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Mathematical Simulation models for real time, SIMBOTs

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Foreword

This CEN Workshop Agreement (CWA 18394:2026) has been developed in accordance with the CEN-CENELEC Guide 29 “CEN/CENELEC Workshop Agreements – A rapid way to standardization” and with the relevant provisions of CEN/CENELEC Internal Regulations - Part 2. It was approved by the Workshop CEN “Mathematical Simulation models for real time, SIMBOTs”, the secretariat of which is held by the “Spanish Association for Standardization, UNE” consisting of representatives of interested parties on 2026-10-02, the constitution of which was supported by CEN following the public call for participation made on 2026-04-08. However, this CEN Workshop Agreement does not necessarily include all relevant stakeholders.

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Introduction

SIMBOTs initial concept was a registered achievement of the SPHERE EU project (https://sphere-project.eu/). They were used to represent some pilot simulated components, to represent building and HVAC equipment's. Models included a detailed description of the ventilation discipline, with human models and complex air fluid mixtures as well. It is explained in a white paper published by SPHERE project[1].

The final intention of SIMBOTs is to reduce the cost and implementation time of simulation models. It is part of a methodology which tries to adopt applications from aerospace or nuclear into the construction business (Building Digital Twin Association ASBL (BDTA), 2026). This needs a drastic reduction in cost and response times. But benefits could be extended since initial design to final exploitation or decommissioning phase.

In mathematical simulation practice (also known as 0D-1D simulation), the operator spends a lot of time collecting information and specs of market equipment's. Many times, the operator has to use parametric models from the vendor libraries and adapt those parametric simulation components to the specific needs of a model, making some assumptions and admitting compromises. This is justified if the cost and time restrictions are not the main ones. But as soon as they are more and more critical, a model is just not affordable or it is not suitable in the normal design process, even if the simulation is providing valuable information. So, standardized and ready to use components and libraries could be helping to reduce this functional gap, opening a new potential methodology affecting design and all the rest of phases (construction, commissioning and exploitation).

Orientation to real time is another key. If simulation can be running quicker than the physical asset behaviour, then an additional source of information other then monitoring could be available, providing a way to make monitoring more robust or the implementation of advanced control solutions.

The concept of SIMBOTs shall be a market agreement for representing the functional mathematical model of equipment and components. This includes all possible disciplines, like electrical, fluid networks, air ventilation, process equipment's, spaces, humans, etc. There is no conceptual limitation. And the natural stakeholders, shall be manufacturers of those equipment's and software developers, implementing libraries to be used in their legacy or open-source software.

For one specific type of equipment, the methodology for representing with SIMBOTs the market models could be similar, just changing the performance curves. And this could have some practical implications in the test lab or certification of the model. But this is out of the scope of this CWA.

[1] SPHERE EU PROJECT Grant Agreement No. 820805. "From BIM representation to functional simulation and real time advanced control", https://sphere-project.eu/download/from-bim-representation-to-functional-simulation-and-real-time-advanced-control/

1 Scope

This CEN Workshop Agreement (CWA) aims to define a methodology for creating SIMBOTs.

This methodology includes:

1. SIMBOT conceptualization: input, outputs and parameters for tracking;
2. How to define performance curves based on product information (usually public data sheets);
3. How to generate the semantic information to add in the knowledge Graph of SIMBOTs;
4. How to implement a library component in a legacy simulation software using the semantic information extracted from the knowledge graph;
5. How to use in practice the SIMBOTs for big models;
6. Practical details and use of simulation for real time.

This methodology helps to improve the collaboration between manufacturers and software developers, reducing the time and cost of model implementation.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp/

— IEC Electropedia: available at http://www.electropedia.org/

3.1
simulation
software process which replicates a system functionality in order to predict actual behaviour

3.2
simulation component
fundamental, modular element of a software simulation system, representing a subsystem or entity with a predefined, generalized, and reduced behaviour that can be reused across different simulation models

3.3
component digital twin
CDTw
digital twin (3.4) of a component

[SOURCE: EN 18162:2026, 3.4, modified — Note 1 to entry and Example have been removed]

3.4
digital twin
DTw
digital representation of a target entity with data connections that enable convergence between the physical and digital states at an appropriate rate of synchronization

Note 1 to entry: Digital twin has some or all of the capabilities of visualization, simulation, surveying, monitoring, forecasting, control, etc.

