Universal energy information model for industrial communication

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Abstract- With the use of an energy management system in an industrial company according to ISO 50001, a step-by-step increase in energy efficiency can be achieved. The realization of energy monitoring and load management functions requires programs on edge devices or PLCs to acquire the data, adapt the data type or scale the values of the energy information. In addition, the energy information must be mapped to communication interfaces (e.g. based on OPC UA) in order to convey this energy information to the energy management application. The development of these energy management programs is associated with a high engineering effort, because the field devices from the heterogeneous field level do not provide the energy information in standardized semantics. To mitigate this engineering effort, a universal energy data information model (UEIM) is developed and presented in this paper.

Keywords- energy management, energy information model, standardized semantics

I. INTRODUCTION

By using energy management systems according to ISO 50001 [1], a successive increase in energy efficiency in industrial plants can be achieved. In this context, energy saving strategies are deployed and then tested for their impact on energy consumption. The technical realization of these strategies requires hardware and software components. These components are summerized under the term technical energy management system (tEnMS) [2]. The components of a tEnMS are used to collect, communicate, store, evaluate and display measurement data. In addition to enabling energy monitoring applications, the tEnMS can also implement so-called load management functions that allow to set energy consumers to energy-saving modes or to reduce load peaks of the plant [3]. For the realization of energy monitoring and load management functions, an exchange of information between the field devices and the energy management system is necessary. This information is named energy management information (EmIn).

In the context of tEnMS, EmIn can be provided by different types of field devices like dedicated measurement devices, frequency inverters or industrial robots. Some of these field device types are able to communicate directly with an energy management application, e.g. an IIoT-device equipped with an OPC UA protocol stack [4]. Other devices provide EmIn via different fieldbus systems, industrial Ethernet-based communcation systems or point-to-point connections. Due to the different communication systems, the EmIn are typically provided in non standardized, proprietary semantics. On the control level, edge device programs or PLC programs are nessesary to adapt data types, scale values, and provide the EmIn to the energy management application via suitable communication interfaces. The development of these energy management programs causes a high engineering effort [2], as the field devices with their heterogeneous communication infrastructure do not provide the EmIn in a standardized format. When developing the energy management program, the semantics of the arriving EmIn in raw data format must be retrieved from the respective device manuals. Based on these semantics, it must be determined which calculation steps are to be applied for the respective EmIn so that they can be integrated into the energy management application.

This paper presents the stepwise development of a universal energy information model (UEIM) to reduce the conversion effort. With the help of the UEIM concept, it is possible to provide the EmIn to the energy management application in a semantically standardized form, independent of the field device type and its specific semantics.

To gain a deeper insight into the communication systems involved in providing EmIn and the semantic description of EmIn, relevant literature is presented and discussed in Section II. In the subsequent Section III, the operating principle of the UEIM is summarized. The development of the UEIM is presented in the following Section IV. In the last Section V, the paper is summarized and an outlook on further research activities is given.

II. STATE OF THE ART

In order to design the UEIM, this section takes a closer look at the provision of EmIn to the energy management application and the processing of EmIn at the field level and the control level. Then, the advantages and disadvantages of suitable communication systems are discussed in more detail.

A. Communication of energy data from field level

To provide energy monitoring or load management functions, the tEnMS can be installed in a parallel setup or in an integrated setup [2]. In the parallel setup of a tEnMS, separate field devices, such as smart meters, are additionally installed. In the integrated setup, devices that are primarily used to run the automation process (e.g. industrial robots) are

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used to provide EmIn in addtion to their control function, such as energy metering values. Fig. 1 shows that the field level (1) can be considered as heterogeneous, since different field device types with different Ethernet-based or non-Ethernet-based communication interfaces (2) are used to provide energy management functions to the control level (3). Examples of non-Ethernet-based device types can be IO-Link devices [5] such as current monitoring relays or PROFIBUS DP-based [6] frequency inverters that can provide EmIn that are relevant for the energy monitoring (for example, current, power factor or energy metering values). Ethernet-based device types support communication interfaces such as Modbus TCP [7] or PROFINET [8]. Some Ethernet-based device types support so-called energy profiles to provide the EmIn in a standardized semantics. These energy profiles are assigned to a specific communication protocol. Such energy profiles are PROFIenergy [9] for PROFINET, sercos Energy [10] for sercos III or CIP Energy [11] for DeviceNet and EtherNet/IP. By using the energy profiles, the EmIn can be provided to a PLC (3A) or an edge device (3B) in a standardized format based on the respective energy profile specification, so that the tEnMS functions are provided to higher-level systems. The EmIn of the previously described Ethernet-based and non-Ethernet-based device types are accessible in different semantics on the edge device or PLC and are available for further processing by an energy management program to provide the EmIn to the energy management application (5) via suitable interfaces (4) such as OPC UA. In parallel to this, IIoT devices from the field level (1C) have suitable communication interfaces (e.g. MQTT) to be conntected directly to the energy management application.

