SIMBOTS

Paula de Miguel

SUSTAINABLE PLACES 2025

BDTA
BUILDING DIGITAL TWIN ASSOCIATION

AGENDA

1
WHY SIMBOTS?
Open, simplified, real-time oriented models for market equipment.

2
HYCOOLIT PROJECT
EU-funded project on hybrid cooling & digital twins for data centers.

3
MODELS
From lab prototypes (SimulationX) to full data center plant (EcosimPro).

4
CHALLENGES
Stability, solver issues, model size vs. execution time.

5
IMPACT & PROJECTION
Standardization, interoperability with BIM, future SIMBOTs roadmap.

6
REAL TIME DEMO
Live example: from simulation to real-time supervision.

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WHY SIMBOTS?

DEFINITION

Open semantic expression (or library component) of the mathematical model of a market equipment.

BASED ON

Standard or basic components, mathematical functions, fluids, and ports.

ORIENTED TO

Real-time execution and aligned with the manufacturer's performance description.

ORIGIN OF CONCEPT

- The concept was first published in the SPHERE project (EU), applied to digital twins in construction.
- It was used in advanced control, embedded simulation, and software-in-the-loop.
- It was demonstrated with human models, complex fluid mixtures, and commissioning applications.

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NEED AND MOTIVATION

Simulation is already a key tool in advanced engineering (aerospace, nuclear, oil & gas...), but in construction its use is often limited by cost and time constraints.

SIMBOTs address this challenge

And enables use throughout the **entire lifecycle**.

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KEY FEATURES

- SIMBOTs bring real-time simulation to data centers.
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- Relying on open standards and BIM interoperability.

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KEY FEATURES

Simplification to maintain mathematical viability.

Minimal and simple configuration parameters → usable even by non-experts.

Designed for fast convergence and very low integration times.

Ability to detect operation or maintenance failures.

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KEY FEATURES

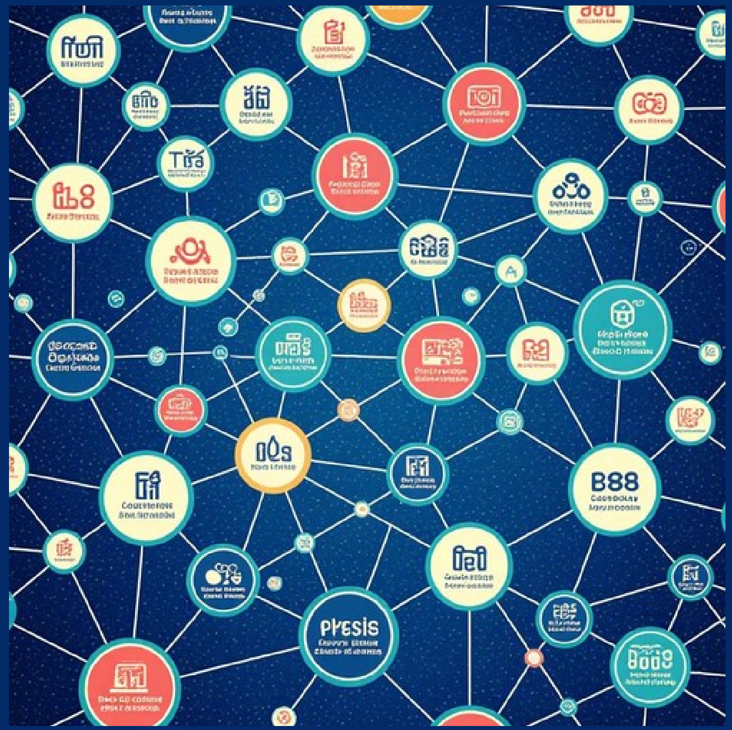
They respect the manufacturer's confidentiality.

Joint effort with software developers

STANDARDIZATION AND INTEROPERABILITY

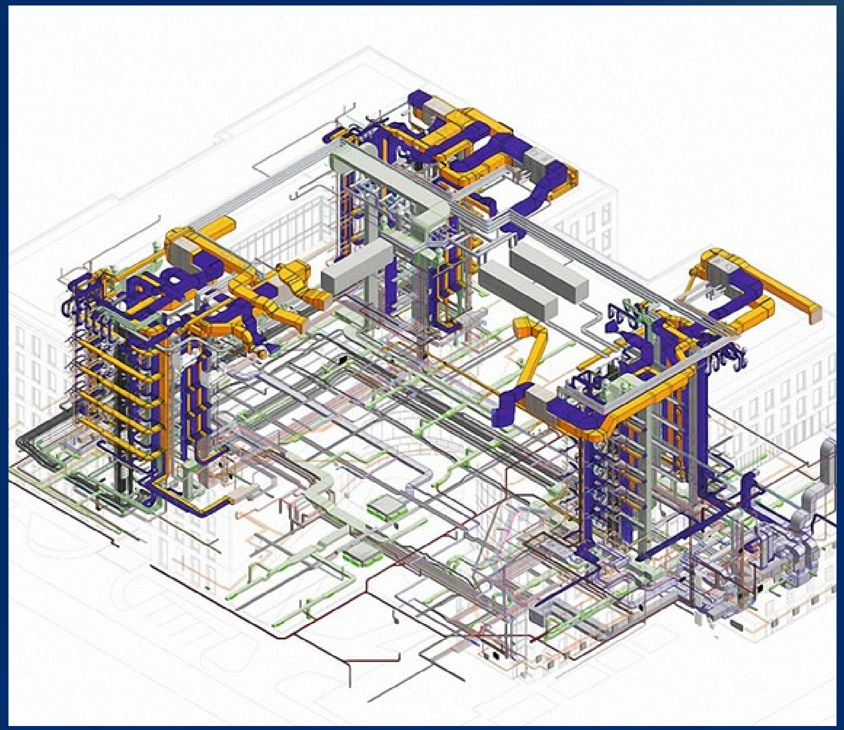
OPEN REPRESENTATION

A common and open representation available for all software vendors, ensuring transparency and consistency across platforms.



