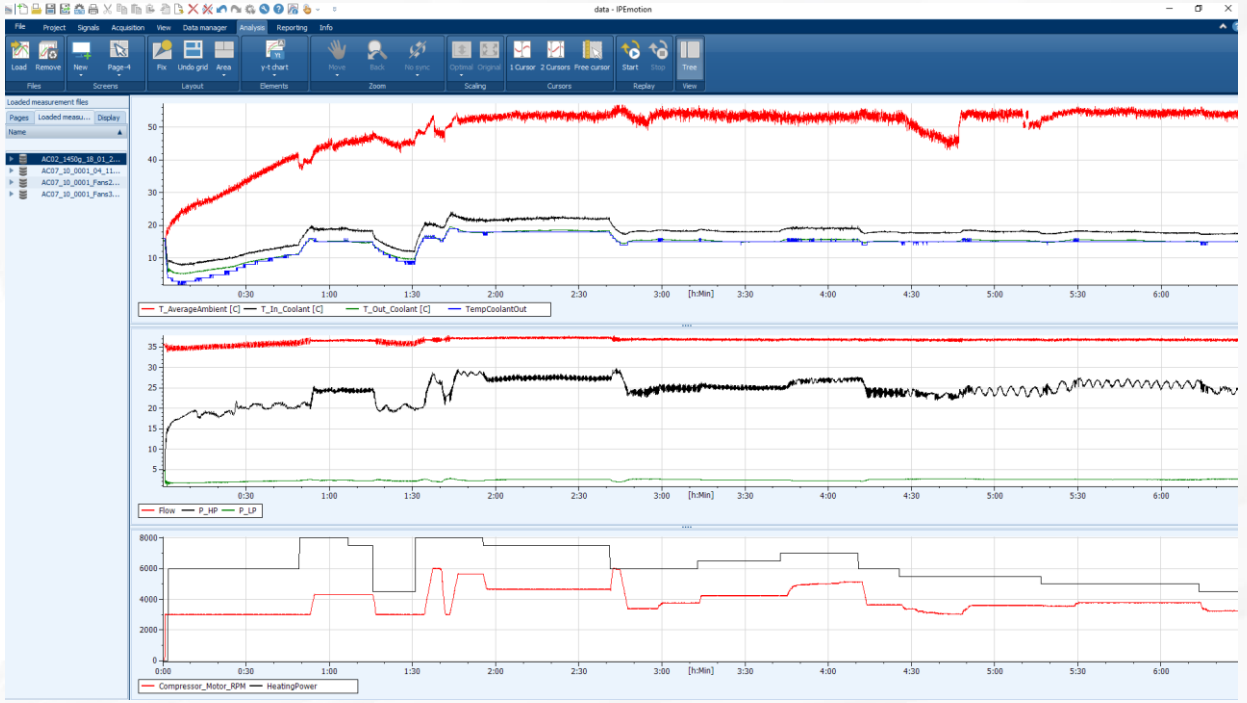
Test results





Tests in few steps:

- **Component verification**
- BTMS parameters at different conditions with manual control
- **BTMS control algorithm in automatic mode**

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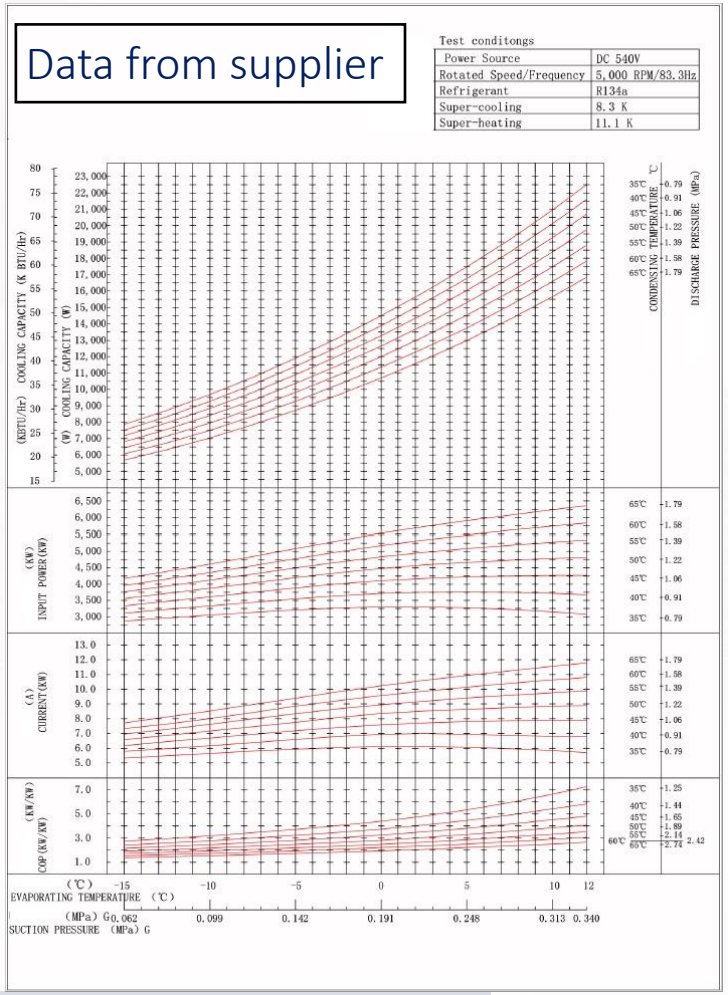
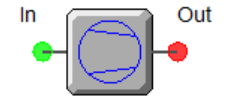
First step of KULI model – component models

