Technical Framework Virtual Power Plant

Vol. 1

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Disclaimer
The content of this document is merely informative and does not represent any formal statement from individuals and/or the Austrian Research Promotion Agency (FFG), the Austrian Climate and Energy Fund, or any official bodies involved. Instead, it is a public document from contributing editors with visionary perspective based on years of experience with interoperability testing and energy system safety. The opinions, if any, expressed in this document do not necessarily represent those of the entire IES project team and/or its funding bodies. Any views expressed are those of the contributing person at the time being and do not commit a common position.

Table of Content

1 About the Document

A **Technical Framework** represents a technical specification, which is integrated into a predefined document structure. Please note that a technical framework does not equal a new standard. It rather describes the normalised use and application of existing standards and practices to avoid interoperability issues. Integration Profiles state constraints/recommendations that define how to apply standards and good practice to realise a specific feature of a Business Function in an important interoperability fashion. The technical framework is embedded in a business domain overview, which is accessible from the project homepage at http://www.iesaustria.at. The concept is based on the IHE technical framework that subdivides a technical framework into two part: volume 1 for an informative and volume 2 for a normative description. This document describes volume 2.

The document structure of the technical framework is as follows:

Volume 1:

- Business Case Overview (informative)
  - Typical use cases
  - Relevant meta-actors
  - Related standards
- Business Functions (informative)
  - Describe the interoperability issues with the IEC 62559 Use Case Methodology
  - Use case diagrams

Volume 2:

- Integration Profiles (informative and normative)
  - Technical solution for a specific interoperability issue from the Business Function
  - Definition of transactions that are needed
  - Definition of actors that are involved
- Transactions (normative)
  - Specification of actors that shall be implemented
  - Specification of the IT standards and how options/variants shall be used

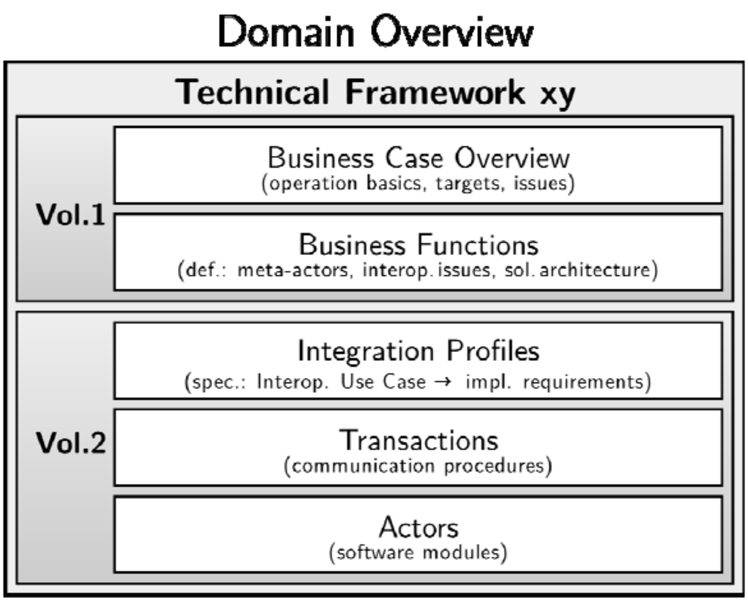

Figure 1: Structure of the Document (IES Technical Framework Template)

2 Definitions

Actor (based on IHE)
is a functional component of a system that executes transactions with other actors as defined in an IHE Integration Profile

Conformance Testing
is a standalone process to ensure that the implementation conforms to specified standards and profiles, i.e. the implementations outputs and response are checked against rules and patterns.

Interoperability Testing
is a process to check whether the system interacts effectively with foreign systems, i.e. when different vendors meet to test their interfaces against each other (e.g. Connectathon).

Interoperability Use Case
is the part of a Business Function that relies on data exchange between different actors according to an Integration Profile (i.e. where interoperability is required).

Meta-Actor
joins functional components (actors) in order to fulfil all the functionalities required for a Business Function (IHE grouping).

