Today, mass presence of Distributed Energy Resources (DERs) connected to the grid is often seen as having adverse effects on grid reliability and robustness. The apprehension is that it complicates or even compromises network management. The EC funded research project OS4ES (FP7-ICT-2013-11) therefore will provide an Open System for Energy Services (hence OS4ES) to enable dynamic and automated integration of millions of DERs into the electrical network. A distributed registry for DERs allows Smart Grid actors, e.g., distribution system operators, to book flexibly aggregated DERs like dynamic virtual power plants for an energy service (e.g., active power control) and activate them in case of need. Standardized interfaces based on international standards (IEC 61850 und CIM) guarantee now and in future stability and interoperability of this software solution whose practicability will be demonstrated in lab and field tests.
Given the definition of roles and services in the frame of the OS4ES project, the Flexibility Users (Distribution System Operators - DSOs, Transmission System Operators - TSOs and Balancing Responsible Parties - BRPs) request energy services from the Aggregators, based on their own needs (Figure 1). On the other hand, Resource Providers offer DER system energy services to the aggregators, which are based on the technical capabilities of the DER systems owned by the Resource Providers. Therefore, the Aggregator is the role responsible for managing and aggregating DER system energy services into aggregator services that fulfill the needs of the flexibility users. The scope of this article is limited to these DER system energy services.

This provides an introduction to the concept of energy services as it is understood in the OS4ES project and shortly addresses the energy services that have been identified as useful services for distribution and transmission system operators, and balancing responsible parties at present and in the near future. Based on the energy services a semantic data model for energy services is deduced and described. Besides, shortfalls of the current IEC 61850 standard for DERs (IEC 61850-7-420 Ed.1 - Basic communication structure - Distributed energy resources logical nodes) will be pointed out and it will be shown how they can be dealt with in the next edition of 7-420 by mapping an exemplary energy service to IEC 61850-7-420.

Energy services

Basic Concept of Energy Services: A DER system may be built up of 1-n DER units (e.g. PV unit, battery, CHP) or a hierarchy of any combination of DER units and systems. The common characteristic of all these DER units must be that they are physically connected to the same Point of Common Coupling (PCC) (Figure 2) and that they are interfaced, in terms of control and monitoring capabilities, as a single entity. In the OS4ES project energy services are considered from the viewpoint of which are the capabilities that a DER system can provide at a PCC. Hence they describe what a DER system would be able to provide as an energy service to aggregators at a given time. The reason for choosing this approach is that an aggregator searching for energy services is not interested in the characteristics of the various DER units within a DER system but rather in the capabilities of the DER system itself. This concept is fully in line with the current work of IEC 61850 Task Force 90-15 (Grid integration of a DER system) of TC57 WG17 which also implies that DER systems offer the aggregated capabilities of their underlying DER systems/units.

According to Figure 3 showing the interaction between Aggregator, OS4ES Registry and DER systems via the OS4ES Core, DER systems publish their energy service(s) in the Registry, a distributed database for DER system data with white and yellow pages, and update their data whenever data changes occur. The Registry stores the energy services data and makes it accessible to authorized aggregators who can search for matching energy services, to contract and reserve them, and finally operate them. When an energy service, or parts of an energy service, has been reserved by a specific aggregator, the registry informs the DER system of its reservation in order to allow it to send forecasts of its expected capabilities to the aggregator. It should be noted that the reservation of an energy service by an aggregator does not necessarily require immediate activation: a reserved and contracted service can be used as control reserve.

With the above definition, an energy service is a consumable resource that can be contracted, reserved and activated by the aggregator. To make this scenario happen, both a semantic data model for DER systems and the registry have been developed. It is so generic that it hides the complexity of single DERs - may it be generators, loads or storages within a DER system and provides generalized and aggregated data. Besides, the data model allows matching algorithms to operate on clearly defined data objects and to find the correct aggregation of energy services for a given network problem and use these services to e.g. perform frequency control or voltage regulation. The key elements of the data model are the energy services provided by the DER systems and the associated parameters. Information associated to these services is held in the yellow pages of the registry. In addition, location and access related information as well as generic characteristics are stored in the white pages. The model includes as well the objects required to control the DER system, to maintain reservation of energy services, to enable partial reservation and additional detailed characteristics of DER systems that is not required to be stored in the registry. The available services and the values for their parameters are updated by the DER system based on actual conditions and forecasts taking into consideration both own usage of resources and dependencies that may exist between different services offered.

