Energy Service Description for Capabilities of Distributed Energy Resources

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Abstract. The increasing number of volatile Distributed Energy Resources (DERs) in the electricity grid implies a rising level of complexity and dynamics. The integration and management of these DERs have lead to the introduction of the aggregator role, with the aim of providing energy services to system operators and the market. With regard to the often changing capabilities of DERs, the dynamical aggregation of DERs to meet the demand is still a matter of concern. In this paper a generic description for the capabilities of DERs will be introduced in order to allow the aggregator to efficiently search and find DERs suitable for aggregation. These reduced as possible and abstracted descriptions of the DER capabilities are called Energy Services, which should be complete enough for the aggregators search demands.

The Energy Service definition will be part of a recent research project, the Open System for Energy Services (OS4ES) that is going to enable the aggregator to control dynamically configured large scale Virtual Power Plants with IEC 61850. The results of this project and its field test should contribute to the further development of IEC 61850.

1 Introduction

The rising number of heterogeneous and volatile Distributed Energy Resources (DER) in the electricity grid leads to an increasing complexity in grid management [2]. The aggregator role, discussed in several research studies and standards and currently establishing in the energy domain, shall serve as a complexity managing entity [5]. It combines DERs of different characteristics to so called Virtual Power Plants (VPP) for the participation in larger energy markets [7]. The business processes between aggregator and Smart Grid Actors (e.g. system operators and Balance Responsible Parties) are currently under development in many projects (e.g. USEF-project [3]). Still a matter of concern is the interaction and information exchange between aggregators and the DER systems. Classical aggregator concepts assume an often static set of DER systems which the aggregator can use to provide services for the participants. With the rising

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number and variety of DERs, business models, and often changing power flows we assume that in the future aggregators must be able to dynamically reconfigure their portfolios to serve the needs of the electricity domain and to react on flexibility requests from, e.g. the system operator. Furthermore, we assume that in future smart markets, more than one aggregator needs to be given access to available capabilities of a DER system for optimal use of the available resources. For this purpose, the aggregator must be able to find DER systems that provide the needed capabilities as Energy Services in a Smart Market [4]. For such Smart Markets, an active Registry System for Energy Services as described in [6] is necessary that allows the DER system providers to offer the capabilities of their DER systems to aggregators that can search and find these to aggregate them and thus, to participate in larger energy markets (e.g. energy exchanges, ancillary services, or Over The Counter [OTC] trades), as stated in Fig. 1.

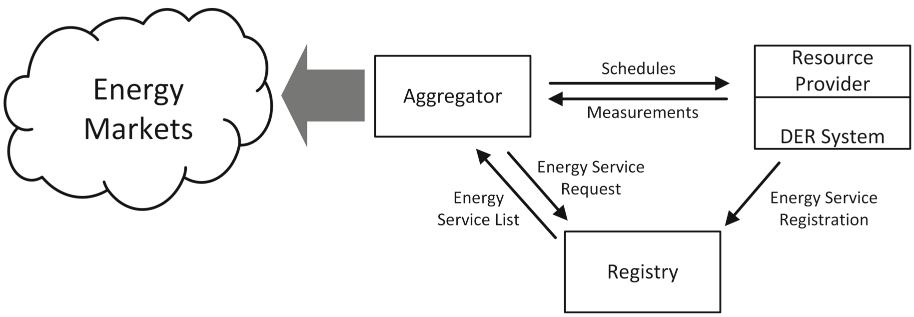

Fig. 1. Interaction between aggregators and DER systems using a common registry system for the exchange of dynamic energy service data. The aggregator utilizes the DER systems based on the energy service descriptions to participate in larger energy markets.

In order to offer often fluctuating DER capabilities that may change due to, e.g. environmental influences to aggregators, a common and generic description of these capabilities is required. This description model should contain as minimum information as possible for several reasons, e.g. data storage requirements and privacy and security concerns. Finally, the aggregator should handle the complexity of the heterogeneous DER systems by searching for relatively generic characteristics of the provided Energy Services. It has to be investigated how far the characteristics of a DER system can be abstracted from the technical base without leaving out necessary information for the aggregator. In this case it is important to distinguish between the search for Energy Services, where the informational complexity should be reduced to provide an easy and efficient search mechanism for the aggregator and the operation of a DER system. In the operational phase, it is likely that the complexity of the DERs cannot be made fully transparent. Recent standards like IEC 61850-7-420 work on semantic