Transaction (based on IHE)
is the specification of a set of messages (1..n) exchanged between a pair of actors that realise the Use Case specific information exchange (in one or both directions, in a strict or loose order) as specified by an Integration Profile.

Operational Use Case
is the part of a Business Function that describes an activity not involving any data exchange between actors. This kind of use cases are mentioned in the IES Technical Framework, but not considered in Integration Profiles because per se they do not raise interoperability problems.

3 VPP Business Overview

The overall operational objective of any energy producer, virtual or not, is to closely follow a committed power generation schedule so as to avoid expensive compensation payments for balancing energy. Distributed energy resources (DERs), in particular those integrating renewable energy sources (RES), are prone to significant deviations from the committed schedule due to their volatile production curves caused by varying environmental conditions that cannot be controlled. In order to decrease their risk, DER operators can decide to integrate their resources into a larger body, called Virtual Power Plant (VPP). The role of a VPP operator in the Energy System is called Aggregator.
A VPP is able to act on behalf of a multitude of DER assets to generate optimal commercial value from the portfolio in the wholesale electricity markets. VPPs create value by mitigating financial trade risks and from operational optimisation of the DER asset portfolio.

To establish a Virtual Power Plant, a reasonable number of small and distributed power plants is aggregated to form a jointly managed set, such that together they achieve the critical size and flexibility required to successfully participate in the energy market. Typically, a VPP consists of distributed energy resources such as combined heat and power generators (CHP), backup generator sets, small photovoltaic plants (PV) and small wind, hydro or biogas installations. VPPs may also integrate power storage and energy consumers, if their power demand can be actively managed. This cluster of distributed generation is collectively run by an aggregating control system. Please note that the technical units contributing to a VPP can be widely spread across regions. The operation mode of a

VPP may optimise different goals, such as energy trading success or ancillary services provisioning (e.g. peak load shifting).

DERs insert the produced energy typically into the low or medium voltage distribution grids (Figure 3). DERs of one VPP may be connected to different grids managed by different system operators (SOs). Planned and actual insertion both need to remain within the agreed limits stated by the responsible distribution system operators (DSOs). The SO may ask the VPP to increase or reduce the current insertion to help stabilize the grid when supply and demand diverge from planned schedules. In that case, the VPP sells balancing energy, which can represent an economic business case for the VPP.

