VIRTUAL CONTROL COMMISSIONING FOR A LARGE CRITICAL VENTILATION SYSTEM: THE CMS CAVERN USE CASE

W.Booth, E.Blanco, B.Bradu, S.Sourisseau CERN

BE Beams Department

Monday, 09 October 2017

Goal


Performance problems?
9 YEARS OF RUN
Safety issues?
Availability?
Obsolescence?

Goal

- LHC has been operational since 2008, no major improvement has been done for 9 years on ATLAS and CMS HVAC plants:

- Decision to upgrade the ATLAS and CMS HVAC Plants control systems during LHC Long Shutdown 2 (LS2) in 2019 in order to:
  - Solve obsolescence problem: current SCADA (Wizcon) is not supported anymore; PLCs are at end-of-life
  - Migrate the control to the CERN UNICOS framework
  - Take into account the experience gained during the LHC operation and improve the control & availability when necessary (e.g. lot of manual actions are currently necessary)

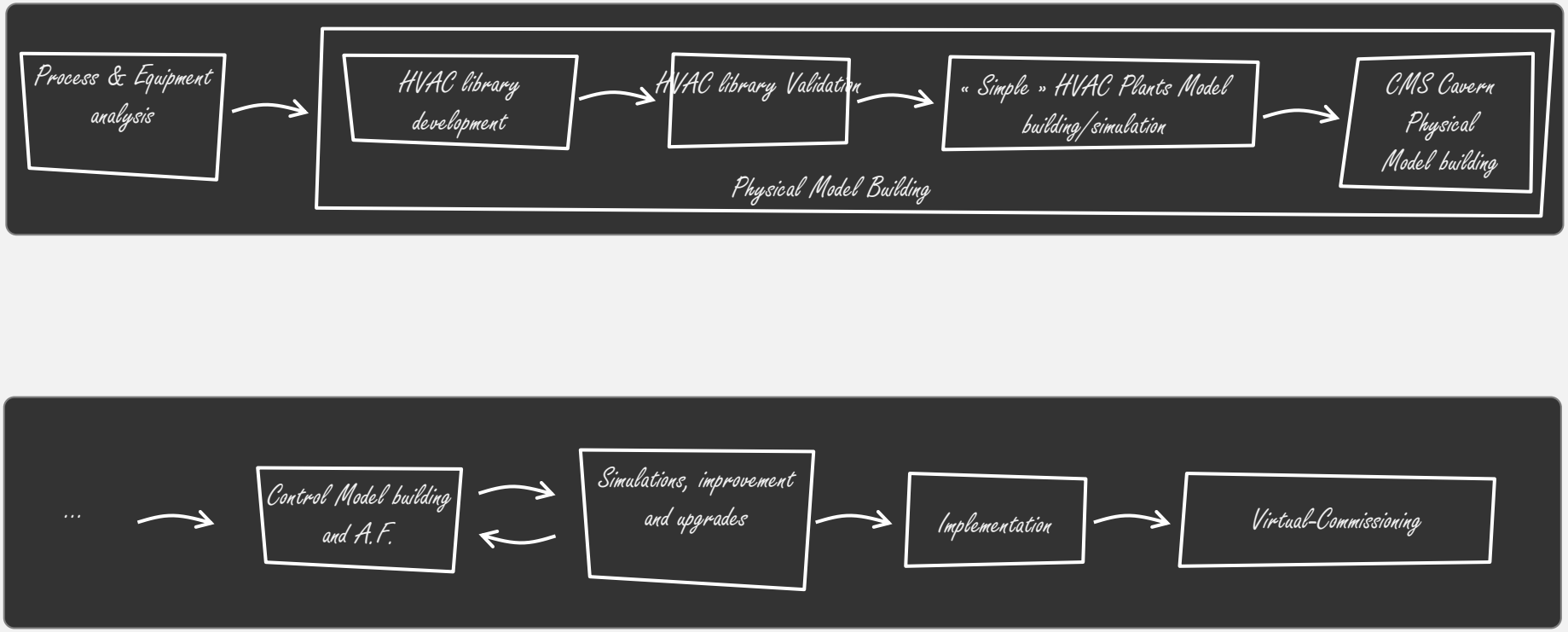
Constraints

- CMS Ventilation plant is running 24h/7d
- Critical during LHC run:
  - Maintain stable under-pressure for safe operation
- Critical immediately after run : purge before interventions
- Critical during interventions (technical stops) : air flow
- Limited intervention time (<3 months)
- Q: how best to ensure smooth upgrade ?
  - Virtual Commissioning

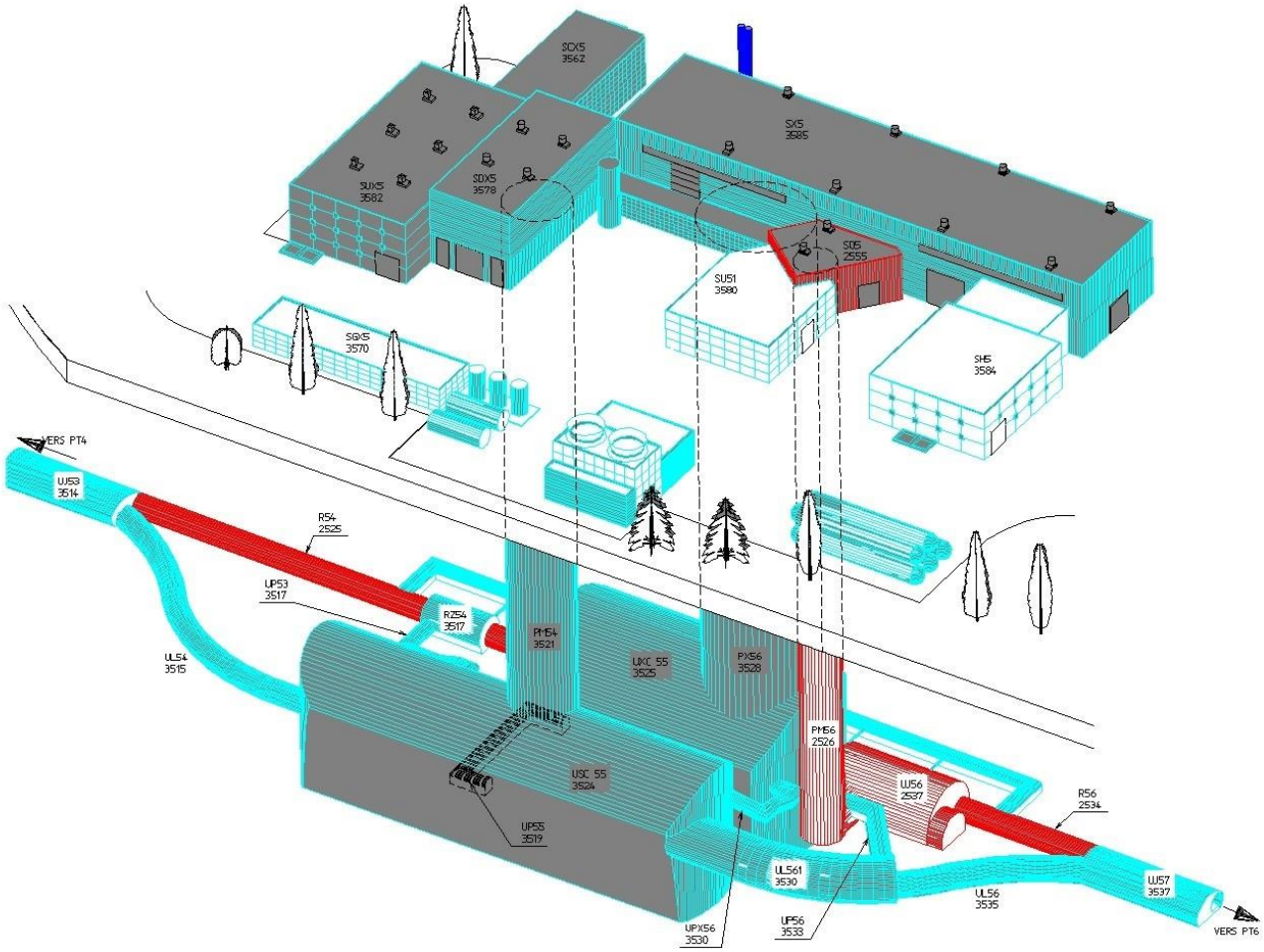
Virtual Commissioning

- Offline, no impact on installation
- Dynamic simulation model to validate new:
  - control strategies
  - switching between operation modes
- Operator training

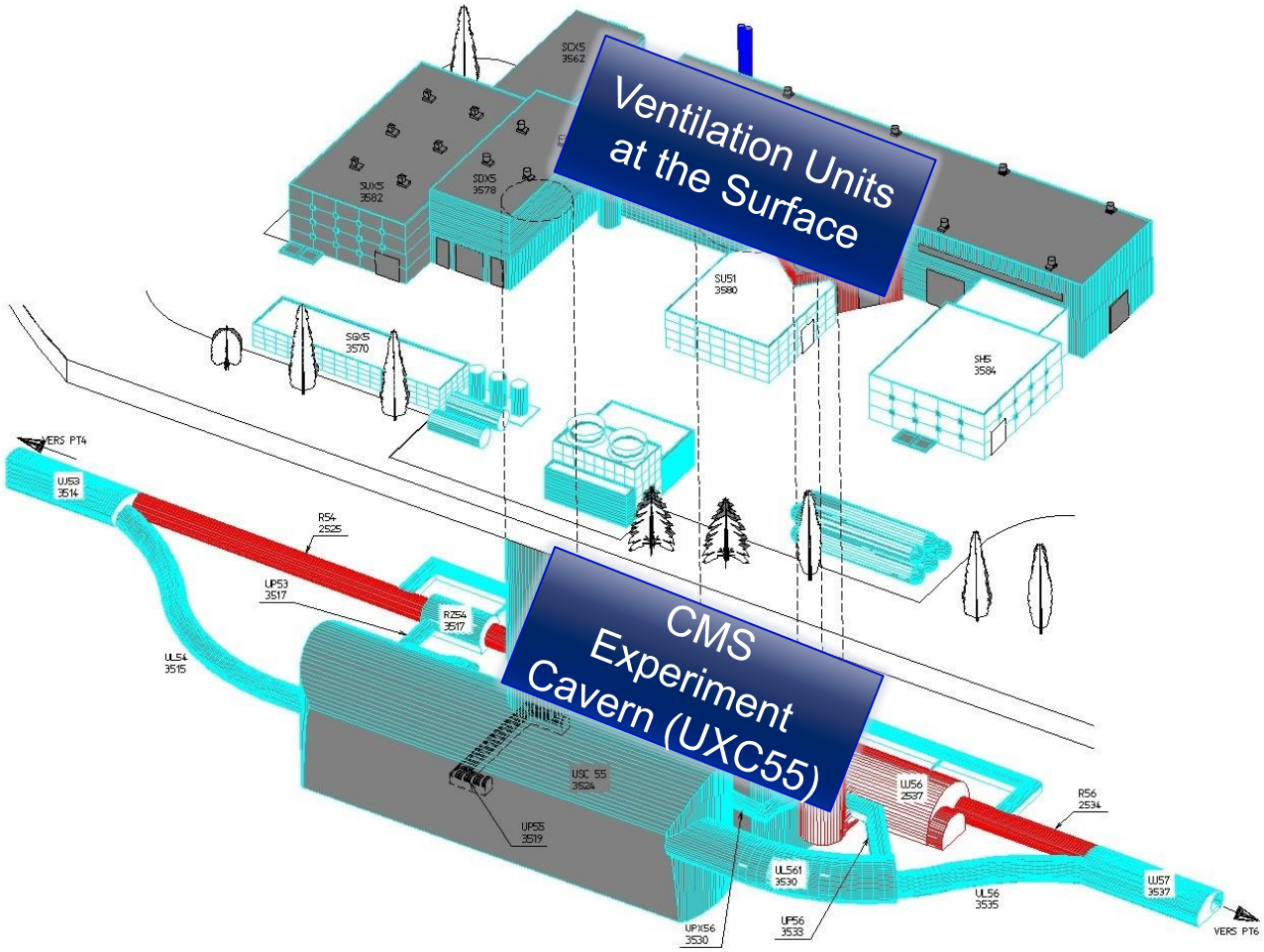
Approach


Process & Equipment analysis
HVAC library development
HVAC library Validation
« Simple » HVAC Plants Model building/simulation
CMS Cavern Physical Model building
Physical Model Building
…
Control Model building and A.F.
Simulations, improvement and upgrades
Implementation
Virtual-Commissioning

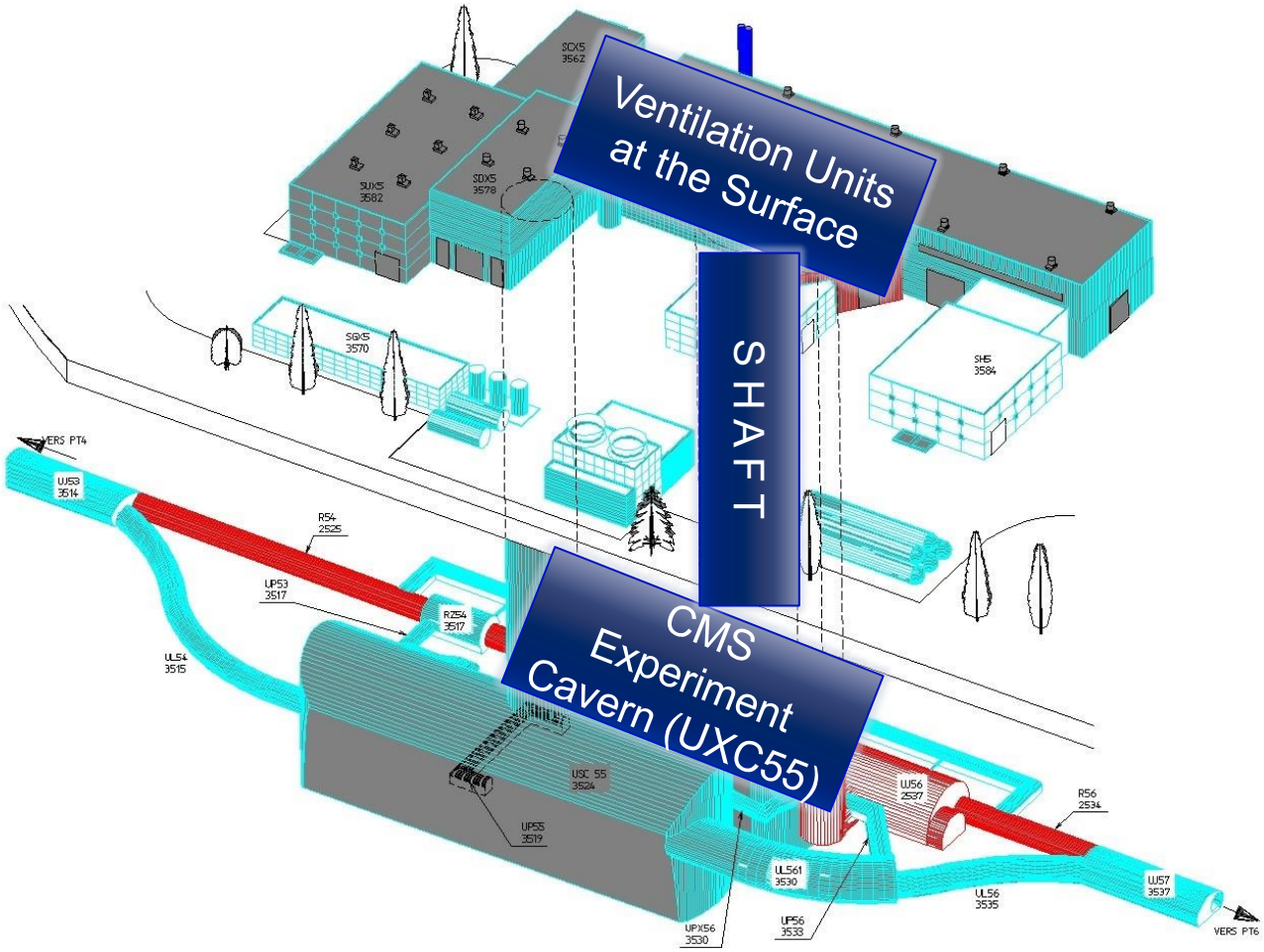
Overview CMS buildings surface and underground