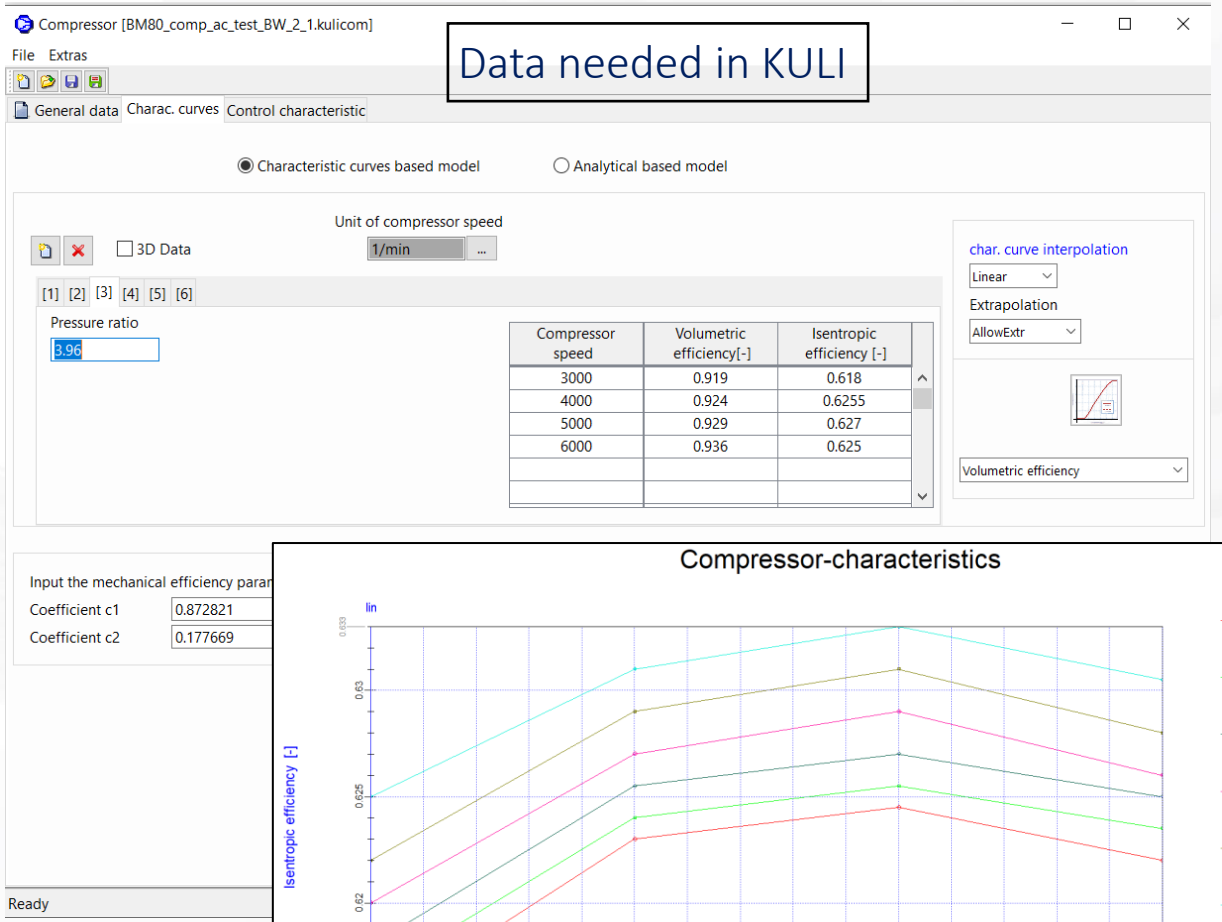
Data from supplier



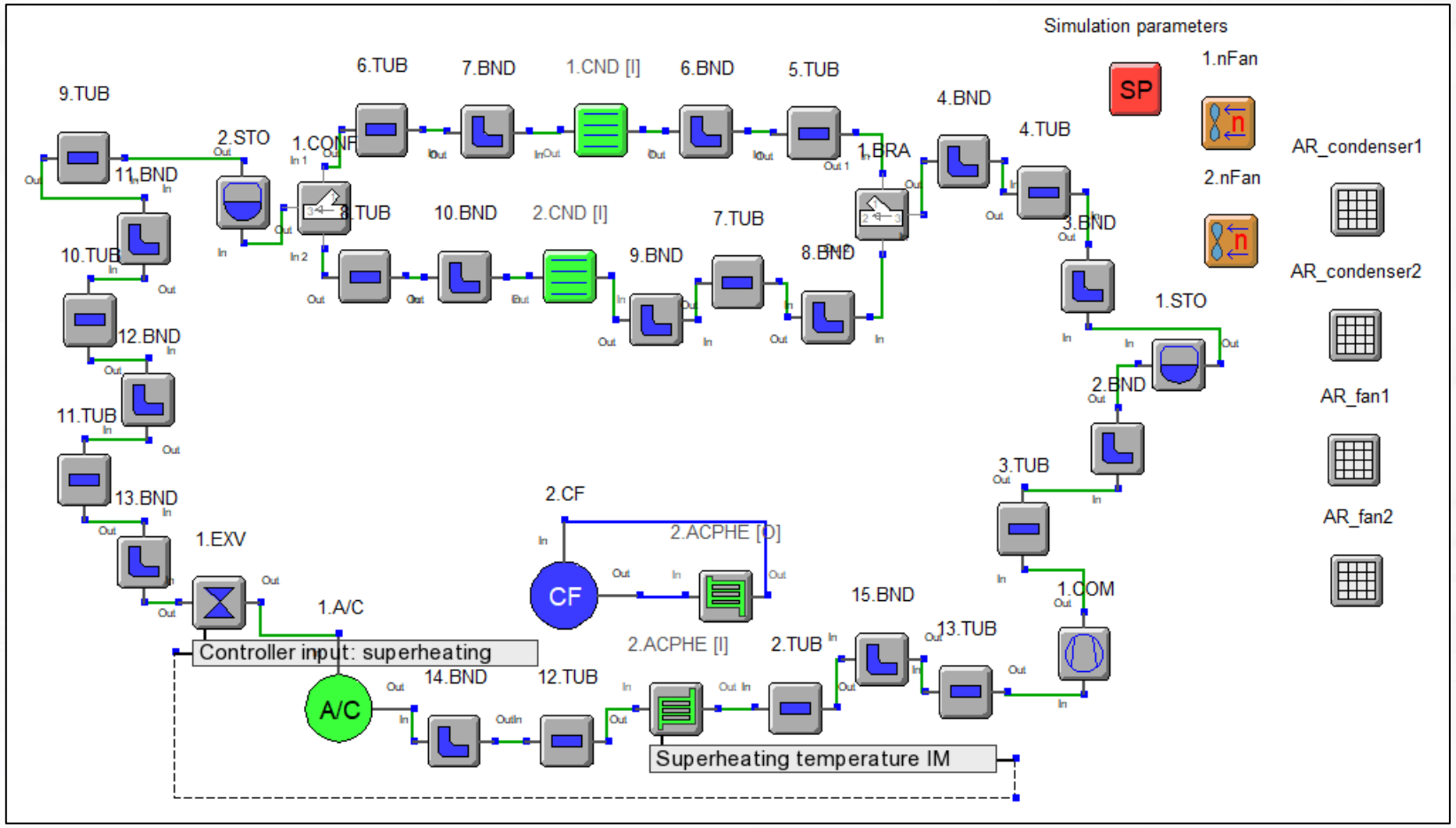
2.COM

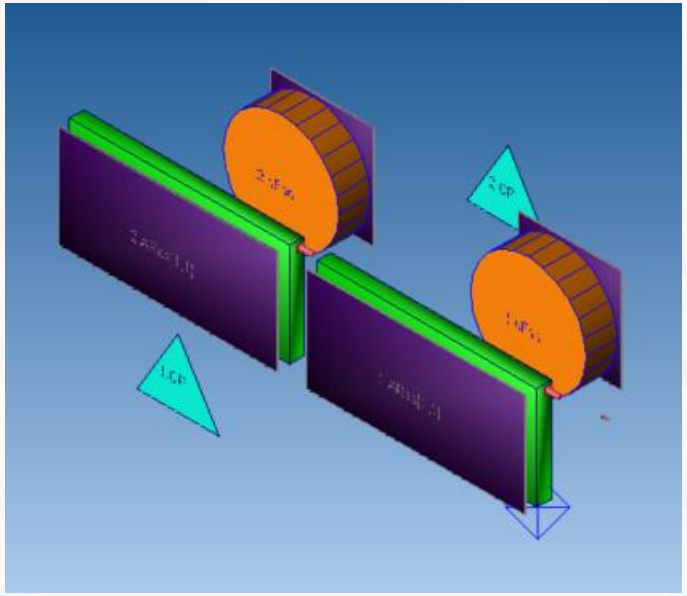


Data needed in KULI



Model of AC circuit only





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