Facilitating DER energy services for grid management via OS4ES: aggregated flexibility, class model and matching algorithms

Olaf van PRUISSEN	Mikel FERNANDEZ	Antonis PAPANIKOLAOU	Christoph BRUNNER
TNO – The Netherlands	Tecnalia – Spain	Hypertech –Greece	IT4 - Switzerland
olaf.vanpruissen@tno.nl	mikel.fernandez@tecnalia.com	a.papanikolaou@hypertech.gr	christoph.brunner@it4power.com

ABSTRACT

The European electricity infrastructure is challenged by the deployment of large numbers of DER systems in the grid. The massive deployment complicates the network management done by System Operators: DSOs, TSOs and BRPs. To cope with these adverse effects, the use of smart strategies using the flexibility potential of DER systems has been advocated. The Open System for Energy Services (OS4ES) framework, with a distributed registry for DER Systems is designed to exploit flexibility and to close the current gaps of information, communication and cooperation between DERs, DSOs and BRPs. This enables a new process for identifying, aggregating and creating value out of flexibility.

In this paper relevant parts for emerging the OS4ES process are outlined. One part presents the OS4ES defined energy services for flexibility involving DERs. Based on this and on the information that needs to be exchanged between DERs and other parts of the system in order for such services to be executed, will introduce the vital and interesting elements of the semantic class model of DERs. OS4ES is strongly based on standardized and interoperable communication interfaces, as well as generic interfaces among components producing, consuming or storing electrical energy. Also the general context and the scope of the matching algorithms that are needed to support OS4ES registry-related functionalities will be sketched, presenting the DER system services searching functionalities to be dealt with.

INTRODUCTION

The deployment of large numbers of Distributed Energy Resources: DER systems, is expected to have adverse effects on the reliability and robustness of the electricity grid [1]. Additionally, with the upcoming deployment of heat pumps congestion grid events can occur due to simultaneous consumption of electricity and heat [2]. For Distribution System Operators (DSOs), Transmission System Operators (TSOs), and Balancing Responsible Partners (BRPs), the availability of a process which enables the searching, contracting, reservation and utilization of aggregated energy services for active and reactive power would help considerably to protect the grid. These energy services include the acquiring of flexibility defined as 'the ability to deviate from an initial intended energy demand or supply, where this deviation can either imply a change in time, amount of energy, amount of power, location or a combination of these'. The role of the aggregator, who closes the gap between the flex users (DSOs, TSOs and BRPs) and the DER system owners, is essential for marketing flexibility. Based on prices requested by the DER systems and internal business logic, aggregators should be able to select the most appropriate mix of DER system services for creating a bundled energy service that possesses the scale to affect the grid stability. The OS4ES framework is capable of managing DER system services which involve flexibility, active power and reactive power provision and frequency and voltage support, enabling the selection of relevant DER system services, e.g. DER systems in a local area where congestion occurs or DER systems in a broad area where reduction of imbalance is needed, thus being able to offer those services to the flexibility users.

The relationships between roles in OS4ES is described in [1], as well as the basic architecture, including the OS4ES semantic middleware allowing communication, message translation and authentication (core). For simplicity in this paper the flexibility aggregator and flexibility provider are considered as one role: the aggregator. The context of the resource provider outlines the arrangement of the DER system and may vary from e.g. a single DER unit, multiple DER-units or a hierarchy of any combination of DER units like a Virtual Power Plant (VPP) aggregating all individual heat pumps in a single building and a substation as described in [3]. It is envisioned that a DER system will be able to forecast its capabilities regarding the adjustment of its intended, PTU based, energy schedule consisting of consumption and/or production. When the DER system cannot provide such a forecast, it is up to the business logic of the aggregator to forecast such capabilities. 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. The concept of DER system energy services as it is understood in OS4ES is provided in the next paragraph.

