# Applying MTP-concept for the standardization of building automation and control systems

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**Abstract.** Energy requirements for buildings and their technical systems are becoming stricter and interfaces of technical systems more complex. Today's processes for monitoring applications are inefficient in planning, commissioning and operation due to the high effort involved. This is caused by lack of semantic specifications in existing standards. A basis for their economic implementation is not given.

This paper proposes a lifecycle spanning standardization of production related technical building equipment systems. The standardization work is based on the information model of the I4.0 Asset Administration Shell including the application of an online repository. Unified properties are defined from aspects of engineering to operation for technical plants. As a result, monitoring applications are possible with little effort. By applying Module Type Package, an information model is available for manufacturer-neutral and service-oriented plant control. A prototype is used to illustrate the advantages and engineering by means of Module Type Package. Quality assurance as an aspect of the commissioning is supported by the development of digital twins. Finally, the effort in the lifecycle phases of engineering, commissioning and operation is reduced. The standards developed will be published in a NAMUR recommendation.

**Keywords.** *Industry 4.0, NAMUR, Asset Administration Shell, Module Type Package (MTP), Asset-Monitoring, Production-related Building Automation.*
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## 1. Introduction

Due to the current lack of standards, information on assets (components of production related technical building equipment (TBE)/building automation (BA)) are only available with increased engineering effort. Necessary properties for plant control, simulation and plant asset management are not available or are only available to a limited extent. Studies in practice [1] show that due to a lack of standards, non-uniform information models and the variety of subsystems (communication, applications), engineering efforts for data integration in e.g. energy- or asset-monitoring applications are often higher than their benefits. In practice, islands of information and data with an increased administrative effort get created. Thus, monitoring applications for energy- or asset-management are possible with increased effort and not widely available.

From perspective of legislation [2], buildings should have functions by 2025 that allow continuous monitoring, among other things. Selected systems for this purpose must benchmark the energy efficiency of buildings, report malfunctions to responsible persons and provide automated information about savings potential. Networked and interoperable system technology is required [3]. In order to achieve these targets and to be able to show the efficiencies, various monitoring applications are needed. As in administrative buildings, requirements for economic and efficient processes apply equally in production buildings, if not with a greater impact of efficiency on a building's emissions.

The NAMUR working group 1.7 "Production related building automation" and the TH Cologne-University of Applied Sciences developing information standards for industrially widespread asset types of production related TBE. The aim is to reduce efforts in processes of engineering, commissioning and operation of production-related building automation. By applying a uniform information model, hurdles to widespread application will be reduced. Monitoring, optimization and maintenance applications of HVAC systems can thus become an economically applicable standard. Figure 1 gives an overview about standardization work for production related TBE. The shown aspects of plant asset management, quality assurance of automation functions and plant control are getting standardized.

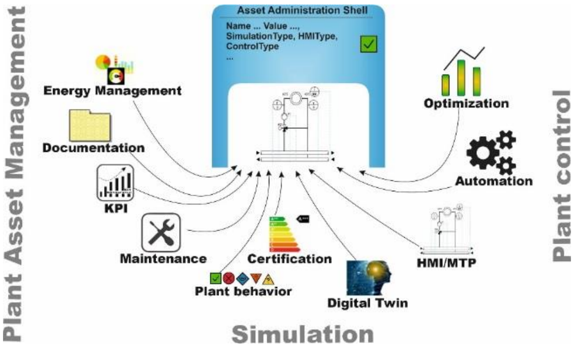


**Fig. 1**- Overview of standardization work

Standardization of production related TBE through suitable information models is a lever to aim the requirements according to [2] through the simplified availability of properties for energy management and asset monitoring applications. The information model of Industry 4.0 Asset Administration Shell (I4.0-AAS) [4] and Module Type Package (MTP) [5] are applied as a solution approach. An I4.0-AAS represents a lifecycle spanning and manufacturer-independent information model, which extends from planning to operation. For the area of automation and plant control, the MTP-concept is available by process industry.

## 2. Today's Standards and guidelines

Today's standards for building automation [6-11] do not include information technology descriptions for asset types and macro functions for TBE systems. Only the task of room automation is covered by macros [12]. Related functions or services for TBE systems, e.g. as macros for automation functions according to [7, sheet 3.2], are expected to be available from 02/2023.