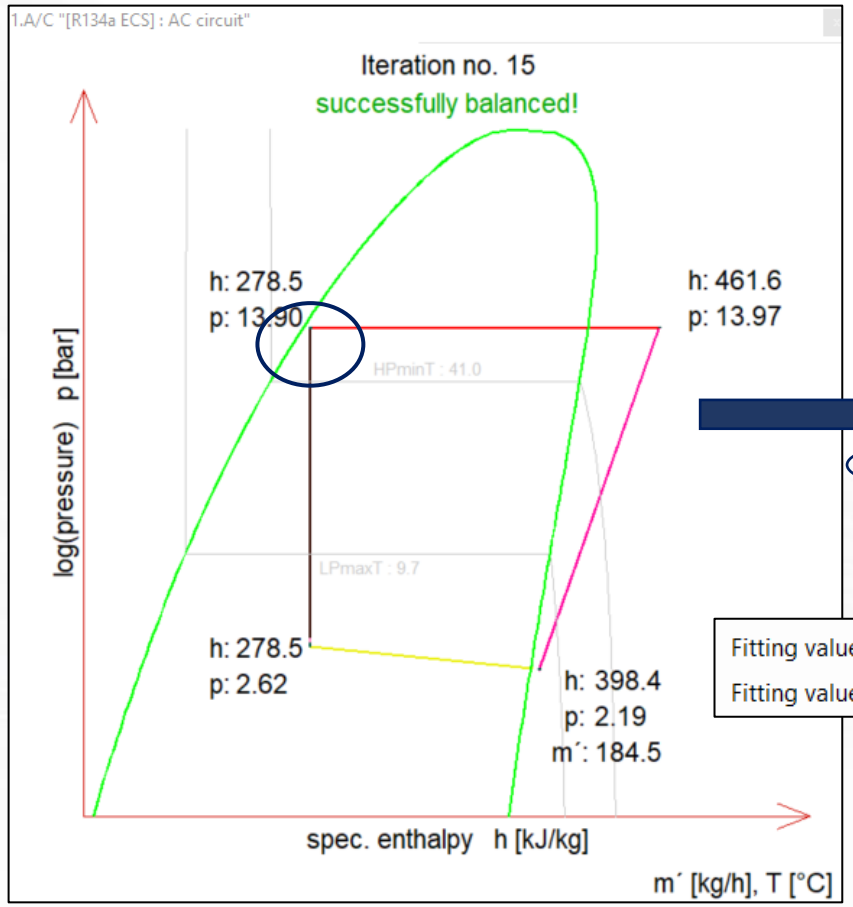
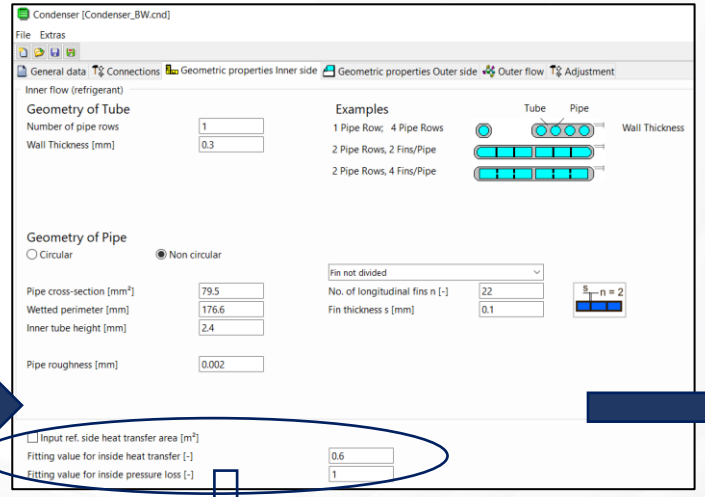
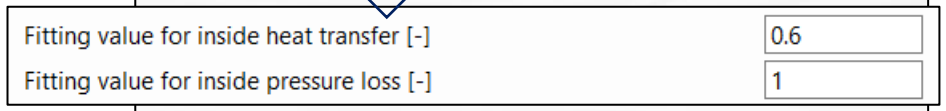
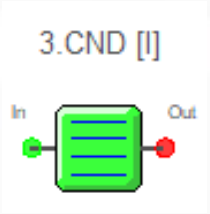
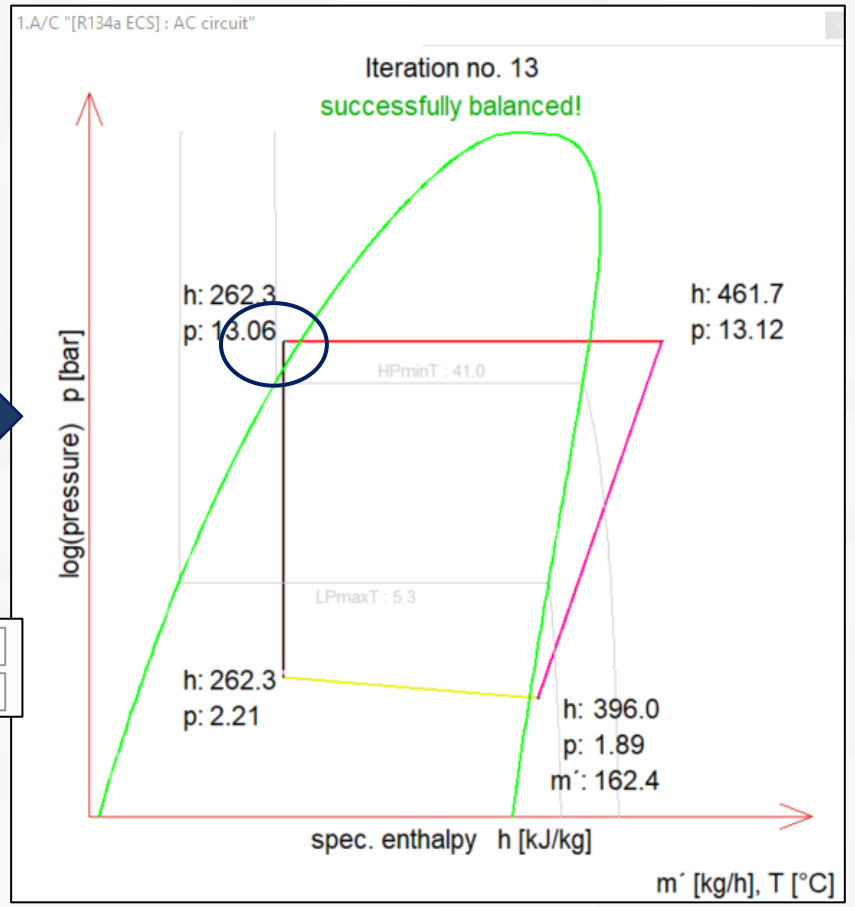
Example of results for model of AC circuit