O4BSIM ONTOLOGY & KNOWLEDGE GRAPH

A shared market functional base that enables standardized models and facilitates seamless integration.



BIM/IFC INTEROPERABILITY

From geometric models to functional models, enabling bidirectional communication between simulation and geometry.

STANDARDIZATION AND INTEROPERABILITY

SIMBOT CODE

```
/*------------------------------------------------------------------------------------------
 LIBRARY:
HVAC FILE:
Fan_Centrifugo_Tejado_SP AUTHOR: P
VL COMPANY:
EAI DESCRIPTION: Centrifugos de Tejado S&P _CTB4_400_160
CREATION DATE: 17/06/2020
-----------------------------------------------------------------------------------------*/


USE MATH USE PORTS_LIB VERSION "1.0" USE THERMO_TABLE_INTERP
------------------------------------------------------------------------------------------

COMPONENT FanCTB4 IS_A AbsFan "Fan S&P CT4_400_160 VENTILADORES CENTRIFUGOS TEJADO - RPM
FIJA 1425"

PORTS DATA DECLS TABLE_1D Qv_vs_dP = \ {{0,24.6,70.6,102.5,124.8,141.5},
                                        {440,400,300,200,100,0}}
                                        UNITS u_m3_h

"Table of volumetric flow vs dP_Pa"

TABLE_1D Power_vs_Qv = \ {{0,100,200,300,400},
                          {24.0,25.4,26.0,26.0,25.4}}
                          UNITS u_W

"Table of Power vs Qv"
REAL eta UNITS no_units

"Fan Efficiency"
CONST REAL tao = 1e-1 INIT -- m = m_o DISCRETE CONTINUOUS --
Fan characteristics equations Qv_m3_h = linearInterp1D( Qv_vs_dP, dP)
Power = linearInterp1D( Power_vs_Qv, Qv_m3_h) --
eta = idealPow(Comb_Gases,Real_Fluid_Table, f2.P,f2.T+273.15,f2.rho,f2.h, m, f1.Cp, max(10,
f1.P),f1.T+273.15,f1.rho,f1.h, vsound) / Power eta = m*dP/f1.rho / Power --
Flow made explicit m' = (min(f1.rho*Qv, f1.A*f1.Gcrit) - m) / tao

-- Artificio para introducir un delay; Gcrit está en el puerto

END COMPONENT
```

ONTOLOGY & KNOWLEDGE GRAPH

```
/*--------------------------------------
LIBRARY:
HVAC FILE:
VL COMPANY:
EAI DESCRIPTION:
CREATION
------------------------*/


LIBRARIES
------------------------
COMPONENTS TO INHERIT

PORTS

TABLES

--------------------------------
ECUATIONS

--------------------------------

END COMPONENT
```

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HYCOOLIT

TARGET

- Innovative hybrid cooling systems, adsorption chillers,
- Digital management methods
- Real-time simulation.

European Horizon Europe project, GA No. 101138623, with a duration of 36 months starting in December 2023.

PARTNERS

POLITECNICO MILANO 1863

POLITECNICO DE MILAN- CNR

Sorption Technologies

SORPTION TECNOLOGIES

EIM

EUROPEAN INNOVATION MARKETPLACE ASBL

Italian National Research Council

CNR

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BDTA

comet Global Innovation

COMET

IDP
A BUREAU VERITAS COMPANY

IDP

iMP
Fraunhofer-Pupin JPO

INSTITUT MIHAJLO PUPIN

R2M
RESEARCH TO MARKET SOLUTION

R2M

KEY CONNEXIONS

SRI PLATFORM

HPC4AI

EcosimPro
Modelling and Simulation Software

BSC
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

CEN442 WG9/WG12:

Standardization process for digital twins in Europe.