DER SYSTEM ENERGY SERVICE DEFINITION

DER system energy services are defined from the perspective of a DER system. The energy services describe what a DER system would be able to provide as a service to aggregators at a given time. In OS4ES energy services are offered th**r**ough a distributed registry.

Aggregators can search the registry for required energy services and contract, reserve and operate matching ones.

<u>Interactions between Registry, DER systems and Aggregators</u>

Figure 1 shows the interactions between DER systems, OS4ES Registry and Aggregators through the core (OS4ES semantic middleware).

DER systems register themselves in the registry via the core as depicted with the green line pointing from the DER systems to the Registry. Here the registry acts as client while the DER system acts as server. DER systems

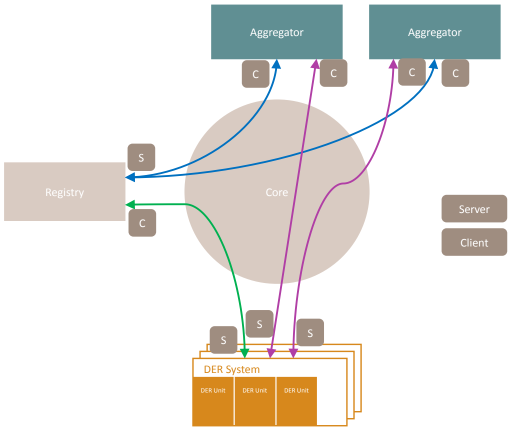

Figure 1: Interactions between DER systems, core, registry and aggregators

register underlying services in the registry, which are modeled as independent entities. Again the green line applies for this process. When an energy service of parts of an energy service of a DER system has been reserved by an aggregator, the registry must inform the DER system of the reservation to allow it to provide its remaining energy service (flex) capabilities. This process is described with the green line pointing from the Registry to the DER systems.

Aggregators search for matching DER system energy services by accessing the registry via the OS4ES middleware (core). Here the registry acts as server while the aggregator acts as client (blue line pointing from the aggregator to the Registry). Upon this search request the registry returns a list of matching DER system services to the aggregator (blue line pointing from the Registry to the Aggregator).

The aggregator may decide to exclusively contract an energy service at a DER system thus setting the pricing conditions that would be applied for the settlement of the service. Contracted services can hence be reserved, which implies that the service, or part of it, is exclusively available to be operated by the aggregator in a concrete time frame. Once an energy service is reserved by an aggregator, the DER system will send 1) an updated forecast of its expected capabilities to the aggregator based on his reservation constraints (purple line pointing from the DER system to the aggregator) and 2) a forecast of the remaining capabilities to the OS4ES registry as offered services (green line pointing from the DER system to the registry).

Energy services

Within OS4ES an energy service is defined as a DER system capability that is published in the registry and offered by the registry to aggregators as a response to their search requests. The services defined can be categorized into services related to active power and services related to reactive power. Variants of the service for active power include autonomous frequency control (used for primary control) and various models for providing flexibility. A variant of reactive power is autonomous voltage control. Use cases as defined in [1] were analyzed and resulted into the differentiation of the following DER services:

- Autonomous frequency control
- Active power – generation
- Active power – load
- Flexibility – energy corridor
- Flexibility – time shiftable profile
- Reactive power
- Autonomous voltage control

To elucidate this differentiation the following line of thoughts was applied.

From the viewpoint of a DER system, there is no difference if the capability to provide active power is used by an aggregator to deliver active power or if it is used to offer secondary or tertiary control power. However, in order to offer primary control power, the DER system needs to be able to measure the system frequency and autonomously provide active power accordingly. This is the reason why the primary control energy service is modeled as an additional service (autonomous frequency control) to the active power service. The same argument applies for reactive power services and autonomous voltage control service.

The main purpose of a DER system is, to supply active power, which is described by active power generation. The key rated parameter of the service is the maximum power that can be supplied under worst case conditions. But depending on the kind of generation device, there is as well a minimum power that can be supplied while switched on. The control of the service is done using a setpoint or a schedule for active power.