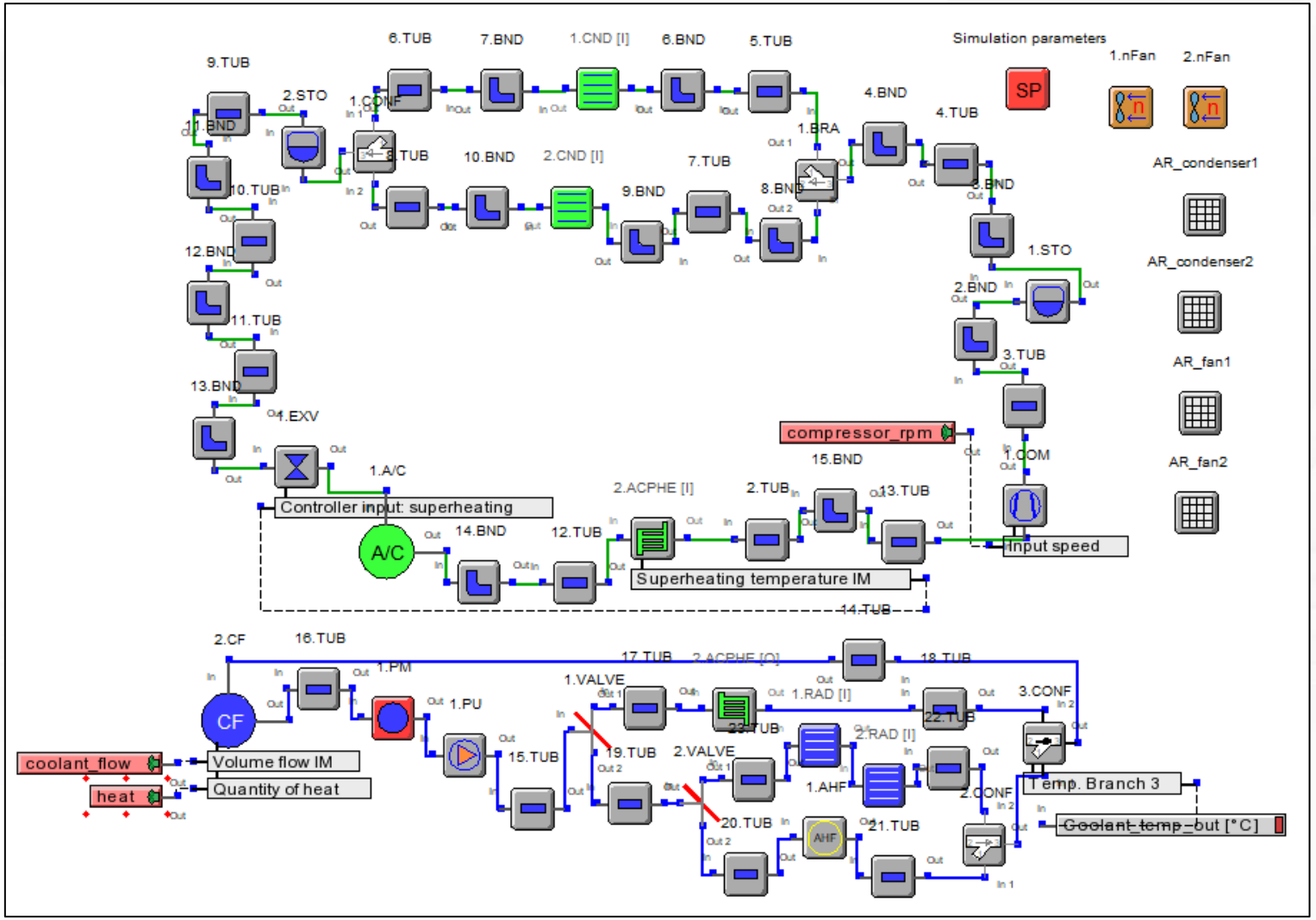


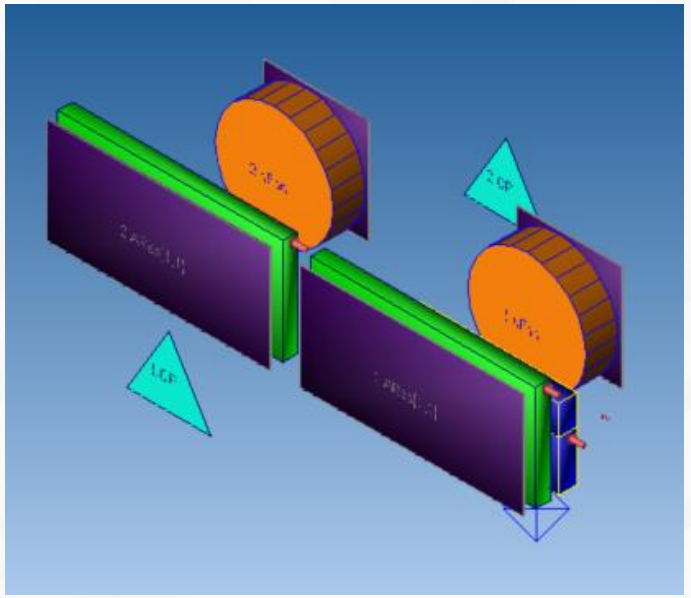




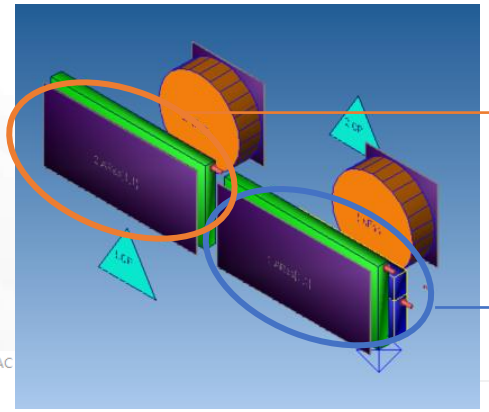


Model of whole BTMS circuit



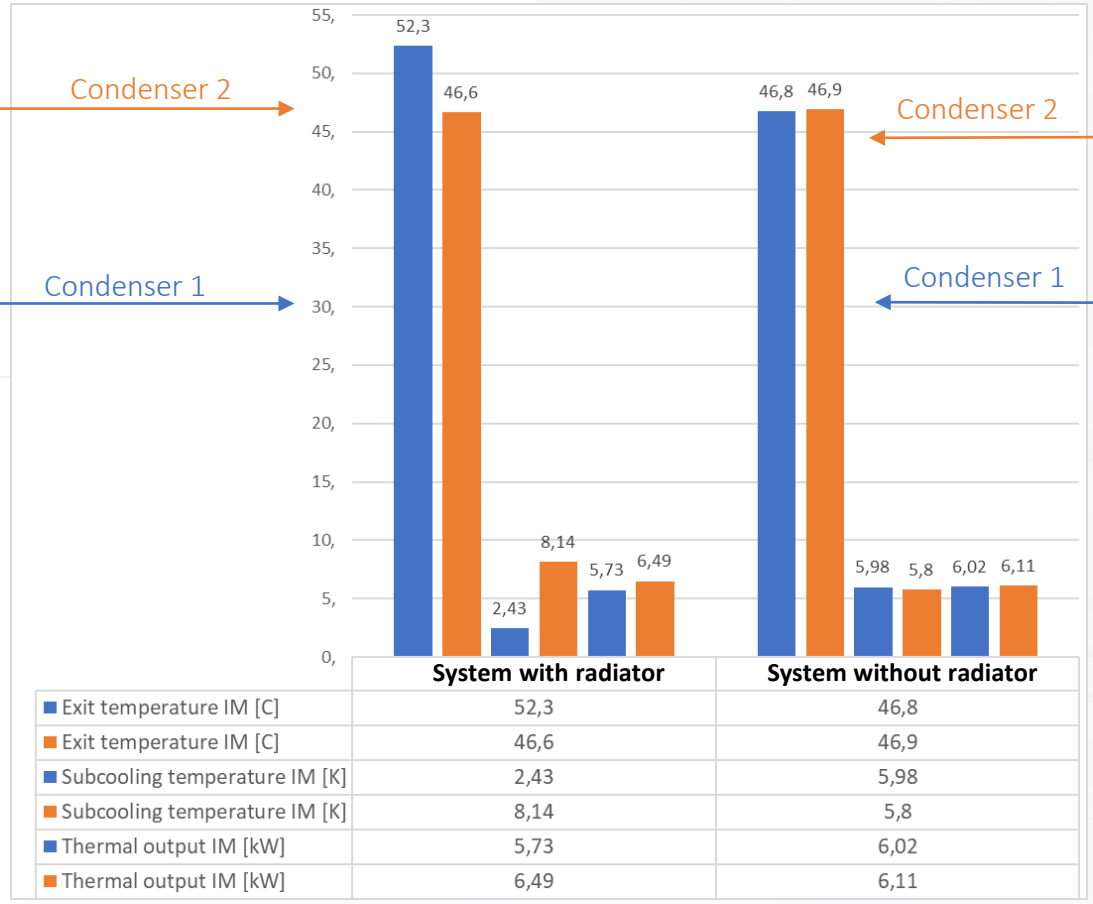


Model of whole BTMS vs AC circuit



Condenser 2

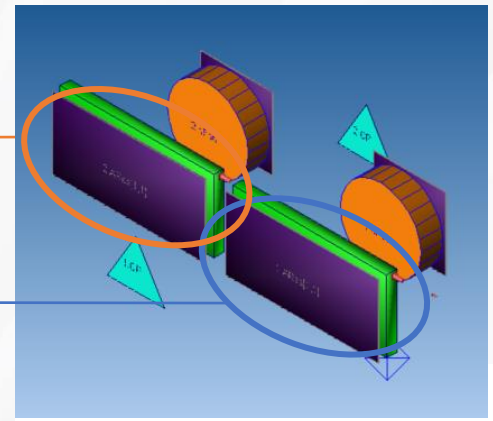
Condenser 1

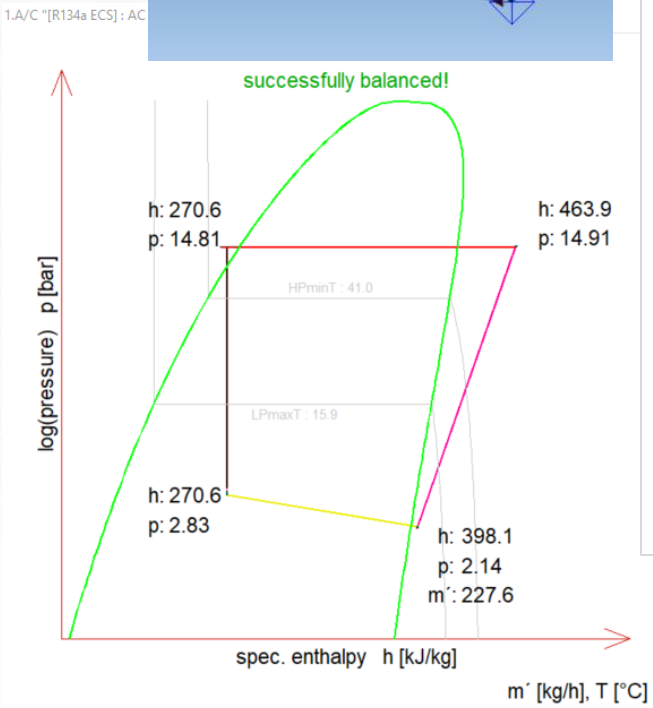


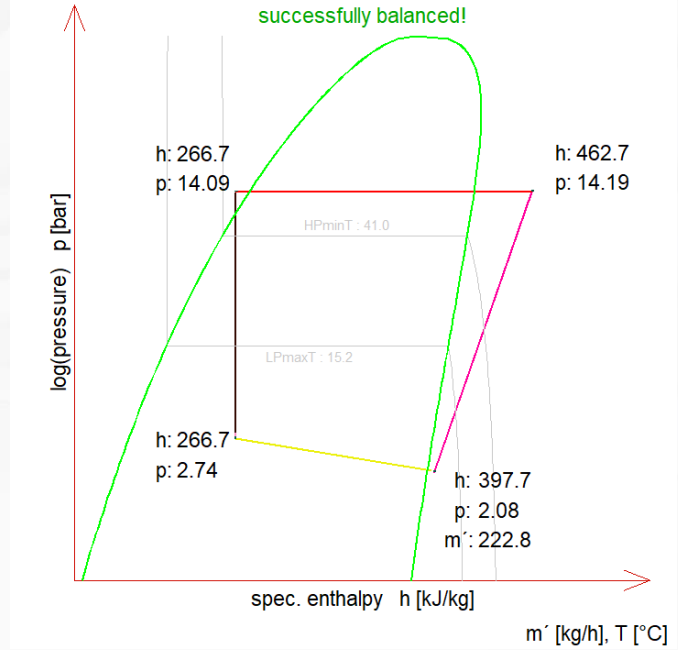
	System with radiator	System without radiator
Exit temperature IM [C]	52,3	46,8
Exit temperature IM [C]	46,6	46,9
Subcooling temperature IM [K]	2,43	5,98
Subcooling temperature IM [K]	8,14	5,8
Thermal output IM [kW]	5,73	6,02
Thermal output IM [kW]	6,49	6,11