Overview CMS buildings surface and underground



Overview CMS buildings surface and underground



Process & Equipment Analysis

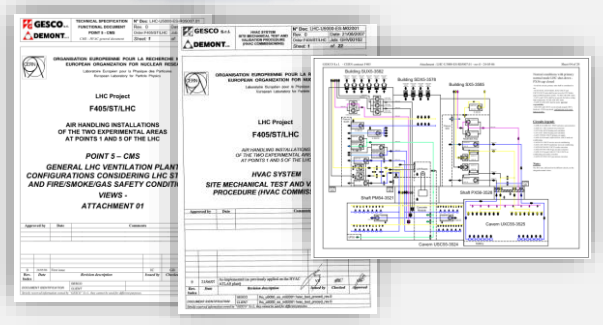
Process & Equipment analysis

EDMS & EN/CV inventory

P&IDs, Equipment datasheets, HVAC Maintenance reports, GA Drawings, Duct routing, …

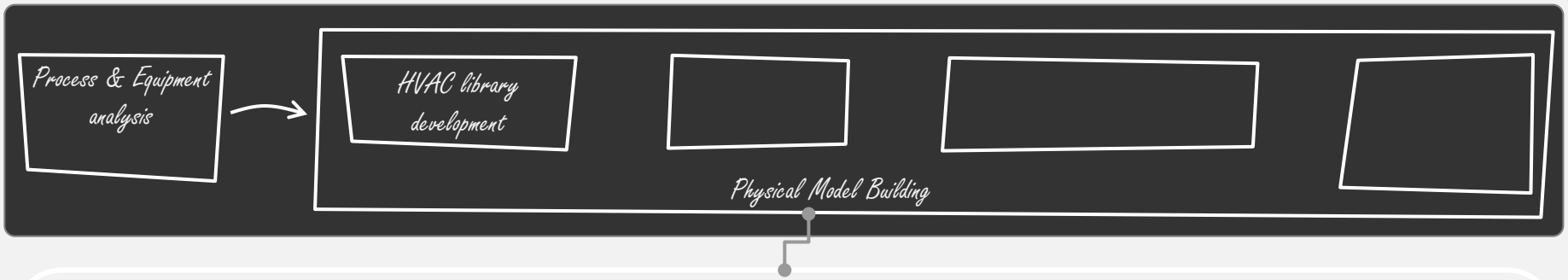
RELIABLE INPUT DATA

CV doc



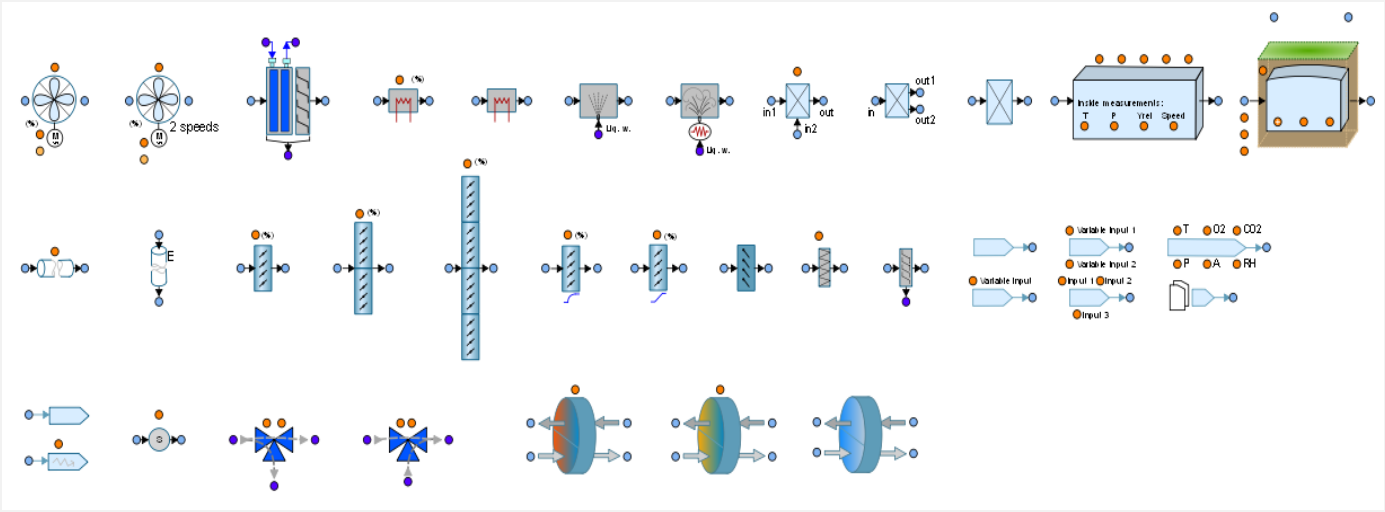
"As Built" Sub-Contractor doc.: A.F., I/O Lists, PLC programs, Alarms Lists, HVAC Commissioning reports

HVAC Library Development

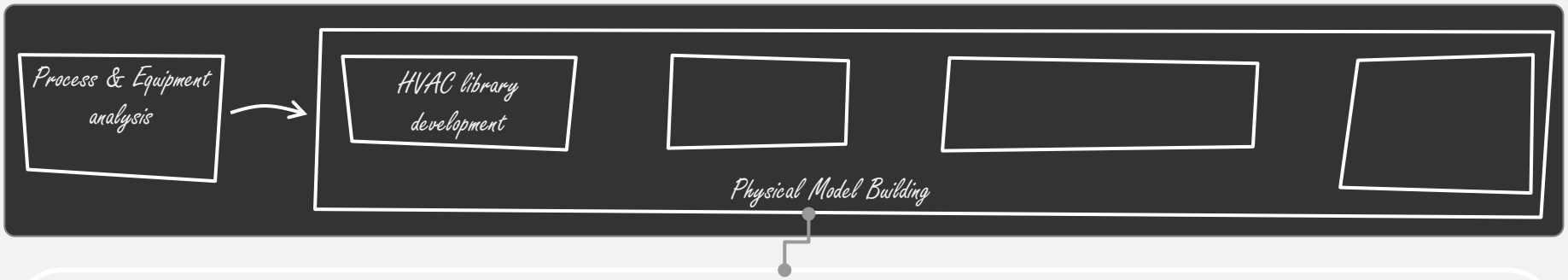


- EcosimPro™

- CERN-developed library of HVAC components

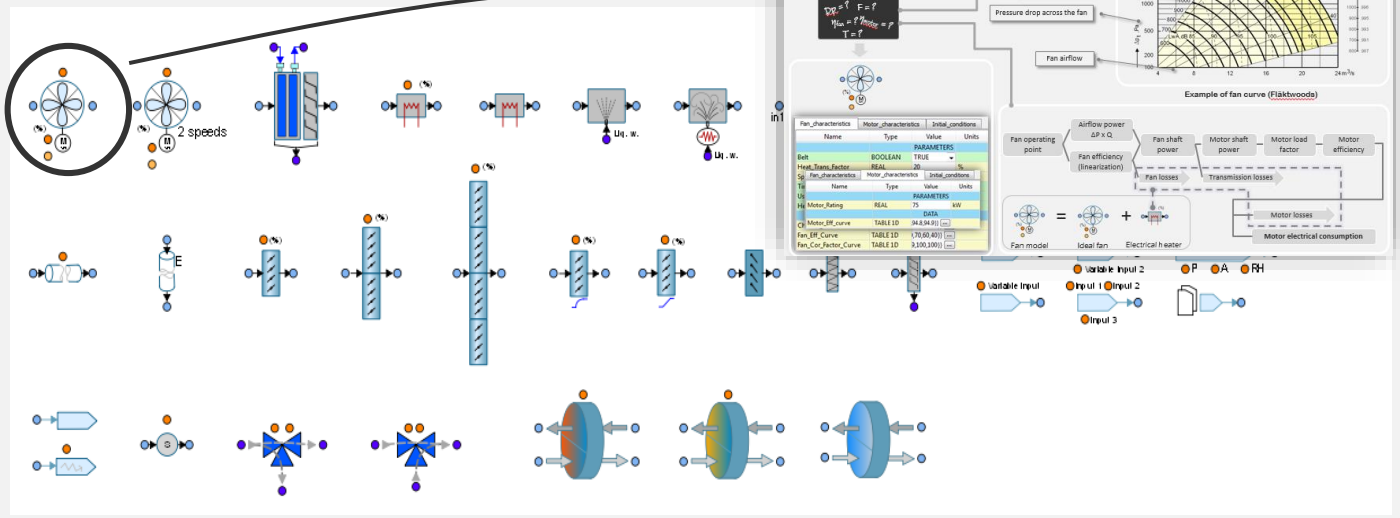


HVAC Library Development



- EcosimPro™

- CERN-developed library of HVAC components



Fan Component Development

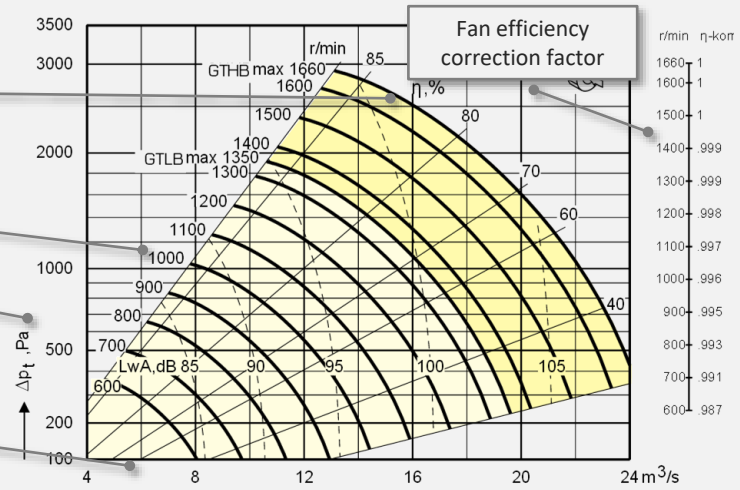
$Dp = ?$ $F = ?$
$\eta_{fan} = ?$ $\eta_{motor} = ?$
$T = ?$

Fan efficiency

Fan rotation speed

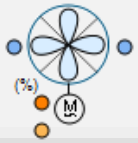
Pressure drop across the fan

Fan airflow



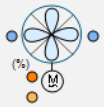
Fan efficiency correction factor

Example of fan curve (Fläktwoods)



Fan_characteristics	Motor_characteristics	Initial_conditions	
Name	Type	Value	Units
		PARAMETERS	
Belt	BOOLEAN	TRUE	
Heat_Trans_Factor	REAL	20	%
Speed_Ref	REAL	1500	rpm
Time_Constant	REAL	20	no_unit
Use_Fan_Eff_Cor_Factor	BOOLEAN	TRUE	
Heat_Fan_Factor	REAL	10	%
		DATA	
Charact_curve	TABLE 1D	57,42437}}	
Fan_Eff_Curve	TABLE 1D	,70,60,40}}	
Fan_Cor_Factor_Curve	TABLE 1D	9,100,100}}	

Fan operating point



Fan model

Fan Component Development

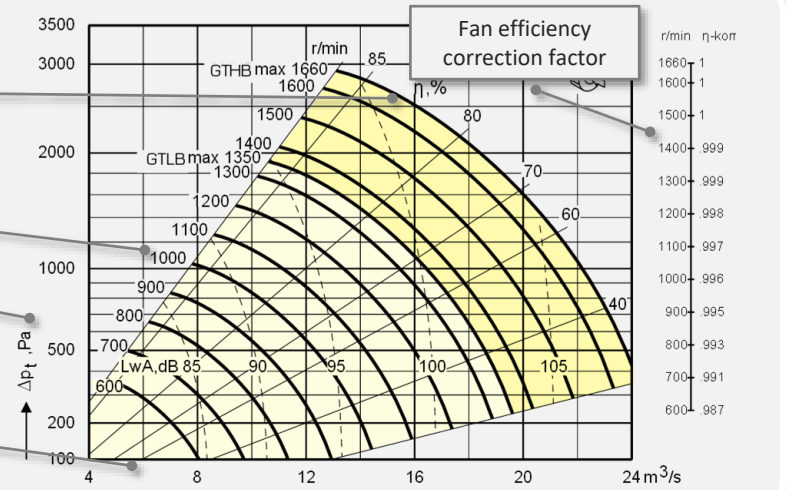
$Dp = ?$ $F = ?$
$\eta_{fan} = ?$ $\eta_{motor} = ?$
$T = ?$

Fan efficiency

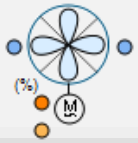
Fan rotation speed

Pressure drop across the fan

Fan airflow



Example of fan curve (Fläktwoods)