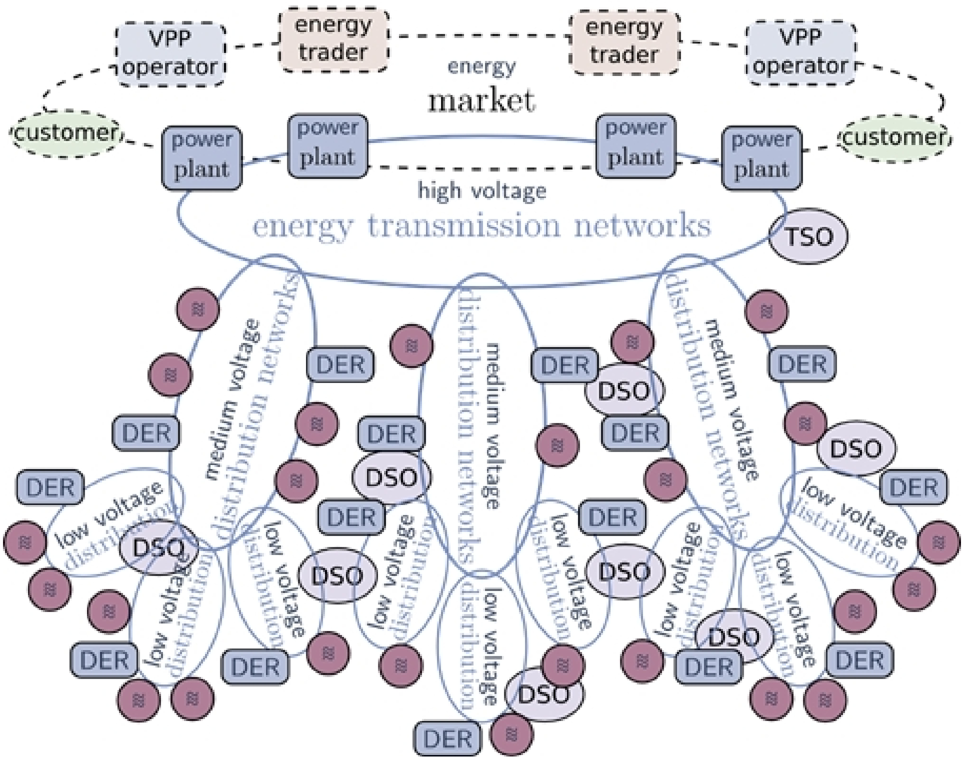

Figure 2: Integration of DER in the energy grid and energy market

From an operational point of view, VPPs can be divided into different types serving different purposes. Archetypes of VPP operation schemes are outlined in Figure 3:

- **Loose cooperation** represents for example price triggered Demand Response (DR) systems.
- **Profile coordinated** VPPs trade the generated energy for the distributed small resources.
- **Remote controlled** VPPs influence the DERs directly by controlling them actively.

Real VPPs may combine features and characteristics of different types to optimally match the resources they aggregate and the market they address.

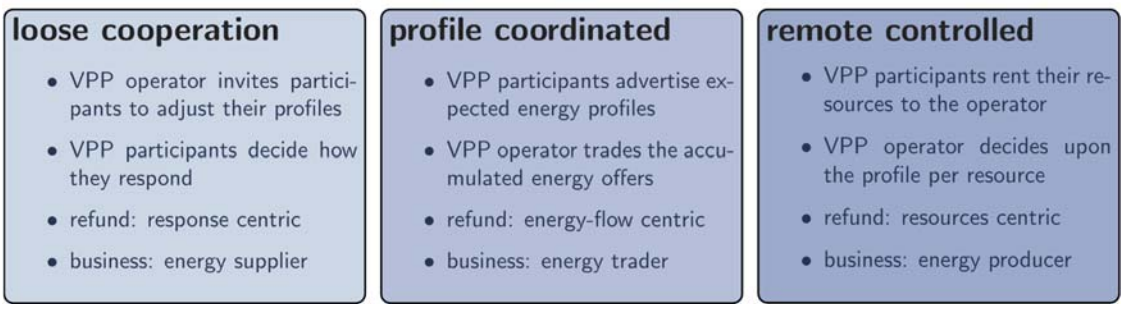

Figure 3: VPP operation archetypes

In the following, we focus on the remote controlled Virtual Power Plant archetype because it is the most complex based on bidirectional communication that constitutes control cycles. The profile coordinated VPP archetype relies solely on unidirectional information exchange from assets to the VPP operator (forecasts), whereas a pure demand response system, being a loose cooperating VPP, requires communication from the VPP operator to the assets only, e.g., energy price adjustments.

3.1 Relevant Actors of a Remote Controlled VPP

Business Functions are specified in the Use Case Management Repository (UCMR - ucmr-ies.offis.de). Details on data exchanges, such as interfaces and data structures, are explained with the different transaction descriptions. This section provides some general explanation and the mapping of actors.

A prime communication issue is the exchange of energy schedules (i.e., generation and load curves) and control messages among actors. There are five different entities involved: the VPP operator (VPPOP), the distributed energy units (DEUs) constituting the VPP via their operation and control units (DEUOP, DEUC), the energy market, and the distribution system operators (DSOs) to whom the DEUs are electrically connected. The basic flow of actions is depicted in Figure 4: VPP-RC operation cycles, with the numbers indicating the sequence of actions. This order is also used for numbering the Use Cases described later in the document. Adjustments can occur repeatedly within sub-cycles. Whenever VPP energy is offered on the energy market the entire cycle is to be repeated.