[SOURCE: EN 18162:2026, 3.5]

3.5
components library
organized, reusable collection of pre-defined, mathematical, or logical models that represent physical or conceptual entities within a simulation environment

3.6
abstract component
foundational, reusable model definition within a component library that cannot be directly instantiated (used) in a simulation on its own. Instead, it serves as a base class or template, defining shared ports, parameters, and fundamental equations that are inherited by more specific child components

3.7
SIMBOT
public semantic expression of the mathematical model of a market equipment describing its functionality (Building Digital Twin Association ASBL (BDTA), 2026). It is oriented to real time execution, and it is in agreement with the manufacturer performance description. This mathematical model should be "parameter free".

Note 1 to entry: A SIMBOT is considered as a vendor-neutral simulation component.

Note 2 to entry: A SIMBOT is considered as a CDTw.

Note 3 to entry: The parameter-free SIMBOT represents the reference behaviour of the equipment. Instance-specific calibration or adaptation may be applied at Digital Twin implementation level without modifying the reference SIMBOT.

3.8
simulation DECK
standalone, executable simulation model exported as a "black box" that can be run independently of the main software environment. It encapsulates all compile-time and run-time dependencies, enabling the creator (supplier) to deliver a secure, interactive simulation to a user who does not have simulation software installed

3.9
OPC Unified Architecture, OPC UA
cross-platform industrial communication standard developed by the OPC Foundation (AISBL, OPC Federation, 2026) that enables secure, manufacturer-independent data exchange between devices, controllers, and enterprise systems

Note 1 to entry: More information about OPC UA Application can be found in IEC 62541 and OPC UA website (https://opcfoundation.org/)

3.10
simulation model tracking system, SMTS
specialized, real-time, or near-real-time computational framework that runs in parallel with a physical process or system. It combines dynamic simulation models with actual field data to track the current operating state of the system, correct model parameters, and predict future behaviour

3.11
performance curve
graphical representation illustrating the relationship between a machine's or system's output capabilities and its operational inputs. These curves are used to predict performance under varying conditions, optimize efficiency, and ensure equipment is properly sized for specific applications

3.12
Digital Product Passport, DPP
EU-mandated digital record containing comprehensive data on a product's origin, materials, sustainability, and repairability

3.13
phasorial representation, DQ
mathematical method in electrical engineering that converts time-varying sinusoidal waveforms (AC signals) into stationary complex numbers or vectors, known as phasors (D real part, Q imaginary part). A phasor represents the magnitude (amplitude) and phase angle of a signal, simplifying AC circuit analysis from differential equations into algebraic operations

3.14
residuals
comparison between simulation generated values and monitoring of the same magnitude. It is made by simple difference (subtraction)

3.15
Supervisory Control and Data Acquisition, SCADA
SCADA in control engineering is a computer-based system combining hardware and software to monitor, control, and analyse process systems in real-time. It enables remote operation of devices, optimizing efficiency and safety

4 SIMBOT information

4.1 General

The information relating to a SIMBOT is divided in:

— general (non-functional) information,

— functional information, and

— ancillary information.

4.2 SIMBOT overall architecture

The creation of a SIMBOT and its implementation in a software vendor library is shown in Figure 1.