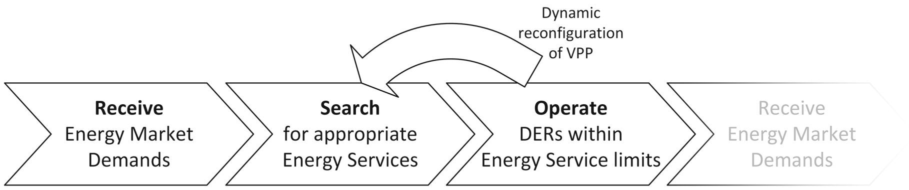

Fig. 2. Phases of the aggregation of a virtual power plant.

data models for DER systems to handle this challenge [1]. The Energy Service definition in this paper will focus on the search phase (see Fig. 2).

The remainder of the paper is structured as follows: in the next Section a state of the art overview on Energy Markets and established interaction models is given. In Sect. 3 the energy Service will be described and defined in the context of existing ancillary services. Section 4 focuses on an implementation project that utilizes the proposed Energy Service definition. The last Section concludes the paper and provides an outlook on recent research efforts and open questions.

2 State of the Art

Currently, existing energy exchange market systems, namely the European Power Exchange Spot market (EPEX SPOT SE) or the German internet platform regelleistung.net, enable the exchange of energy services and the settlement of commercial processes for larger market parties. Members of these auction-based markets, balance responsible parties, system operators and large resource providers (producers, consumers and prosumers), are able to participate in the day-ahead or the intraday markets where energy-orders can be placed and contracts concluded.

Independent from these auction based markets, the market parties may conclude OTC-transactions. Focusing on established energy market player and high-volume producer these market models do not provide easy access for small and medium-sized DERs besides the emerging VPP-concept.

Trying to fill this gap, governmental and non-governmental organizations are developing and publishing approaches which tackle the growing dissemination of DERs and as a consequence thereof the growing number of DERs willing to gain access to the energy markets. One example is the Universal Smart Energy Framework (USEF) [3], which focusses on an open framework containing specification, design and implementation guidelines so that participants or stakeholders are able to create a fully functional smart energy system. Within the projects scope, aggregators can accumulate flexibility and active demand and supply of DERs as well as of smaller aggregators to maximize the value of their energy generation and vend it in the integrated market. Energy Service Companies (ESCo) provide auxiliary services to the Prosumers, e.g. insight services or energy management services. Providing this features USEF may integrate

DERs in the integrated markets but still misses functionalities for aggregators to accumulate DERs directly.

Aligning with the governmental Data Access Manager (DAM)-concept [12] the Energy Service definition proposed here may fill this gap by providing this missing functionality for aggregating DERs by allowing a search by aggregators. The OS4ES-Project (see also Sect. 4) defines generic communication and Energy Service models while using a distributed registry system for storing this information. By enabling the resource povider to register and advertise his DER respectively its Energy Services conveniently as well as providing a centralized Service-search and -booking functionality for an aggregator to adjust or reconfigure his portfolio according to current demands, the OS4ES creates a dynamic system to utilize, accumulate and trade the capabilities of these low-volume producers in the manner of a VPP.

3 Energy Services

This Section should describe the scope of the Energy Services and propose a definition of their characteristics.

3.1 Scope

The proposed Energy Service definition shall cover the the provision of power that needs communication between the aggregator role and the resource provider. The aggregator should use a common registry system such as proposed in [6] to find Energy Services provided by DERs. The aggregator is then able to provide services for other actors, such as system operators, or balance responsible parties (BRPs) as for example described in the USEF-project.

For the aggregator role, three main use-cases are currently identified:

1. **Scheduling of power:** the most common use case, to provide active or reactive power within the context of a VPP.
2. **Ancillary Services:** there are several ancillary services of interest for the aggregator role, especially
   (a) Frequency Control: the aggregator provides a VPP that can perform Frequency Control. For this, DERs are needed that have the capability to measure the frequency and can react on deviations.
   (b) Volt/Var optimization: the aggregator provides the DSO a VPP capable of optimizing the Voltage. Also for this, DERs require special abilities.

In Sect. 3.2 it will be shown that the description of power in conjunction with additional information (e.g. energy profiles and forecasted data) is sufficient for most of the described use-cases within the context of the recent grid management.