REHVA

DATIA PROJECT

tecnalia
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

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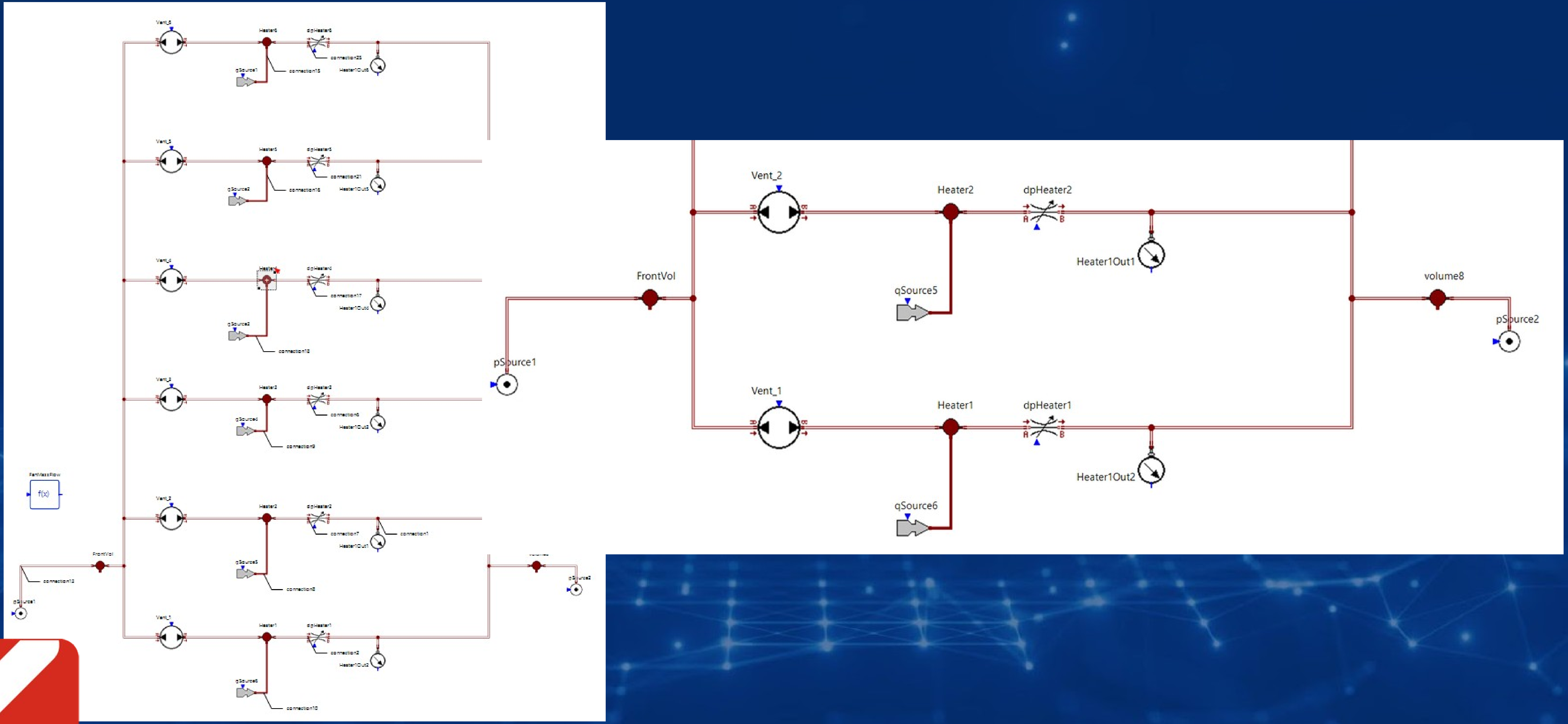
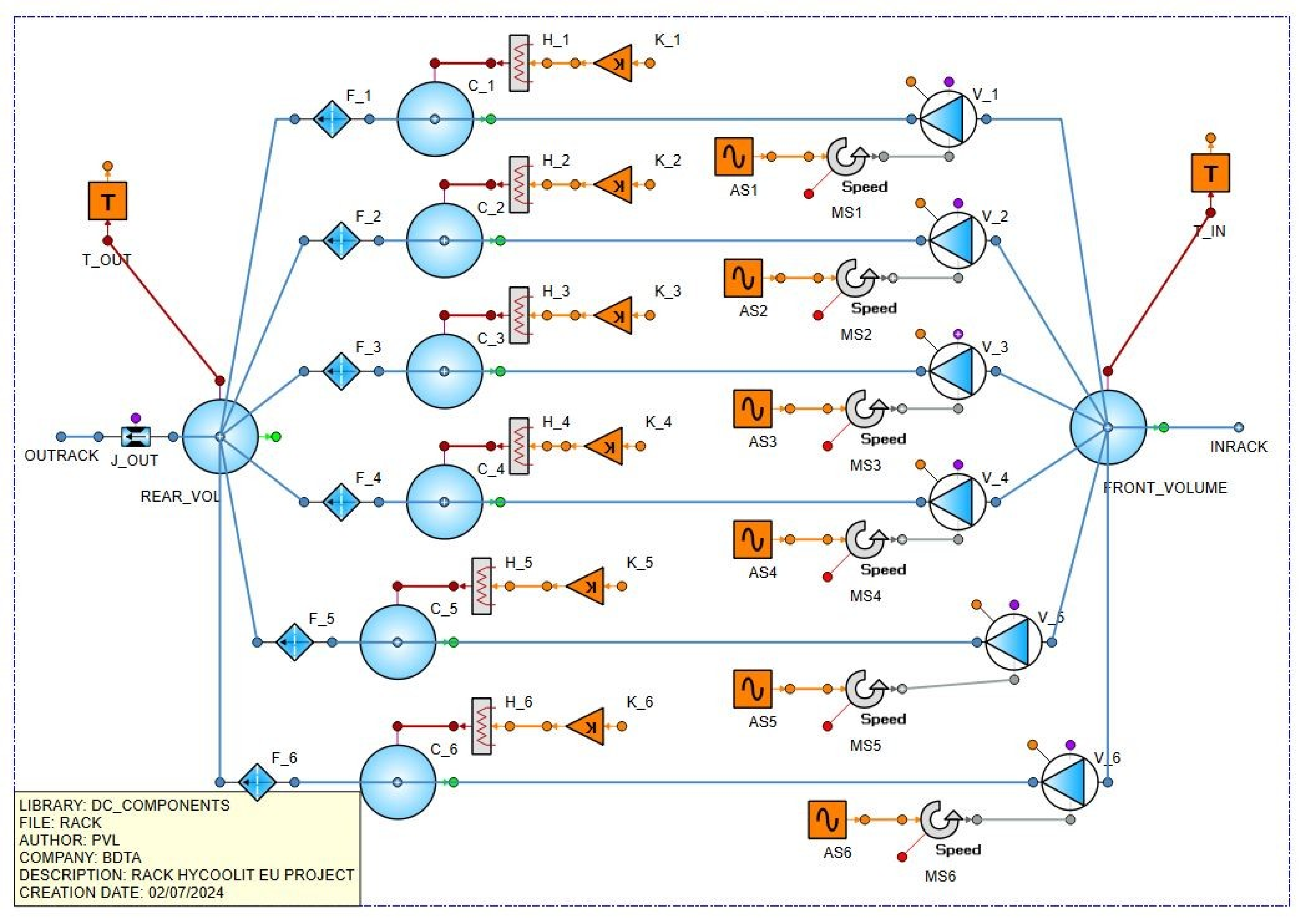
RACK


Vent_2
Heater2
dpHeater2
Heater1Out1
FrontVol
qSource5
volume8
pSource2
pSource1
Vent_1
Heater1
dpHeater1
Heater1Out2
qSource6