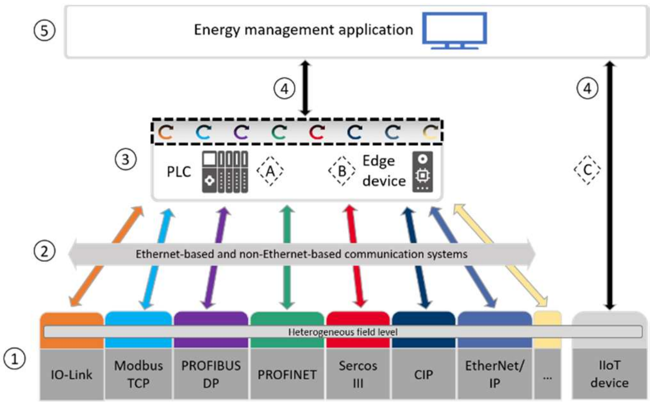

Fig. 1. Provision of the EmIn of the heterogeneous field level

B. *Exchange of the EmIn with the energy management application*

In order to provide the EmIn to the energy management application on the basis of individual information models, the EmIn with different semantics from the field level (e.g. proprietary or energy profile-specific) must be processed on the control level. This processing of the EmIn at the control level and the exchange of the EmIn with the energy management application is described in more detail in Fig. 2. The EmIn from the heterogeneous field level (1) are accessible in raw data format on the PLC (2A) or the edge device (2B). Then a data type is assigned to the raw data and the measured values are scaled if necessary and saved in variables. In the next step, the EmIn will be transferred to variable structures that are mapped onto a suitable communication interface, such as an OPC UA or MQTT interface. When creating the interfaces, different concepts can be considered with regard to the semantic processing of the EmIn. On the one hand, OPC UA or MQTT variables can be created manually, used to provide the EmIn. The variable names as well as the assigned data types can be based on a company-internal standard or on the individual decision of the person developing the program. In this approach, the EmIn are provided in non-standardized semantics via the respective interface (3) to the energy management application (4). At the level of the energy management application, the semantics of the EnMi must be determined and calculated appropriately so that they can be integrated into the program. On the other hand, the EmIn can be provided in the standardized semantics according to a so-called OPC UA Companion Specification [12]. In OPC UA Companion specifications, corresponding information models (e.g. energy profile-based) are represented with standardized OPC UA elements in the format of the OPC UA address space model [13]. In the PLC or edge device development environment, the respective information model can be imported in the form of a so-called NodeSet file, so that individual nodes (e.g. to provide a measurement value) can be instantiated in a standardized semantics. In this approach, the EmIn are mapped onto the corresponding instances and can be provided to the energy management application (4) via the OPC UA interface (3). IIoT devices like in case (C) are able to provide the EmIn directly to the energy management application via integrated OPC UA or MQTT interfaces (4). To support a standardized semantics of EmIn, an OPC UA Companion specification is applicable on the IIoT device.