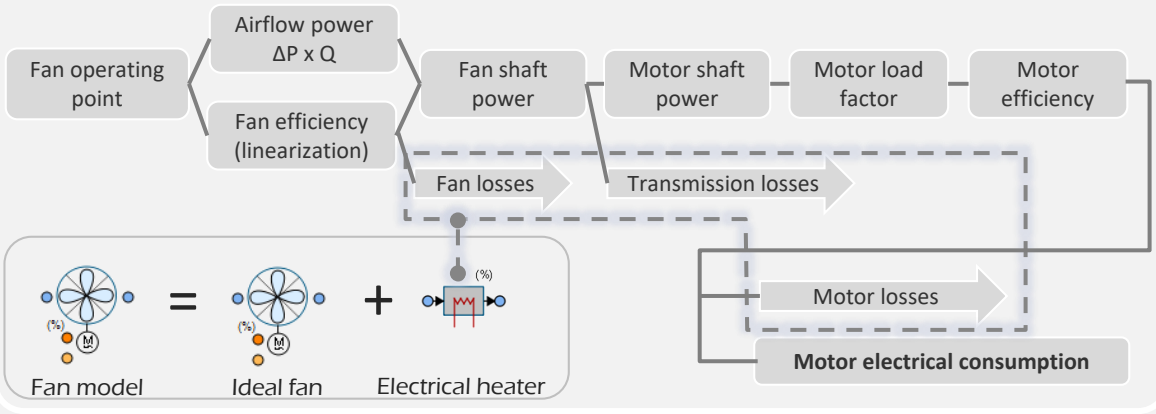


Fan_characteristics | Motor_characteristics | Initial_conditions

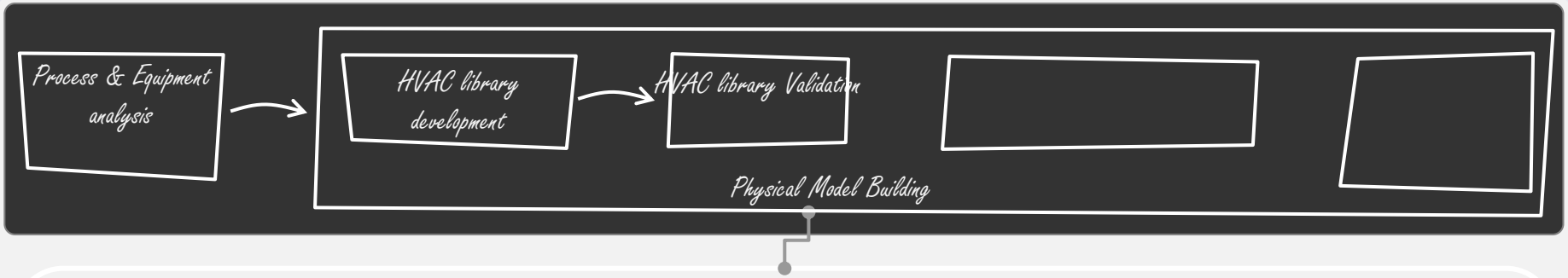
Name	Type	Value	Units
		PARAMETERS	
Belt	BOOLEAN	TRUE	
Heat_Trans_Factor	REAL	20	%

Fan_characteristics | Motor_characteristics | Initial_conditions

Name	Type	Value	Units
		PARAMETERS	
Motor_Rating	REAL	75	kW
		DATA	
Motor_Eff_curve	TABLE 1D	,94.8,94.9}} ...	
Fan_Eff_Curve	TABLE 1D	,70,60,40}} ...	
Fan_Cor_Factor_Curve	TABLE 1D	9,100,100}} ...	

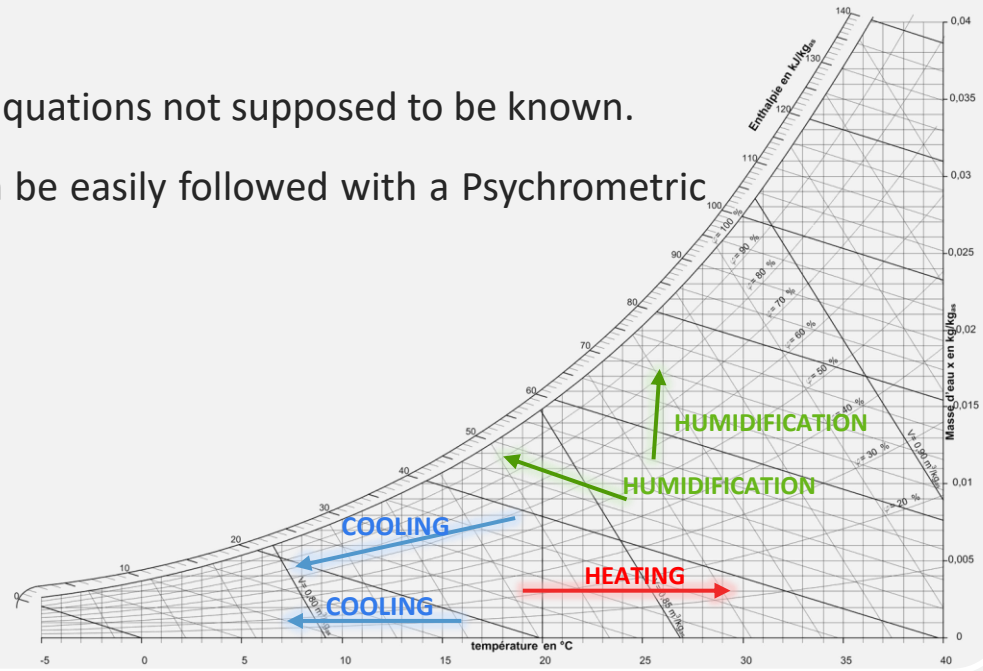


HVAC Library Validation

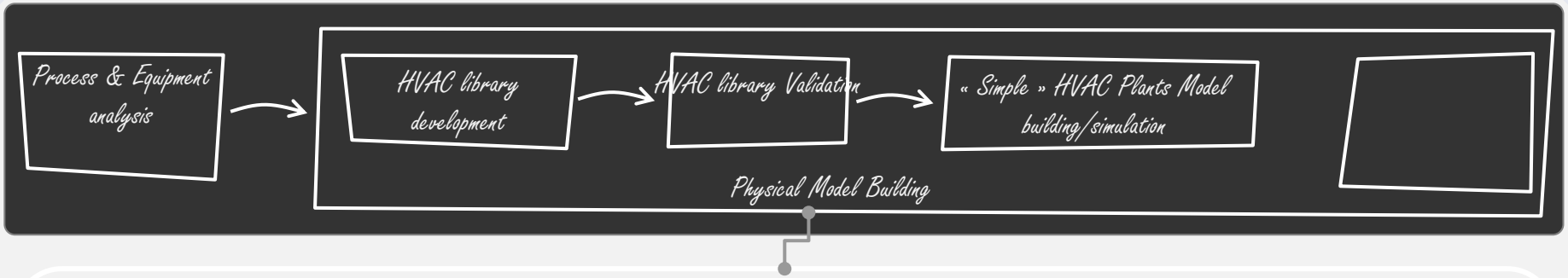


Typical component basic check

- "blind tests" - components internal equations not supposed to be known.
- Basic thermodynamic evolutions can be easily followed with a Psychrometric diagram
- Example: heater
  - Dry temperature ↗
  - Specific enthalpy ↗
  - Relative humidity ↘
  - Absolute humidity →
- Same principle for other components

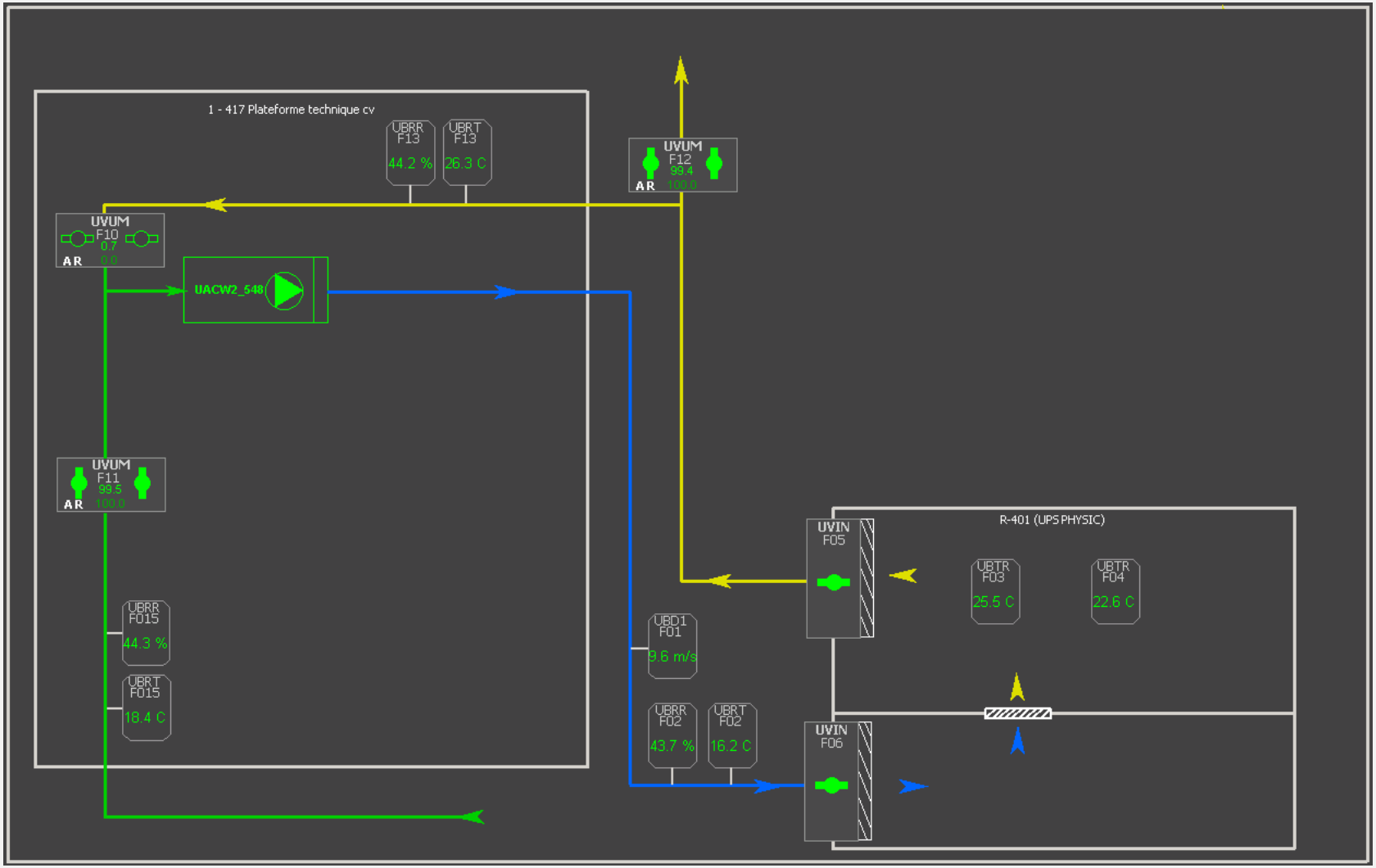


Simple HVAC Plant Model : Room in CERN Computing Centre

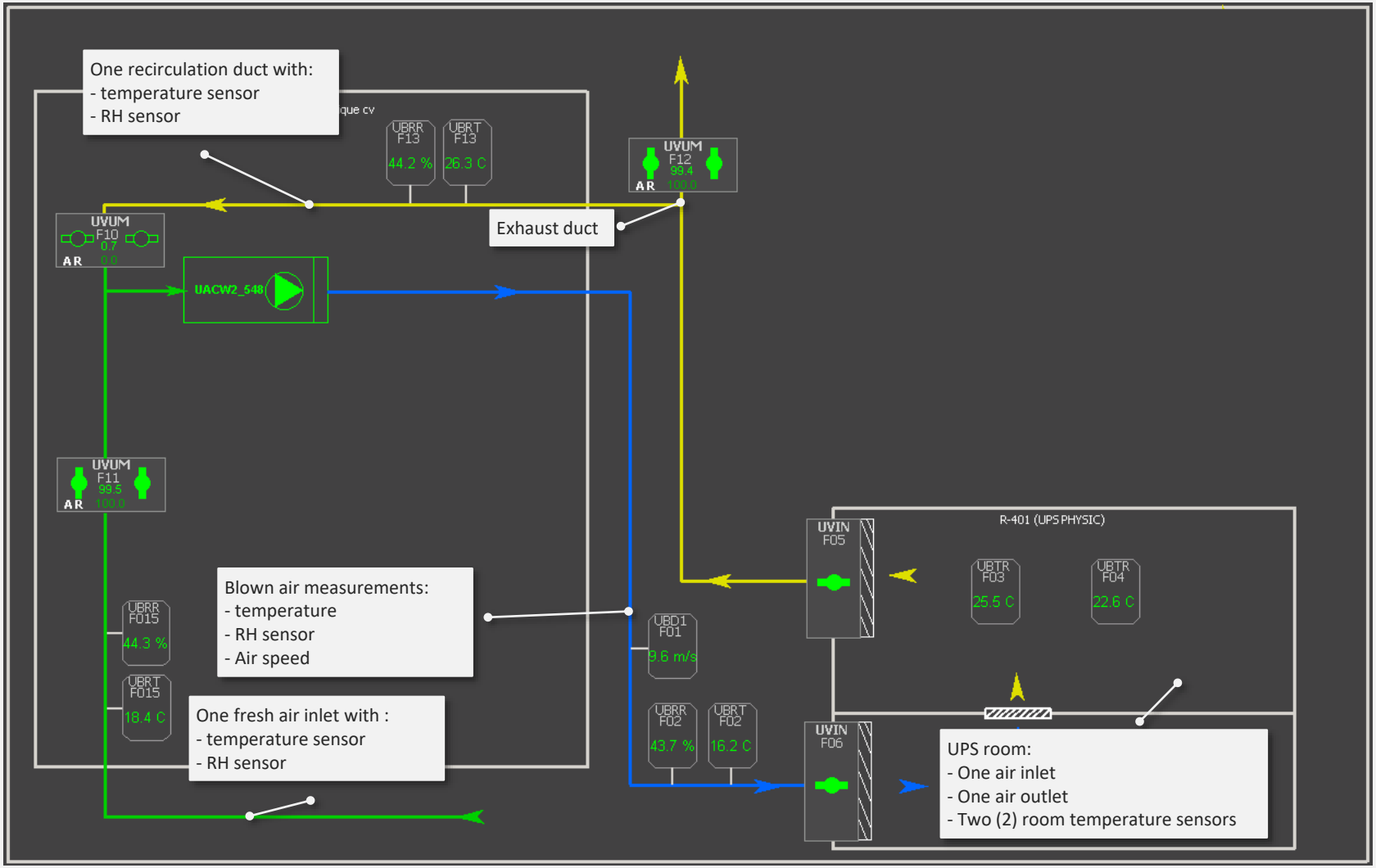


- CERN Computing Centre (Building 513) – R401 UPS Physics
  - Simple ventilation system
  - Similar components
  - Data available to validate model
  - Control studies