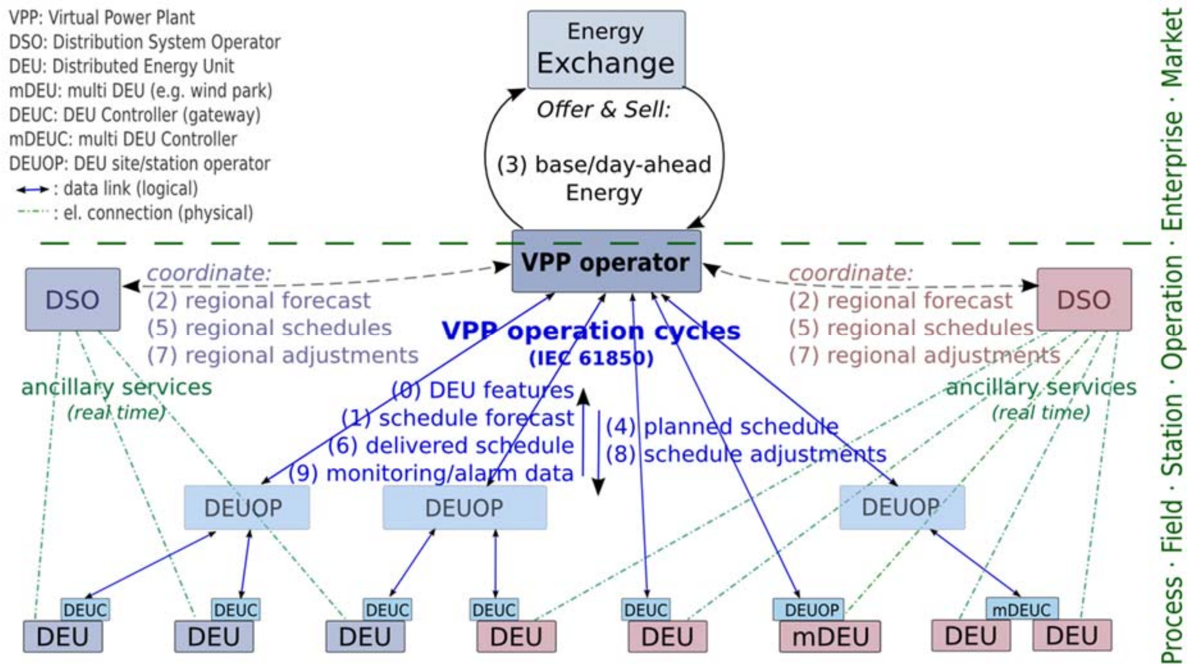

Figure 4: VPP-RC operation cycles

3.1.1 Virtual Power Plant Operator (VPPOP)

The Virtual Power Plant Operator of a remote controlled VPP represents the central control centre. The VPPOP creates aggregated forecasts to trade energy on the energy market and calculates individual schedules for each DEUOP or DEUC to control the energy production (or load) that the VPP inserts (drains). While physically the VPPOP may be connected with a DEUC directly, if no dedicated DEUOP exists, the communication always needs to be either VPPOP-DEUOP or DEUOP-DEUC, depending on which unit (VPPOP or DEUC) integrates the missing DEUOP interface.
In case “ancillary services” are legible and negotiated, the distribution system operator (DSO) can send grid requirements to the VPPOP. DEU control messages initiated by the DSO are then forwarded via

the VPPOP to the addressed DEUOP or DEUC. In VHPready, the VPPOP is the control centre[1] of the VPP, comparable to the same instance of traditional large-scale power plants. VHPready is an industry alliance developing industry standards for managing DERs to participate in the energy trade. [2]

3.1.2 Distributed Energy Unit Operator (DEUOP)

The DEU Operator controls a local group of DEUs and represents a station controller in the IEC Smart Grid Architecture Model (SGAM). [3] The SGAM subsumes different perspectives and methodologies regarding the development and conceptualisation of Smart Grids in a three-dimensional view. This actor operates as the local control centre and handles both the communication with the VPPOP as well as the joint control of several DEUs. It transforms schedules and control signals from the VPPOP into schedules and control signals that alter the behaviour of the individual DEUs. A DEUOP represents the entire group of DEUs in his portfolio as one single asset. In VHPready, this actor is again a control centre (station controller), but a local one, itself controlled by a superior control centre.