One of the main problems in the provision of energy services are conditional interdependencies between them, i.e. the determinism of some services which strongly depend on other services. Some energy services may only be provided if some amount of active power is already scheduled (e.g. reactive power, frequency control). They must rely on the scheduling, planning and the credibility of the active power scheduling. In current grids, these energy services are provided by must-run power plants that are always providing active power.

In OS4ES the provision of an energy service is left at the responsibility of the resource provider. To manage this OS4ES offers mechanisms where already reserved energy services, futures and options play an important role. Measurements at the DER system will improve the reliability strongly and DER system characteristics, such as determinism (with wind turbines and PV systems being intermittent, hence non-deterministic), predictability, dispatch ability and the ability to understand schedules are taken into account; yet the details are too extensive to be explained in this (short) paper.

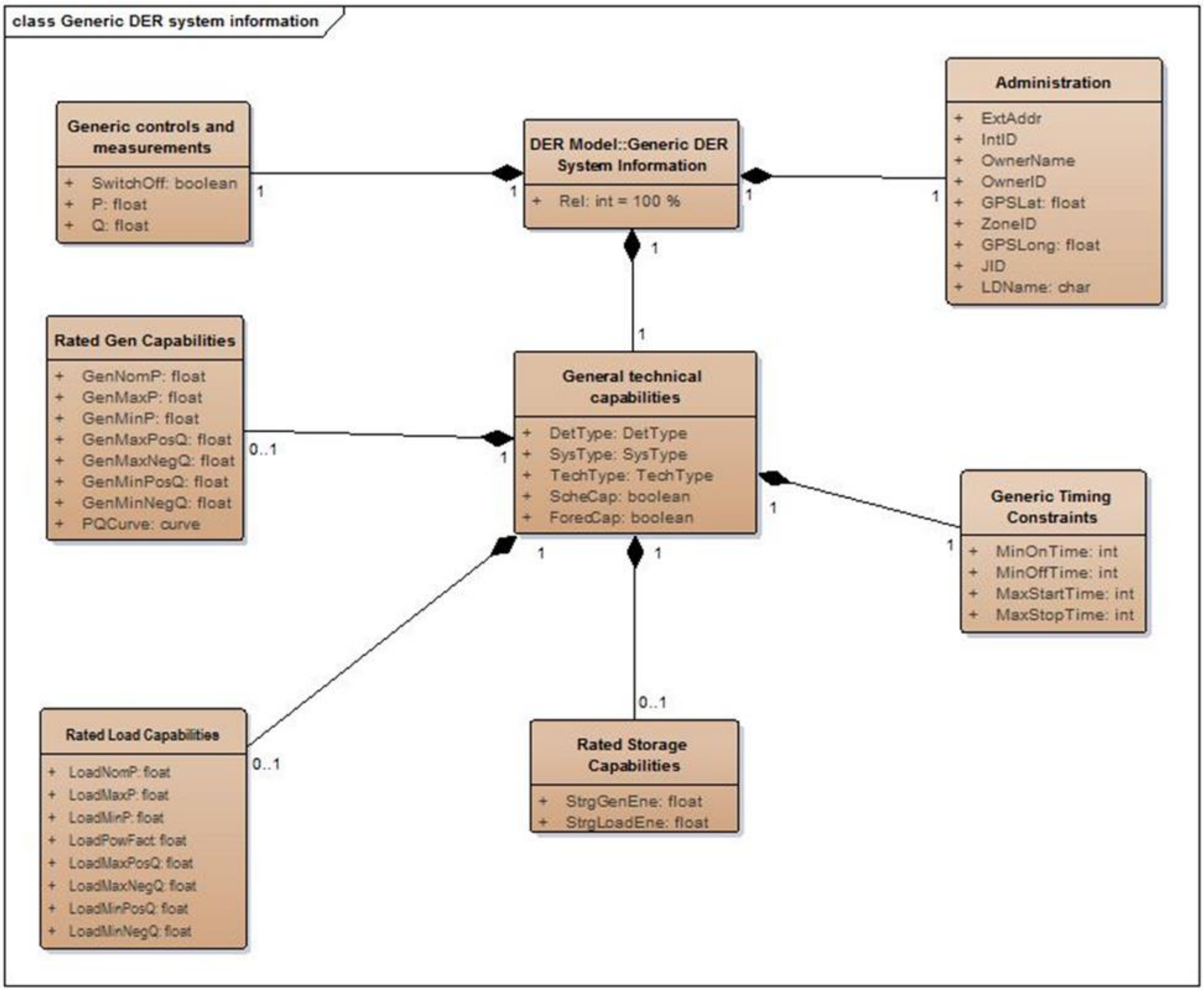

Figure 2 Generic DER system information

The energy service "Flexibility – energy corridor" is used to model the flexibility provided by DER systems with storage capabilities. An example is a generator with storage capacity as e.g. a Combined Heat and Power Plant (CHP) with thermal storage and for controllable loads (e.g. cool house). DER systems with reversible storage capabilities (e.g. a battery) can be modeled the same way. The service "Flexibility – Time shiftable profile" describes typically a load with a fixed profile that has to be executed. The energy service is offered with an earliest start time, a latest start time 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.