Despite the standardization of interfaces and protocols, manufacturer-neutral communication and field bus systems [13-15] can only be integrated into an overall system with a huge effort in engineering. A Leading protocol in building automation is BACnet [6] with a service-oriented structure. BACnet standardizes input and output functions; templates or macros are not available. An analysis of the discussed standards shows that there is a gap for an area of manufacturer-independent automation with templates and HMI for building automation. MTP-concept is currently the only applicable information model for manufacturer-independent and service-oriented automation including HMI visualization. Its application in practice is currently limited to process automation. This standardization work demonstrates that MTP-concept is of importance for building automation. Essential factors for the use in building automation are the manufacturer independence, the service-based automation, the machine-readable data exchange by means of [16] and the integrability into a central information model.

Time-consuming quality assurance of automation functions through simulation is simplified by the creation of digital twins. There are various software tools for creating those [17, 18]. Using existing libraries, e.g. [19-21], linked and complex plant simulations with different targets can be created. A common software environment is Modelica, with the open source version OpenModelica [17]. Various open source libraries are available for simulation processing with Modelica. Another well-known open source library is the CARNOT library [22]. This is an extension of the MATLAB Simulink environment and is tailored to plant and building simulations. Requirements of Good manufacturing practice [23, 24] are spread in the pharmaceutical industry. In relation to the building automation there is only a small impact given and thus, GMP is not part of the standardization work.

Monitoring and observation of processes or procedures in building technology is implemented through technical monitoring according to [25]. For asset condition monitoring, asset monitoring is used according to [26]. With [25, 26], standards are given that can describe the states of the processes and assets. In practice, these standards are applied through complex and manual engineering during operation.

Planning of buildings is increasingly built on BIM (Building Information Modelling). Informational bookkeeping in BIM is based on the Industry Foundation Classes (IFC-standard) [27]. IFC describes a lifecycle-spreading model for planning and operating of buildings. In practice, currently the entire application of the IFC model is missing, thus data for later operation are not available through the meta model of the IFC standard.

In total, there is a lack of a lifecycle-spreading central information model for building automation that can map the in Figure 1 shown aspects of plant control, quality assurance and plant asset management. In fact of standards explained above are each without semantic characteristics, phase-specific information- and data-islands emerge e.g. BIM in the area of planning.

## 3. I4.0-AAS as central Information-model

The information model based on the Industry 4.0 metamodel is used to map the characteristics of assets across the life cycle [4]. Submodels available through the information model can be used as a generic approach for all assets. As well, the MTP concept can be mapped to the I4.0 AAS information model, as already shown in [28]. The IFC [27] metamodel of BIM, on the other hand, requires separate type developments for each asset type. The lack of practical application of BIM for the operational data of buildings and assets leads to choose that the I4.0-AAS as leading information model for this standardization work.

### *3.1 Structure and application of the I4.0-AAS*

I4.0 Asset Administration Shells represent the connection between the physical asset and the Internet of Things and Services (I4.0 component consisting of an asset and its Administration Shell [4]). The Asset Administration Shell (AAS) of a TBE asset or component represents standardized functional aspects as a virtual image, e.g. properties, configuration parameters, states, capabilities and offered services. A central component of the I4.0-AAS are submodels that describe a wide variety of asset functions (simulation, HMI, operation, maintenance, etc.) using a structured set of standardized characteristics and capabilities [4]. In concrete terms, this means that management applications can access the features of submodels of I4.0 AAS. Figure 2 shows the structure of the submodels based on the planning and construction process according to [29, 30].

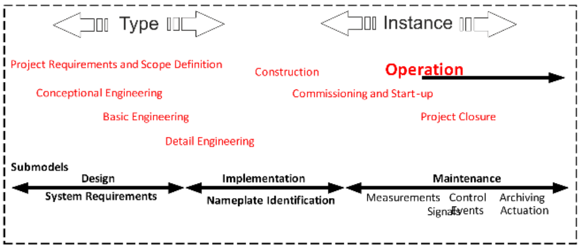


**Fig. 2**-Lifecycle-sketch in relation to submodels

Several years can pass from the planning process to a regulated and ready-to-operate TBE. With the planning phase, types of the I4.0 AAS are available. By entering product-specific characteristics of the aspects named in Figure 1, the I4.0 AAS is instantiated. Due to the lifecycle spanning approach of the information model of the I4.0 AAS, planning and commissioning information is available for later applications through the type and instance model, as the type information remains available even after instantiation through the submodels. During a performance evaluation of plants and components in operation, a comparison of operational data with planning data of respective assets can be carried out in order to identify potential weak points in actual operation.