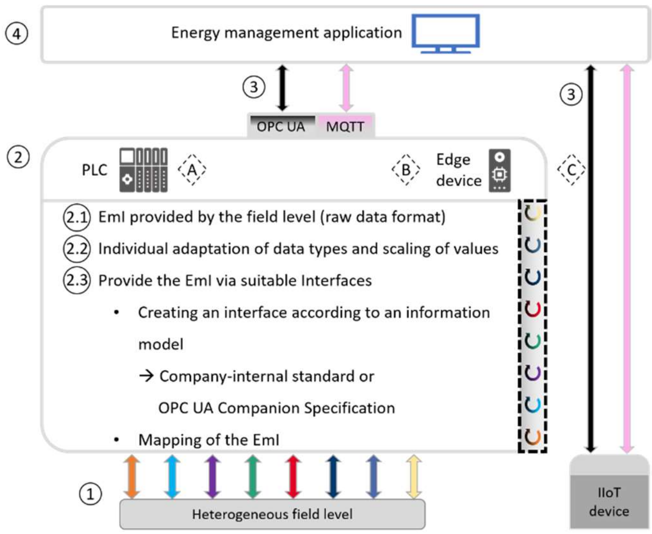

Fig. 2. Provision of EmIn to the energy management application

C. *Comparison of MQTT and OPC UA for the provision of EmIn*

For the comparison of the communication systems Open Message Queuing Telemetry Transport (MQTT) and Platform Communications Unified Architecture (OPC UA), the respective advantages and disadvantages regarding the provision of EmIn are considered.

The MQTT communication protocol was originally developed for the satellite-based connection of oil pipelines. The development requirements therefore focused on efficient data transmission ("lightweight protocol"). Furthermore, the protocol is designed for secure data transmission at low network quality with connection interruptions, low network bandwidth or high latency. Nowadays, MQTT is standardized by the Organization for the Advancement of Structured Information Standards (OASIS) [14] that has been extended with additional features specifically for operation in IoT appliocations. MQTT is a client-server based transport protocol that supports the publish and subscribe message pattern. For example, when communicating in a network, measurement devices (publishers) can provide measurement data for an energy management application (subscriber). The publisher and the subscriber are both to be considered as clients and do not communicate directly with each other. Instead, a so-called MQTT broker (server) is used, to hold the EmIn of all clients and to manage the transmission of the EmIn to the subscribers. Clients such as measurement devices can publish EmIn in the form of hierarchically structured topics as for example *factoryHall1/plant2/conveyor1/current.* Clients can subscribe to these topics to receive the topic-related current measurement value through the broker. In MQTT, no semantic standardization is specified and it is up to the developer which content is transferred in the payload. In order to take advantage of the standardized semantics of the OPC UA communication system, there is the approach of using a so-called MQTT to OPC UA bridge [15]. With an OPC UA bridge, subscribed MQTT messages can be mapped to the OPC UA address space. This requires the transmission of the semantic information in the MQTT payload. [16] [17]

OPC UA is a standard according to IEC 62541 [18] for data exchange based on a platform-independent, service-oriented, client-server architecture. For example, EmIn can be deployed on an edge device (server) and used on the energy management application (client) for energy monitoring. For OPC UA a Publish and Subscribe Message Pattern was also specified [19], which can be used optionally. The focus of the communication system is on providing a semantically standardized data transmission using an information model. On the side of the server, object-oriented data modeling is supported. An OPC UA interface has a hierarchical structure in that a server is extended with subordinate variables and objects. Regarding EmIn, the semantics of variables and objects are defined in OPC UA Companion Specifications and respective parts of the information model can be instantiated in the program development environment as described in Section II.B. [20] [17]

The OPC UA Companion specifications which are relevant in the context of the provision of the EmIn are oriented to energy profiles such as PROFIenergy, sercos Energy or CIP Energy. An OPC Companion specification [21] has already been published for PROFIenergy. In the case of the sercos Energy profile, a general OPC UA Companion specification has been published [22], which is designed for the sercos III bus system. For the CIP communication system, the development of a general OPC UA companion specification has been announced [23]. As shown in Fig. 3, the semantics of the OPC UA Companion Specifications are based on the semantics of the respective energy profile. In the example examined, the realization of the energy meters in the energy profile specifications PROFIenergy [9], Sercos Energy [10] and CIP Energy [11] is compared. The measurands differ in the designation and also in the data type, related to the value of the energy meter. In the case of PROFIenergy, three optional data types are available for selection in order to be able to retain the data types of the source devices. In the case of PROFIenergy, three optional data types are provided to support the specific energy metering values of the measurement devices:

- Smaller data types like Float32 are supported by simple devices (tendency to fast overflow)
- Large data types like Float64 can represent large floating point numbers (cost-efficient systems often do not support such data types)
- The data type Int32 has a constant resolution (e.g. for visualization of energy-time diagrams)

In the case of sercos Energy, the Float64 data type is supported, since sercos III-capable devices such as frequency inverters can provide large data types of this kind. In CIP Energy, a large range of values from 0 kWh to 999,999,999,999 kWh can be represented using a structured data type.