Condenser 2

Condenser 1

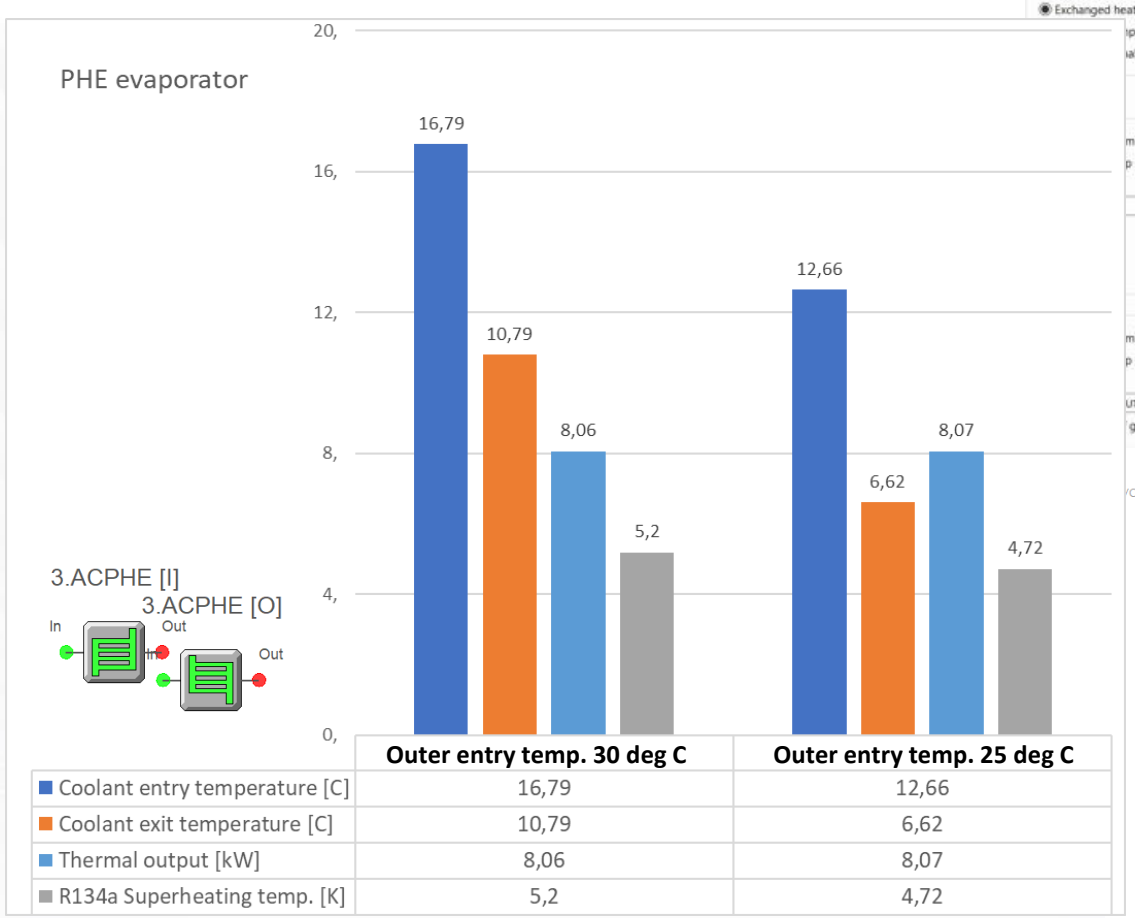




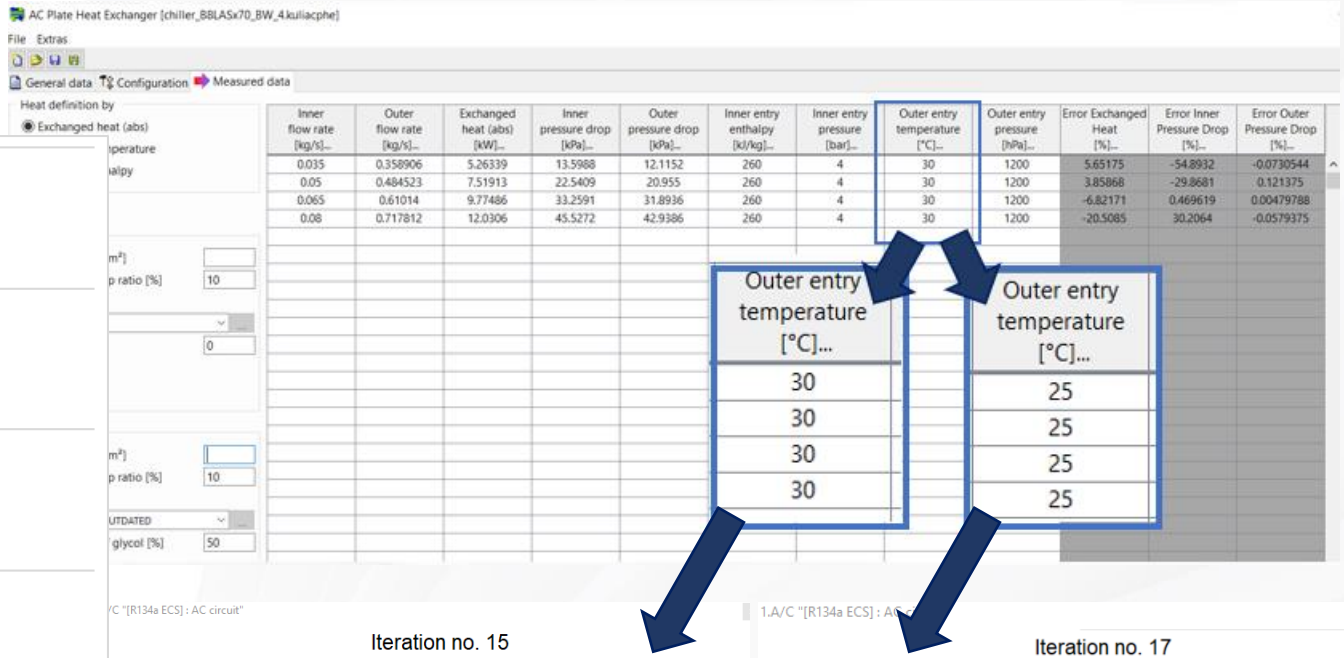


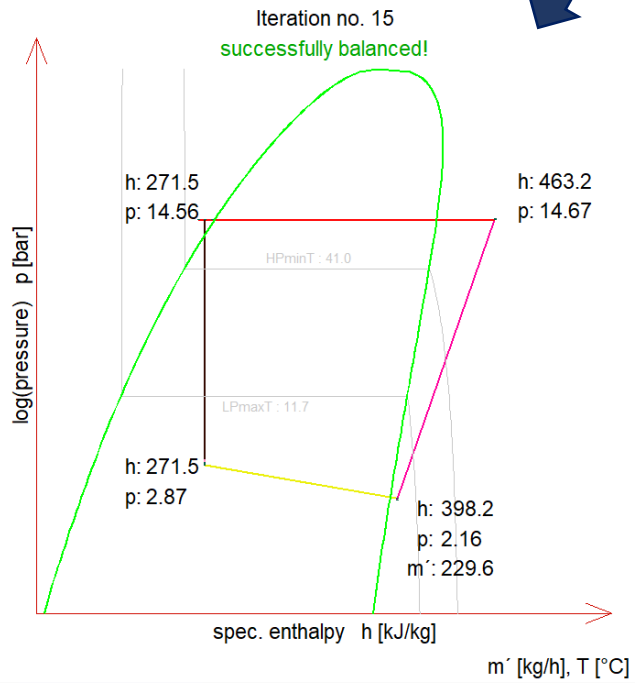
PHE evaporator	Superheating temperature	K	5,2	3,3
	Entry vapour quantity	-	0,37	0,35
	Thermal output	kW	8,06	8,01
	Entry temperature OM	°C	**16,8**	**15,9**
	Exit temperature OM	°C	**10,8**	**9,9**

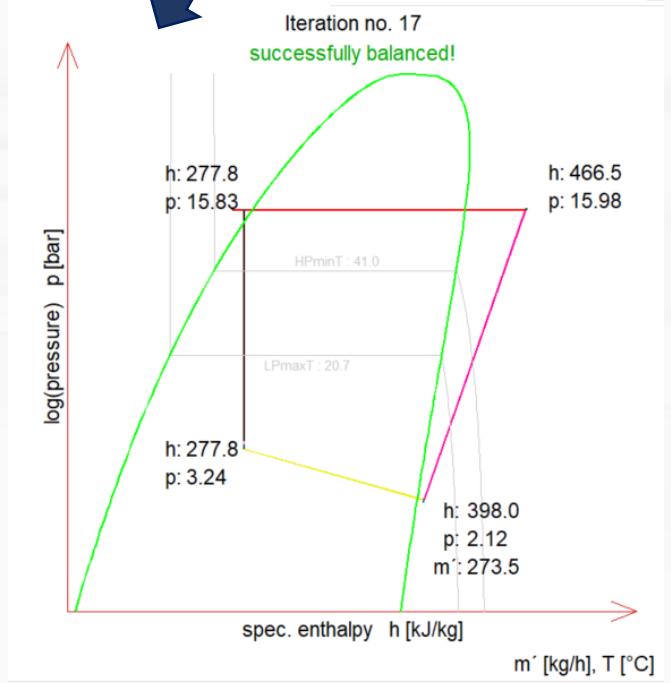
PHE evaporator



	Outer entry temp. 30 deg C	Outer entry temp. 25 deg C
Coolant entry temperature [C]	16,79	12,66
Coolant exit temperature [C]	10,79	6,62
Thermal output [kW]	8,06	8,07
R134a Superheating temp. [K]	5,2	4,72







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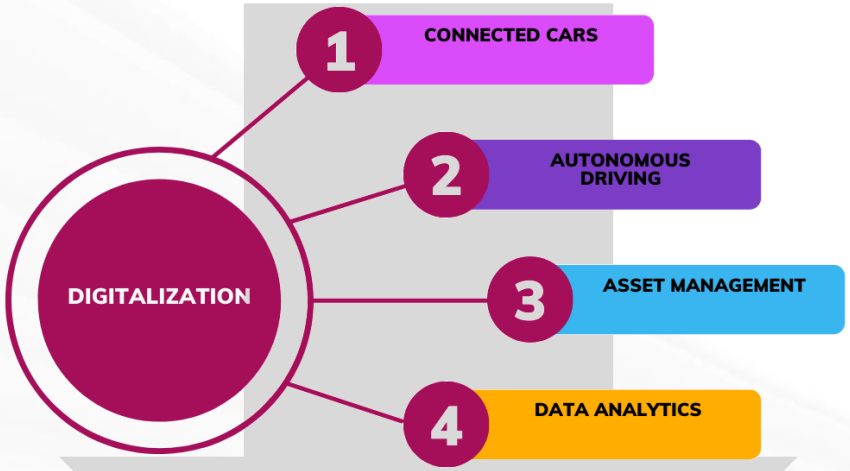
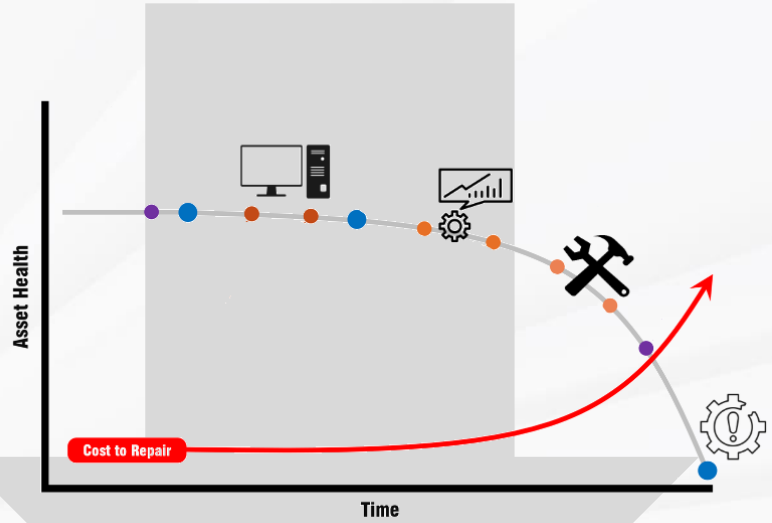
MATLAB & SIMULINK

Why KULI + Matlab & Simulink





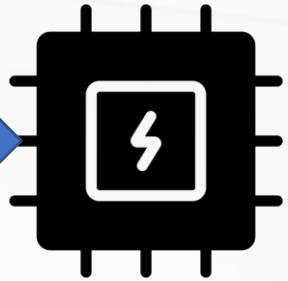
„Softwareization”