The Energy Service definition must be distinguished from other service definitions i.e. the Service-terminology in computer sciences [9]. Energy Services are the representation of physical capabilities that are in general limited and thus not repeatable. Therefore, an Energy Service is a consumable object, which means when an aggregator reserves the Energy Service by expressing the intention to use it and then activates the capability (i.e. uses it), the Energy Service is no longer available for other parties.

3.2 Definition

For the classification of the proposed Energy Service definition it is important to determine the taxonomy and relation of the definition within the Smart Grid terminology. As stated in Fig. 3A, the central role in this context is the DER system. Every DER system is connected to the grid through at least one Point of Common Coupling (PCC) or grid connection point, so each PCC has a set A of logical DER systems. Every PCC is connected to a zone, i.e. the grid-zone of the according system operator. In Europe, this can either be the transmission grid or the distribution grid.

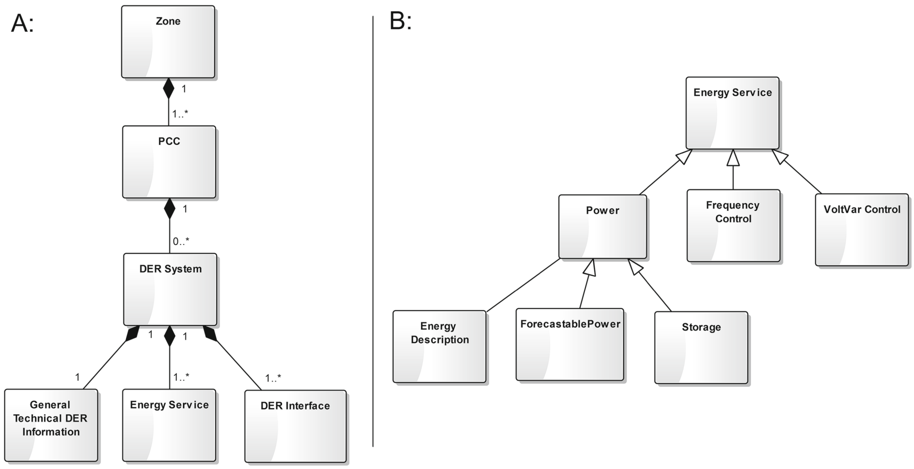

Fig. 3. A: UML-class diagram of the relation between the energy service and the organizational entities. **B:** Example structure of an energy service

A DER system $a_i \in A$ represents a physical or logical device and is composed of three different datasets. The general technical DER information contains all data relevant for the DER system, e.g. PCC and position data, owner, type of installation etc. The interfaces provide information how to communicate with a DER system and how to control it. Each DER system that can provide services for the grid holds a set of Energy Services S_i. The Energy Services $s_i \in S_i$ can be reserved and consumed by the aggregator. It is possible that a DER provides multiple Energy Services at the same time which may exclude each other. The set of rules C_i, describing how the parallel Energy Services influence each other must be defined by the resource provider and stored at a Registry System for Energy Services, where they can be executed when an aggregator reserves an Energy Service. The execution of the rules manages the visibility of other Energy Services provided by the same DER system for search requests by other aggregators.

Based on the scope of the Energy Service definition described in the previous Section, information about the provided power (active and reactive) is considered as the most important aspect for most use cases. The description of the maximum power available over time may be sufficient to describe nearly unconstrained power plants such as gas generators for the search. Depending on the type of DER system and its characteristics, additional data could be necessary. A forecast-based DER such as a wind turbine may also provide forecasts on the expected power in wost-case/best-case corridors until a certain forecast border (see Fig. 4A). Such a DER can provide three informational horizons:

1. The actual power: P_{actual} measured at the DER system, could be used by aggregators to project the capability of the DER system
2. The forecast-based area: a DER system can provide information on the projected corridor of power available within the Energy Service. Although, for environmental-dependent DERs some risk could be included. Such forecast-models can just provide reliable information within a certain period of time.
3. Nominal-value-based: beyond the forecast border, no further information on the characteristics can be given. aggregators can just rely on the maximum nominal-value of power P_{max} a resource provider has defined for this specific Energy Service entity. This implies that the aggregator must consider the type and characteristics of the DER system as well as environmental conditions. Thus, the aggregator must be also able to access the general technical information of the DER system to get information on the DER type.