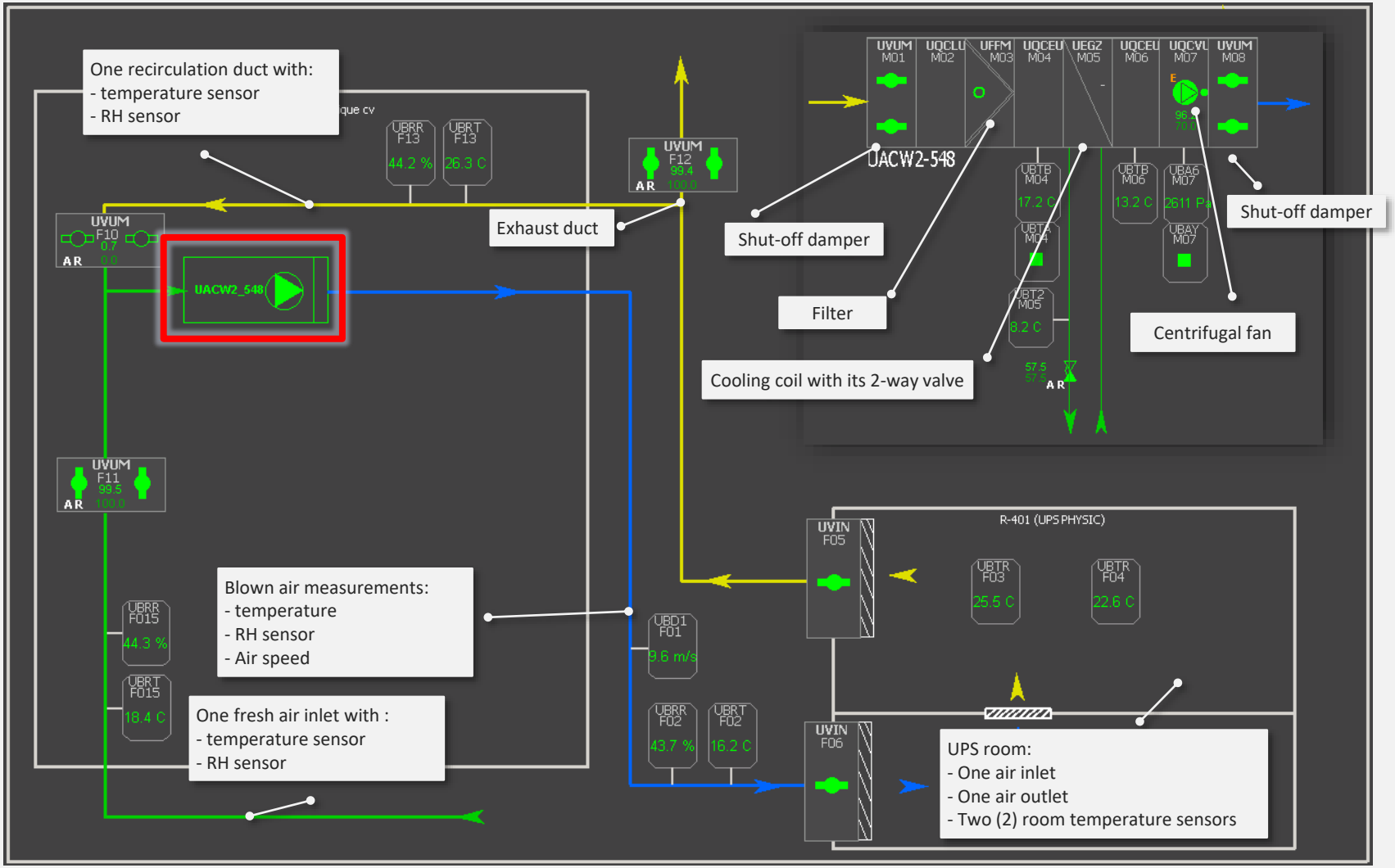
Simple HVAC Plant Model : Modelling



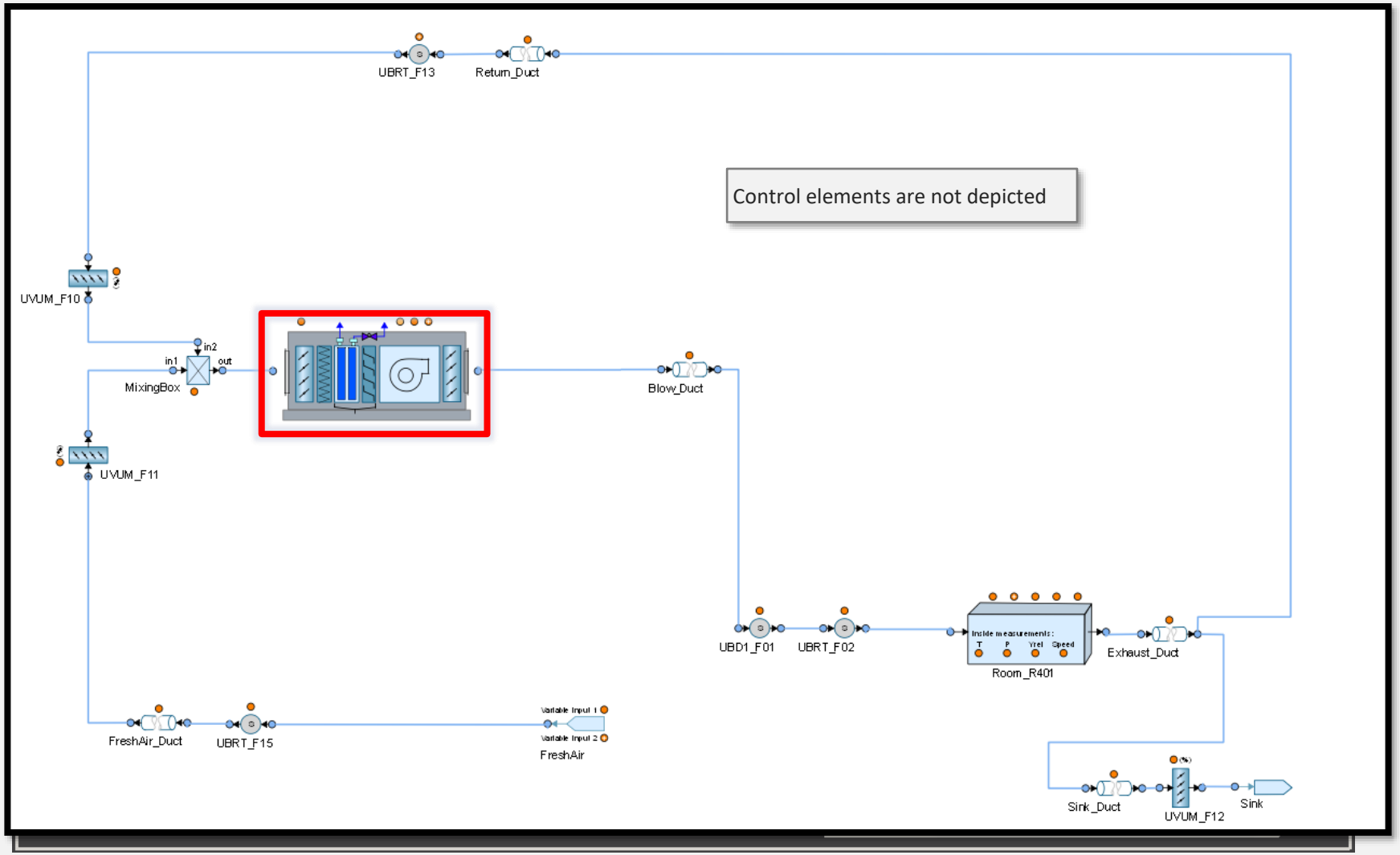
Simple HVAC Plant Model : Modelling



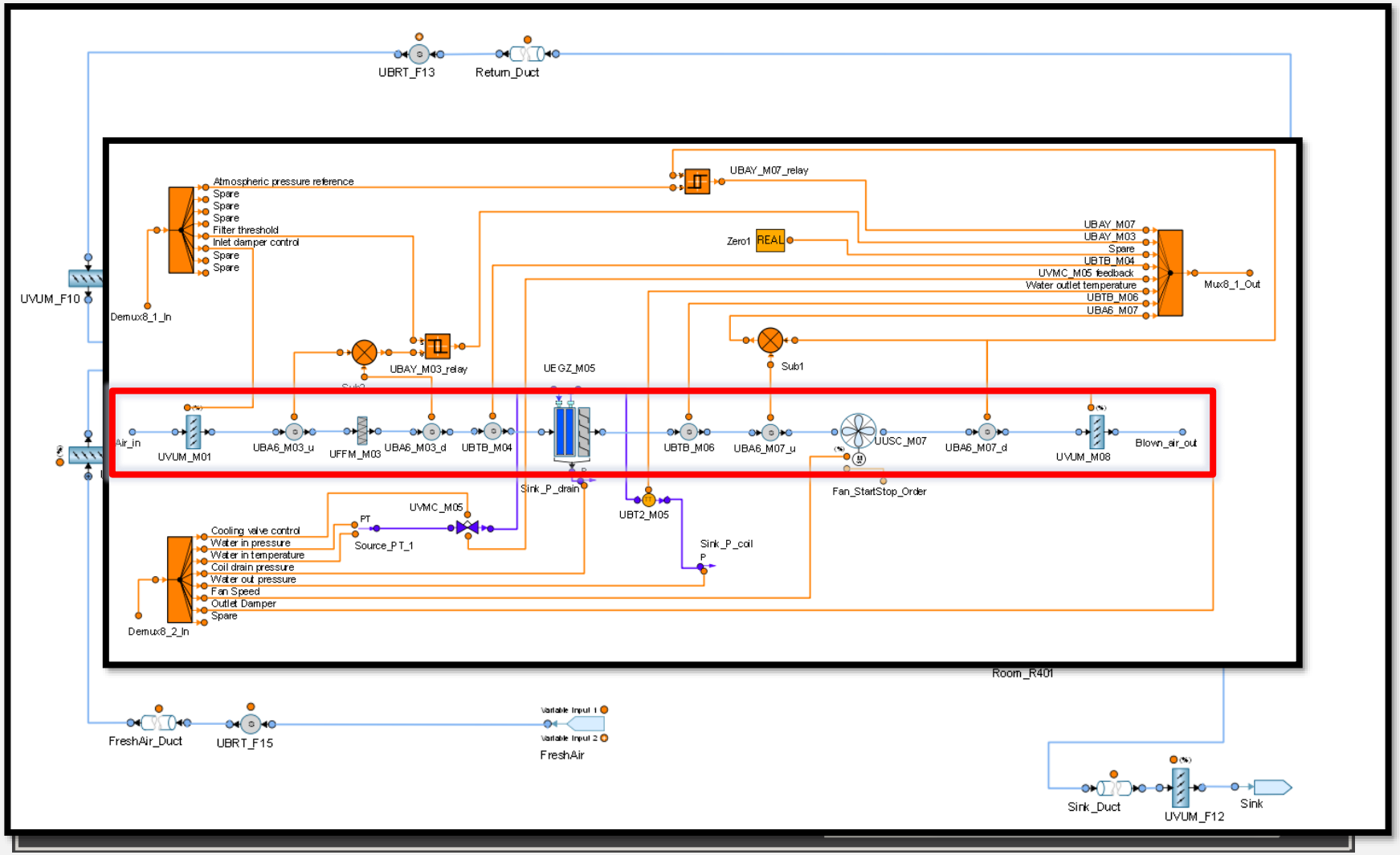
Simple HVAC Plant Model : Modelling



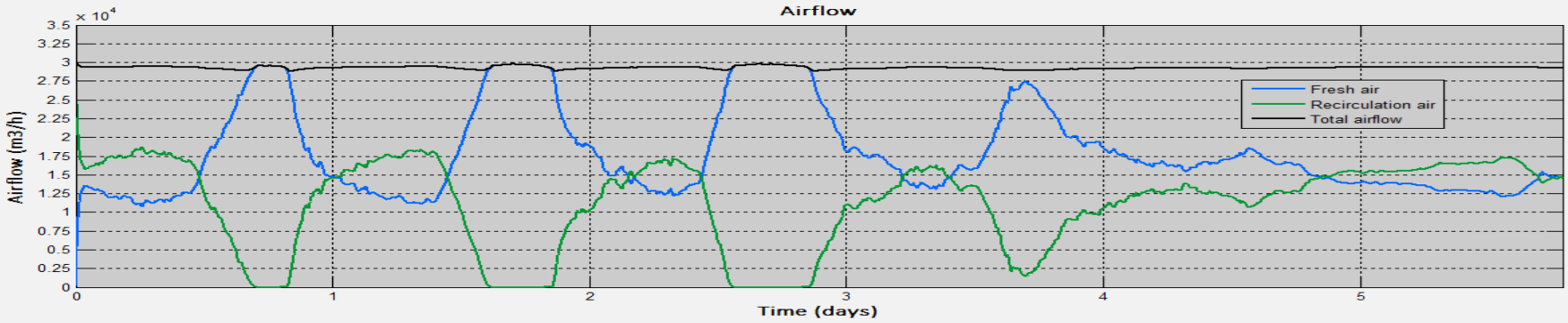
Simple HVAC Plant Model : Modelling



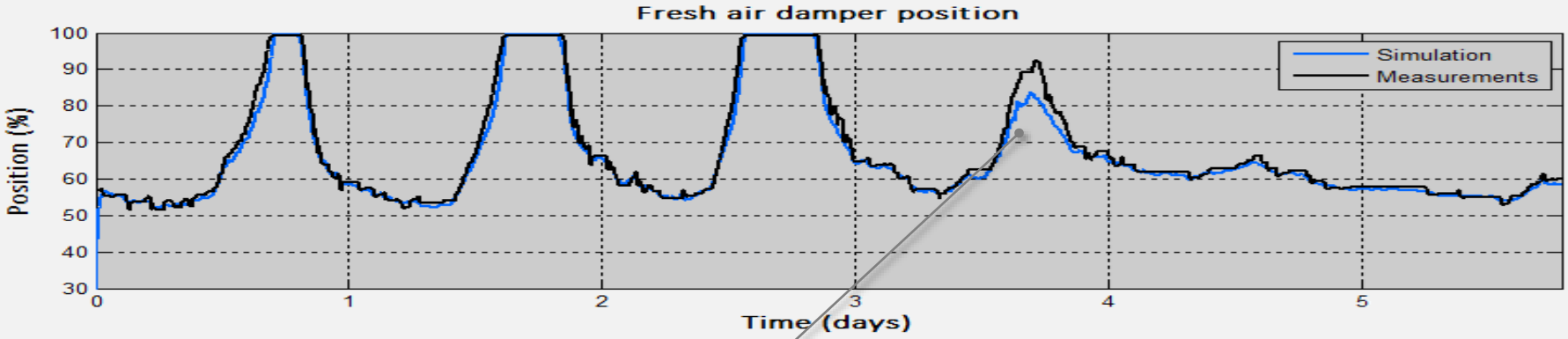
Simple HVAC Plant Model : Modelling



Simple HVAC Plant Model : Simulation Results (1)