Complex requirements

Additional features

Matlab toolbox

Code generation



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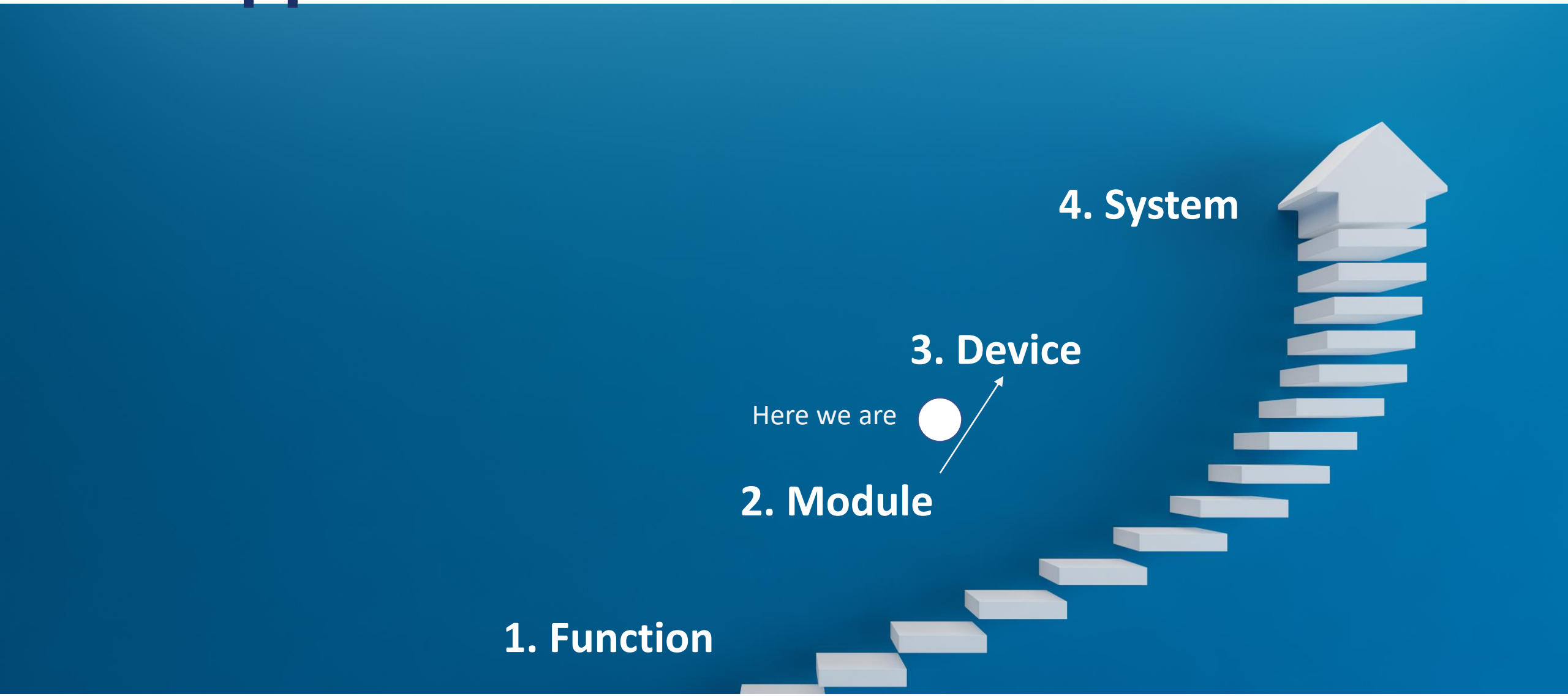
Our approach



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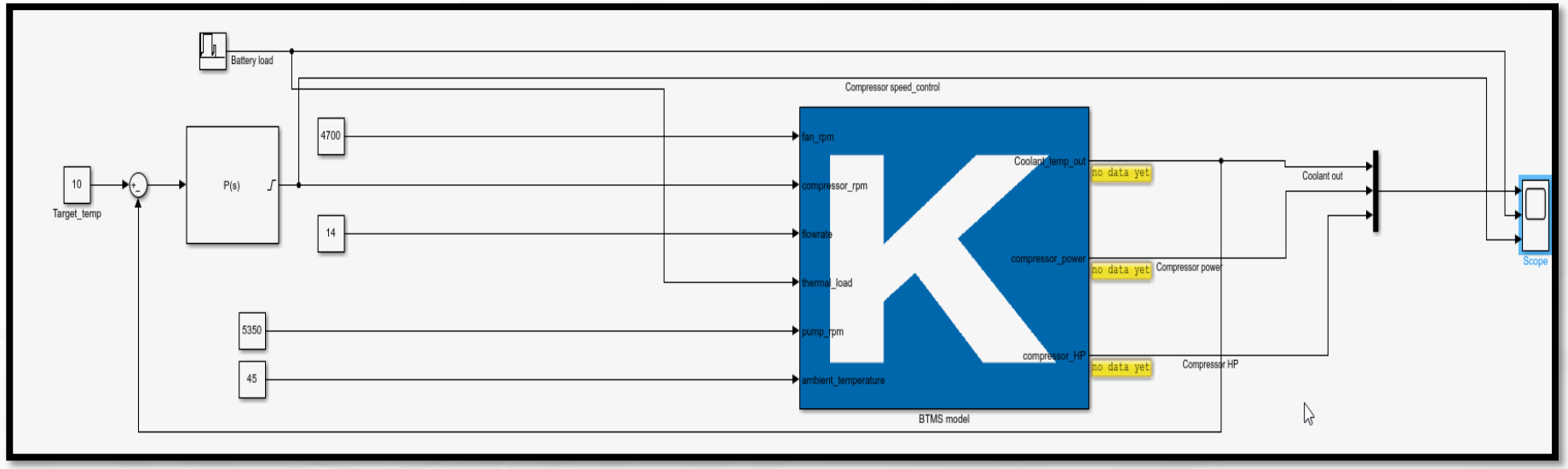
FMU & Simulink setup

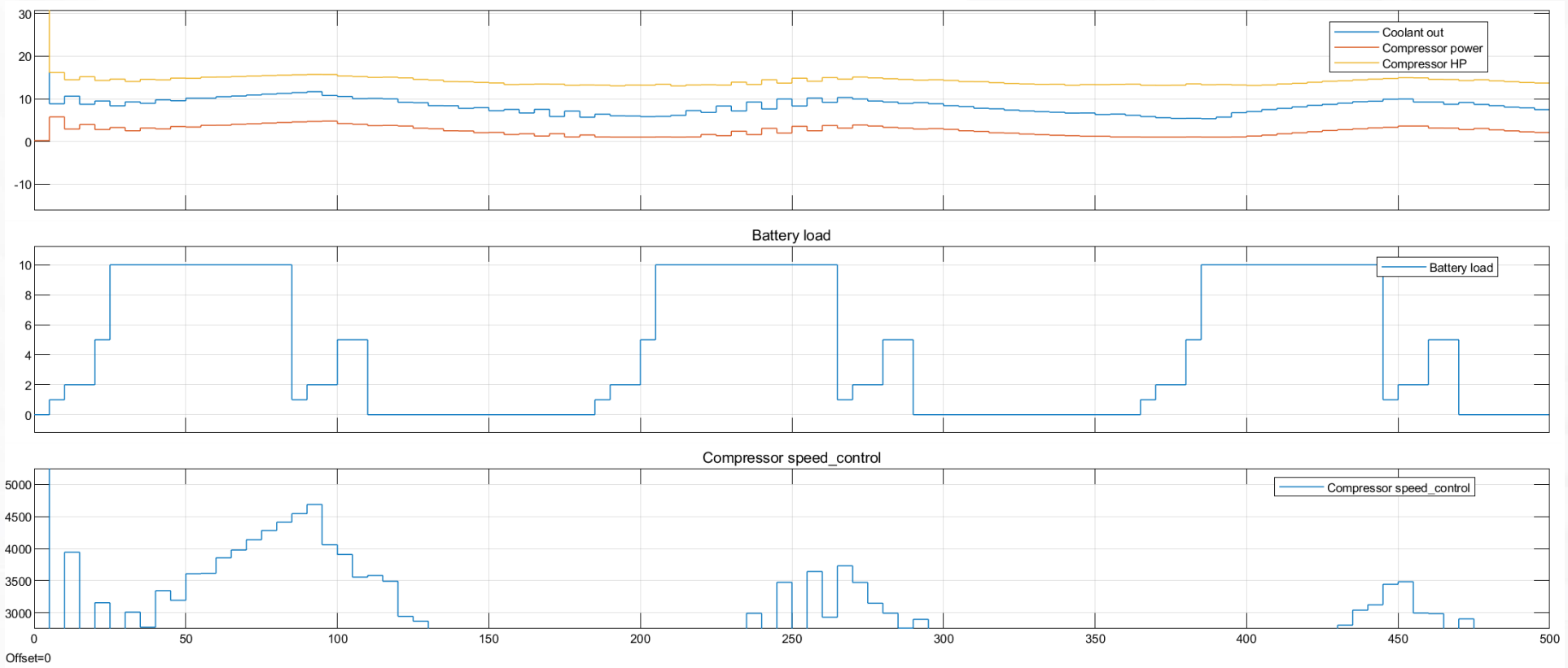
- Inputs
  - Fan RPM
  - Compressor RPM
  - Pump Flowrate
  - Thermal load
  - Ambient temperature



