Communication of energy data in automation systems

Leif-Thore Reiche (HSU), Maxim Runge (HSH), Karl-Heinz Niemann (HSH) and Alexander Fay (HSU)
Helmut-Schmidt-University (HSU)
Institute of Automation Technology
Hamburg, Germany
University of Applied Sciences and Arts Hannover (HSH)
Faculty I – Electrical Engineering and Information Technology
Hannover, Germany
Email: Leif-Thore.Reiche@hsu-hh.de

***Abstract*—With regard to climate change, increasing energy efficiency is still a significant issue in the industry. In order to acquire energy data at the field level, so-called energy profiles can be used. They are advantageous as they are integrated into existing industrial ethernet standards (e.g. PROFINET). Commonly used energy profiles such as PROFIenergy and sercos Energy have been established in industrial use. However, as the Industrial Internet of Things (IIoT) continues to develop, the question arises whether the established energy profiles are sufficient to fullfil the requirements of the upcoming IIoT communication technologies. To answer this question the paper compares and discusses the common energy profiles with the current and future challenges of energy data communication. Furthermore, this analysis examines the need for further research in this field.**

***Index Terms*—energy profiles, energy management, energy data information modeling**

I. Introduction

Rising energy costs, increasing energy awareness among employees and increasing a company's energy efficiency are the main drivers for adopting an energy management system according to ISO 50001 in a company [1]. An energy management system is particularly used to pursue its own energy policy by setting energy targets and trying to achieve these targets with the help of action plans and processes [2]. In addition to the organizational energy management system, a technical energy management system (tEnMS) is used in the industry to acquire energy data [3]. With the help of a tEnMS companies have the possibility to measure, monitor and display energy data of a production plant [3]. On the one hand these systems can be added in parallel to already existing automation systems. On the other hand it is possible to integrate these systems into the existing automation systems [4]. The communication of energy data within the integrated systems can be done via so-called energy profiles. Common energy profiles are PROFIenergy, an energy profile from the PROFINET International Organization [5], and sercos Energy [6], an energy profile from the bus developer Sercos for mainly drive components (e.g. frequency inverter for the operation of a electric motor).

Due to the changing conditions in the industrial environment (e.g. growing number of IIoT protocols, migration of systems to cyber physical systems, connection to smart grids, feed-in of renewable energy into the grid) the question arises whether the established energy profiles meet the requirements of future energy management tasks. The advantages and disadvantages of the energy profiles and new requirements that are not covered by the energy profiles need to be analysed.

Therefore, this paper provides an overview of existing energy profiles. Furthermore, the existing energy profiles are evaluated and checked for potential improvements. In the following chapters, the possibilities and shortcomings of these profiles are discussed and future efforts in relation to energy data communication are presented.

II. Related Literature

This chapter gives a brief insight into the available technologies and the related literature. In the first part the different types of tEnMS are explained. The second part describes common energy profiles and further energy data related literature.

A. Energy data acquisition in automation systems

When considering the transport of energy data in automation systems, two different systems are described in the literature.

In [4], the authors present these systems, see Figure 1. This figure shows in part (A) a tEnMS, that runs in parallel to the control system. Part(B) shows an integrated version. In the parallel variant, which is also described by the authors of [7], a parallel autonomous tEnMS is added to the existing automation system. The energy data is acquired from the field level via measuring points (A1) and communicated up to the planning level (A2-A4). Energy data can also be transfered into a cloud system (A5/B5) [8].

A contrast to this is the integrating tEnMS (B). This system transfers the energy data via so-called energy profiles (e.g. PROFIenergy). The energy consumption is recorded via measuring points which are integrated into the field devices (B1). The field devices communicate the energy data to the tEnMS by using energy profiles (B2-B4).

According to [4], the integrated tEnMS offers various advantages. For example, no additional resources for data acquistion and communication are required, as the existing

DOI des Originals: 10.1109/WFCS46889.2021.9483607

control system can be used. This saves engineering effort for an additional system and keeps hardware costs low. Depending on the degree of integration, it is also possible to implement load management by using the already existing peripherals. Integrated tEnMS are also described in [9]. According to the authors, it is advantageous for an energy management system to use ”adequate communication” in combination with an integrated system.