3.1.3 Distributed Energy Unit Controller (DEUC)

The Distributed Energy Unit Controller represents an addressable control interface that controls a specific Distributed Energy Unit. Depending on the controlled DEU, the DEUC includes DER, load or storage controllers on the field zone from the SGAM perspective. DEUCs provide the hardware specific interface to control DEUs, and establish the media conversion where required. In VHPready, this unit is described as “gateway”.

3.1.4 Distributed Energy Unit (DEU)

A Distributed Energy Unit produces, consumes, or stores energy. A DEU can be a DER, an adjustable load or an energy storage device. In VHPready, DEUs are called technical units[4]. A DEU may itself consist of a group of technical units controlled by a single control unit (DEUC) only if no differentiation of the individual components is required. If individual control of components (technical units, e.g., wind-mills) is intended, they need to be manged by a DEUOP, and thus each component must have its own DEUC. However, different DEUC software instances may be executed by a single physical device (control computer). Logically, this unit does not be a DEUOP because the individual DEUC instances are not merged into an aggregate unit. Likewise, a DEUOP may integrate a number of DEUCs by providing the direct interfaces to the different DEUs it manages. In that case, the different DEUCs exist only virtually (as an address and assets specification) because no dedicated software instances are required.

3.1.5 Distribution System Operator (DSO)

The DSO owns and manages an electric power distribution grid, which is naturally confined to certain areas in which the DSO operates in a rather solid monopoly situation. Therefore, regulation policies commonly exclude DSOs from any energy trading business. While DSOs manage the interconnections with the superior transmission system and neighbouring distribution systems, they have no direct control over the total energy flows across their grids. Still, they are responsible for safe and reliable operation of the electric power distribution across their grids, and may interfere with power flows only to maintain grid stability.

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[1] In German, VHPready mentions the control center “Leitstelle”.

[2] For further details about VHPready see https://www.vhpready.com/about-us/

[3] Smart Grid Architecture Model (SGAM) Framework: For further details see https://ec.europa.eu/energy/sites/ener/files/documents/xpert_group1_reference_architecture.pdf

[4] In German, VHPready names the technical unit “Technische Einheit”

3.1.6 Energy Exchange

The Energy Exchange represents the marketplace for buying and selling electric energy. As electricity cannot be stored in the grid, sales and purchases are time bound. The aggregate energy insertion needs to match the aggregate consumption at any time. Sellers and buyers agree on so called “schedules” that specify the precise amount of energy delivered and consumed instantaneously over a given time interval. Pricing conditions must be transparent and non-discriminatory for all authorized participants, and the energy exchange must be legally independent of the buying and selling business entities.[5]

3.1.7 Notation according to model

IES	SGAM	VHPready
VPPOP	Missing in SGAM, located in the DER domain and enterprise and operation zone.	central control centre
DEUOP	Station Controller	local control centre
DEUC	DER, Load and Battery Controller	“gateway”
DEU	DER, Battery and Load	Technical unit

3.2 Related Standards

Standards that are applied in the Technical Framework for the VPP are introduced in this section.

3.2.1 ISO TR 28380 – Health Informatics IHE Global Standards Adoption Process

The ISO/TC 215 develops healthcare specific standards and the IHE initiative describes IT profiles for technical frameworks to implement the information exchange in the healthcare. The profiles are reviewed by a rigorous testing process, the IHE Connectathon, where various vendors meet to check the interoperability of their interfaces. After a successful Connectathon, the profile can be used to create products that are easy to integrate with products of other vendors who realize the same profile.

This concept is adapted for the energy sector and described in this document by creating volume 1 and 2 of the technical framework (cf. Section 1).