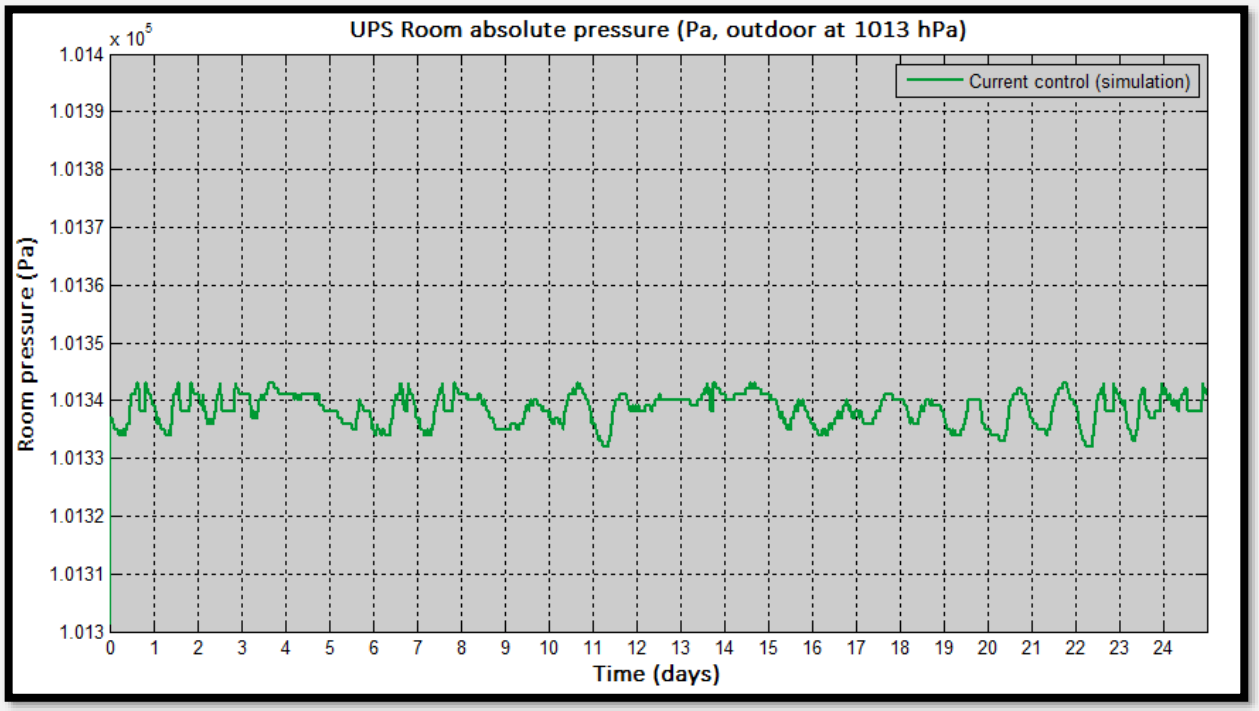
5-days simulation: dampers authority settings



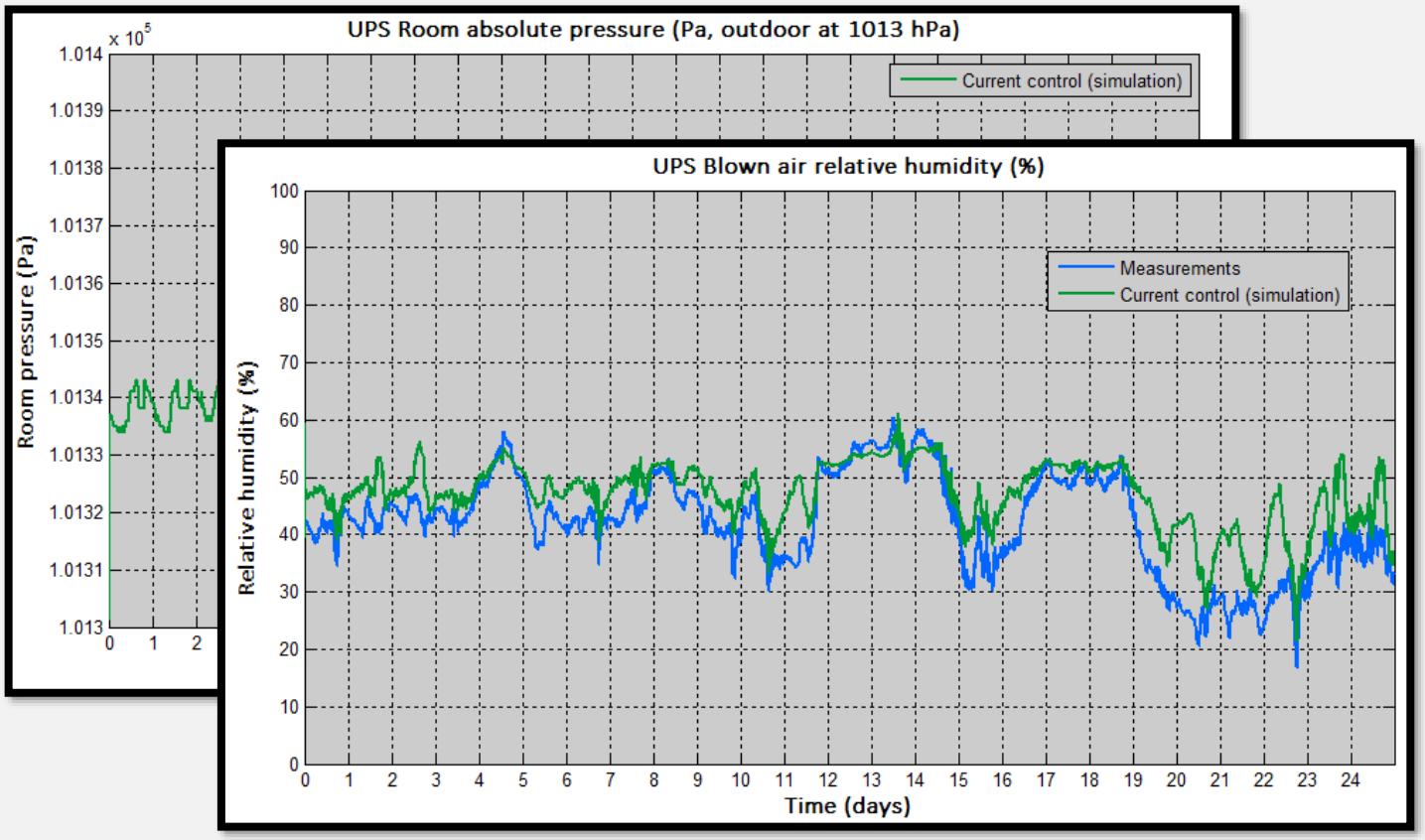
5-days simulation: comparison between simulation and measurements

As control loops are activated, this discrepancy is not necessarily due to the dampers settings, e.g. room heat load variation.

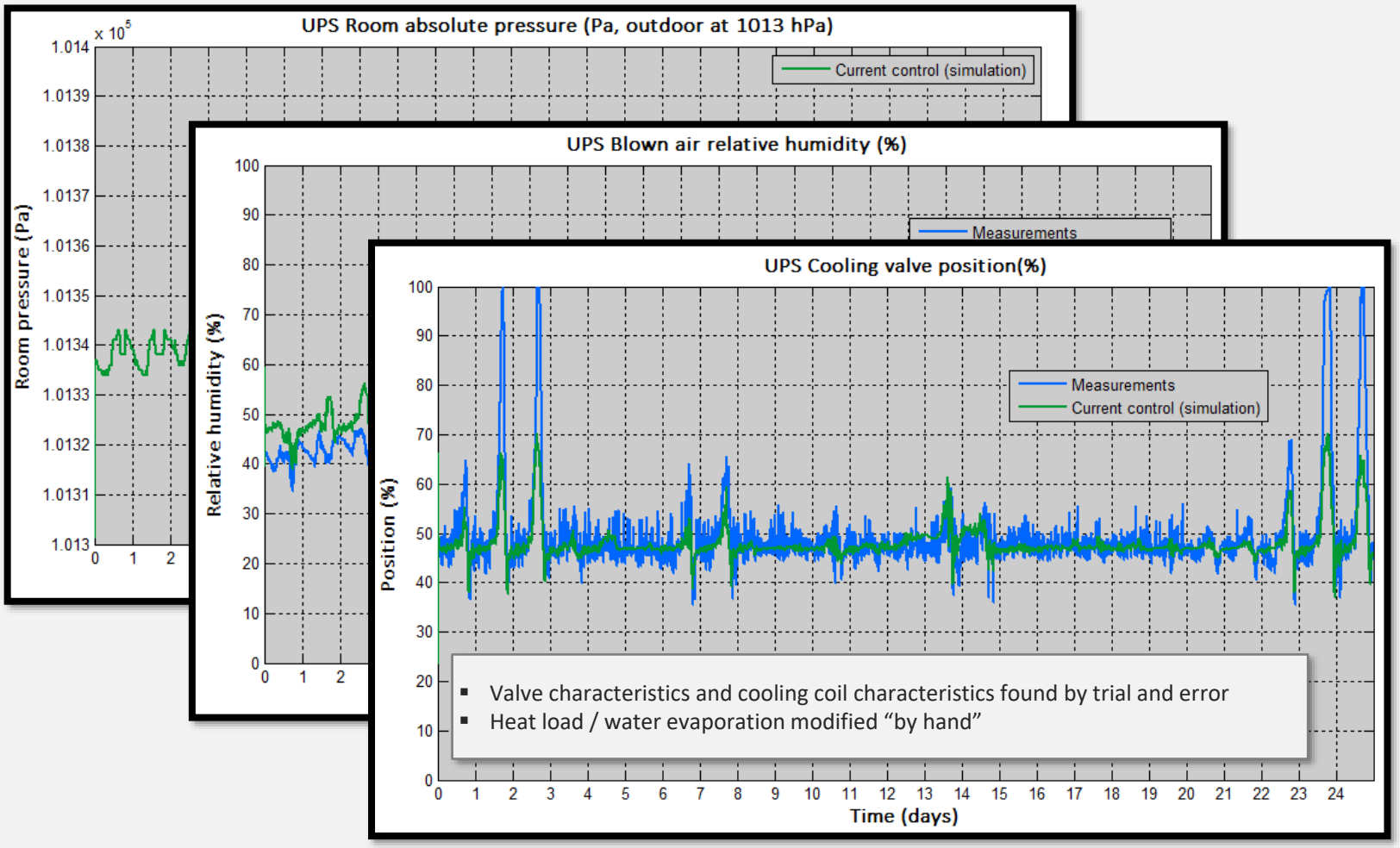
Simple HVAC Plant Model : Simulation Results (2)



Simple HVAC Plant Model : Simulation Results (2)



Simple HVAC Plant Model : Simulation Results (2)



CMS Experimental Cavern Ventilation System : Process & Instrumentation Diagram

Process & Equipment analysis → HVAC library development → HVAC library Validation → « Simple » HVAC Plants Model building/simulation → CMS Cavern Physical Model building

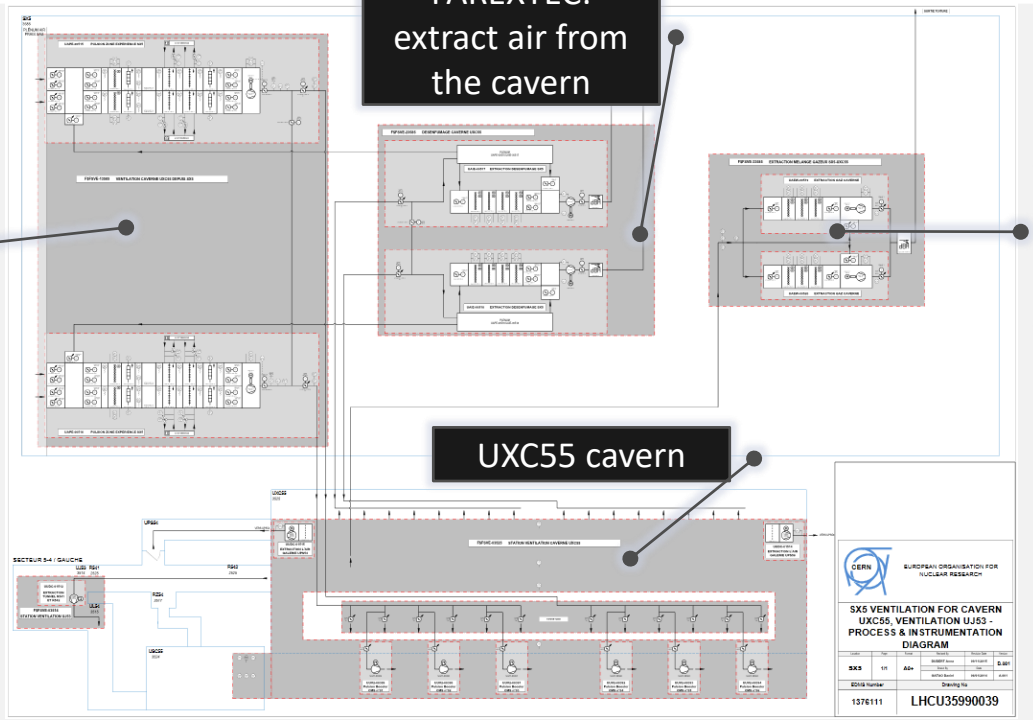
Physical Model Building

FAREXTEC: extract air from the cavern

FARSUPEC: supplies air into the cavern

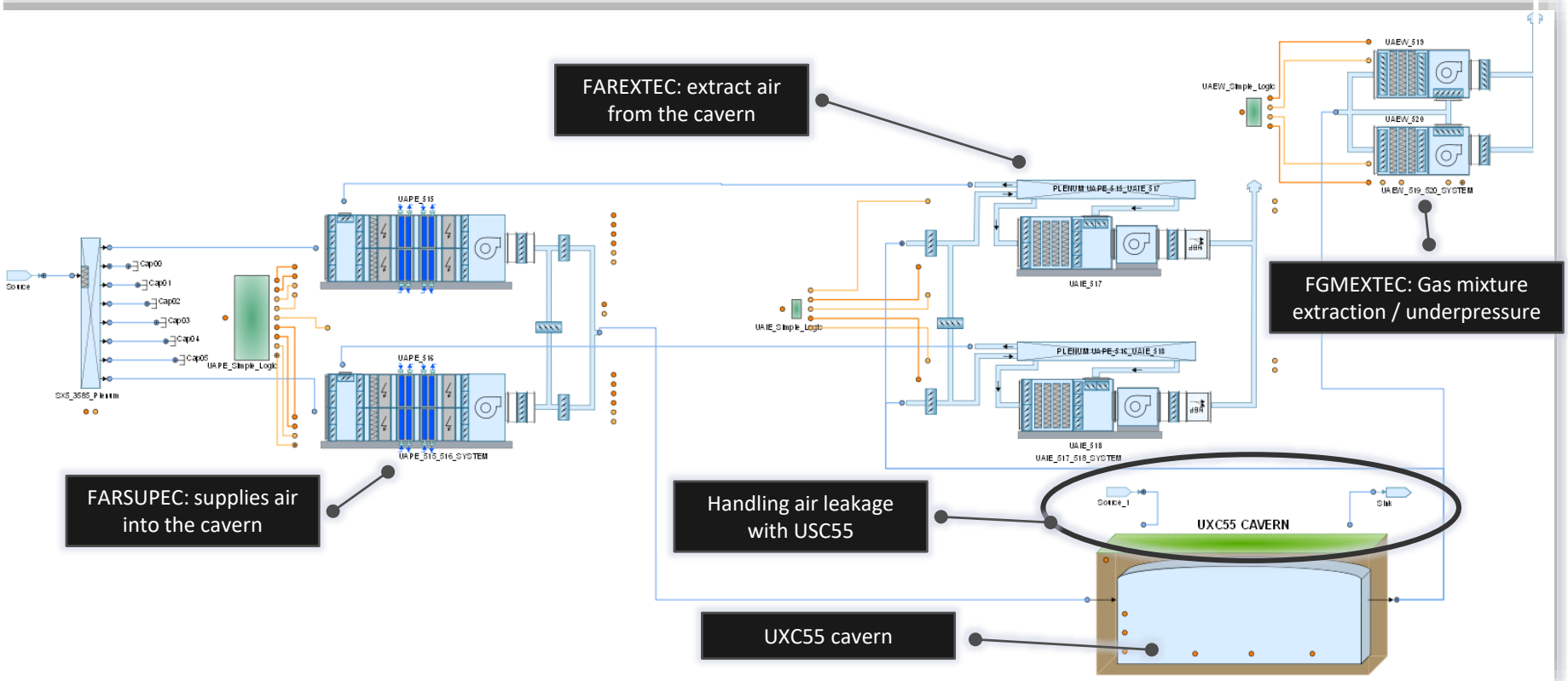
FGMEXTEC: Gas mixture extraction / underpressure