3

RACK



EcosimPro
Modelling and Simulation Software

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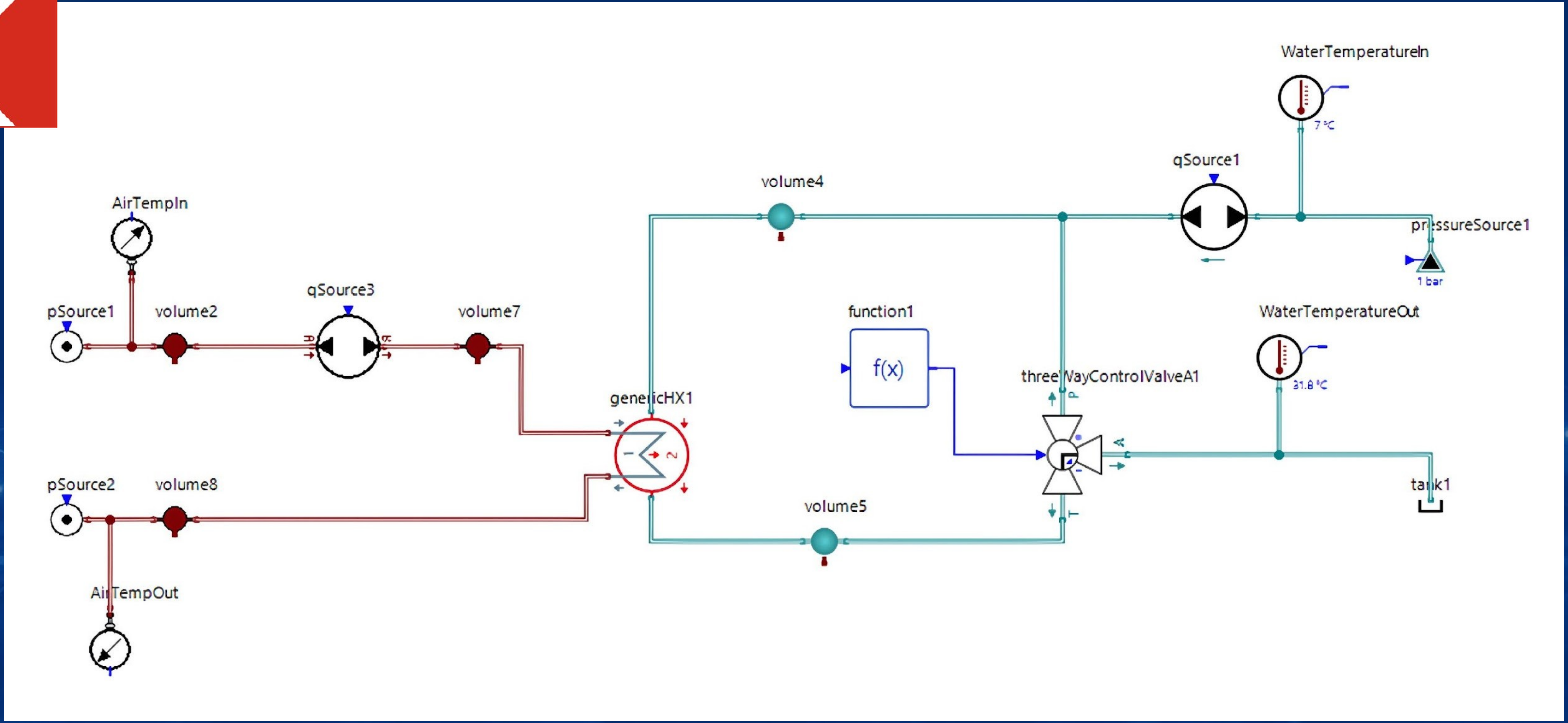
INROWCOOLER



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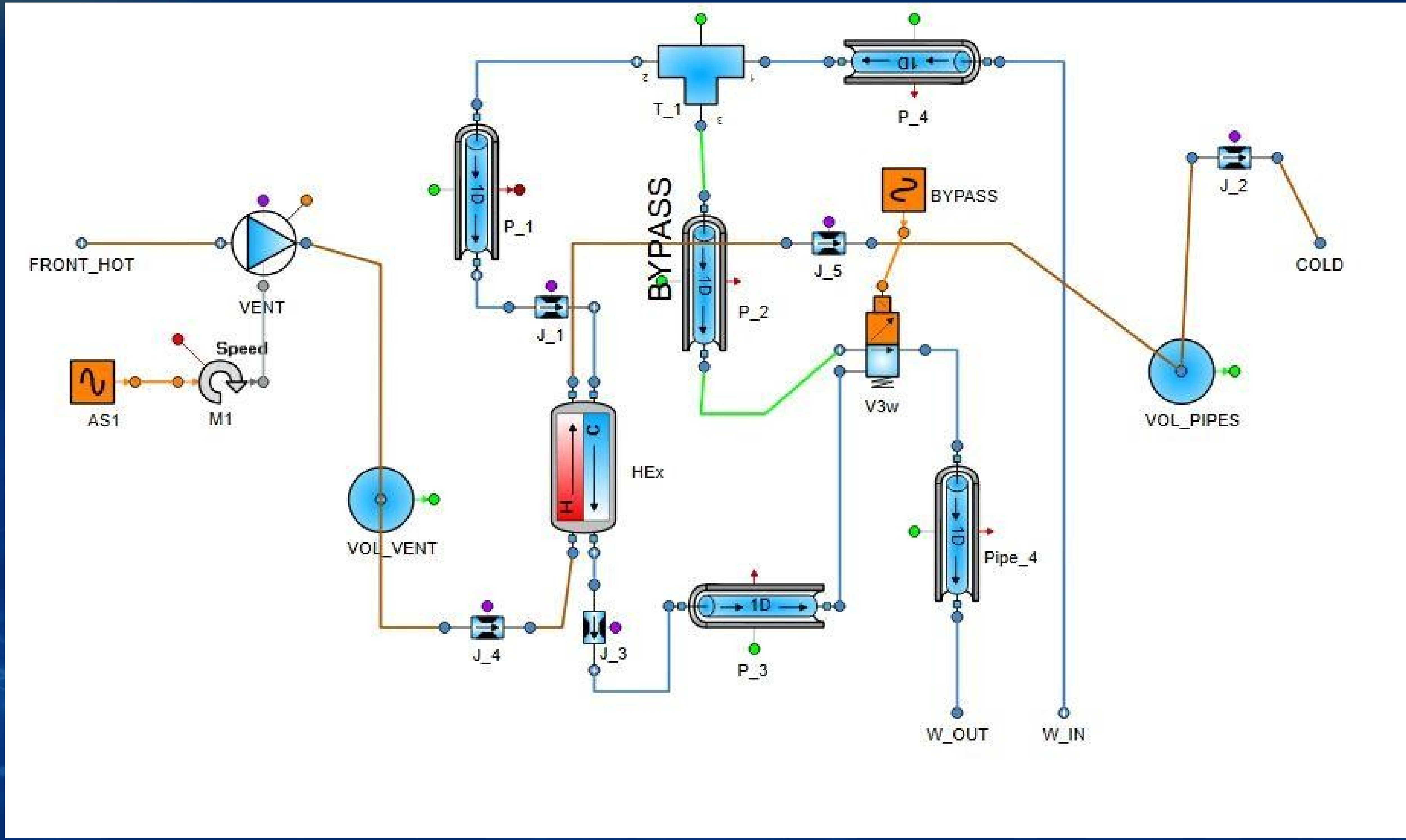
INROWCOOLER