3.2.2 IEC 62559 Use Case Methodology

The European mandate M/490 and the resulting IEC SRG group develops a Use Case Methodology to collect requirements and specifications in a structured way. The standard series IEC 62559 describes the Use Case Methodology; the first part includes a description of the process and methodology, the second includes the template, the third describes an exchange data format, and the fourth includes an overview of best practices. The Use Case template is a part of the IES process to collect Use Case in a consistent manner. The template allows the description of systems functionality from different viewpoints; it starts with a general description and ends with a step-by-step analysis that shows the involved actors and information objects exchanged.

3.2.3 IEC 61850

- IEC 61850-1/-2/-3/-4
  The first parts of the standard include the basic information about the standard series: an introduction and overview, glossary, general requirements, as well as system and protection management, which are needed to understand the topic of the IEC 61850 and to see the links between other standards parts.

[5] See also IEC Electropedia: http://www.electropedia.org/iev/iev.nsf/display?openform&ievref=617-03-01.

- IEC 61850-5: Communication requirements for functions and device models
  All communication requirements of the functions being performed in the substation automation system and to device models are identified.
- IEC 61850-6: Substation configuration language
  This part specifies a file format to describe the functional structure of intelligent electronic devices (IED) and to exchange the IED descriptions between engineering tools and different manufactures in a compatible way. The description includes: IED parameters, communication system configurations, switchyard structures, and the relation between them. The defined language is the substation configuration language (SCL).
- IEC 61850-7-1: Communication reference model
  This part gives an overview of the IEC 61850 communication architecture. It introduces the modelling methods, communication principles, and information models that are used in various parts of the IEC 61850-7-X series.
- IEC 61850-7-2: Abstract Communication service interface
  This part provides the services to exchange information for the different kinds of functions and how to exchange the information.
- IEC 61850-7-3: Basic communication structure – Common data classes
  This part of the standard series IEC 61850 defines the attributes of the common data classes which are linked in the logical nodes (cf. IEC 61850-7-4/-420).
- Information Model EN 61850-7-4, Communication networks and systems for power utility automation, Part 7-4: Basic communication structure – Compatible logical node classes and data object classes.
  This standard defines the information model used for communicating information between instances of logical nodes (LNs) and/or logical devices (LDs). The model uses a strict hierarchy. A logical device can be composed out of one or more logical nodes, where each logical node represents a certain information element with dedicated functionalities. The LNs itself are based on data objects that can be used in different LNs. The common data classes are the bases of the data objects and group common attributes. The bases of this hierarchy are the standard data types.
- IEC 61850-8-1: Communication networks and systems in substations - Part 8-1: Specific Communication Service Mapping (SCSM) - Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3
  The standard IEC 61850-8-1 defines the mapping from data classes and logical nodes/logical devices as specified by IEC 61850-7-4 (or IEC 61850-7-420) to MMS objects. Additionally, MMS services are defined for the single MMS objects, specifying the remote procedures that may be supported.

3.2.4 ISO/IEC 8824

ISO/IEC 8824-1:1999, Information technology – Abstract Syntax Notation One (ASN. 1) ITU X.690 (07/2002)[6], Information technology – ASN.1 encoding rules: Specification of Basic Encoding Rules (BER)

This standard defines data types, values, and constraints on data types for the BER. Therefore, a number of simple types, with their tags from more basic types are defined, and a notation for referencing these types are specified. For constructing new types, a notation is given to specify new types.

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[6] ITU X.690 – ASN.1 encoding rules: https://www.itu.int/rec/T-REC-X.690-201508-I/en

3.2.5 RFC 5246

The Transport Layer Security (TLS) Protocol Version 1.2 – Communication security over the Internet[7]: This protocol provides privacy and data integrity between two communication partners; so it allows client/server applications to communicate in a secured way that prevents eavesdropping, tampering, or message forgery.

3.2.6 IEC 62351

Power systems management and associated information exchange - Data and communications security. It includes authentication of data transfer through digital signatures, ensuring only authenticated access, prevention of eavesdropping, prevention of playback and spoofing, and intrusion detection.