Energy profile specific OPC UA Companion Specification:	OPC UA PROFIenergy	OPC UA Sercos Energy	OPC UA CIP Energy
Name of the measurand:	Active Energy Import/ Export	Supplied / Consumed Energy Odometer	Generated / Consumed Energy Odometer
Data type:	Optional Signed Integer/ Float32/ Float64	FLOAT64	Struct Integer to describe the exponents of a specified function

Fig. 3. Example of the semantics of energy profiles

III. WORKING PRINCIPLE OF A UNIVERSAL ENERGY INFORMATION MODEL

The analysis of the device types with regard to the semantics of the EmIn in Section II.A has shown that the field level is heterogeneous: The field devices have different communication systems and provide the EnMi in proprietary semantics or in the semantics of different energy profiles. In order to provide the EmIn to energy management applications in standardized semantics, a UEIM is designed to structure the EmIn of the heterogeneous field level in a uniform way.

Fig. 4 shows the concept of the proposed UEIM in the field and control level. At the field level, the EmIn of Ethernet-based and non-Ethernet-based field devices (1) are provided via the respective communication system (2) to a PLC (A) or an edge device (B).

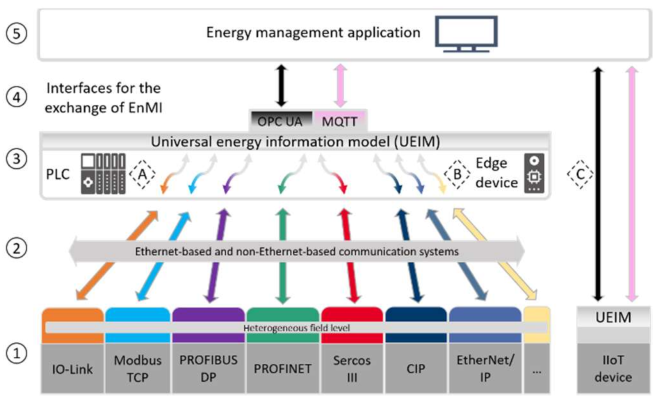

Fig. 4. Implementation of the UEIM at the field and control level

The proprietary or energy profile-based EmIn arriving at the control level (A or B) are converted with an energy management program to match the UEIM. In the next step, the converted EmIn are mapped onto an OPC UA or MQTT communication interface (4). With the OPC UA or MQTT based interface (4) the EmIn can be provided in the standardized semantics of the UEIM to the energy management application (5). In case (C), IIoT devices can realize direct provision of EmIn in the standardized semantics of the UEIM via OPC UA or MQTT communication interfaces.

IV. Developement of the universal Energy Information Model

This section presents the development of the UEIM for providing measurement information based on the working principals presented in Section III. First, an overview of the procedure for developing the UEIM is given. Then a closer look is taken at the properties of the energy profiles. Based on the analysis of the properties of the energy profiles, the UEIM is developed and described in the form of a class diagram. Subsequently, concepts for the adoption of the semantics of the UEIM are presented.

A. Model building procedure

In order to develop the UEIM to provide measurement information in standardized semantics, a stepwise procedure is applied. Fig. 5 shows the stepwise modeling procedure for the development of the UEIM.

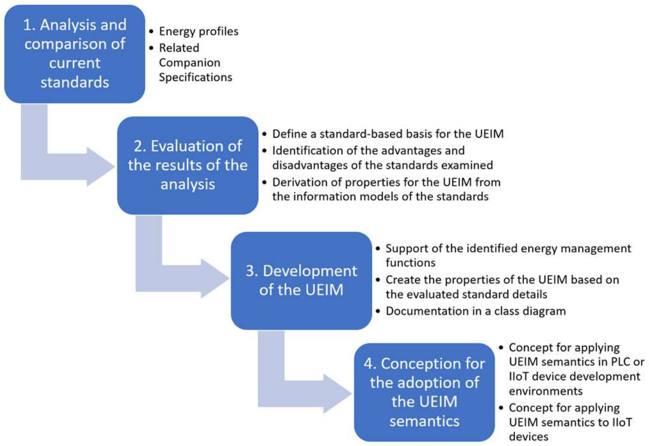

Fig. 5. Model building procedure

In a first step, an analysis of the energy profiles PROFIenergy, Sercos Energy and CIP has been carried out in order to get an overview of the supported energy management functions, the semantics of the measurement data provision and the associated information model properties. In addition, the OPC UA Companion Specifications corresponding to the energy profile were analyzed and the semantics of the measurement functions were considered. Based on the analysis of the standards from step 1, an evaluation of the identified properties of the information models can take place in step 2 and the following questions can be answered:

- Which energy management functions need to be supported?
- How are the energy management functions implemented in the standards?
- What are the advantages and disadvantages of the implementations of the energy management functions?
- Which conclusions can be derived for the development of the UEIM?