CLASS MODEL

This section provides a condensed overview on the semantic data model of DER systems. Two class diagrams are shown and discussed, exhibiting the concept design of the OS4ES class model.

The generic DER system information shown in Figure 2, illustrates the specific DER system information model, in which the general technical capabilities include the overall rated characteristics of the DER for generation, load and storage capabilities as well as generic timing constraints. Figure 3 provides an overview on the data model, in particular the embedding of the DER system in the network structure.

DER systems are connected through a Point of Common Coupling (PCC) to the utility grid, with a PCCId based on an EAN code identifying the PCC.

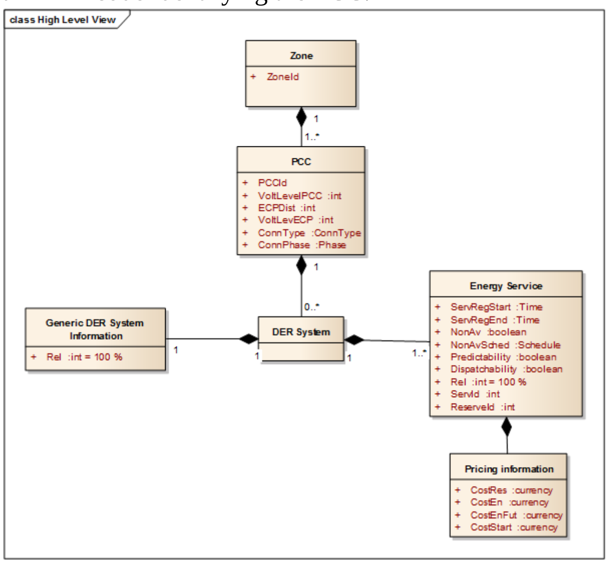

Figure 3 Overview on the class model

A DER system is also defined by the nominal voltage level to which the DER is connected (VoltLevelPCC), the distance of the electrical connection point to the PCC

(EPCDist), the connection type of the DER at the ECP (ConnType, can be 1-phase or 3-phase), etc. A DER publishes its energy services in the OS4ES registry, displaying its starting and ending date and time of the period for which the service registration is valid (ServRegStart and ServRegEnd) and characteristics like Predictability etc.

Reliability is a parameter which informs the aggregator about the certainty of the DER system of actually delivering the service. An specific algorithm supports the judgement of reliability at the aggregator side. To assess the matching possibilities of the DER service, pricing information can be passed to the aggregator and is denoted by the cost of reservation, for supplied energy, supplied energy that has been reserved as futures and (extra cost) of starting generation (CostRsv, CostEn, CostFut, CostStart).