UXC55 cavern



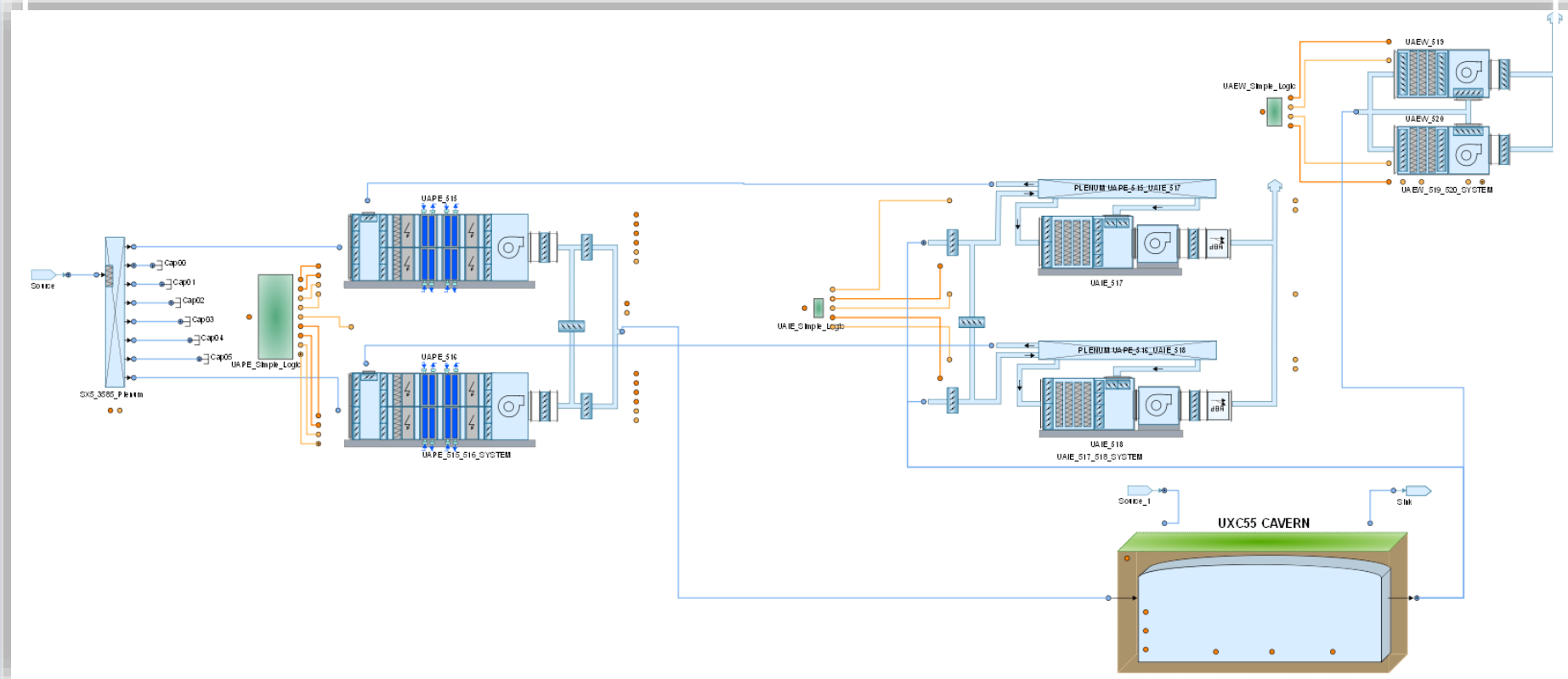
CMS Experimental Cavern (UXC55) Ventilation System : EcosimPro Model

UXC55 EcosimPro model:



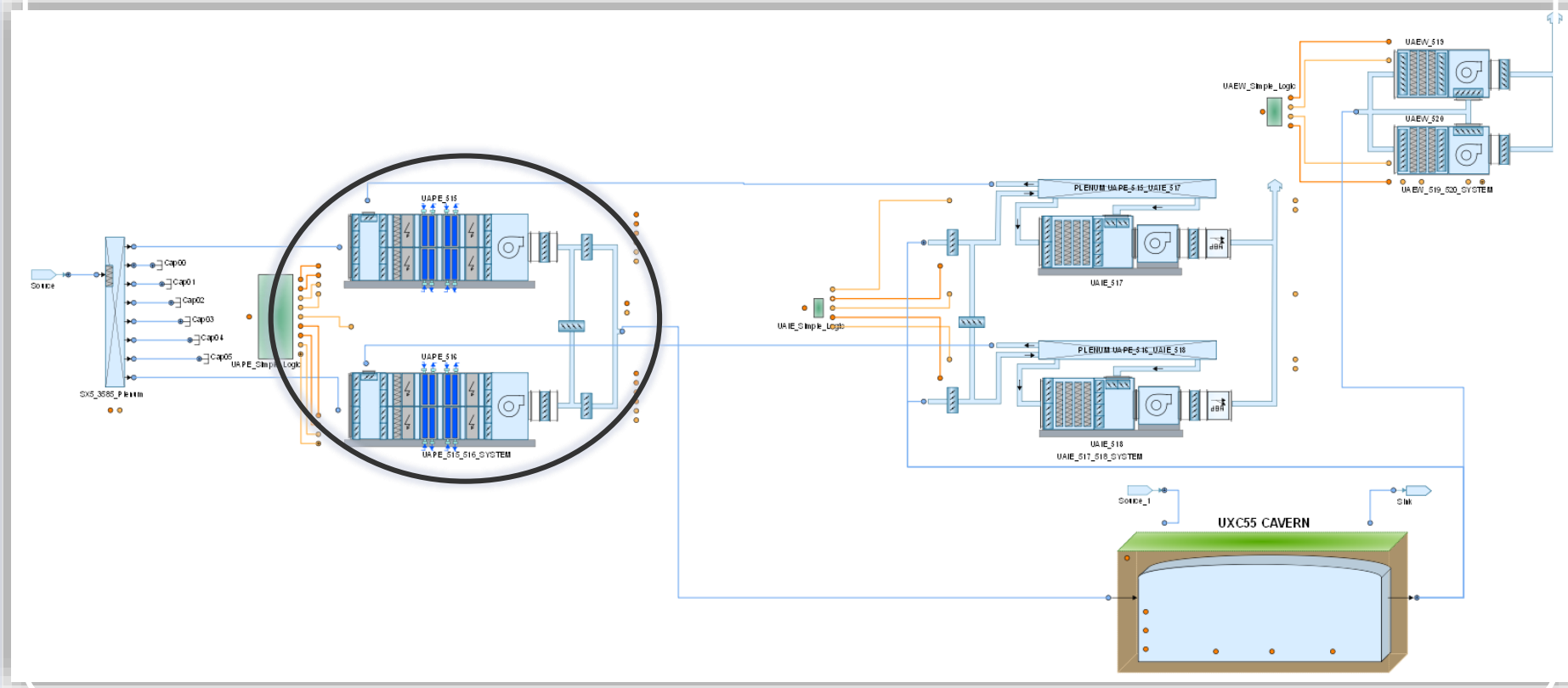
EcosimPro Model Supply Units

UXC55 EcosimPro model:



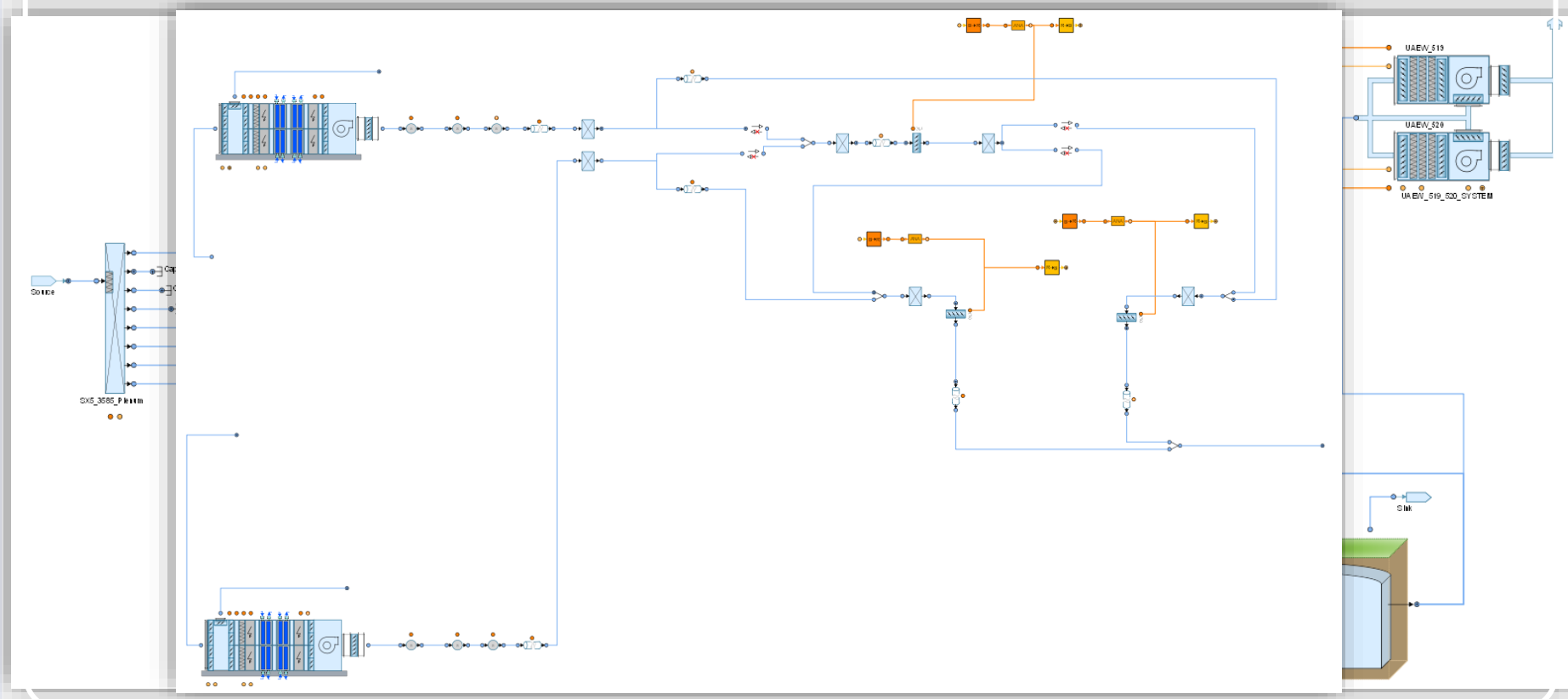
EcosimPro Model Supply Units

UXC55 EcosimPro model:



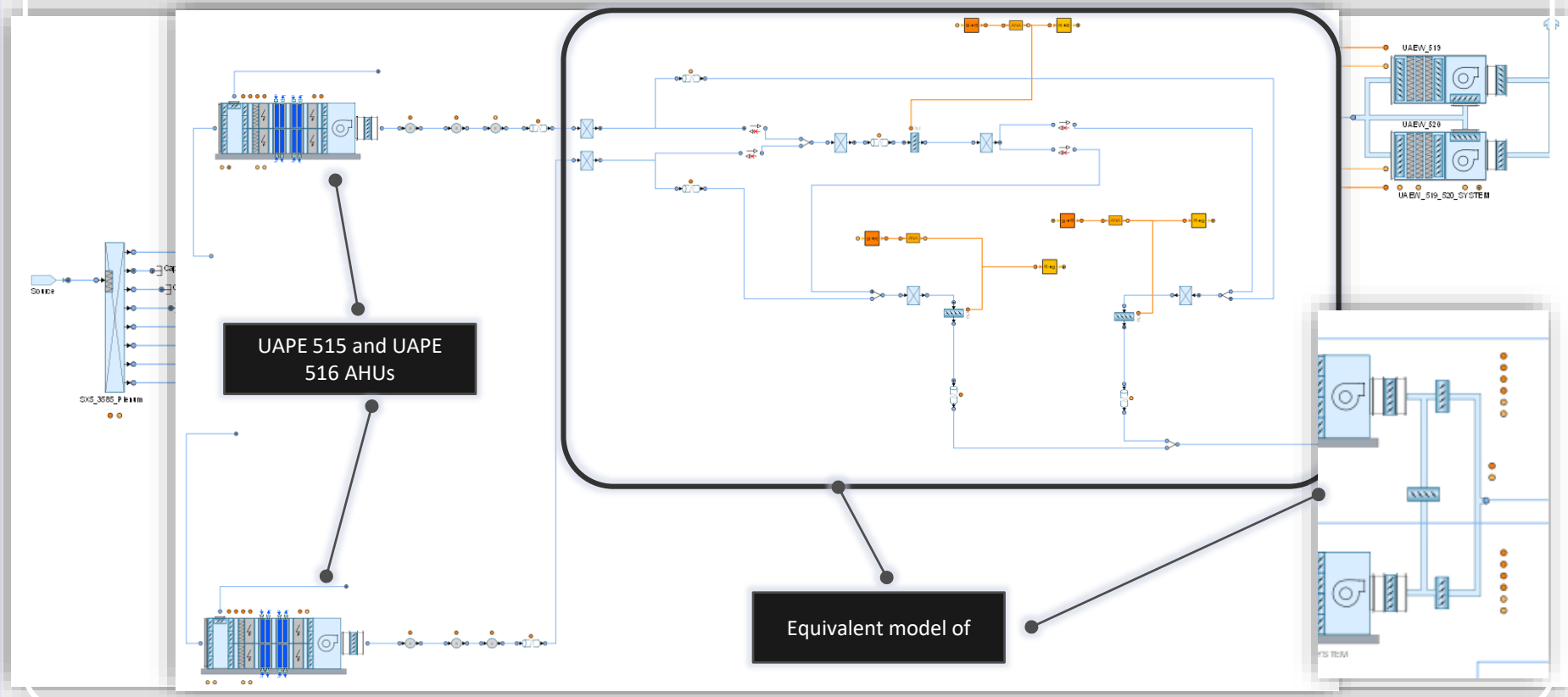
EcosimPro Model Supply Units

UXC55 EcosimPro model:



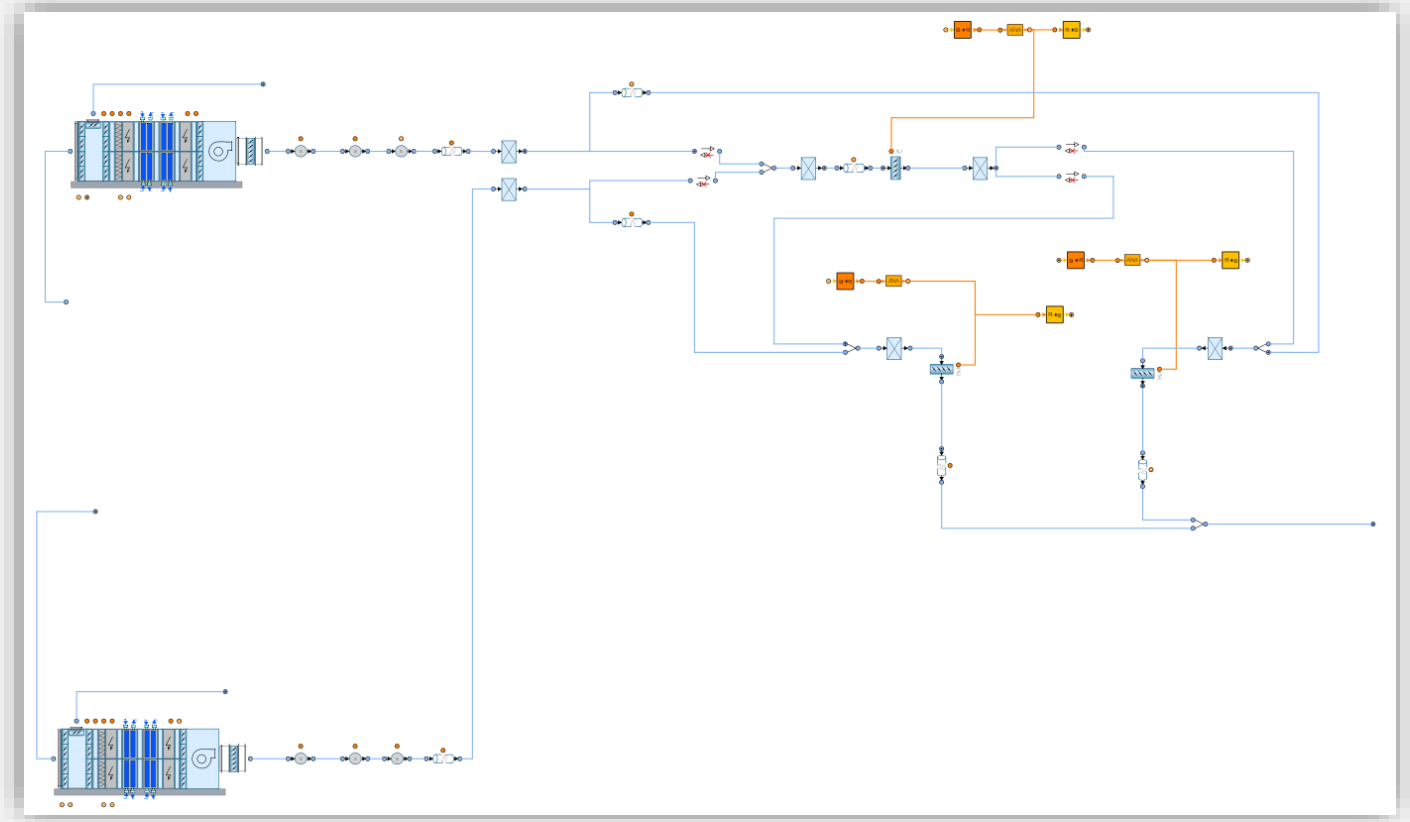
EcosimPro Model Supply Units

UXC55 EcosimPro model:



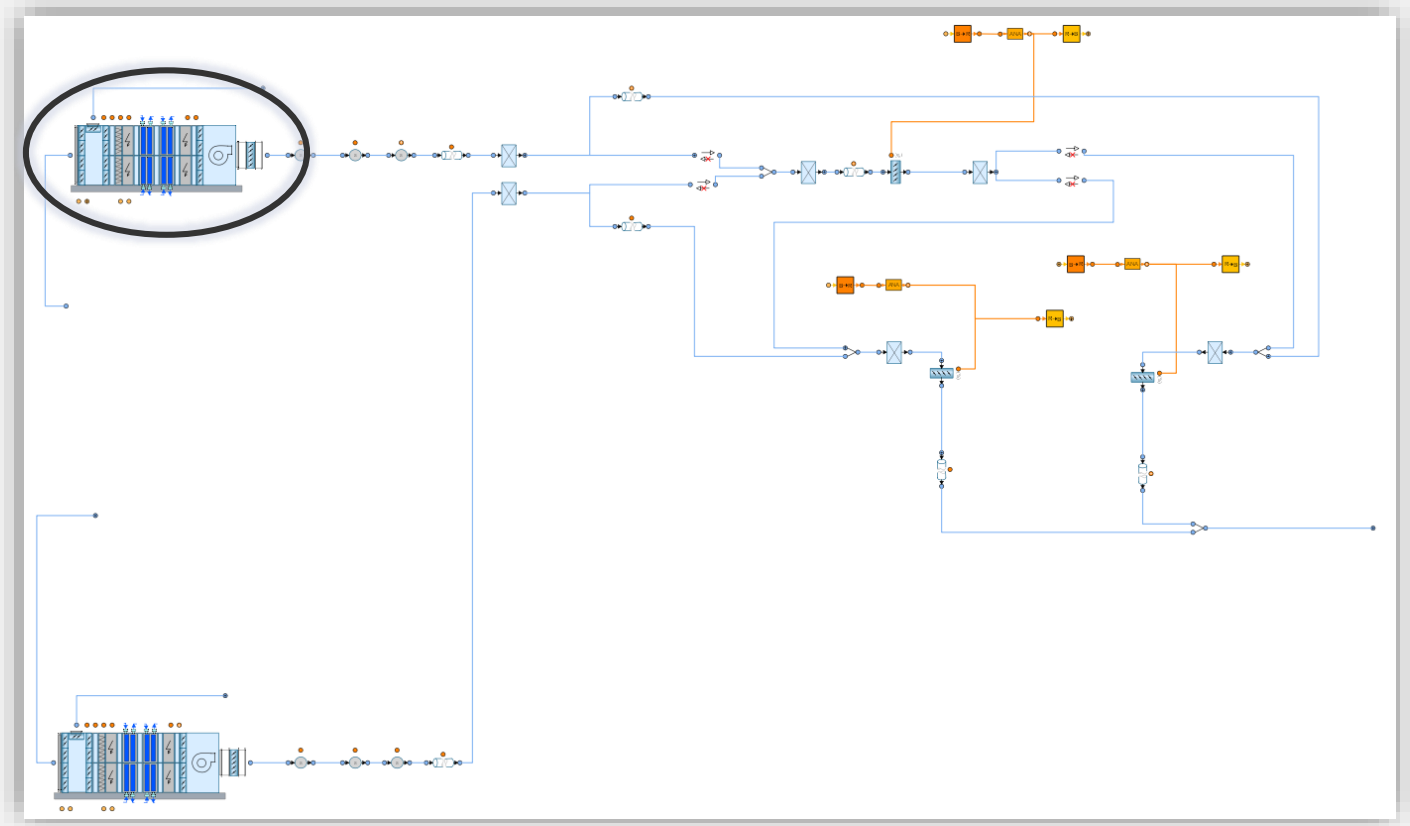
EcosimPro Model : Main Supply Air Handling Unit

UXC55 EcosimPro model:



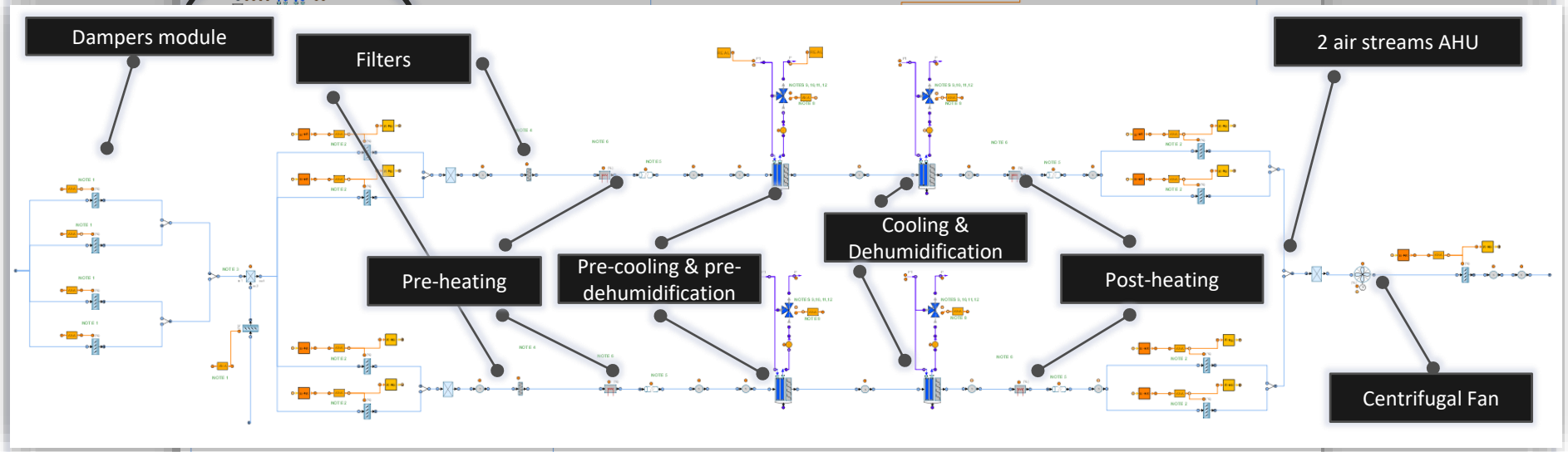
EcosimPro Model : Main Supply Air Handling Unit

UXC55 EcosimPro model:

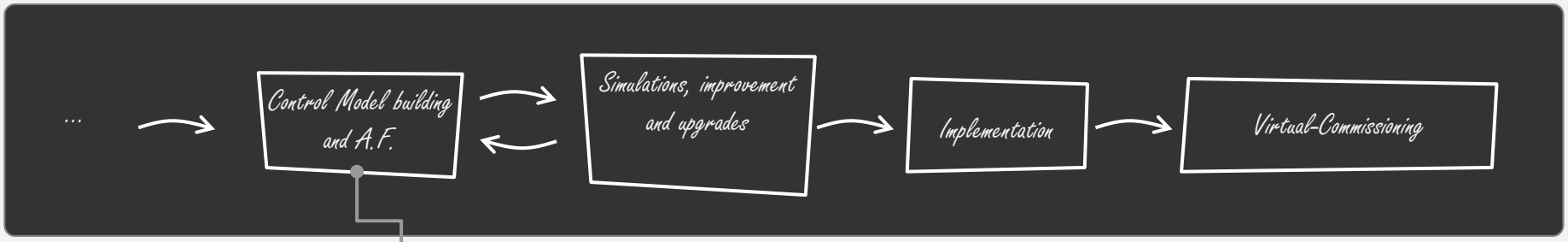


EcosimPro Model : Main Supply Air Handling Unit

UXC55 EcosimPro model:

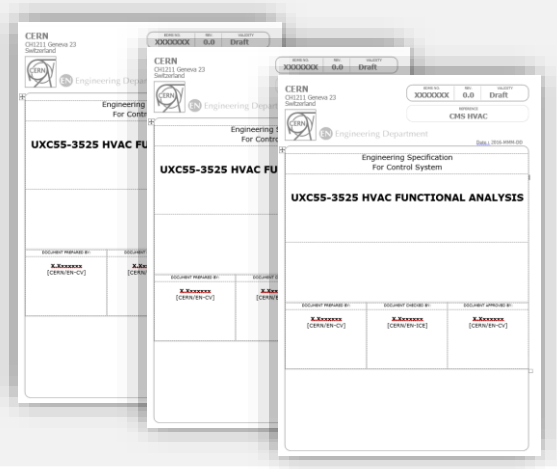


Control Model Building and Simulation



Control Model building and A.F.