EcosimPro
Modelling and Simulation Software

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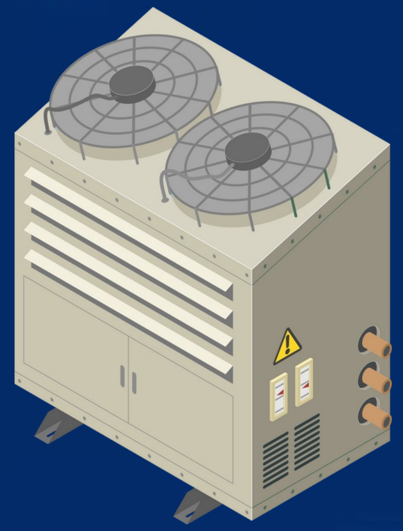
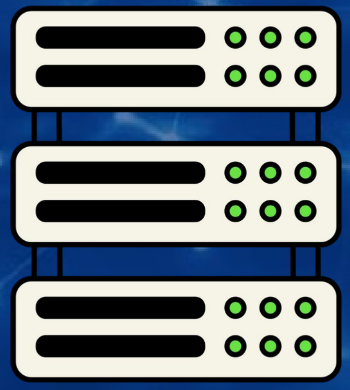
TEST 1

TARGET

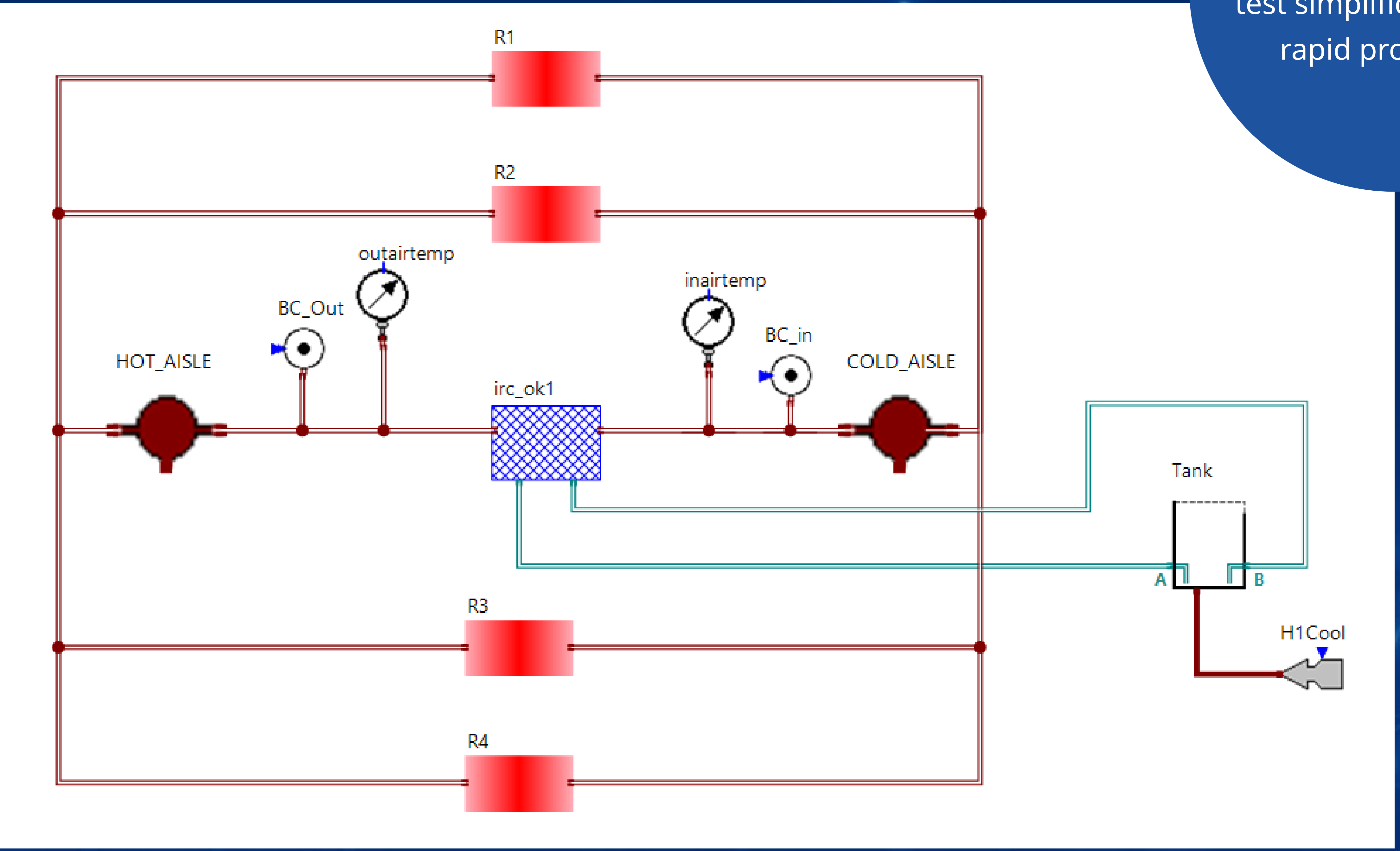
Validate stability, test simplifications, and rapid prototypes