In step 3, the UEIM is developed in the form of a class diagram based on the preliminary work. For the development of the UEIM, the support of the energy management functions identified in step 2 and the ability to provide the available measurands of the standards considered are fundamental. Subsequently, in step 4, concepts for the adoption of the semantics of the UEIM are designed.

B. Comparison of existing standards

In this section, the exisiting and standardized energy profiles PROFIenergy, Sercos Energy and CIP Energy, as well as the associated OPC UA Companion Specifications are analyzed with regard to their energy management functions in the context of measurement data acquisition. The intention of the analysis is that all energy management functions of the considered standards shall be implemented in the UEIM. Thus, the energy management functions are identified and analyzed with regard to their semantic implementation. Based on the analysis, the advantages and disadvantages of the standards are compared to derive results for the development of the UEIM.

TABLE I summarizes the contents of the analysis and presents the results derived from it for the development of the UEIM. Each standard supports different numbers of electrical measurands (e.g. energy or current) and non-electrical measurands (e.g. heat quantity, volume flow of compressed air). For the development of the UEIM, all identified measurands of the considered standards shall be supported. The measurands are accessible in each energy profil via specific numbers and can be uniquely identified by them. The unique identification of measurands is a feature to be assumed for the UEIM. As already shown in Fig. 3, the designations of the specification properties are different in each case. In order to ensure that the specification properties are named as precisely as possible, the most precise designation of the standards considered is selected individually or, if necessary, new designations are created. In case of the data types of the measurands, the standards also differ. PROFIenergy offers the possibility to select a preferred data type for some measurands and is considered for the development of the UEIM due to its flexibility. The largest measurand-specific data types of the standards must be considered in addition so that a lossless mapping of the incoming EnMi can be realized. For instance a measured value with the datatype INT32 can not be mapped to a measured value with the datatype BYTE, as the value range of the second datatype is smaller. For the representation of units in the UEIM, the SI unit mapping table [24] is applied, since a standard-based reference can be used. With the PROFIenergy specification, several kinds of measurement accuracies, including standard-based options are supported. This feature of the information model can be assumed for the UEIM, since the measurement accuracy options of the other standards are included in the PROFIenergy specification.

TABLE I. Comparison of existing standards

Property discription	PROFIenergy	Sercos Energy	CIP Energy	Derived results for the development of the UEIM
	Energy profiles			
Support of electrical measurands	✓	✓	✓	The two categories electrical and non-electrical measurands shall be supported by the UEIM.
Support of non-electrical measurands	X	X	✓	
Quantity of supported electrical measurands	40	2	39	All identified electrical and non-electrical measurands shall be supported.
Quantity of supported non-electrical measurands	0	0	12	
Identification of measurands	Specific Measurement ID	Specific parameter number	Specific Attribute ID	The measurands shall be clearly identifiable by a identification number.
Uniform designation of the specification properties (see also Fig. 3)	X	X	X	For the properties of the UEIM, the most precise designation is assumed or, if possible, a more precise designation is created.
Uniform data types for each measurand (see also Fig. 3)	X	X	X	The flexible system from the PROFIenergy specification is assumed so that, if necessary, several data types are available for selection.
Additional features from the associated OPC UA Companion Specification	For the specification of measurment units, an EU-wide recommendation of the United Nations Economic Commission for Europe (UNECE) is applied. The OPC Foundation provides a mapping table [24] for a standardized data mapping.	Parameters of the energy profile can be retrieved via the OPC UA Companion Specification (1:1 mapping).	OPC UA Companion Specification has not been published yet.	The reference to the recommendation of the UNCE [24] is assumed.
Standard-based specification of measurement accuracy	✓ Optionally based on EN 50470-3, IEC 61557-12 or relative deviation referred to full scale reading/ actual measurement value	X No information on measurement accuracies in the energy profile specification	X Relative deviation referred to full scale reading/ actual measurement value	The specification of the measurement accuracy is assumed from the PROFIenergy specification, since a standard-based specification of the measurement accuracy is possible and the accuracy specification from CIP is covered.