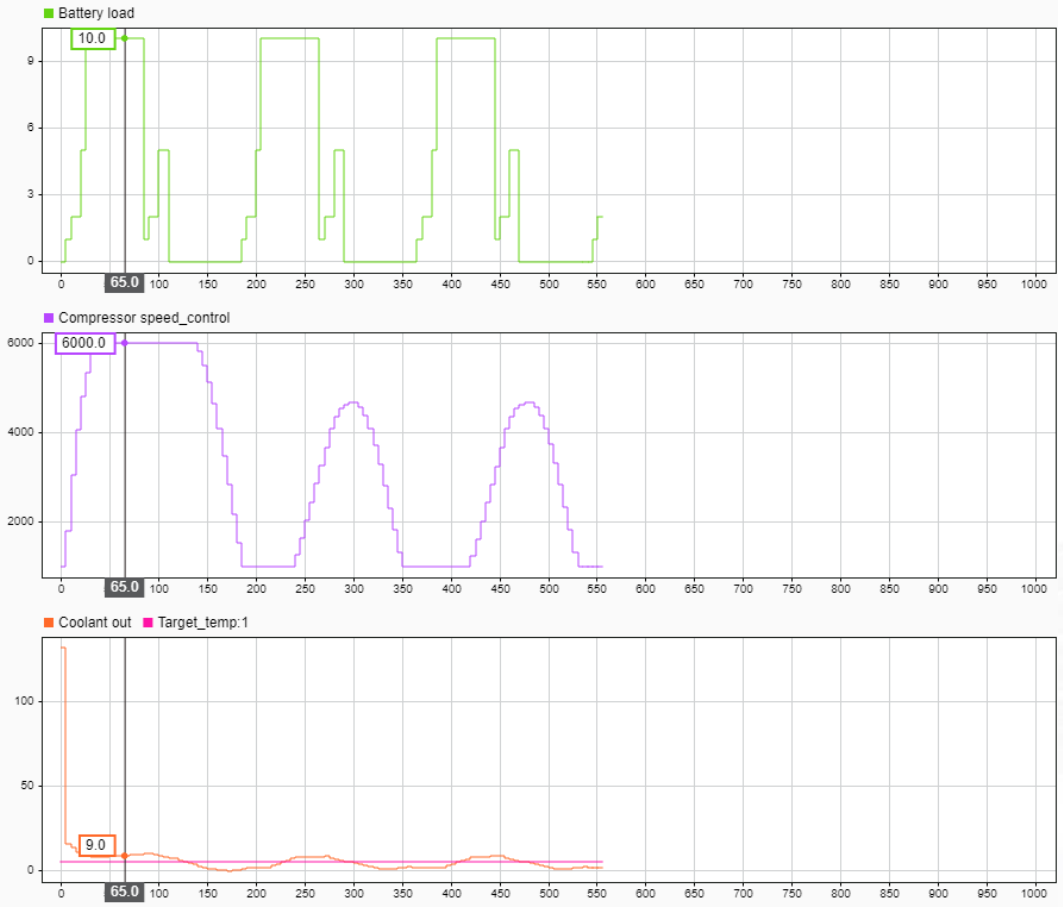
- Outputs
  - Coolant outlet temperaturę
  - Compressor power consumption
  - HP Pressure

Focus on Active cooling

Control example – P

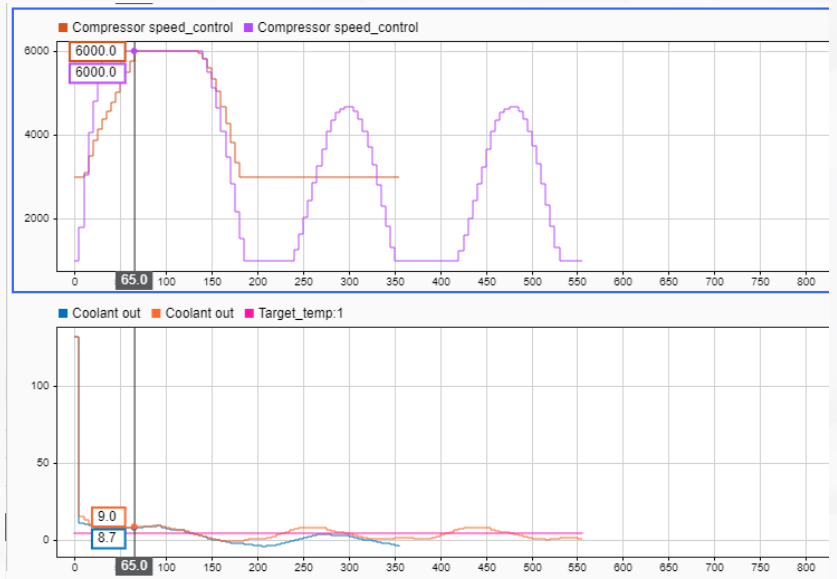


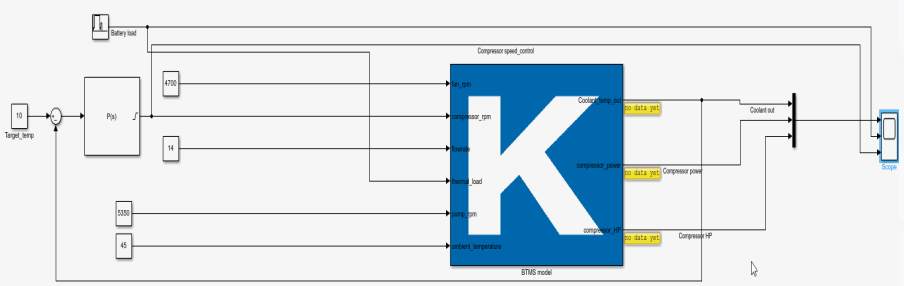
Control example – PI



Max dT = 3K

Parameter impact analysis





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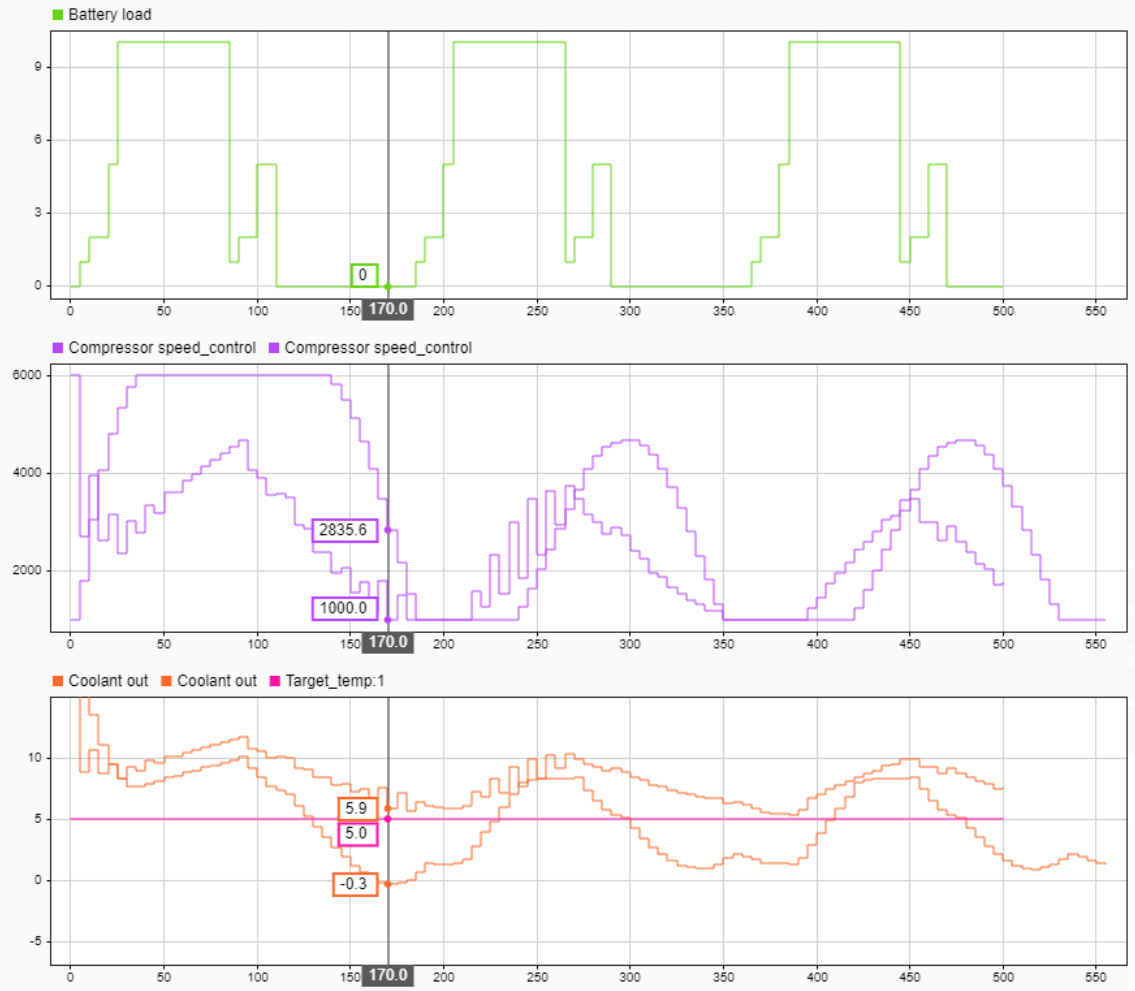
Comparison




```c
#include <stdlib.h>
#include <stdio.h>
#include <stdbool.h>

struct stats { int count; int sum; int sum_squares; };

void stats_update(struct stats * s, int x, bool reset) {
    if (s == NULL) return;
    if (reset) * s = (struct stats) { 0, 0, 0 };
    s->count += 1;
    s->sum += x;
    s->sum_squares += x * x;
}

double mean(int data[], size_t len) {
    struct stats s;
    for (int i = 0; i < len; ++i)
        stats_update(&s, data[i], i == 0);
    return ((double)s.sum) / ((double)s.count);
}

void main() {
    int data[] = { 1, 2, 3, 4, 5, 6 };
    printf("MEAN = %lf\n", mean(data, sizeof(data) / sizeof(data[0])));
}
```