INROWCOOLERS





RACKS



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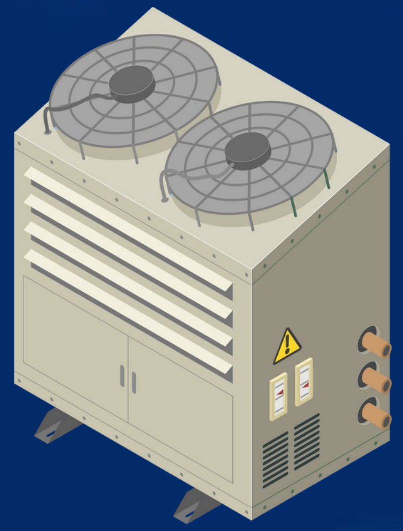
TEST 1

INROWCOOLERS



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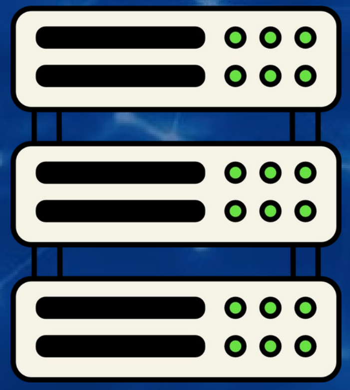

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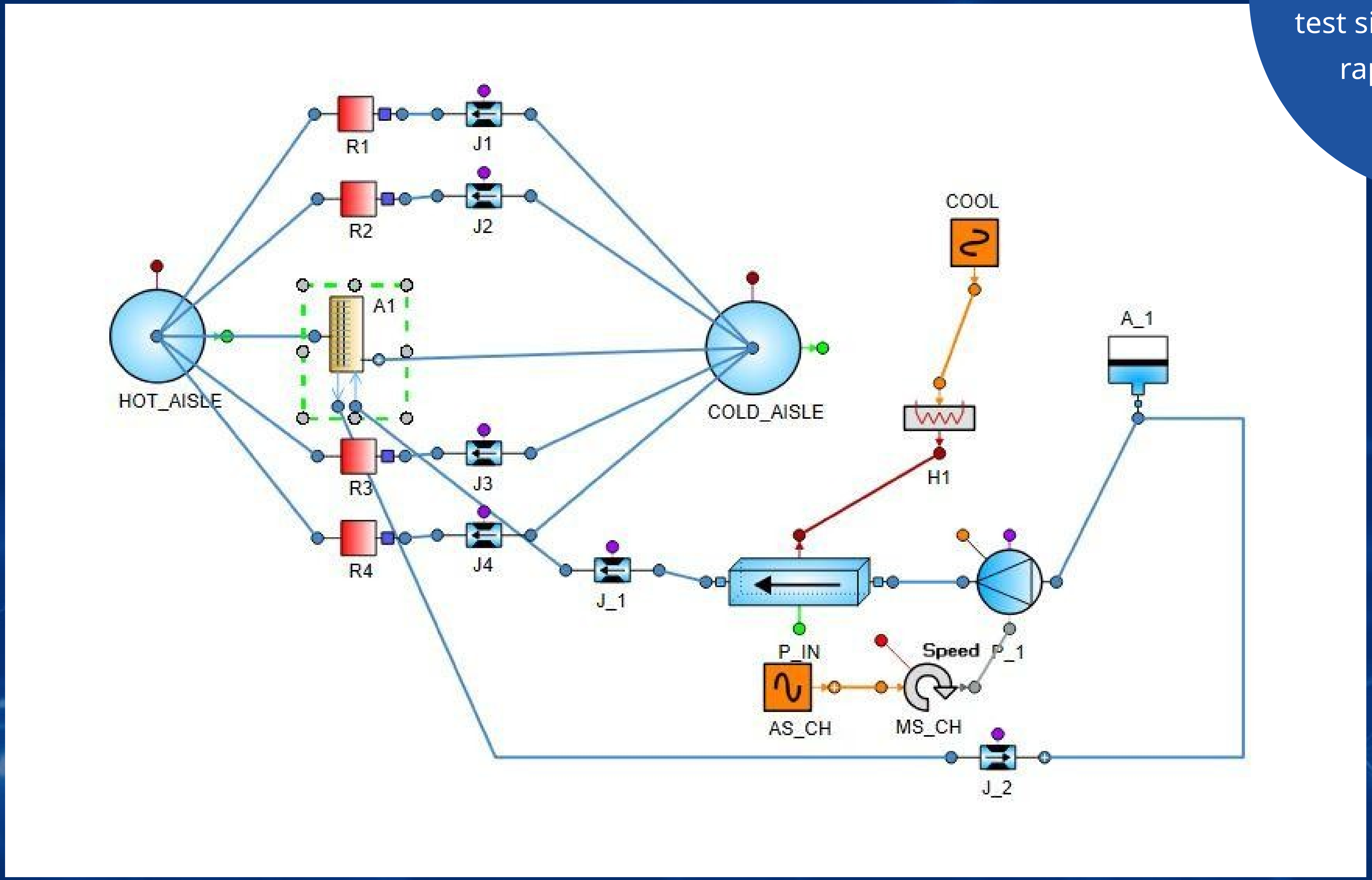