The structure of the the PROFIenergy OPC UA Companion Specification information model offers an infrastructure to provide measurement-related EnMi. In addition, interfaces are specified to provide groups of device type-specific measurands (see Section C). Based on the comparision of the standards, many properties of the PROFIenergy specification can be assumed in order to the develope the UEIM. Additionally, the PROFIenergy OPC UA Companion Specification is designed to be generic, thus non-PROFIenergy-based EnMi can also be provided with the associated information model. As a result of the analysis of the considered standards, the information model of the PROFIenergy OPC UA Companion Specification can be used as a basis for the development of the UEIM class diagram.

C. *The UEIM in a class diagram*

Based on the analysis of the standards considered in Section B, the UEIM is developed in the form of a class diagram and presented in this section.

As shown in Fig. 6, the class structure is based on the PROFIenergy OPC UA Companion Specification. To provide a measurement value, an instance of the *EnergyMeasurementInformationType* class must be created. Each *EnergyMeasurementInformationType* class instance contains a MeasurementType instance that describes basic attributes and methods of the measurement information. A provided measured value is associated with an entity, e.g. an industrial robot system. This entity can consist of subordinated components. For example, the servo motors of the individual rotary axes of an industrial robot system could provide individual measurement information for each axis. The attribute *Object_Number* can be used to uniquely match the subordinate objects of an entity. The *TimeStamp* attribute can be used to provide a device-specific time stamp, which can be created using a time synchronization protocol. Thus, the quality of the time stamp can be determined individually at device level. If an energy meter is realized by the MeasurementType instance, the actual meter value can be influenced by the methods *SetEnergyMeter* (set an initial meter value) and ResetEnergyMeter (reset the meter value to zero). The *Measurement_Value* class instance of the *MeasurementValueType* class contains more in-depth information about the measurement value, as described in the following class description.

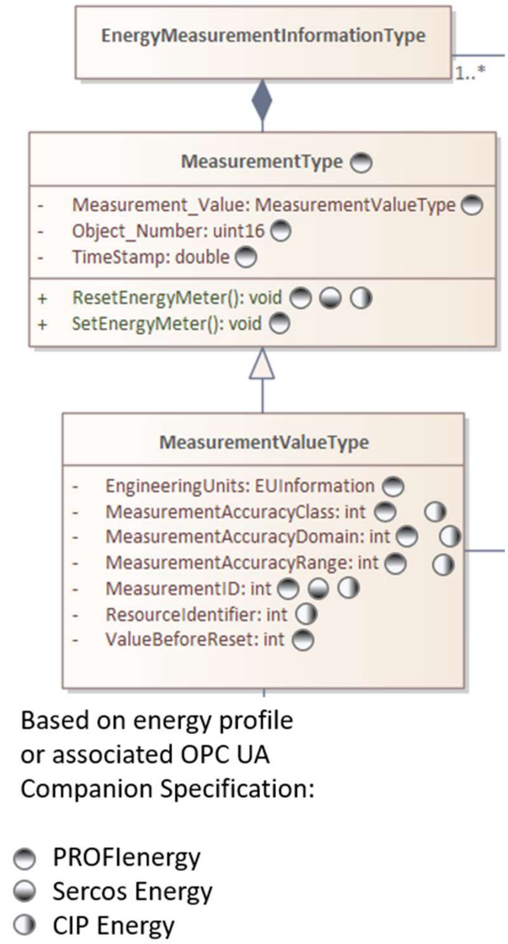

Fig. 6. Class diagram of the UEIM

For a unique identification of the associated measurand, an identification number is assigned in the MeasurementID attribute. The identification number refers to a measurand table which was created on the basis of the PROFIenergy specification. Using the measurand table, each identification number is associated with a measurand, a unit, an associated data type and further information specific to the measurand. This measurand table was extended by the additional measurands of the other considered energy profiles (see Section 4). In particular, the non-electrical measurands were added to provide this category of measurands as well. In order to create a unique identification of measurements to a resource type, the attribute ResourceIdentifier is created. Based on the CIP Energy specification, the identification number assigned to the attribute is related to a resource type, such as electricity or compressed air. The attributes with the prefix *MeasurementAccuracy* provide the possibility to assign a measurement accuracy in order to support information about a maximum measurement deviation. The value of the *MeasurementAccuracyDomain* attribute determines which measurement accuracy type is applied. On the one hand, the measurement accuracy can be related to the full-scale reading (value: 1) or the actual reading (value: 2). On the other hand, measurement accuracies can be configured according to IEC 61557-12 (value: 3) or EN 50470-3 (value: 4). The value of the *MeasurementAccuracyClass* attribute is configured to define the maximum percentage of measurement deviation that can be expected. An accuracy class according to the PROFIenergy specification has a defined specific percentage value. If the measurement deviation refers to a full-scale reading, it can be entered in the *MeasurementAccuracyRange* attribute. If the measurement value represents an energy meter, the meter value can be written to the *ValueBeforeReset* attribute before resetting using the provided methods. To assign a unit of measurement to a specified measured value, the *EngineeringUnits* attribute of type *EUInformation* was specified.