Taxonomy: By analysis and means of abstraction the taxonomy of energy services, shown in Figure 4 in UML syntax has been de-
Reservations of Energy Services: A reservation of an energy service may be required. From the perspective of a generic model, a user of a service offered by a DER system may reserve that service for a specific time and a specific amount if applicable. Once the energy service or part of the energy service has been reserved, the DER system cannot update its availability schedule anymore in a way that would violate the reservation. Partial reservation of an energy service is supported by the data model and concept of OS4ES where reasonable. However, what exactly partial reservation means depends on the energy services. Partial reservation requires as well individual setpoints in the DER system for each of the parts that are reserved.

Reservation of a service can be schedule-based. This means, the service user can provide a schedule about what he wants to reserve from a specific service offered by a DER system.

Rated values, availability and forecast for energy services: When a DER system registers its data in the registry, it provides general (generic) DER system information including the rated parameters of the DER system itself.
When a DER system registers a service, it provides the service related rated parameter values for that service. The service is then offered from the provided start time on until an optional end time. If no end time is provided, the service is available until further notice. The start time may be in the past - in that case the service is available immediately. The availability of the service may be further restricted by the availability schedule.

Once the service is offered, the DER system provides continuously updates of the actual parameter values for that service. Optionally, a non-deterministic DER system may as well be able to provide a forecast as a schedule. The content of a forecast and the possibility to forecast depends on the kind of energy service.

**Semantic Data Model**

In a first step, a semantic data model of the DER system has been developed. This model was then mapped to define IEC 61850 logical nodes, and is explained in detail in the following subchapters.

**Overview of the Semantic Data Model:**

Figure 6 provides an overview on the data model, in particular the embedding of the DER system in the network structure.

A PCC is associated to a zone in the utility grid. Zones are logical representations of a physical system. DER systems are connected through a PCC to the utility grid. If multiple DER units are connected to the same PCC, these DER units can either be handled as a single DER system or as multiple DER systems. The information for a DER system consists of generic information related to the DER system and the energy services supported by the DER system with its information. Details of the DER System are shown in Figure 8.

**DER System Information:**

The focus in Figure 7 shall be on some capabilities of DER systems that are of relevance in the context of the energy services and which are modeled in the class General Technical Capabilities:

- **DetTyp**: A DER system may be deterministic or it may be intermittent. Typically, wind turbines and PV systems are considered as intermittent. The determinism is of relevance for the evaluation of the energy services. For deterministic systems it can typically be assumed that the actual or rated values can be expected as well in the future unless some maintenance is foreseen or part of the service is used locally. For intermittent systems, a forecast of the expected service capabilities is important. That forecast, which is typically weather based but for a PV system depends as well on the time of the day, can be prepared by the DER system itself or it can be made by an aggregator or the registry based on experience with that DER system. A DER system can as well be hybrid - combining both deterministic and intermittent DER units. DetTyp is as well available as an attribute of the energy service itself.

- **SysTyp**: A DER system can be classified as generator, load or reversible storage. Reversible storage is characterized by the fact that energy can be consumed (as load), stored and later be supplied.
6 Overview of the data model

A DER system can be as well hybrid, combining e.g. a reversible storage capability with a generator.