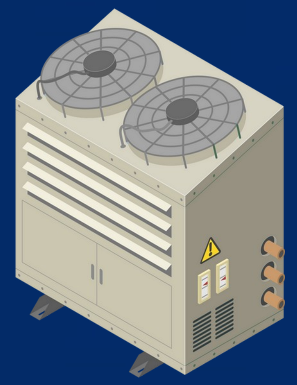
TARGET

Validate stability, test simplifications, and rapid prototypes

3

TEST 2

INROWCOOLERS



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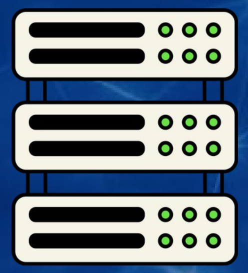
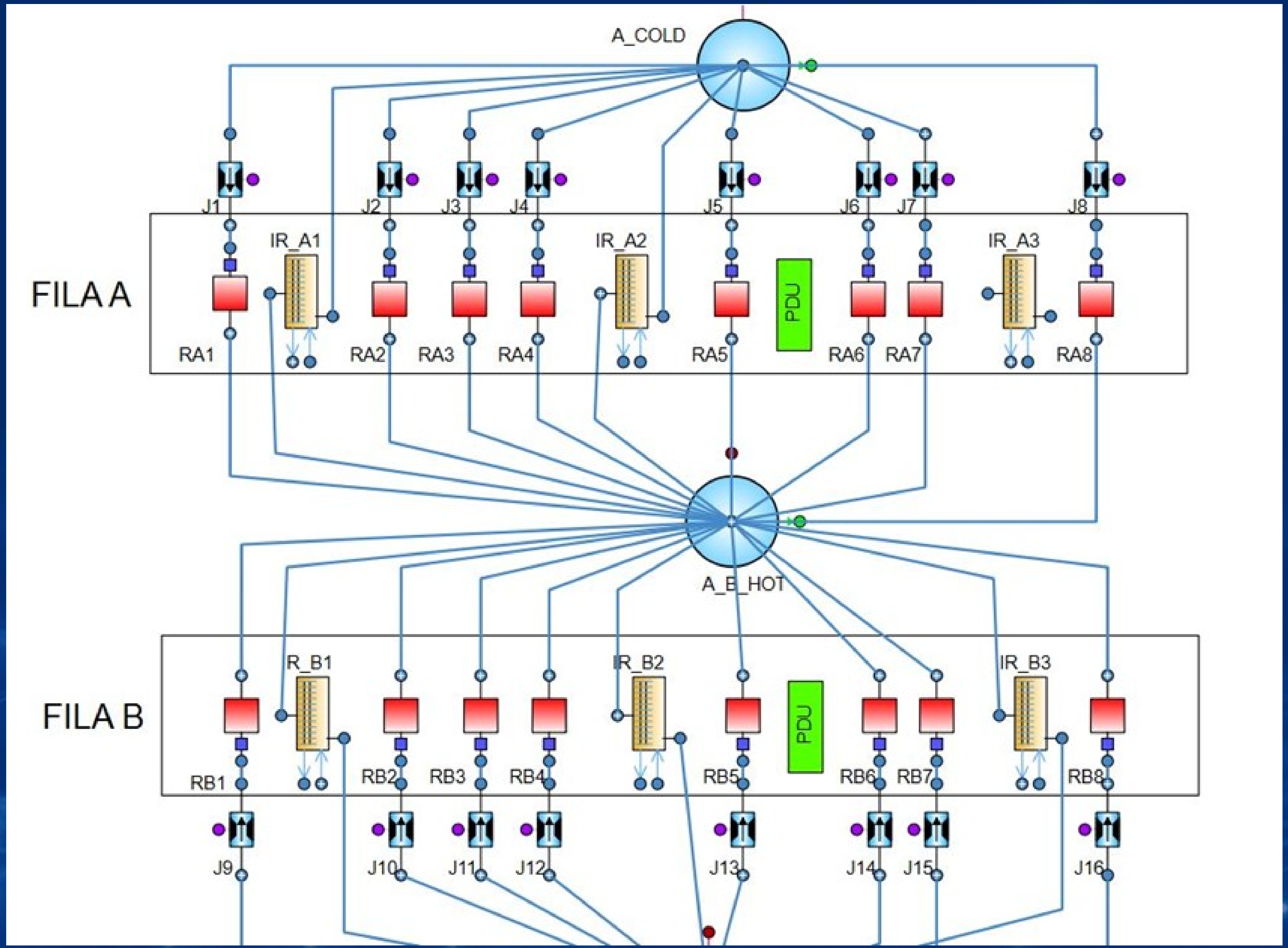