With the class *EUInformation* (see Fig. 7) the measuring units specified according to [24] can be provided. The *NameSpaceURI* is used to identify the company or standard organization. Each unit has a unique *UnitID* (e.g. 4937544 for the unit of energy) assigned to it and has a suitable *Description* (e.g. kilowatt hour) and an abbreviated *DisplayName* (e.g. kWh).

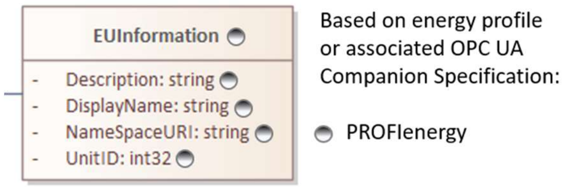

Fig. 7. Description of Units

The *MeasurementValueType* class can implement different interfaces to support a device type specific set of predefined electrical (Fig. 8) or non-electrical (Fig. 9) measurand configurations.

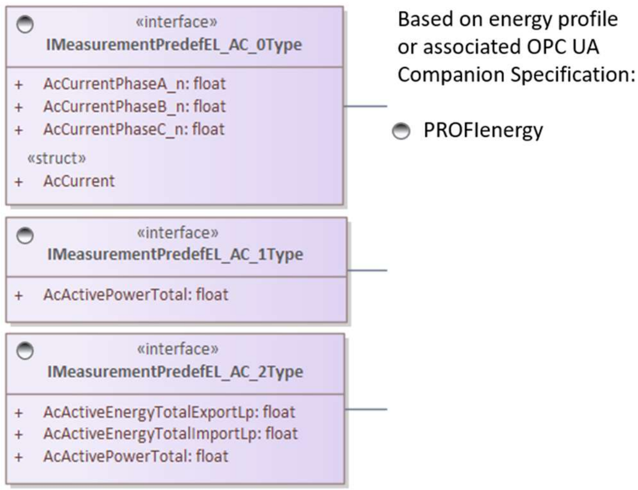

Fig. 8. Example interfaces for the provision of electrical measurands

For example, a measurand configuration can include three individual phase currents provided during integrated monitoring of the phase currents of an intelligent 3-phase motor protection circuit breaker. Whereas the interfaces for the electrical measurands were designed on the basis of the PROFIenergy OPC UA Companion Specification, the class diagram is extended by additional interfaces for non-electrical measurands. To differenciate between electrical and non-electrical interfaces, a suitable suffix is appended to the designations. The suffixes *El_AC_nType* or *El_DC_nType* are added for electrical measurand configurations from the AC and DC systems. Non-electrical measurand configurations are appended with the suffix *nonEl_nType*. The added non-electrical interfaces are designed for devices like flow meters (*IMeasurementPredef_nonEl_0Type*) and non-electrical energy meters (*IMeasurementPredef_nonEl_1Type*). For the provision of energy meter values, data types of different sizes are available for selection in order to be able to provide measured values in the most efficient manner.

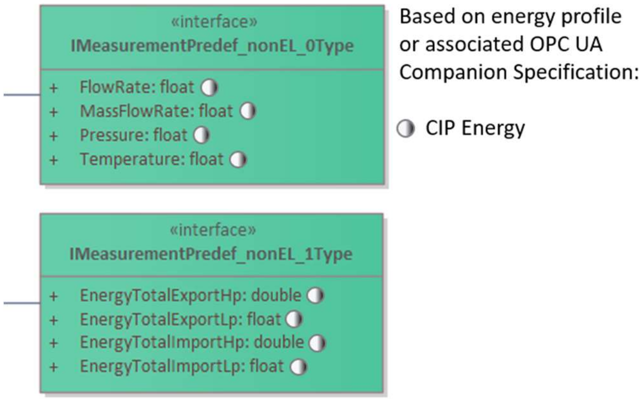

Fig. 9. Interfaces for the provision of non-electrical measurands

D. *Conception for the provision of UEIM semantics*

In order to apply the semantics of the UEIM and the designed class diagram for the development of energy management programs, concepts have been developed that are presented in this section. If the measurement information at the control level should be provided to the energy management application in the format of the UEIM, a suitable interface has to be selected. Based on the previous research (see Section II.B and II.C), the communication systems OPC UA and MQTT are suitable for this purpose.