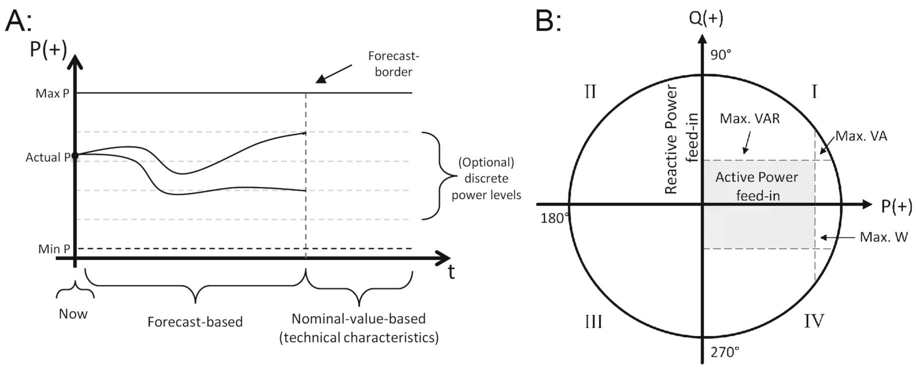

Fig. 4. A: Graphical description of a forecast-based energy service providing active power. **B:** Consumer-Producer reference frame reflecting active and reactive power relation, abridged from [11]

The proposed power-description model is applicable for both, active and reactive power, so that in some cases rules are needed, when a resource provider offers an Energy Service for active and reactive power in parallel. In the most simple case both Energy Services are totally decoupled, so the DER system can always offer an Energy Service with P_{max} and one with Q_{max}. Thus, the resulting complex power pointer S can be anywhere in the gray marked area of Fig. 4B. Defined as a rule, the resource provider can limit this area to reflect the technical abilities of the DER system, e.g. $|S| \ll \sqrt{P_{max}^2 + Q_{max}^2}$.

An aggregator can claim an Energy Service instance for a certain time-period, so the actor is allowed to send control signals within the limits of the reserved Energy Service i.e. $P_{min} \leq P_{demand} \leq P_{max}$ (for reactive power respectively). As the DER can be dependent on environmental conditions, the delivered power can be $P_{actual} \leq P_{max}$, which must be taken into account by the aggregator. In order to allow an optimal utilization of the DER system, the resource provider must be able to quantize the Energy Services, e.g. split the total nominal power of the DER system into multiple Energy Service instances.

Following the DER system definition in IEC 61850-7-420 it is assumed that a DER system is composed out of one or more DER Units and serves as an overlay and managing instance for all subsidiary DER Units. DER systems can be ordered hierarchically i.e. a DER system can be part of another DER system as a DER Unit. As the complexity of such systems may rise with the hierarchical depth of the system, it is recommended to logically decompose complex DER systems when describing the capabilities with Energy Services. Thus, the above described data will be more clearly defined, resulting in an easier search and the aggregator would be able to interpret the characteristics of the DER system better.

Depending on the class of the DER system in conjunction with the power profiles (see Fig. 4A), it is obviously that additional information are necessary to plan the devices. These information specialize the Energy Service description for the characteristics of the DER system while adding only little complexity to the search. In contrast to more market oriented DER-classifications, e.g. the FPAI-class model [8] the here proposed DER-class-model for Energy Services stated in Table 1 should strongly focus on the generalization of technical aspects. The

Table 1. Device classes

Type	Description	Example
Storage	Device that stores energy and can provide it bidirectional	Battery system
Shiftable	Device that can shift under certain constraints or stores energy unidirectional, needs additional energy description and maybe forecast model	Thermal storages, household appliances
Deterministic	Controllable device, can depend on forecasts-model	Gas generators, PV inverters

three classes of DERs are currently under consideration are storages, shiftable DERs and deterministic DERs.

Deterministic DERs can be almost fully described by their provided power and have only few additional constraints that can be expressed through further information within the power profile (e.g. the already described predictability with forecasting horizons).

The shiftable DER class includes shiftable consumer devices (e.g. household appliances) or thermal storages. For these are often forecast data necessary but also information on the total expected energy demand, the energy storage capacity, and the shifting characteristics. In this case, an additional dataset can be given as stated in Fig. 5. It describes the interrelation between the minimum power needed and the maximum power over time, determining a corridor of allowed energy consumption. Figure 5 can be a description of the daily energy demand of a household that has a minimum energy demand for maintaining the lowest temperature but also has the ability to consume additional energy.