### *3.2 Application in production-related building automation*

In addition to the Bill of Material, the mtp-file is available as a separate *Module* Type *Package* sub-model for use in third-party applications. Figure 3 shows an excerpt of the I4.0 AAS information structure. If the information of the I4.0 AAS is viewed by using an XML viewer [31], the features with attributes are recognizable, e.g. the file path of the mtp-file, as marked in Figure 3.

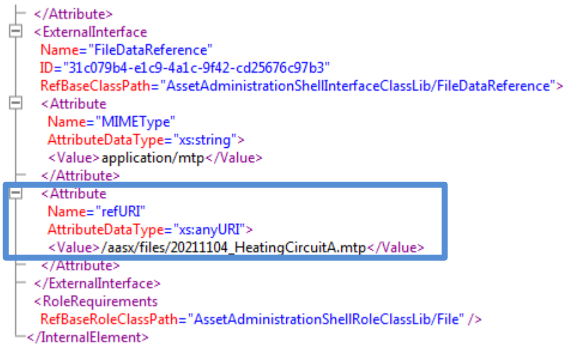


**Fig. 3**-Extract from the AAS-file

Figure 4 shows the prototypical implementation of a TBE, using the example of a heating circuit and the composition as a composite component. All belonging I4.0 components of heating circuit are linked to the composite component.

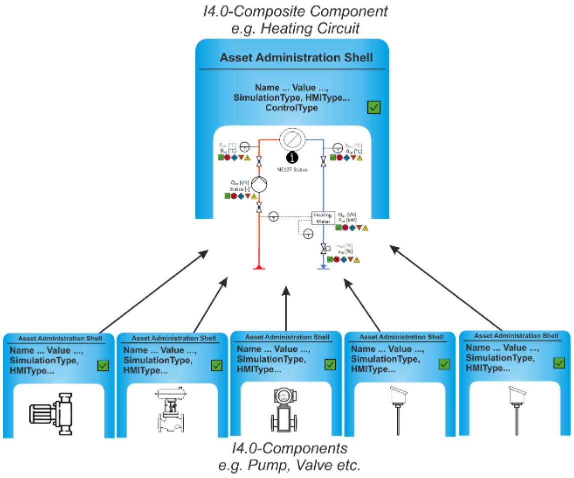


**Fig. 4**-Sketch of an I4.0 AAS composite component

Heating circuits of a HVAC-system are standardized by means of information model of the I4.0 AAS. By using AAS Package Explorer [32], as one possibility of AAS generation, the I4.0-AAS “Heating Circuit” has been set up as composite components. Composite components themselves do not represent a physical asset. A composite component represents a relationship complex of two or more AAS, which contains a higher and new functionality [33]. This results in a composite component that represents the entire heating circuit in addition to the individual AAS of temperature sensors, valve, pump and heat meter. A composite component maps the comprehensive information such as energy requirements and consumption, the MTP file and overall performance on a system-specific basis.

## 4. MTP for building automation

MTP-concept describes the modularization of complex production plants in terms of operation, visualization, alarming, communication, etc. [5]. Production related process equipment assemblies (PEA) are defined, which can consist of several modular functional units. Scope of standardization are systems of production related TBE, which includes HVAC and room automation systems.

MTP concept is currently applied in the process industry. Due to the characteristics of service-based automation and the availability of an information model applicable to building automation, the MTP-concept is applied to plant control aspect of this standardization work. With use of I4.0 AAS information model as the leading information model, MTP-concept must be integrated into it. Application of submodels of the I4.0 AAS enables this integration, as Figure 5 shows.

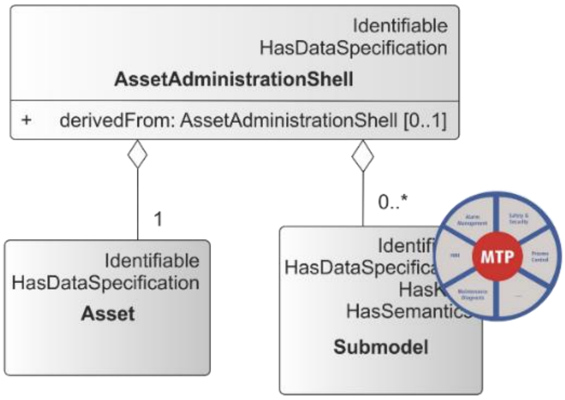


**Fig. 5**-Integration of the MTP into the I4.0 Asset Administration Shell [28]

The combination of PEA in complete systems requires an orchestration. Thus, a *Process Orchestration Layer* (POL) [1] is used which represents the automation and information technology level for the operation of modular plants. Goal is manufacturer-independent use with the same representation of a PEA by the HMI of MTP. An asset with multiple functions or partial functions, provides a separate service for each individual function. For example, a ventilation system, depending on the equipment, contains the services heating, ventilating, cooling, humidifying and dehumidifying. These defined services are available to the user in an executable form without having to carry out the engineering or create the visualization. A parameter set with setpoints is supplied with the service call for each PEA. HMI are available through templates. Service-oriented modelling and the use of templates for HMI of complete plant components, result in a reduction of engineering effort and simplification of configurations.