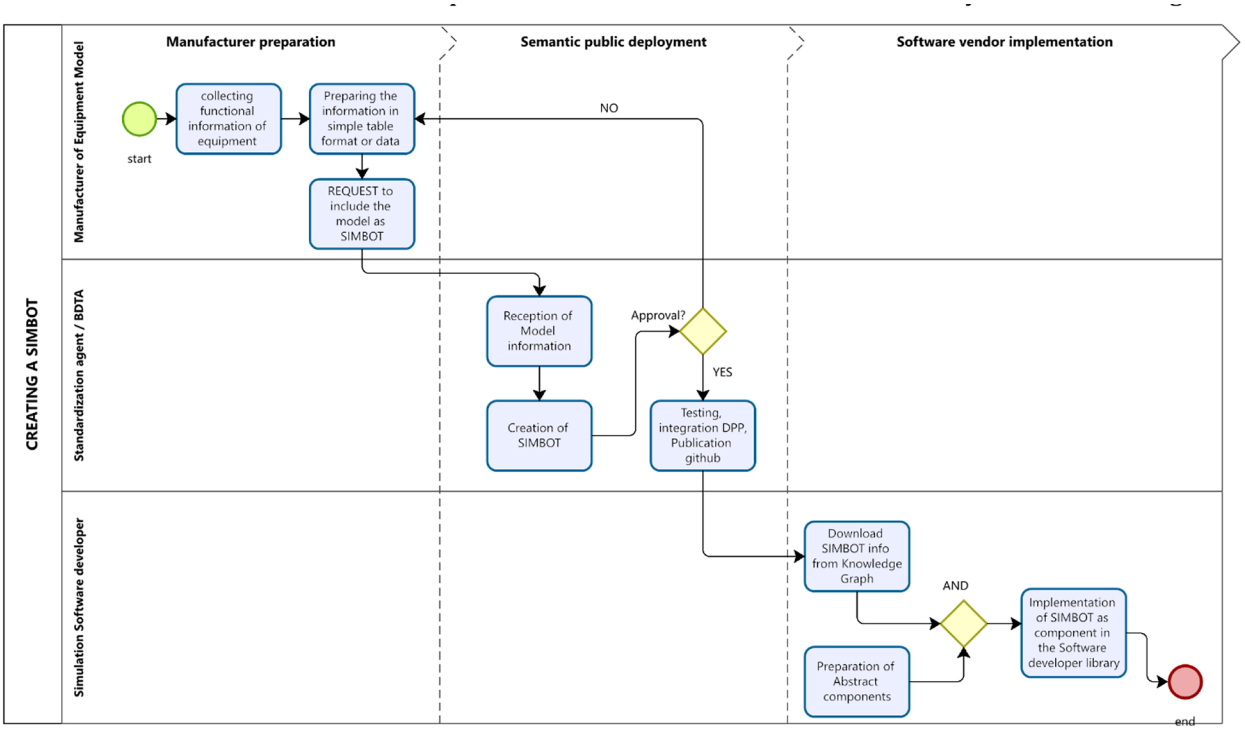


Figure 1 — Creation of a SIMBOT and its implementation in a software vendor library

In this diagram there are three stakeholders interacting (manufacturer, the standardization agent and the software vendor). Three phases have been considered (preparation of information by the vendor, implementation of the knowledge graph (or reference library) by the standardization agent and the final implementation of a legacy library by the software vendor. This legacy library shall have other simulation components (not SIMBOTs) which are incorporated in the models.

The process for real time model creation is included in Figure 2.