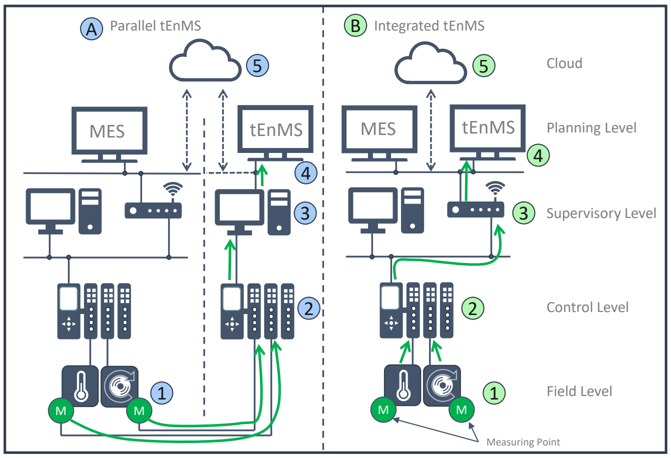

Figure 1. Energy data in parallel and integrating systems based on [4]

B. Communication of integrated energy data

Various Ethernet-based protocols, such as PROFINET, but also non-Ethernet-based protocols, such as IO-Link, can be used to transmit energy data. For some Ethernet-based protocols, so-called energy profiles exist. With the help of an energy profile, energy data measured in a field device (e.g. power consumption (kWh)) can be communicated to the control level. Furthermore field devices can be set to energy saving modes with the help of energy profiles [5]. Each energy profile contain standardised semantics for mapping the energy data.

The energy profile PROFIenergy [5] uses the acyclic data channel of PROFINET. With the help of the energy profile, energy related status information of the supported devices can be determined and energy data can be acquired in a uniform manner. In addition, load management functions can be used to set devices to energy-saving modes during production pauses (referred to below as standby management).

The sercos Energy [6] energy profile is mapped via the acyclic data traffic of the sercos III based protocol. The energy profile also supports querying of device status information, acquisition of energy data and load management functions such as standby management. In addition, partial load operation is supported, which can be used to reduce energy consumption during ongoing production. With the partial load operation function the energy consumption of a machine can be lowered so that the product is ready exactly at the time of delivery or the mean power-based costs are reduced.

The CIP energy profile [10] is provided via the Common Industrial Protocol (CIP). CIP is mainly established on the American market and is avilable for fieldbus and communication systems such as DeviceNet and EtherNet/IP. The energy profile also supports functions of energy data acquisition and load management.

Further contributions that deal with the communication of energy data are published in [7], [11]. In these papers the authors describe the development of a description language for energy data called Energy Information Description Language (EIDL). This description language is specifically used to describe machine tools from an energy perspective. Because EIDL is a very generic XML-based description language, it can be adapted in addition also to other automation structures or single devices.

[12] presents a concept for describing manufacturing processes to evaluate energy efficiency. As part of this concept, an energy ontology was developed to provide semantically consistent definitions for topic-specific terminologies. This energy ontology is based on existing standards and norms such as ISO 18629 [13] and VDI 4661 [14].

III. Energy data in integrated energy management systems

The energy profiles PROFIenergy and sercos Energy introduced in chapter II have several commonalities: The described energy profiles provide an additional standby management which allows to realize different energy saving modes (e.g. standby, sleep mode) during production pauses. The energy profile sercos Energy can additionally set the devices to an energy-saving partial load mode. Due to the fact that the energy profiles are based on established communication standards, it is possible to make energy data available to the corresponding network using the energy profile-specific bus system (e.g. PROFINET). Even if the use of energy profiles supports industrial energy management significantly, the existing profiles still have limitations. As an example, energy data that is transmitted via PROFINET with PROFIenergy can only be communicated up to the PLC (control level). However, this data is required at the planning level for energy management. For this reason, it is necessary that systems above the control level also receive energy data. In order to communicate energy data via the protocols of the higher-level systems, it is necessary to map the energy data onto the information models of the higher level used protocols. This data mapping is performed manually and therefore results in additional engineering effort. This drawback has recently (at least partly) been addressed by an additional companion specification based on PROFIenergy [15]. In this specification, it is defined how energy data can be communicated from the control level via OPC UA to the systems in higher-level network structures. Within this solution the data format of PROFIenergy remains and is only represented via OPC UA.

Sercos Energy has a similar limitation. This energy profile is mainly oriented towards drive technology. If energy data is acquired in drives in the field level, it can only be communicated with sercos Energy up to the PLC (control level), like in the case of PROFIenergy. Also in the case of sercos Energy the energy data is required at the planning level for energy management. Again, if the energy data shall be communicated to higher-level systems in the network structure, an additional effort is necessary to map the energy data onto the information models of the Ethernet protocols of the higher levels (e.g. OPC UA).

For existing energy profiles, it can be concluded that an additional engineering effort is required, if the energy data of the energy profiles should be mapped onto the information models of Ethernet-based protocols which are used above the control level. To reduce this additional engineering effort, companion specifications like in [15] could be developed. However, a separate companion specification would have to be developed individually for each energy profile and protocol combination. With the number of Ethernet-based protocols used in the industry, this would result in a number of companion specifications.