### *4.1 Application in production-related building automation*

Figure 6 shows how visualization aspects are standardized in terms of information technology. HMI of a heating circuit with function template of pump for operation is shown.

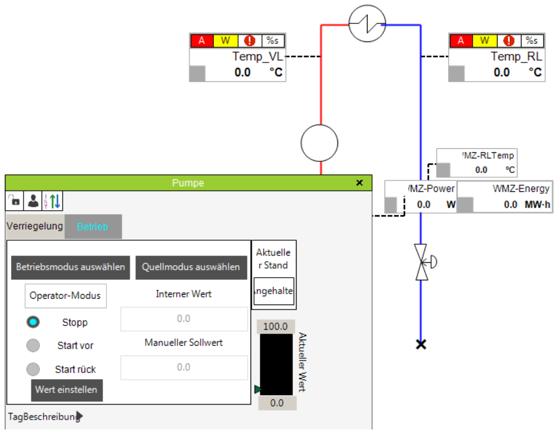


**Fig. 6**-View visualization with function template

Structure of TBE systems is developed and specified by users in Namur working group. The information technology standardization of assets is independent of the TBE structure. A basis for the information technology standardization of assets is the mapping of ISO/IEC standard ECLASS [34]. By specifying ECLASS version and ECLASS-IRDI, described data point can be represented unambiguously. Target systems, such as a POL, can represent the data point correctly by applying the semantic specification.

Heating circuit is automated by means [5, sheet 4]. State machines define a service-oriented interfaces for calling plant-control functions. A state machine executes fixed defined functions based on certain input status. Without functional requirement, the state machine is in *IDLE mode*. The executable program is started by the status word *Start.* As with the request of a service, a status word is also required for termination. *Complete* terminates the service in a controlled manner and the state machine is set to the initial state *IDLE.* Figure 7 shows entire state machine including intermediate states Pause, Cancel, Hold and Stop. Service-oriented plant control uses the advantage that not every field device control is processed individually in the state machine, but a single service (e.g. heating) can be executed. A service call leads to a predefined sequence of functions and processes in execution, e.g. continuous setpoint control. State machines can change the execution of the service by means of defined status words (start, abort, end, stop, completion, etc.).

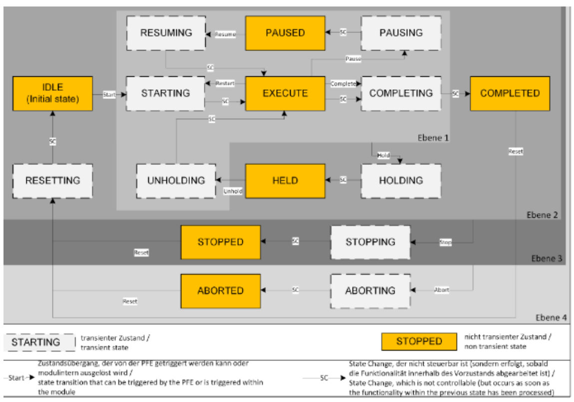


**Fig. 7**: Service State Machine [5]

PEA to be developed within the framework of the standardization work are always to be understood as integrable modules, which are integrated into a POL in a fully specified functional manner. In addition to the standardized HMI and function templates, the respective services are developed as program code. Each service has at least one procedure that processes the service. Services can only operate and be called in defined procedures, which are executed exclusively as continuous procedures. If several services are required that are to be processed in one procedure, e.g. cooling and humidification in an air conditioning system, recipes are written that structure the sequence of the individual services. As part of standardization work, HVAC-systems etc. are developed as independent PEA.

Applied to a heating circuit, this results in the service Heating, which is executed by the *Start* status word or terminated by the *Complete* status word*.* With the *Start* command*, the* required parameters (temperature setpoint, volume flow) are transferred to PEA. If service is executed in the *Execute* status, PEA continuously controls temperature setpoint and volume flow. New parameters are only applied when service is terminated and restarted. The decision as to how long which service is to be executed is therefore made in the higher-level POL.