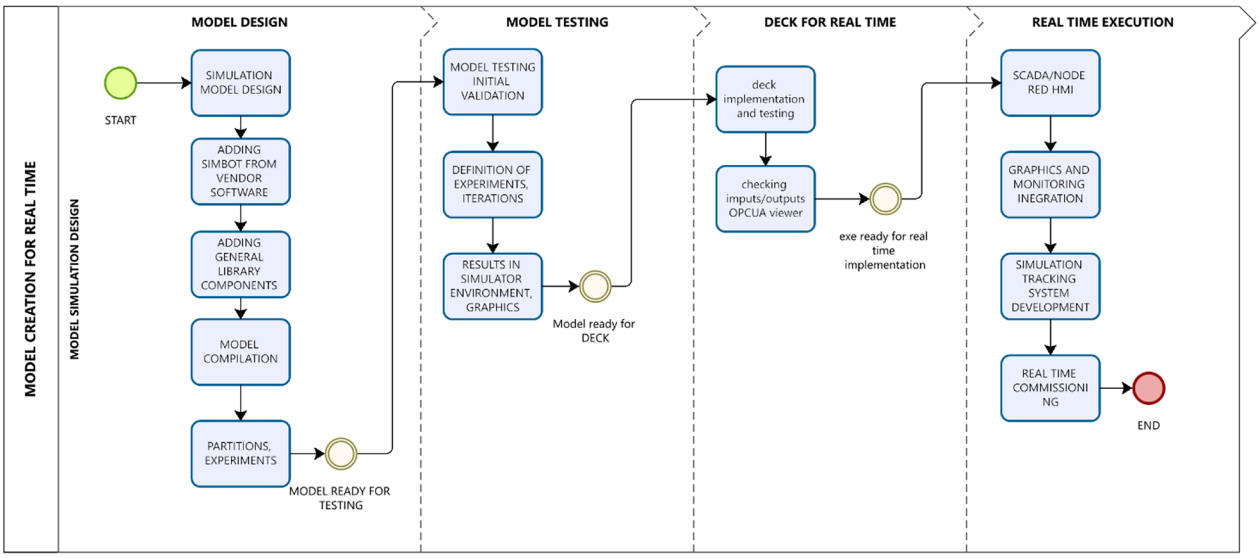


Figure 2 — Process for real time model creation

The model creation is executed by an engineering services company. They use the simulation tool provided by a software vendor, which incorporated SIMBOTs in the libraries. Four phases have been considered: the simulation model creation, model testing, preparation of the DECK for real time and the final deck running in real time interacting with scada systems and sensors. In this process, the DECK may be providing the inputs and outputs with a real time protocol as OPCUA (AISBL, 2026). The outputs of the simulation can be compared with monitored values, implementing a simulation model tracking system (SMTS).

4.3 Server SIMBOT information: general information

General information is any information that refers to the SIMBOT as an entity, adding the necessary context to identify a SIMBOT in a unique and precise, unambiguous way. This general information includes the entities contained in the following table.

Table 1 — Server SIMBOT general information

Entity	Values
Manufacturer	Original manufacturer (not reseller). Owner intellectual property, specifications and controlling the update, downgrade or recycling
Model	Specific model of the equipment. This shall not be a generic description or a series of models, but a precise market model
Discipline	This value shall be one of the c disciplines classifications [a]
Abstract component	This is not only a name supporting the mapping with the vendors abstract components, but the identification of a mathematical model applied to the equipment. One model equipment could have several models depending on the use of the SIMBOT, and this field would be identifying that mathematical model. mapping. The software vendor may have or not the same abstract component name in their legacy library
Version	SIMBOT version. In Annotations, history of versions shall be described
Date	Date of publication in the knowledge graph. History of publications shall be detailed in Annotations
Power	This value in W shall describe the nominal power of the equipment
Status	This value shall be one of the status classifications [b]
Annotations	MODEL history. Data sheet reference. SIMBOT Version history. SIMBOT Date of publication history. Reference to Digital Product Passport information.

[a] Disciplines classification values can be for example: Building, HVAC, Electro_DQ, Data Centers, etc.

[b] Status classification values can be for example: Market, DEMO, prototype, etc.

General information shall not replicate information which is already present in digital product passport knowledge graphs. Functional information of SIMBOTs must be aligned with catalogues or DPP information, but not replicating information which is already there. Instead, SIMBOT must be focussed on functional description, rather than geometrical, potential use, market utilities or maintenance instructions. That non-functional structured information shall be accessible thanks to general information of the SIMBOT.

4.4 Functional information

The performance information shall contain the name of the concept, the input(s), the outputs, performance curves linking the input(s) and outputs, and outputs used for SMTS. Input(s) and outputs shall be defined with initial values, format and units. Performance curves shall be defined as curve by points, and they may have several dimensions. SMTS shall be several outputs to get redundancy with monitoring values.

4.5 Ancillary information, testing and certification for SIMBOT implementation

Ancillary information shall be included references of the basement information to define the SIMBOT. This may be references to specs or datasheets, certified lab tests or any other methodology.

5 Ontology definition

For the representation of the SIMBOT a semantic expression shall be adopted. It is neutral and can have all the mathematical content needed. Information about general data of the market model shall be avoided, and the ontology and knowledge Graph shall be aligned with digital product password applications but not including information which may be present in those resources. An example is provided in annex A.

The SIMBOT information shall be semantically structured following a public ontology.

6 Disciplines and abstract components: mapping with software vendor applications

6.1 General

The organization by disciplines and the existence of abstract components implies the preparation by the software developer of these abstract components and functional libraries on their own software platform. The abstract component name included in the SIMBOT information has no content. However, there must be an equivalent component on the part of the software developer.

The final organization of the component libraries by the developer shall be the sole responsibility of the developer and shall include component validation models.