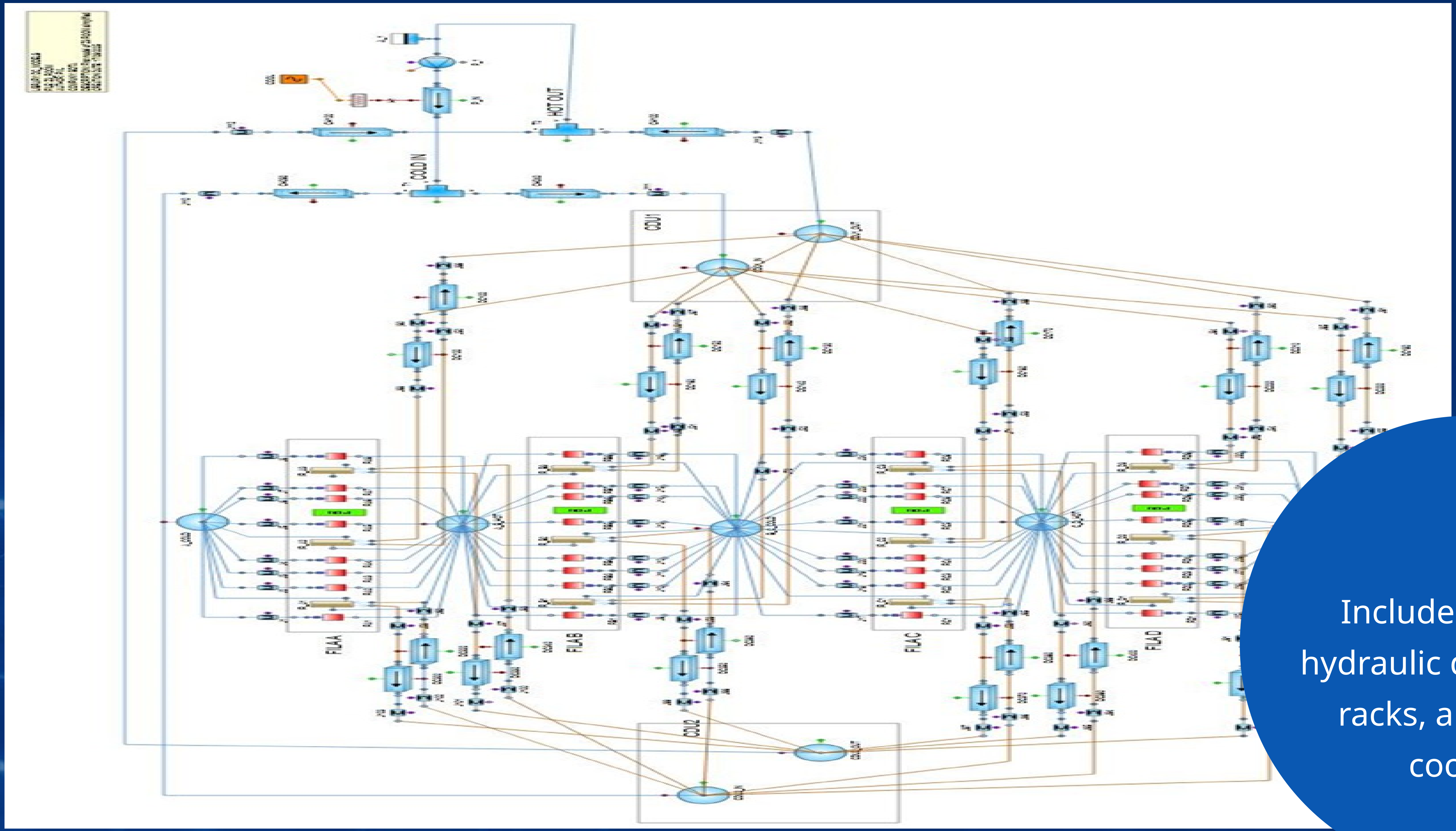
RACKS



Validate stability, test simplifications, and rapid prototypes

3

COMPLETE MODEL



Includes chillers, hydraulic distribution, racks, and in-row coolers.

4

CHALLENGES

MODEL DEVELOPMENT

1 Building functional models with the right level of simplification.

MATHEMATICAL PARTITIONING

2 Defining efficient partitions to reduce stiffness and speed up execution.

CONVERGENCE & SOLVE

3 Ensuring numerical stability while balancing accuracy and speed.

RESULTS ANALYSIS & CONSISTENCY

4 Validating outputs and checking coherence with physical reality.

REAL-TIME SIMULATION INTEGRATION

5 Connecting with BMS/DCMS and other systems under real-time constraints.

4

CHALLENGES

PROPERTY TABLES

Contain constants and general parameters defined by developers.

Must be consistent, smooth, and validated to avoid solver instabilities.

FLUIDS DEFINITION

Fluids must be correctly defined (INCOMP, HEOS, etc.).

Thermodynamic properties must match the prop tables to guarantee reliable results.

BASIC LIBRARIES

Each developer provides basic components (tubes, valves, pumps).

Serve as the foundation for higher-level SIMBOTs.

CHALLENGES

ABSTRACT COMPONENTS

Adaptable to different prop tables depending on the equipment.

Allow flexibility without breaking the general methodology.

WORKSPACE INTEGRATION

PROPERTY TABLES

FLUIDS DEFINITIO N

BASIC LIBRARIES

ABSTRACT COMPONENTS

5

IMPACT AND PROJECTION

SIMPLE BUT FUNCTIONAL

Reduce unnecessary complexity, keeping only what is essential for stability and reliability.

REDUCED COSTS AND TIME

Cut implementation times by up to one order of magnitude.

FAST AND STABLE REAL-TIME INTEGRATION

Ready to operate within BMS/DCMS sampling limits.

5

IMPACT AND PROJECTION

COMMON AND OPEN METHOD

Standardization -> Replicable across simulation software

INTEROPERABILITY WITH BIM AND OTHER DOMAINS

Direct integration with IFC models and ontologies (O4BSIM, BOT).

SUPPORT FOR AI MONITORING

Detect operational faults or degradation, reinforcing operation tasks.

THANK YOU

for your

atention

Paula de Miguel

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DEMO

VIDEOS

SOLVER
AND CONVERGENCE ISSUES

BDF

Implicit solver, robust for stiff systems (common with incompressible fluids).

Stable
Computationally heavier

↓

Slower execution

Suitable for long-term stability and accurate results in hydraulic systems.

MEBDF

Extension of BDF, better handling of very stiff or highly nonlinear systems.

Improves convergence in problems with discontinuities

↓

Pressure drops in HX

Often more stable than BDF, but at higher computational cost.

CVODE

General-purpose solver with both implicit (BDF) and explicit (Adams) modes.

Flexible: can switch depending on system stiffness

More efficient for mixed problems (combination of hydraulic and thermal dynamics).

4

FLUIDS

Several instabilities appeared with incompressible fluids in SimulationX: the INCOMP approach improved speed but was highly sensitive to boundary conditions and pressure drop data. Stability was achieved by smoothing tables and limiting abrupt variations.

INCOMP fluids → efficient but numerically sensitive.

Pressure drop tables must be smooth and physically consistent.

Stability improved by limiting pressure losses (≤ 20 Pa on air side)