In case of mapping the EmIn onto an OPC UA interface, the UEIM can be imported into the respective PLC or edge device development environment using a UEIM-specific NodeSet file. Specific OPC UA variables and objects are standardized in the UEIM and can be instantiated in the energy management program to apply the semantic format of the measurement information.

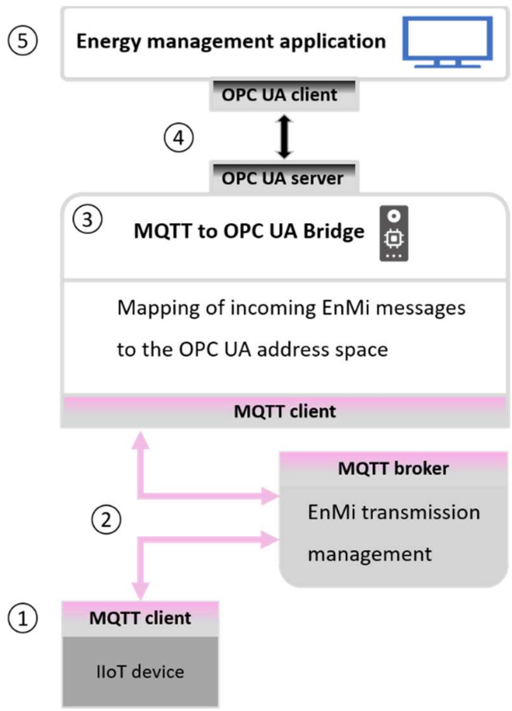

Fig. 10. Application of UEIM semantics for IIoT devices

When using the MQTT communication system, no standardized semantic is supported in comparison with OPC UA. If devices such as energy meters only have an MQTT interface, it is necessary to find a way to provide these EnMi in the UEIM format as well. For this problem the authors propose the approach [15] to realize an MQTT to OPC UA Bridge (see Section II.C). The implementation of the approach is shown in Fig. 10. The measurement information provided by an IIoT device (1) is published via the MQTT interface and transmitted o the subscribing MQTT to OPC UA Bridge (3) via the MQTT broker (2). The measurement information transmitted in the payload has to be additionally enriched with the semantic information of the UEIM. On the MQTT to OPC UA Bridge (3), the received semantic information can be processed to map the incoming measurement information in the format of the UEIM onto an OPC UA interface and make it available to an energy management application (5).

V. Conclusion and Future Work

On the basis of an in-depth analysis of the existing semantic standards of measurement information, it can be concluded that measurement information can be provided in a universal energy information model (UEIM). To follow this objective, this contribution presented the development of a UEIM to provide measurement information in a unified semantic. In order to assume uniform semantics according to the UEIM, the semantics of the measurement information of the source devices must be capable of being mapped to the UEIM on devices of the control level, such as edge devices or PLCs. The mapping of the measurement information to the UEIM has the advantage that no different information models such as different OPC UA Companion Specifications have to be considered in order to provide the measurement information to a energy management application. Thus, the engineering effort for the development of the energy management programs can be reduced, since the program development can be done on the basis of only one documentation. Furthermore, concepts were proposed to automatically apply the semantics defined in the UEIM to devices that have an OPC UA or MQTT interface. From the perspective of the energy management application, it can be expected that the access and use of the measurement information will be simplified, since the measurement information can be provided in uniform semantics.

In the next steps, the proposed concepts for the automatic adoption of UEIM-based semantics will be implemented in practice. The development of the UEIM requires a scientific procedure to merge the features of the existing energy information models. This procedure will be described in further papers. In order to verify the function of the UEIM, a project demonstrator will be built. In the project demonstrator, measurement information such as energy metering values will be provided to an energy management application in the format of the UEIM.

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VI. References

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