Both the organization by disciplines and the relationship of abstract components require continuous maintenance and publication, and the knowledge base of the O4BSIM ontology is used for this purpose.

6.2 Electro interaction

In general, almost all equipment requires electrical power to work. The introduction of the electrical discipline with sampling frequencies on the order of minutes makes it necessary to use a phasorial representation. The components of this discipline, therefore, shall not include electrical components for the time domain, but DQ components with phasorial representation.

6.3 Controls and SIMBOTs

In general, SIMBOTs interact with internal and external control loops. In the case of an internal regulation of the SIMBOT, all those adjustments that have a temporary response below the dynamics that are significantly faster than the intended sampling interval shall be avoided, simplifying the behaviour of the equipment only with a performance curve.

7 Real time

7.1 General

Real-time simulation means that the integration of the system is solved during the physical execution. This requires a very careful and efficient representation of the components, so that integration times do not exceed the pace of execution in large models. We can consider the simulation to be executed satisfactorily if the integration times are approximately one order of magnitude below the physical execution. For example, physical sampling every 5 min (300 s) would require integration times of approximately 30 s.

In real time, the simulation model (which can be an executable or what we call DECK) would receive information from adjustments or field signals. The DECK returns values integrated in that range. And finally, these values can be compared with monitored values, monitoring the operation of the equipment in real time.

Simulation models including SIMBOT's should include general aspects like general controller applications, or interfaces for MiL, SiL or HiL tests. This also regards general system dynamics like physical inertia, controller delays, switch-on/off-times, etc. Another important aspect of SIMBOT's design considers the availability of input data and parameters. Finally, as manufacturers often only provide little data regarding their machinery, SIMBOT's input data must be aligned to available data sets.

7.2 Time dynamics of SIMBOTs

Time dynamics of SIMBOTs shall be addressed, as current performance curves primarily capture steady-state relationships rather than transient behaviours. In practice, equipment response times vary significantly; a fan might reach a stationary state in just five seconds, while a larger system like a chiller could require several minutes to fully stabilize. These dynamic responses become crucial for accurate real-time simulation, especially when the equipment's stabilization period is similar to or slower than the tracking system's sampling rate. Incorporating basic time constants or transient response parameters into the SIMBOT definition would ensure the models realistically reflect these operational delays and control loops without overcomplicating the foundational manufacturer data.

For dynamic behaviour with response in the same order of magnitude than the sampling interval, a time constant could be included in the SIMBOT definition. The function to be integrated in the abstract component will consider this dynamic response based on the time constant value.

7.3 Limitations

7.3.1 One-step delay

Because the simulation is run with field inputs, there is an intrinsic one-step delay in the simulation output versus monitoring. This should be taken into account in the SMTS.

7.3.2 Co-simulation

It would be possible to integrate multiple DECKS using inputs and outputs from both. However, the practical co-simulation that would be achieved in this way can falsify the real behaviour of the system. If this is the case, thinking about large models, it is important to avoid the mutual influence that may exist between sections of the installation.

7.3.3 Level of detail and methodology

For the development of models, a common representation methodology is necessary, in addition to having component SIMBOTs. This would affect, on the one hand, the most basic processes that are

simulated and, on the other hand, the way in which systems are implemented that are faster in their response than sampling times. Engineering practice and new standards help solve that problem.

7.4 Observation window

An observation window in a simulation model tracking system is the specific time interval or spatial range during which a sensor, model, or entity actively records data and monitors the system's state. It defines the boundaries for data collection, filtering, and analysis, separating relevant events from noise or data outside the area of interest.

For the implementation of SMTS it is not essential to have historical data, so only a portion of the data over time would be enough for the execution of the comparison algorithms. Therefore, we can speak of a observation window in time for SMTS processes, which depends on the dynamics of the processes of the system.

7.5 SMTS algorithms, residual and other resources

Algorithms for comparing simulation and monitoring results can be of many types. Not to be forgotten is the limitation described in 7.3.1.

A first comparison can simply be made by differentiating values between simulation and monitoring. These values are named as residuals.

More advanced algorithms could compensate for one-step delay, take into account additions or other operations between variables, or consider not only current values but also derivatives or integrals. In some cases, these operations can already be performed in the simulation DECK, but in others they can be carried out in the simulation and monitoring integration platform (which could be a SCADA system or a similar software resource in real time).