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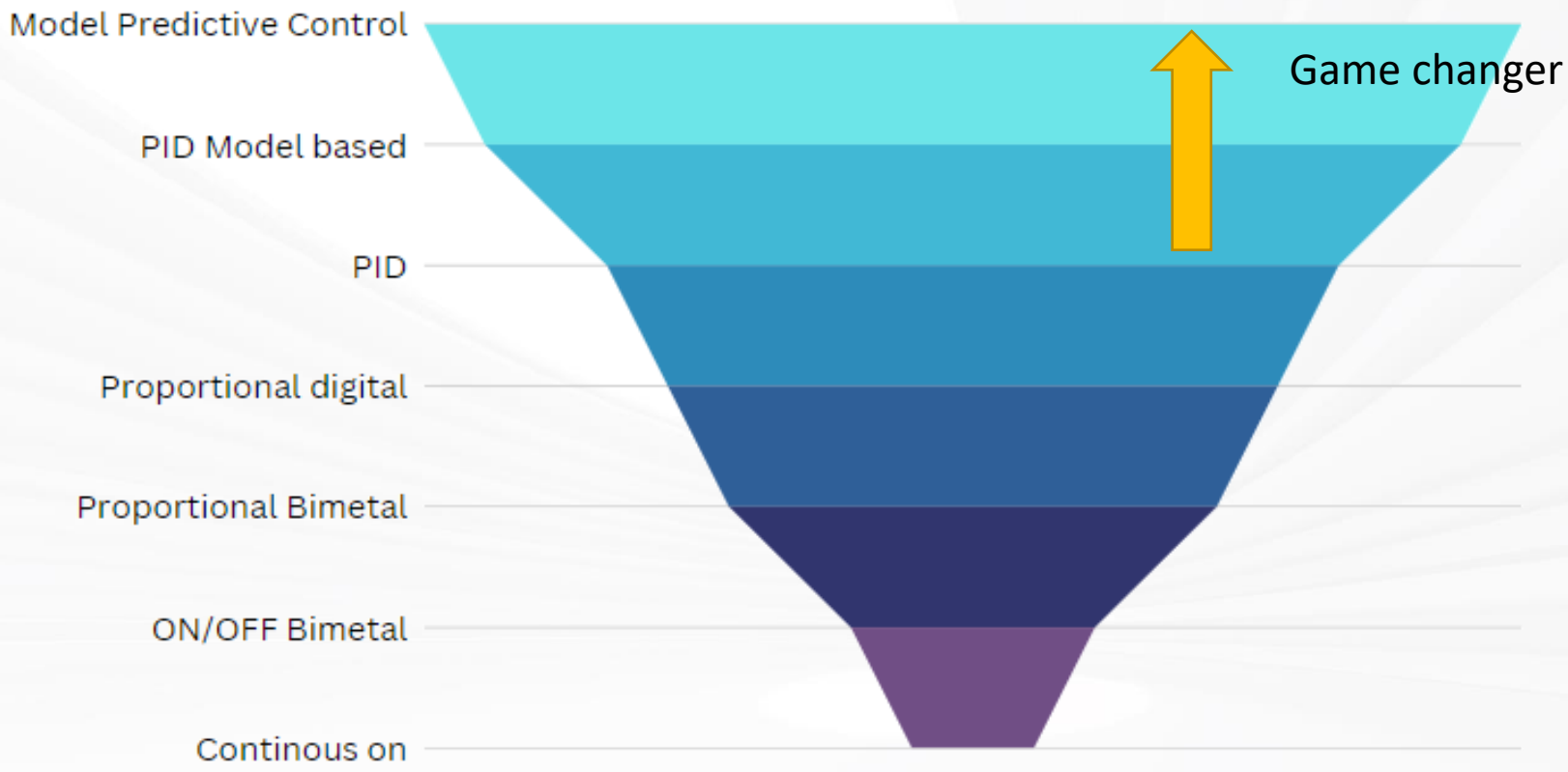
Controls evolution



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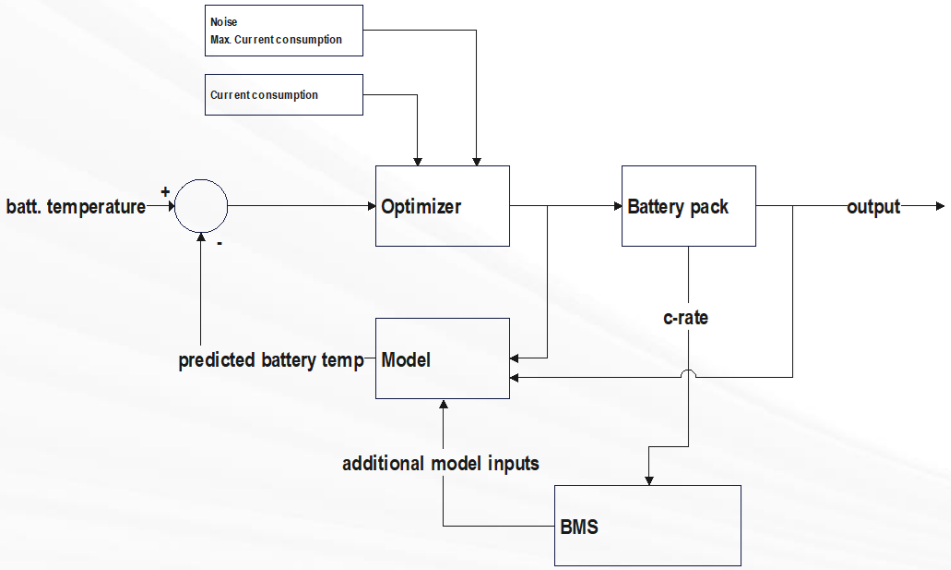
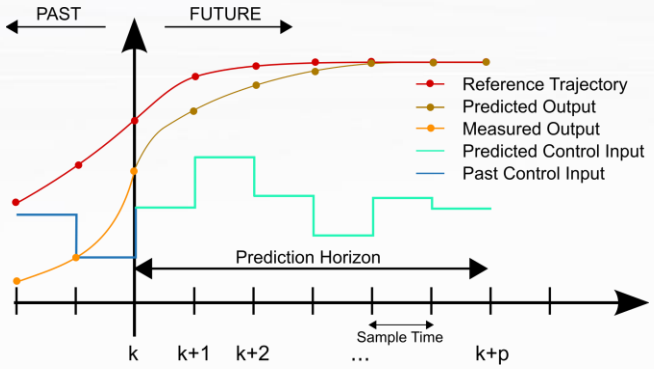
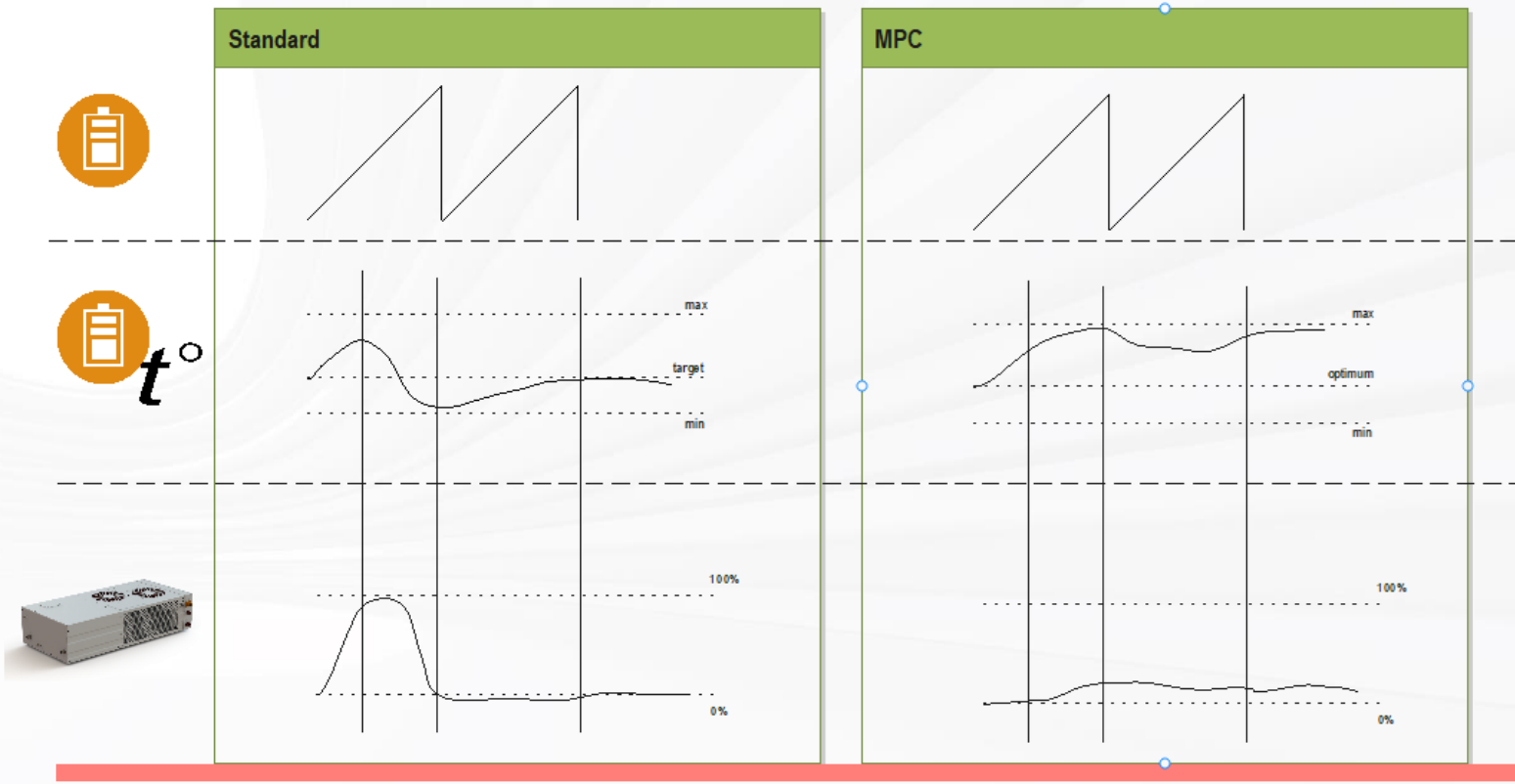
Future BTMS controls





Potential opeation comparison



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Short Summary & Thank you!