MATCHING ALGORITHMS

An overview of the interactions and functionalities required at the OS4ES registry to interact with the aggregator and DER system/Resource provider is shown in figure 4, please note that the order of functionalities is not always sequential.

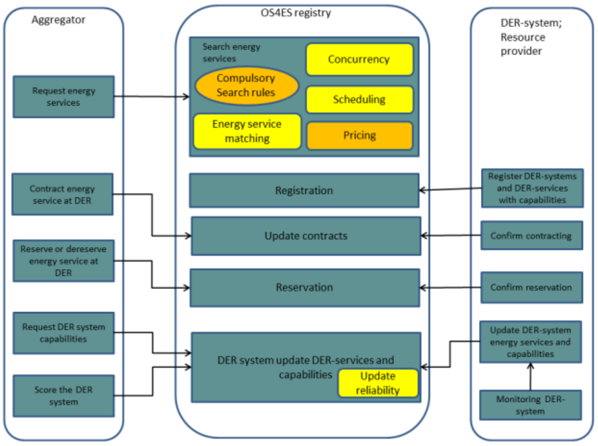

Figure 4 Functionalities at the OS4ES registry interacting with stakeholders.

Yellow blocks indicate matching algorithms, whereas orange oval blocks indicate simpler rule based functionalities. When merely the parsing or updating of values is required then just the functional block in blue is shown.

At the top-most functional block in the block representing the aggregator, energy services are requested by the aggregator in a specific area of interest. Upon receiving this message a search will be initiated within the OS4ES registry and results will be passed to the aggregator who raised the search question.

As figure 4 shows, both DER systems and their services should be registered at the registry. The registration and the updating of the DER system energy services and capabilities can be straightforwardly handled by creating the relevant objects and writing values to attributes with passed parameters. Energy service matching is indispensable, but too spacious to describe further here. When an energy service request is received by the OS4ES registry sometimes a lot of processes must be handled in a short time frame. Other service requests from other aggregators can be received between the time that the search is started and while performing the search. Coinciding reservation requests for services from an aggregator having taken this decision on earlier search requests, will occur. OS4ES will preferentially employ soft searching to solve this concurrency issue: no reservation of DER services at searching, but at a conflicting reservation request, reservation of just the services which are not reserved yet will be realized and the start of a new cycle intended for reserving the missing services is requested. This process is cycled up to a maximum amount of cycles. If this maximum of cycles is exceeded, a restart from scratch (perhaps with another concurrency algorithm) is required.

SUMMARY

From the side of DER systems, the OS4ES framework is capable of managing services which involve flexibility, active power and reactive power provision and frequency and voltage support, enabling the selection of relevant DER system services, e.g. DER systems in an area where congestion occurs, thus being able to offer those services to the flexibility users (DSOs, TSOs and BRPs). From the side of the flexibility users, OS4ES enables the handling of concurrent types of requests to compose a list or a number of lists of DER systems, optionally with schedules, which are able to make the aggregated flexibility available within certain constraints as start time, end time, maximum power, minimum power, reliability and rate of change. Aggregators are thus facilitated to select the most appropriate mix of DER system services for creating a bundled energy service that possesses the scale to affect the grid stability.

REFERENCES

[1] G. Venekamp, R. Kamphuis, J. Laarakkers, M. van den Berge, 2014, "OS4ES: Increasing awareness of DG-RES and demand response processes by registry enabled services", *Powertech*, IEEE Eindhoven 1-5

[2] O. van Pruissen, R. Kamphuis, 2011, “High concentration of heat pumps in suburban areas and reduction of their impact on the electricity network”, Powertech, IEEE, 1-6

[3] Olaf van Pruissen, Koen Kok, Aldo. Eisma, 2015, "Simultaneous imbalance reduction and peak shaving using a field operational virtual power plant with heat pumps", CIRED, 2015, Lyon.