7.6 SCADA systems y DECKs

The simulation DECK needs control commands (RUN, RESET, integrate a single step, simulation time, etc.) as well as variables, INPUTs/OUTPUTs. To exchange information with the DECK, several communication protocols are possible. Among them, the OPC UA protocol would allow us to exchange control commands and variables. The communication protocol must be used by both the simulation DECK and the SCADA or real-time system being used (it could also be a real-time database).

8 Respect for the manufacturer's know-how

Since the SIMBOT functionally describes the behaviour of a computer, there could be the potential danger of making public knowledge and proprietary information of the manufacturer. By expressing the SIMBOT with performance curves, the aim is to avoid any detail that could compromise the manufacturer's ownership. This marks a limit in terms of the developments of the SIMBOTs, which shall not incorporate the internal programming of the equipment or details of internal materials or systems. In this way, the manufacturer's know-how is protected.

9 Software developers and protection of intellectual property

Based on the open and semantic definition of the SIMBOT, all development and implementation of the developer's software system library is owned by the developer. That is, from the definition of the performance curves and the name of the abstract component, all subsequent development corresponds to the developer. The SIMBOT therefore respects the intellectual property of the developer, who keeps his development system intact without the need to make the programming of its components public.

10 Certifiers and testing laboratories

10.1 General

Performance curves can be constructed from public information from the manufacturer in product specifications or data sheets. In some cases, these properties are certified by third parties, and the information incorporated responds to standardized test conditions. The development of SIMBOTs does not require anything new in relation to the functional information that already exists today.

10.2 Testing and validation of SIMBOTs

The SIMBOTs shall be tested and validated to ensure they accurately reflect the intended equipment behaviour. While SIMBOTs rely on existing manufacturer data sheets and performance curves that are often already certified, establishing practical testing guidelines would help to verify that the resulting mathematical models work correctly during real-time execution. Realistic validation tasks could focus on confirming that the performance curves are correctly translated into the semantic model, and verifying that the simulated outputs—such as dissipated power or temperatures—reasonably align with standard tracking metrics. This would provide a reliable way to assess the quality of the SIMBOT implementations without requiring complex new data generation or compromising manufacturer know-how.

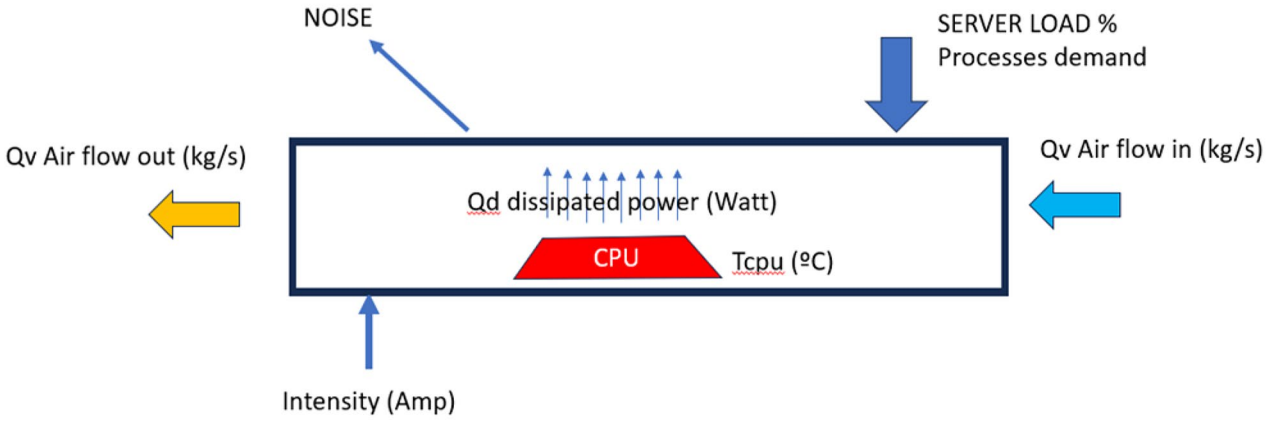
Annex A
(informative)

SIMBOT example of Air ventilated server in a data center

A.1 Functional concept of the server SIMBOT

A.1.1 General

The same equipment may have several ways to be conceptualize. In this example case, an air ventilated server of the market (2P 2U HPE ProLiant DL180 Gen10) is circulating air through the box to keep the CPU temperature under control. It can be considered the CPU LOAD as input. Based on CPU LOAD demand value, we can be calculating the Tcpu (CPU temperature), the Qd (dissipated heat power (W)), the Qv_in and the Qv_out (mass flow ventilation in kg/s) and the NOISE generated by the air flow.