# 5. Quality assurance of automation functions

TBE are brought together into an overall system by many technical installations at great expense. Technical systems from different manufacturers are to fulfil one or more tasks together. Due to heterogeneous field of technical systems and manufacturers, interfaces are unavoidable. Therefore, it makes sense to test the technical installations and systems of TBE systems virtually for quality assurance purposes before commissioning. One possibility is to simulate automation functions of digital twins for building automation. A digital twin can be defined as a representative of an asset in simulation environments, which simulates its dynamic behavior. Virtual representatives thus enable a check of building automation control functions before commissioning, e.g. by hardware in the loop [35]. Furthermore, certifications of systems or components are made possible based on the simulation models. For user, simulation represents an element for quality assurance of automation functions. Incorrect or missing parameters as well as process errors in control code become visible through virtual commissioning and the dynamic system behavior is tested.

Regardless of software used, the digital twins are linked as a file in I4.0-AAS and made available for higher-level simulation tasks. By means of [36], these simulation models can be exported as a Functional Mock-Up Unit (FMU). The FMI standard represents an exchange format for simulation models based on xml- and C-coded program code. This FMU is available for third-party applications for simulation in complete systems. In an appropriate simulation environment, generated FMU can be integrated for simulation without loss. With the standardization work, digital twins are developed for the individual assets and made available for quality assurance. Users of production-related automation practice demand, that quality assurance measures are required even before commissioning. [42]

# 6. Asset monitoring

Requirement for continuous monitoring according to [2] is not limited to energy monitoring. It is necessary to monitor and evaluate system conditions in order to enable efficient operational management.

In practice, the means of technical monitoring described in [25] are used to implement energy monitoring. This includes plant monitoring for recording and analysis of operating states for technical plants. Asset monitoring according to [26], which is known in the process industry, describes value-preserving and value-increasing maintenance by processing condition information of plant components. While asset monitoring according to [25] is carried out through limit value monitoring, characteristic value formation and elaborate graphical methods, asset monitoring in process industry uses concrete condition information of assets. This information is used to evaluate health status and plant behavior, e.g. with [37].

Due to a lack of uniform semantics, monitoring applications can only be implemented through costly engineering. Since effort currently exceeds the benefit, the aspect of low-effort asset monitoring is implemented through standardization work. Submodels of information model of I4.0 AAS are used to make asset information available for monitoring applications. For energy management applications according to [11, 38, 39] or asset, plant and maintenance monitoring according to [26, 40], status information of respective assets is provided without configuration.

Semantics missing in previous standards are provided by the online repository ECLASS [34]. For example, energy consumption of a heating circuit is measured by a heat meter. The consumption value is represented in I4.0 AAS by *Measurement* sub-model with the property *Total cumulative thermal energy (meter reading)*. The energy monitoring applications can reference through ECLASS-IRDI *0173-1#02-AAE300#006* that it is a feature on the *energy consumption of conventional heating* [34]. The procedure applies equally to asset monitoring applications. *Condition Based Maintenance / Breakdown Maintenance* submodels provide, for example, the status according to NE107 [37], which can be referenced with the ECLASS-IRDI *0173-1#02-AAV962#00.*

Through standardization work and use of an online repository, features with semantic characteristics are made available. This means that the contents can be accessed in a machine-readable way, which in practice leads to a simplification in engineering and in subsequent operational management.

## 7. Conclusion

Information standards are created based on the meta model of I4.0 AAS for TBE. This results in benefits for plant planners and operators throughout the entire life cycle. Engineering effort is reduced by predefined asset types. Measures of quality assurance of automation functions are already possible before commissioning through digital twins, and effort of commissioning is reduced through manufacturer-independent integration of MTP-file into an overall plant. During operation, applications for energy and asset monitoring, maintenance and service management, as well as performance evaluation are available with less configuration and reduce effort of asset management. The engineering process of a complete system will be based on standardized asset types and application of Namur recommendation.

The described procedure for implementing a technical building equipment system by means of information modelling of I4.0 AAS and MTP concept, represent the beginning of a series of standardizations. After completion of the prototypical implementation of a heating circuit, results will be transferred to cooling circuits. Subsequently, remaining trades of cost group 400 [41] will be processed, including ventilation and air-conditioning and room automation systems. The standardization work is limited to systems in area of production related building services.

Results of standardization are documented in a Namur Recommendation. All achieved results of the standardization work will be made available and published as an open source library consisting of digital twins, I4.0 AAS and amL files.

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## *Data Statement*

The datasets generated during and/or analysed during the current study are not available because the study is still in progress. But the authors will make every reasonable effort to publish them in near future.