- **TechTyp**: This attribute classifies the technology of the DER system (e.g. PV, CHP, etc.)
- **SchdCap**: Some DER systems may be allowed to receive schedules instead of direct setpoints. Such capability is modeled with SchdCap
- **PlanCap**: If the capabilities of a DER system are as well used for the local grid, the amount of a service (e.g. active power) offered to the grid may vary over time depending on the own usage. In that case, it is important for an aggregator, that the DER system provides an availability schedule taking into consideration the availability of the DER units, own usage and futures. However, not all DER system will be able to do plan and provide an availability schedule. The capability to do so is modeled with this attribute
  - **Pred**: For non-deterministic DER systems, the capability of what the DER system can provide as energy service in the future, typically depends on weather information. Therefore, for the aggregator, it is important to get a forecast. If the DER system is able to provide that forecast, it is considered predictable
- **Energy Services**: The class Energy Service is shown in Figure 4. It shows some general attributes of an energy service like:
  - **SvcId**: Service Identifier
  - **SvcRegisStr**: Starting time, for which the service is provided. This attribute together with SvcRegisEnd is only used, if the service is not available permanently
  - **SvcRegisEnd**: End time, after which the service is not provided anymore
- **DetTyp**: Service determinism
- **Disp**: An energy service of a DER system is dispatchable, if the DER system is able to be operated with setpoints provided from an aggregator. If the DER system is not dispatchable, it can only be switched on or off. If switched on, it will provide the service based on current capabilities
  - In some cases, a non-dispatchable DER service can have multiple units that can be switched on or off. If the units have all the same size,
DER systems with reversible storage capabilities (e.g., a battery) can be modeled the same way (Storage), with an average power a little bit below zero (corresponding to the loss of the storage system). Here, the power can either be between the minimum and maximum power for generation, between the minimum and maximum power for load or the DER system can be switched off.

The rated values of this energy service include the values from the active power load and/or active power generation service. In addition, there is a rated value for the energy storage capability, and in the case of reversible storage capabilities some additional parameters. The actual values include as well the actual values of the active power generation and/or load service. In addition, the actual values describe the energy corridor as explained above.

If the offered service is an energy corridor load or generation and is not reserved by an aggregator, the DER system may need to produce/consume power on its own costs. It may as well update the start time and the service parameters depending on the capabilities.

For active power generation and active power load service, it is possible, that the service is not dispatchable. In that case, it can only be switched on or off. This needs to be done in a way that it stays within the storage limits.

**Flexibility Time Shiftable Profile:** This energy service describes typically a load (but could as well be a generator) with a fixed profile that has to be executed. The rated parameters describe the profile. It as well describes if the profile can be interrupted-by default, once started the profile has to be executed without interruption to the end. The energy service is offered with an earliest, a latest start, and a preferred start time. If the service is interruptible, interruptions are only possible as long as the profile ends within the service end time. The service can only be reserved as a whole. If the service is not reserved, the DER system needs to decide when it has to start the profile at its own costs and remove the service from the offer or offer it for e.g., the next day. It is assumed that this service is only offered by deterministic DER systems.

**Autonomous Frequency Control:** This service is used to provide primary control power. The DER system is measuring the frequency and increases or decreases the power based on the frequency deviation. The rated characteristics include the upper and lower power band and the slope. It is assumed that this service is only offered by deterministic DER systems or at least the service itself is deterministic.

**Reactive power:** This service is used to provide reactive power. The rated parameters include minimum and maximum values for both positive as well as negative reactive power (capacitive or inductive).

**Autonomous Voltage Control:** This service is used to provide voltage control. The system is measuring the voltage and provides reactive power if the voltage deviates from a setpoint. The forecasted values take into consideration already reserved parts of the DER system. It is assumed that this service is only offered by deterministic DER systems or at least the service itself is deterministic.

**Outlook**

During lab and field tests the data model and the matching algorithms operating on the data of the data model will be tested and if necessary revised. Any of these revisions will also be fed back to the standardization committee of IEC 61850 TC57 WG17 to allow for a good and concise standard for the integration of DERs into the grid. Furthermore, in terms of standardization activities a comprehensive semantic model to describe functions offered by a DER system has been developed and been realized in IEC 61850. It will be implemented and the concepts verified in the OS4ES project in 2016/2017 and it is proposed to the IEC standardization of IEC 61850-7-420.