Key

SERVER LOAD	It is the process demand in % of the server (CPUs, GPUs, and other internal devices)
Intensity (Amp)	Electrical intensity Amp absorbed from the power network (Amp)
Tcpu	CPU temperature (C)
Qd	Dissipated heat by the CPU which is added to the circulated air inside the server box (W)
Qv in	Mass Air flow entering the box in Kg/s
Qv out	Mass Air flow going out the box in Kg/s with increased temperature
NOISE	Noise dissipated by the box in DB's

Figure A.1 — Functional concept of server SIMBOT

A.1.2 Server SIMBOT information: general information

The general information of the server SIMBOT can be summarized in the following table.

Table A.1 — Server SIMBOT general information

Entity	Values
Manufacturer	HP
Model	HPE DL180 Gen10 8LFF
Discipline	DATA CENTERS
Abstract component	AbsServer
Version	0.0
Date	9APR2026
Power	1000
Status	DEMO
Annotations	For demo purposes only

A.1.3 SIMBOT input, outputs and parameters for SMTS

In case of this concept of air ventilated server, we consider INPUT the SERVER_LOAD. This would be the demand processing of the server (instantaneous or the mean value over a period of time). We can use the OUTPUT of one of the performance curves as INPUT for another relationship. For example, we can use the mass flow as INPUT to calculate the NOISE.

From the SERVER_LOAD several outputs are calculated. The mathematical relationship (performance curves) is described in the following table.

Table A.2 — Performance curve of server SIMBOT

Entity		Performance curve	Notes
SERVER_LOAD_vs_Power		{{0,100}, {2.5,26.3}}	Table of SERVER_LOAD (%) vs Qd (W)
SERVER_LOAD_vs_Tcpu		{{0,100}, {30,90}}	Table of SERVER_LOAD (%) vs Tcpu (C)
SERVER_LOAD_vs_m		{{0,100},{0,2.27e-2}}	Table of SERVER_LOAD (%) vs mass flow (kg/s)
SERVER_LOAD_vs_Amp		{{0,100}, {0.5,10}}	Table of SERVER_LOAD (%) vs Amp (A)
Qv_vs_Noise		{{0.,2.27e-2}, {35,65}}	Table of Qv (kg/s) vs Noise level (dB) for noise level

A.2 Semantic information of the server SIMBOT

The information related to a SIMBOT will be expressed in a knowledge graph or reference library following a specific ontology. The semantic content or knowledge about a SIMBOT shall be expressed in triples following the standards RDF/OWL. SIMBOTs are collected at the O4BSIM ontology.

NOTE 1 More information about RDF/OWL standards can found in the following links: https://www.w3.org/RDF/ and https://www.w3.org/OWL/

NOTE 2 More information about O4BSIM ontology can be found in the following link: https://github.com/PabloVicenteLegazpi/O4BSIM

A.3 Implementation of SIMBOT in library of software vendor

As an example, a software vendor could be integrating the information of the SIMBOT in a component following the code below:

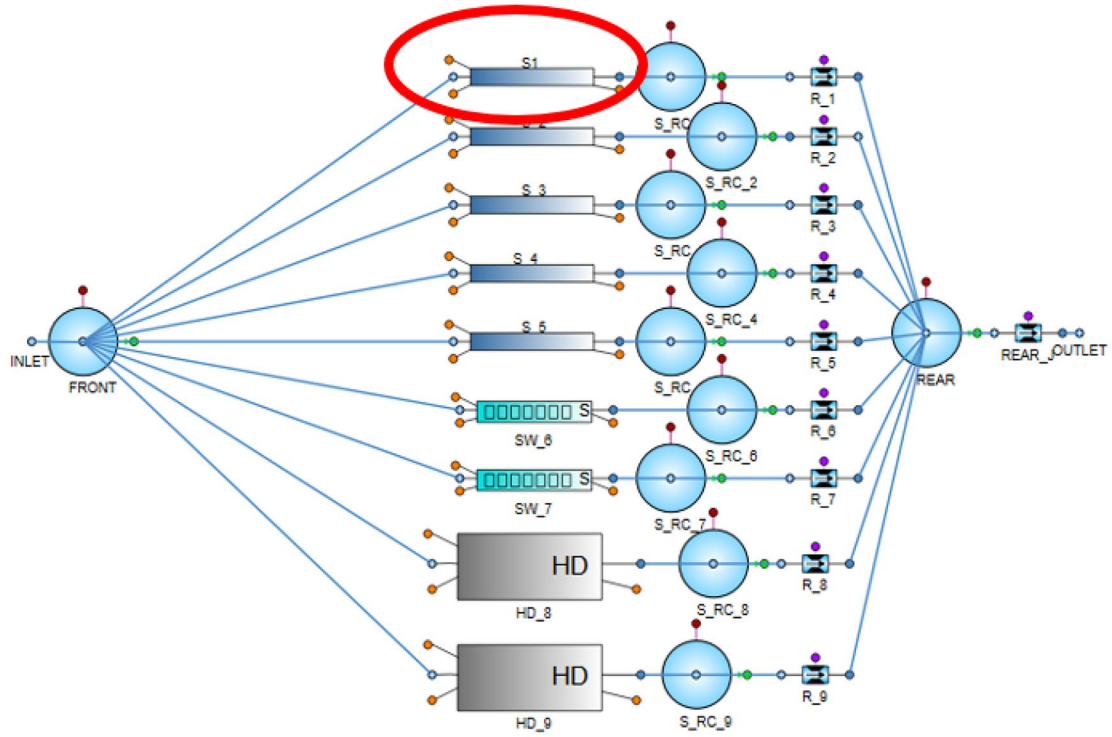
```
/*-----------------------------------------------------------------------------------------
LIBRARY: DC_COMPONENTS
FILE: HP_HPE_DL180
AUTHOR: PVL
COMPANY: BDTA
DESCRIPTION: DC - SERVER - HP - HPE DL180 Gen10 8LFF
CREATION DATE: 13/02/2026
-----------------------------------------------------------------------------------------*/
USE MATH
USE DC_COMPONENTS
-----------------------------------------------------------------------------------------
COMPONENT HP_HPE_DL180 IS_A AbsSERVER "Server HP HPE DL180 Gen10 8LFF"
PORTS
DATA
DECLS
CLOSE SERVER_LOAD_vs_Power = {{0,100}, {2.5,26.3}} --Table of SERVER_LOAD (%) vs Qd (Watt)
CLOSE SERVER_LOAD_vs_Tcpu = {{0,100}, {30,90}} --Table of SERVER_LOAD (%) vs Tcpu (C)
CLOSE SERVER_LOAD_vs_m = {{0,100},{0,2.27e-2}} --Table of SERVER_LOAD (%) vs mass flow (kg/s)
CLOSE SERVER_LOAD_vs_Amp = {{0,100}, {0.5,10}} --Table of SERVER_LOAD (%) vs Amp (A)
CLOSE Qv_vs_Noise = {{0.,2.27e-2}, {35,65}} --Table of Qv (kg/s) vs Noise level (dB) for noise level
INIT
DISCRETE
```

In this component we can see it is included in a library called DC_COMPONENTS (Data Center components), the name of the component is the name in the HP_HPE_DL180, it is using an abstract component of the vendor called AbsSERVER and the performance curves are included in the DECLS section of the code.

The vendor can assign a symbol to the component and work in schematic model, connecting the component with other components of the vendor or other SIMBOTs translated into components.

A.4 Integration in a model, deck generation

In the following figure the server SIMBOT as library component of the vendor inserted in a schematic of a rack is included.



Key

Red circle	One of the components created based on the server SIMBOT
Y	definition for Y

NOTE In the rack schematic other components as switches and hard disks are included. All of them are connected with fluid ports to spaces and other vendor components.

Figure A.2 — Example of schematic including the library component created with the SIMBOT HP_HPE_DL180

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