For the storage class, covering classical battery systems with bidirectional power flows energy is also an important information on the capacity of the storage.

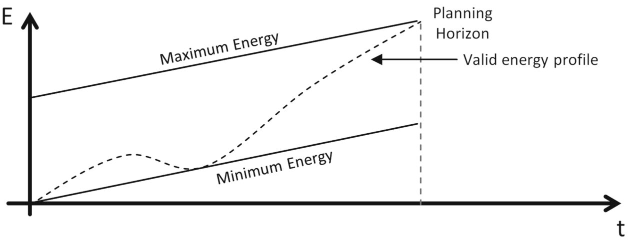

Fig. 5. Description of valid energy profiles, supporting the power description.

This class model allows the definition of an Energy Services class system (see Fig. 3B). The power-subclass describes deterministic DERs which can be specialized into forecastable DERs. The Energy Description as in Fig. 5 can be added when necessary. The Energy Service should not only realize the direct exchange of power and energy, but also on further use and business cases. The Energy Service *Frequency Control* uses the power description model together with additional information on the control energy capabilities (e.g. primary control capability, secondary and tertiary capabilities) while *Volt/Var* is comparable. Thus a large number of possible use cases for DER systems can be covered.

4 Case Study: The Open System for Energy Services

The EU funded research project Open System for Energy Services (OS4ES)[1] will provide a platform that allows aggregators to search and find matching

[1] http://www.OS4ES.eu.

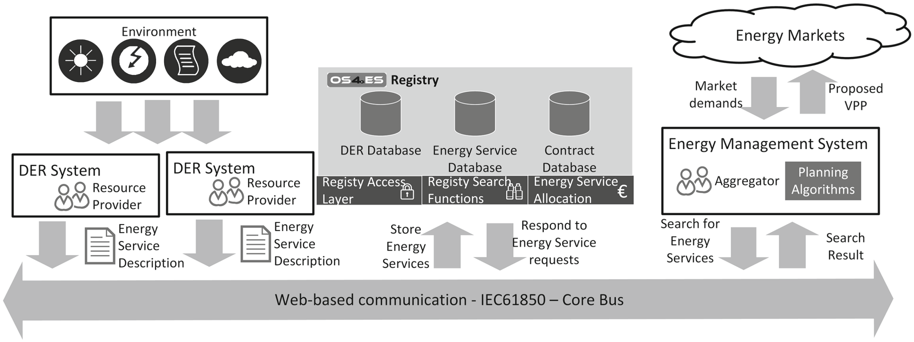

Fig. 6. OS4ES system

DER systems for energy service requests received from a DSO or TSO. Figure 6 shows how this will be achieved.

The resource provider of a DER system (e.g. a PV plant, a wind power plant, a combined heat and power plant, an electric vehicle or any combination of these) registers the data of its DER system in the OS4ES Registry. This DER system data can be categorized in:

- Data as it is can be found on technical data sheets (e.g. owner of the DER system, location, voltage level, point of common coupling, nominal power, type of DER system) corresponding to the White Pages of UDDI and
- Data for the energy service(s) the DER system offers (e.g. data relevant for primary control, Volt/VAR control or offering flexibility) corresponding to the Yellow Pages of UDDI [10].

According to these two categories the technical data sheet data is stored in the DER Database of the OS4ES Registry while the energy service related data is stored in the Energy Services Database. An aggregator receiving requests from the Energy Markets (e.g. flexibility request of 30 MW for the next day) can search the OS4ES Registry for DER systems that can provide the requested service and will receive a list of matching DER systems. With the help of the Planning Algorithms of his Energy Management System the aggregator can check which DER systems match best and can then reserve those DER systems for the requested time frame. This information is stored in the Contract database of the OS4ES Registry. When another aggregator searches the registry the information of this Contract database is used to evaluate if a DER system that has already been reserved for an energy service can provide another of its offered energy services without endangering the delivery of the reserved energy service. In order to achieve the above described scenario the OS4ES project will provide all necessary building blocks:

Web Based Communication Protocol: It has to be ensured that all communicating parties understand the communication protocol by means of which, e.g. DER system information is sent from the registry to an aggregator. The international standard IEC 61850 (Communication networks and systems for power utility automation) is a future-proof and the most outstanding standard for electrical networks at field and station level which also provides a standards-compliant communication framework and data model for being applied to Smart Grids. However, DER manufacturers and the industry miss a simple and low-cost web-based communication protocol in the IEC 61850 series of standards. This shortcoming has been taken up by a task force within IEC 61850 TC57 WG17 which currently evaluates web based communication protocols as alternate communication protocols to the existing IEC 61850 communication protocol MMS but only on a theoretical level. OS4ES contributes to find an apt web-based communication protocol in order to push the usage of IEC 61850 in Smart Grids. After having defined communication requirements for the OS4ES use cases it does not only evaluate web based communication protocols like OPC-UA, DPWS, XMPP, SOAP and REST on a theoretical basis - based on these requirements - at present, but will also perform practical tests based on representative network scenarios using communication network simulators. A prototype IEC 61850 web based solution will be developed for the communication protocol that turns out to be the most appropriate one among the tested ones. Results of the test simulations will be fed back to TC57 WG17. Besides, IEC 61850 protocol converters will be provided for those DER systems used in OS4ES lab and field test which only have proprietary communication protocols.

Generic Data Model for der Systems: In the same way as the communication protocol must be understood by the communicating parties it is also indispensable that all communicating parties understand the exchanged data that is transported by means of the communication protocol. Based on IEC 61850, a semantic information model for DER systems will be defined that provides the DER system data at the point of common coupling (PCC) that is relevant for the aggregator to easily and swiftly find matching DER systems for energy service requests in the registry, e.g. for setting up VPP, perform frequency control or voltage regulation. For this purpose, the information model will be so generic that it will hide the complexity of single DERs may it be generators, loads or storages - within a DER system and will provide generalized and aggregated data. Currently the OS4ES project is setting up this data model based on the use cases that have been defined in the OS4ES project. An integral part of this work is to define the Energy Services proposed in this paper. In a next step it will be analyzed in how far the part of IEC 61850 relevant for distributed energy resources, IEC 61850-7-420, needs enhancement in terms of data for the generic description of DER systems with the aim to bring in missing data in the next edition of this part of the standard. The result of this work will then be brought into the relevant standardization committees for consideration in the next edition of IEC 61850-7-420.

Registry: The registry is a core component to make a dynamic search for Energy Services and their provision possible. The distributed OS4ES registry shall bridge the gap between inventory lists for DER systems (e.g. the EEG lists in Germany) and Smart Markets for larger participants by enabling DERs to announce their availability for grid services. In addition to functional requirements such as: (a) the ability to detect matching services by defining apt filter criteria, (b) the feasibility to find single resources and (c) the availability of databases for datasheet data as well as market-related data (provided energy services, accounting-related data). The OS4ES registry consists of various core components that are designed distributed in order to meet the specified requirements:

- Index service (white pages service): a directory service of all available DER systems with nominal data and specifications as well as ICT information (e.g. communication address, voltage level).
- Yellow pages service: DER systems in the index service provide their Energy Services by the means of the Yellow pages service.

The distribution of components is based on zones that each cover parts of the power grid topology (see taxonomy in Sect. 3.2)

Middleware: A middleware is needed to allow for a seamless integration of the above mentioned components. Such a middleware will be specified and implemented in the OS4ES project. When all components (data model, communication protocol and registry) are available and are integrated in the middleware, extensive lab and field test will be conducted. Based on these results the middleware will be revised where necessary to provide a reliable and smooth central gateway for energy service provision.

5 Conclusion

In this paper, the concept of Energy Services as a generalized capability description for DERs was proposed. The concept enables the aggregator to search and find DER systems providing needed capabilities for VPP. The proposed description model handles the technical complexity of heterogeneous DER systems by providing a generic description model as Energy Services, that abstract from the technical base without leaving out necessary information for the aggregator.

The proposed Energy Service is based on the description of power in conjunction with additional information based on the DER class. One of the main research questions will be the modeling of complex DER system behavior, e.g. CHP integration with the proposed classification and description paradigm. A detailed formalization of the approach is also topic of further research efforts.

With the described Open Systems for Energy Services (OS4ES) a case study was introduced where a distributed registry system for Energy Services is currently under development. The ongoing implementation will facilitate the generalized description model of Energy Services presented in this paper to offer a registry where aggregators can search and find offered Energy Serviced based on the generalized description model. The results of the project and the field tests especially with regard to the data model implying the Energy Service definition and the registry system shall be considered in the further development of IEC 61850.

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