- Functional Analysis Re-writing:

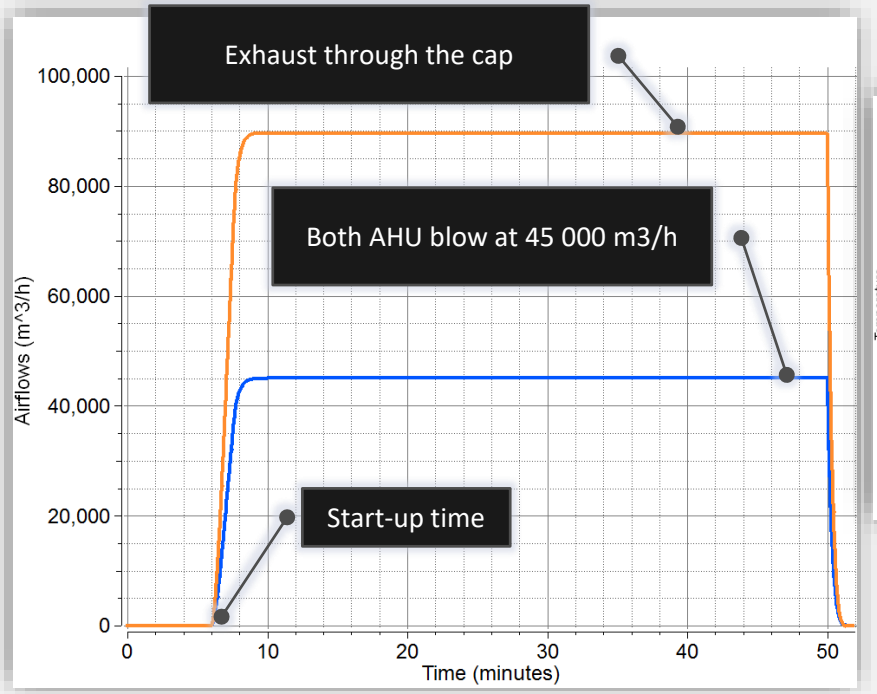


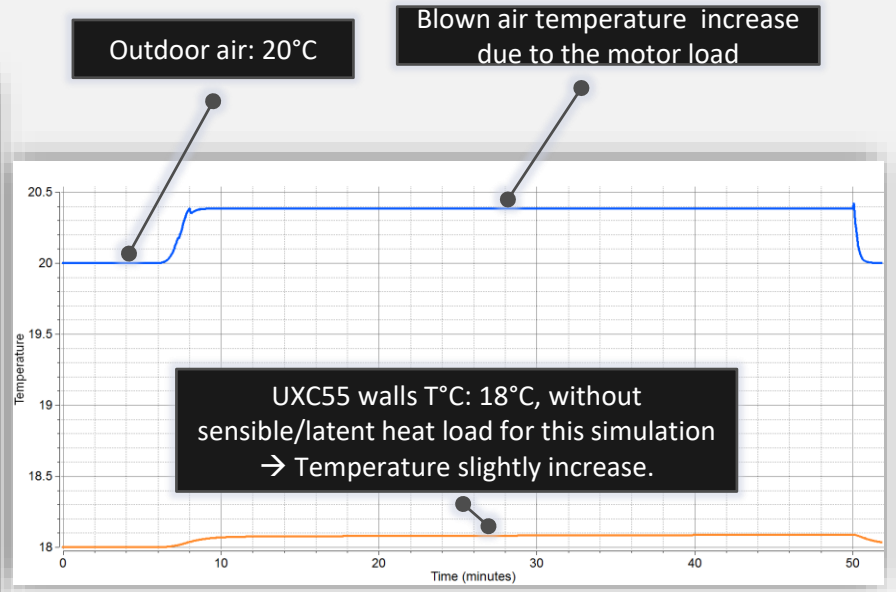
- UNICOS approach
- Improvements

CMS HVAC Plant Example Simulation Results (1)

Example: Start-up Gas detection in UXC55 – Cap Open

→ In this case, both UAPE AHU are running:

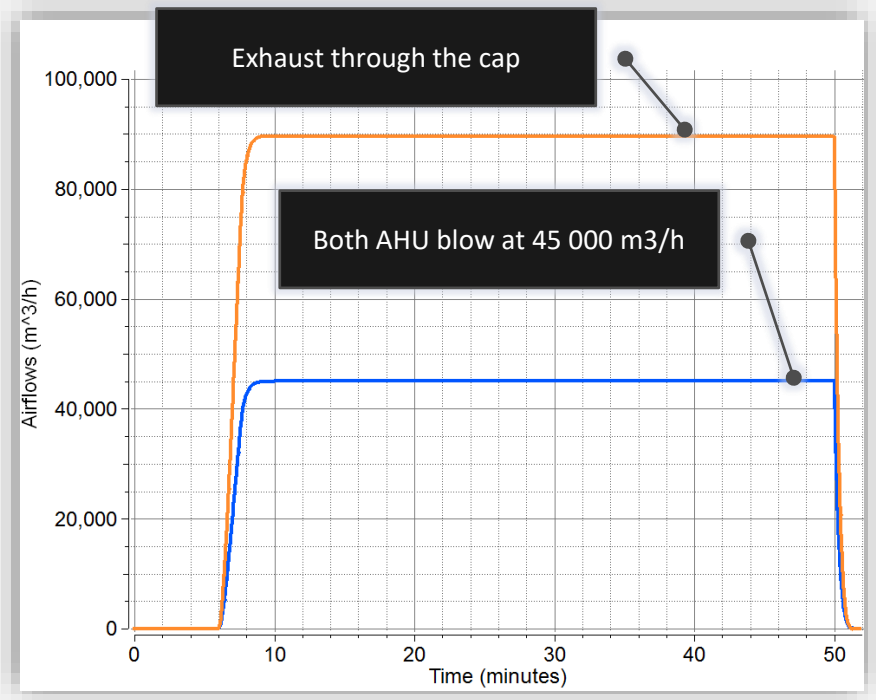


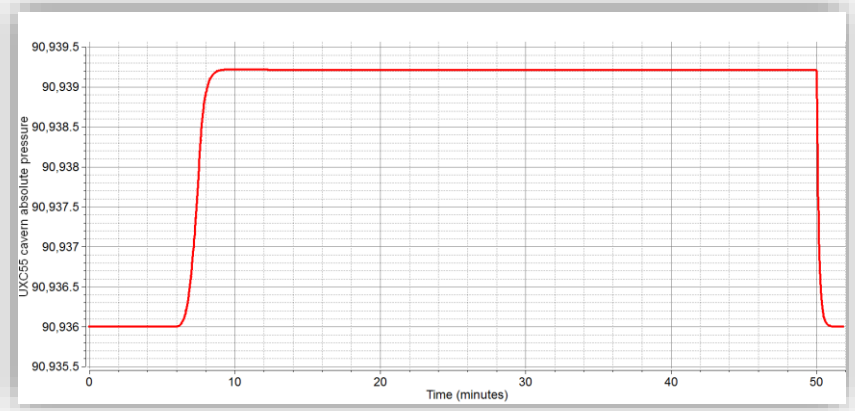


CMS HVAC Plant Example Simulation Results (2)

Example: Start-up Gas detection in UXC55 – Cap Open

→ In this case, both UAPE AHU are running:

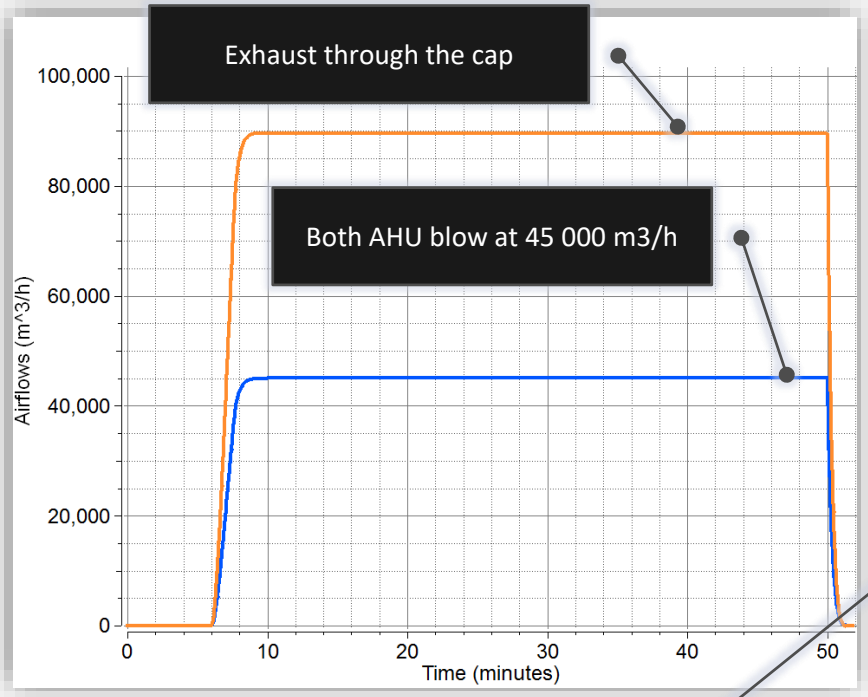


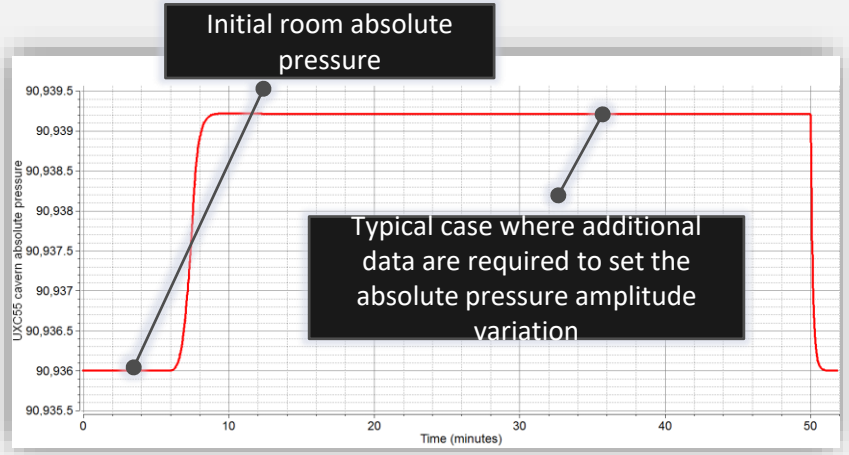


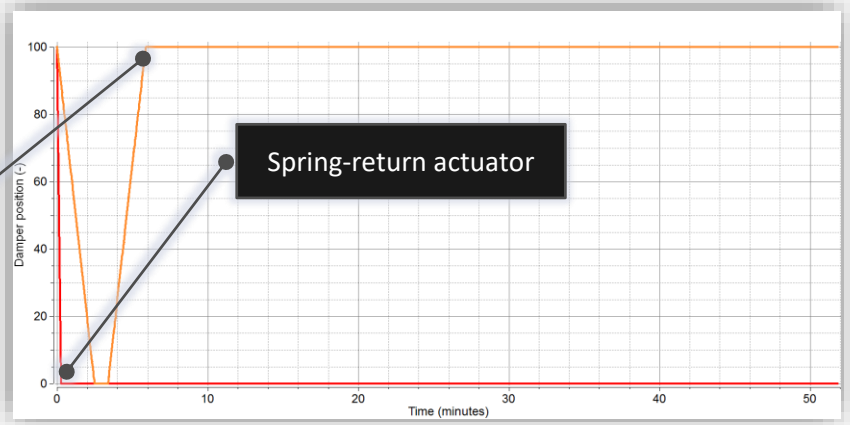
CMS HVAC Plant Example Simulation Results (2)

Example: Start-up Gas detection in UXC55 – Cap Open

→ In this case, both UAPE AHU are running:

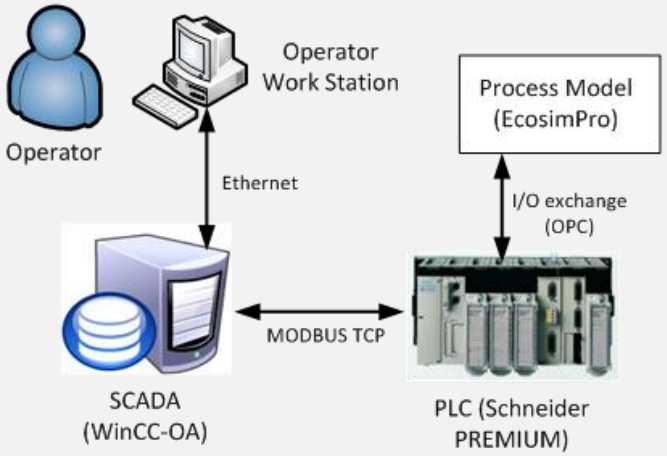


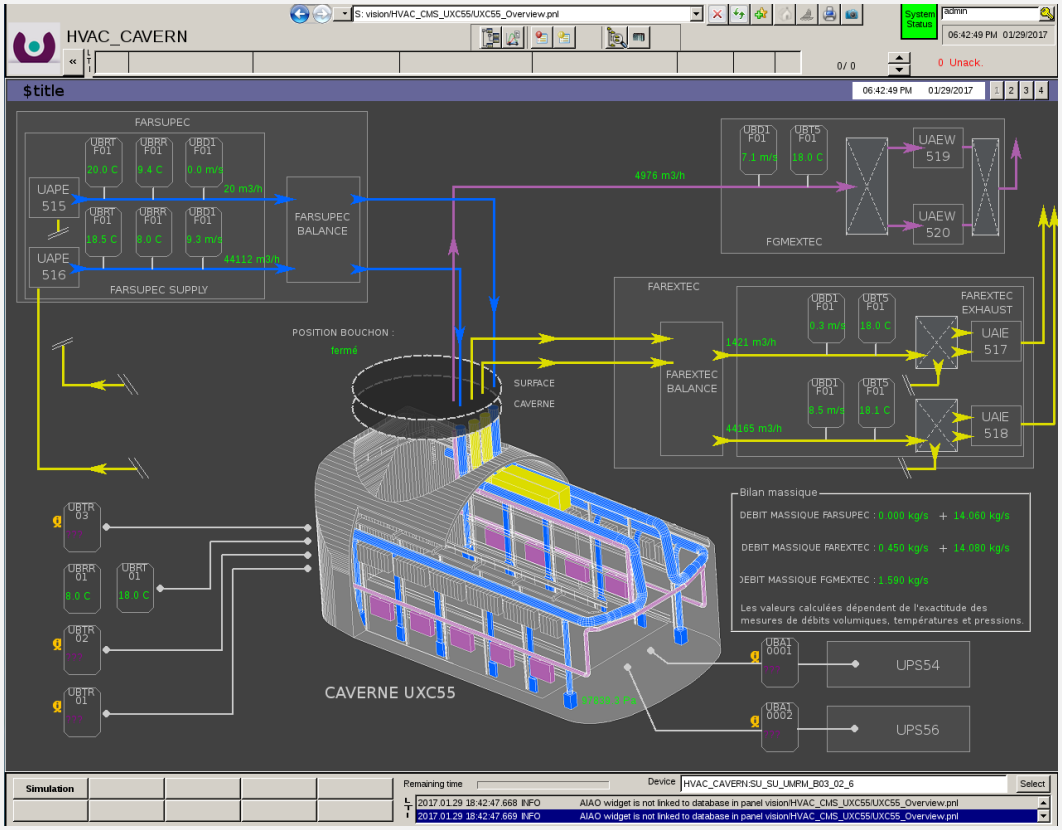




Interlocks: the AHU fan cannot start when the modulating dampers are not open

Dynamic Simulation with PLCs in the Loop





Conclusions

- EcosimPro HVAC library improved and validated
- Small HVAC plants modelled, good comparison with data
- EcosimPro CMS Cavern Physical Model:
  - All the technical inputs are now known or estimated (damper size, fan curve, duct pressure drops, …)
  - UXC55 HVAC Plant model is built
  - Most simulation issues (convergence, simulation time) resolved
- Simulations with simple model control for various operating scenario
- Model hooked up to 3 PLCs in the lab for manual simulations
- Development of control system is ongoing, in collaboration with Cooling and Ventilation team at CERN
- Then Virtual Commissioning

Thank you for your attention