The presented energy profiles are based on Ethernet protocols. Energy data can also be communicated with simple sensor-actuator protocols (not Ethernet-based). These simple non Ethernet based protocols (e.g. IO-Link), are increasingly established in the industry and can already provide energy data in some cases today [16]. If this trend continues, simple sensors and actuators will be able to provide more energy data in the future and thus ensure more energy demand transparency at the field level. Since the energy data of individual simple sensor and actuator protocols have not yet been included in the energy management, it is necessary to take this energy data into account for transparent energy management.

In the future, simple sensors and actuators will have integrated computing soft- and hardware so they can provide value-added data and be designated as cyber-physical system (CPS) [17]. The value-added data may also contain energy data which can be used for energy management. IIoT protocols such as MQTT are also used in this context, for example to provide communication to a cloud application. If such protocols (e.g. MQTT) and technologies (e.g. cyber physical systems) evolve in the future, the question arises how energy data should be communicated in a standardized format.

This chapter explained various ways in which energy data can be provided via Ethernet-based and non-Ethernet-based protocols. Due to the different protocols, the energy data is available in different data formats. In order to make this energy data available within the context of energy management, e.g. at control or planning level, there is the need to provide the energy data in a standardised form. This leads to the demand for research, how energy data of different sources can be described in a standardised form.

IV. Concept of a universal energy data information model

A possibility is to map the energy data of the existing energy profiles to the information model of each protocol (e.g. mapping energy data of PROFIenergy onto MQTT). However, this would mean that a separate information model is required for each communication protocol as described in [15].

Due to the energy data information models included in the energy profiles, another possibility is to unify these information models to a single protocol independent information model. In the future, this information model could be the basis for descriptions of energy data in a wide variety of IIoT protocols and technologies. Established standards such as ECLASS could be incorporated into this information model to provide a semantical correct description of the energy data. If such an energy information model is going to be developed, the following questions have to be answered:

- How should energy data be mapped onto an universal energy data information model in order to meet the requirements of uniform machine-readable semantics?
- Can the energy data from the currently established energy profiles be mapped completely into this energy data information model?
- What are further requirements for such an information model?

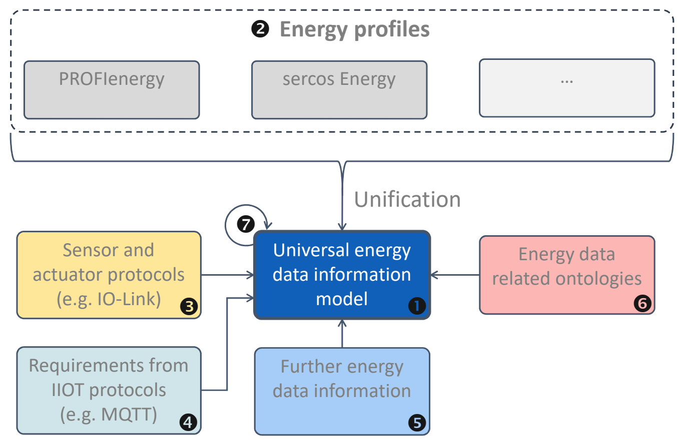

Figure 2. Modelling a universal energy data information model

Figure 2 illustrates how a universal energy data information model ❶ can be modeled.

From the existing energy profiles ❷, the energy data related information of the information models could be extracted and consolidated as the basis for the universal energy data information model.

In order to be able to represent the energy data of very simple sensors and actuators via a universal energy data information model, it is necessary to consider non-Ethernet based protocols like IO-Link ❸ when creating the universal energy data information model. Only if the information model contains information and requirements (e.g. protocol structure) of non-Ethernet protocols, it is possible to transmit energy data by using these protocols.

The same applies to the utilization of the latest established IIoT protocols such as MQTT ❹. If energy data should be communicated via these protocols, it is necessary to provide information and requirements of the protocols in the universal energy data information model.

In addition, other energy data related information ❺ can be added as described for example in [7], [11]. This literature to the

"Energy Information Description Language" (EIDL) provide for example a structure for energy data or usage scenarios where energy data is needed. Such information can provide an added value to the universal energy data information model.

With the help of ontologies, it is possible to represent information in a semantically consistent way. Because ontologies such as [12] have already been modeled to represent energy related information, these type of ontologies are analyzed and usable information for the communication of energy data will be considered in the universal energy data information model ❻.

In order to comply with the state of the art, the energy data information model have to be updated event driven ❼. Possible events could be for example new energy data related standards, new energy profiles or upcoming new IIoT protocols.

V. Conclusion and Future Work

In order to be able to transmit energy data in an integrated tEnMS, energy profiles like PROFIenergy are used to provide energy management functions (e.g. monitoring of energy data, standby management). If the energy data should be used for energy management, it is necessary that the energy data is mapped to protocol-specific information models. After the mapping, it is possible to communicate the energy data up to the planning level (e.g. PROFIenergy on OPC UA). However, each mapping requires an individual engineering effort, due to the fact that each protocol has its own requirements. In addition, the access to the energy data from the planning level is difficult because there is no standardised representation for energy data.

Moreover, it was demonstrated in the paper what requirements (e.g. energy data in non-Ethernet protocols) will have to be addressed in the further development of the energy profiles in the future. With the help of a uniform energy data information model, it is possible to describe energy data in a standardized way.

In order to adress the identified issues, the project IoT_EnRG[1] was launched in November 2020. The project, which is funded by the German Federal Ministry for Economic Affairs and Energy, will address the following topics

- Creation of an energy data information model that enables the mapping of energy data into IoT technologies.
- Generation of an energy data interface for various IoT technologies such as IO-Link, OPC UA or MQTT.
- Planning, design and construction of a demonstrator to show how energy data can be transmitted integrated in an automation system via IoT technologies.

Results will be provided to the community at upcoming conferences.

References

[1] F. Marimon and M. Casadesús, *Reasons to Adopt ISO 50001 Energy Management System*, ser. Sustainability. MDPI, 2017, vol. 9.

[1]IGF project 21329 N, which is funded by the Federal Ministry for Economic Affairs and Energy (BMWi) on the basis of a resolution of the Deutsche Bundestag.

[2] International Organization for Standardization, "ISO 50001:2018-08 - Energy management systems - Requirements with guidance for use," 2018.

[3] A. Würger, K.-H. Niemann, and A. Fay, "Concept for an Energy Data Aggregation Layer for Production Sites A Combination of AutomationML and OPC UA," in *2018 IEEE 23rd International Conference on Emerging Technologies and Factory Automation (ETFA)*, 2018, pp. 1051–1055.

[4] A. Würger, K.-H. Niemann, A. Fay, M. Gienke, and M. Paulick, "Integriertes Anlagenengineering zur Erhöhung der Energieeffizienz," *atp magazin*, vol. 61, p. 70, 2019.

[5] PROFIBUS Nutzerorganisation e.V., "Common Application Profile PROFIenergy," 2019. [Online]. Available: https://dk.profibus.com/downloads/profienergy

[6] Sercos International e.V., "Energy Profile," 2011. [Online]. Available: https://www.sercos.de/news-events/newsdetail/sercos-energy-spezifikation-des-energieprofils-fuer-sercos-iii-verfuegbar/

[7] P. Eberspächer, H. Haag, R. Rahäuser, J. Schlechtendahl, A. Verl, T. Bauernhansl, and E. Westkämper, "Automated provision and exchange of energy information throughout the production process," in *Leveraging Technology for a Sustainable World*, D. A. Dornfeld and B. S. Linke, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2012, pp. 381–386.

[8] Siemens AG, "powermanager power monitoring with direct cloud connection," 2019. [Online]. Available: https://assets.new.siemens.com/siemens/assets/api/uuid:3139892a-d70f-4632-b898-c465f27e5201/PR2019020154EMEN.pdf

[9] D. Mora, M. Taisch, A. W. Colombo, and J. M. Mendes, "Service-oriented architecture approach for industrial "system of systems": State-of-the-art for energy management," in *IEEE 10th International Conference on Industrial Informatics*, 2012, pp. 1246–1251.

[10] ODVA, "Optimization of Energy Usage," 2016. [Online]. Available: https://www.odva.org/wp-content/uploads/2020/05/PUB00246R2_ODVA-Optimization-of-Energy-Usage_EN.pdf

[11] J. Schlechtendahl, P. Eberspächer, S. Schrems, P. Sekler, A. Verl, and E. Abele, "Automated approach to exchange energy information," in *Future Trends in Production Engineering*, G. Schuh, R. Neugebauer, and E. Uhlmann, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2013, pp. 47–54.

[12] T. Linnenberg, A. Müller, L. Christiansen, C. Seitz, and A. Fay, *OntoENERGY – A lightweight ontology for supporting energy-efficiency tasks*. KEOD (IC3K) vol.1 pp. 337-344, 2013.

[13] International Organization for Standardization, "18629-1:2004 Industrial automation systems and integration — Process specification language — Part 1: Overview and basic principles," 2004.

[14] VDI-Gesellschaft Energie und Umwelt (GEU), "Energetic characteristics - Fundamentals - Methodology," 2014.

[15] PROFIBUS Nutzerorganisation e.V., "OPC UA for Energy Management," 2020.

[16] Siemens, "IO-Link – continuous communication through to the last metre," 2020. [Online]. Available: https://assets.new.siemens.com/siemens/assets/api/uuid:7460eb69-efa0-4426-9213-af4d3619b567/dffa-b10447-01broschuereiolinkdeengb-144.pdf

[17] H. A. Müller, "The Rise of Intelligent Cyber-Physical Systems," *Computer*, vol. 50, no. 12, pp. 7–9, 2017.