4 Business Functions

Based on the Business Overview, a number of Use Cases can be defined according to the IEC 62559. These Use Cases are located within a SGAM plain in Figure 5 to demonstrate which domains and zones from the electrical energy conversion chain and energy management processes are involved. In total, ten Use Cases were identified to represent the VPP processes as described in Figure 4. In the next step, a brief overview of the Use Case VPP-04 is given.

Note: Currently, a complete description of all Use Cases can be found in the IES Use Case Management Repository (http://ucmr-ies.offis.de) and in on our project website (https://mahara-mr.technikum-wien.at/group/integrating-the-energy-systems/usecases).

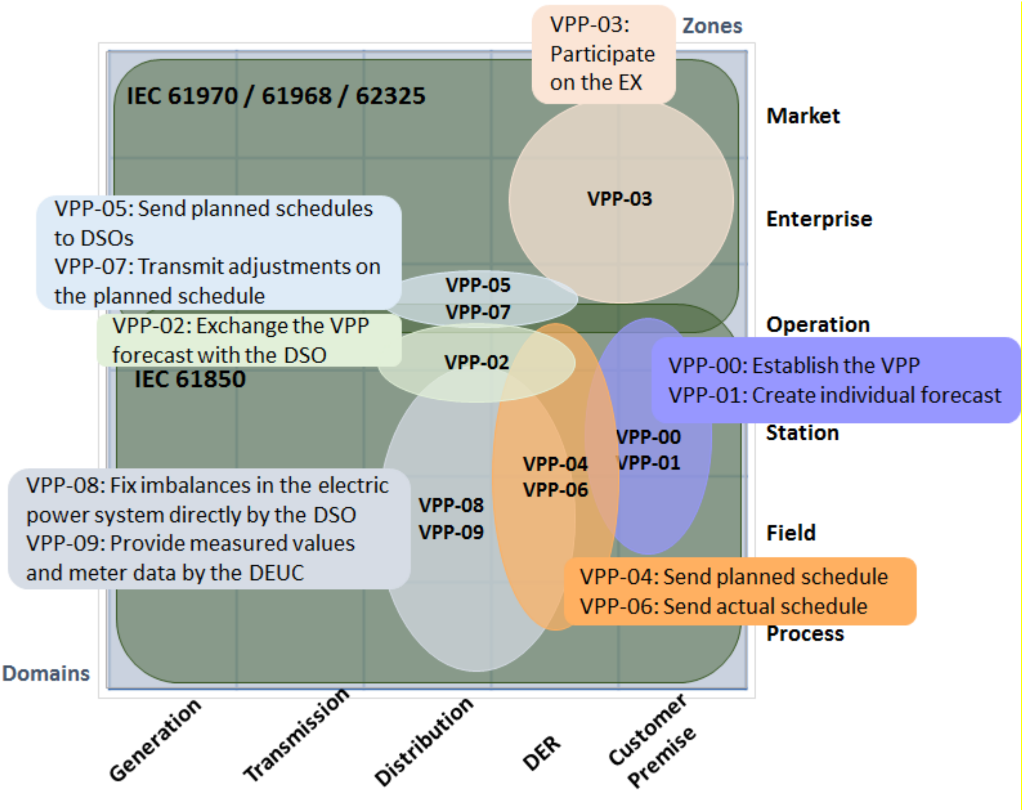

Figure 5: VPP Use Case Overview

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[7] TLS Protocol Version 1.2: https://tools.ietf.org/html/rfc5246

4.1 VPP-00: Establish the VPP

The VPP is composed by various DEUs. Before the VPP can interact as a power plant, the DEUCs have to provide their configuration details to the VPPOP and DEUOP. These data are sent from the DEUC to the VPPOP and the DEUOP; however, the DEUOP is an optional actor and is only a part of the use case if a local operator is needed next to the central one. Based on that data, the VPPOP composes a VPP that can take part on the energy exchange and can control the DEUs as a power plant. Additionally, the VPPOP and the DEUOP need these data to know how the schedule of the DEUC has to be structured and managed (e.g. FSCH). The configuration data should contain following data: the current behaviour, name, namespace, type, status and technical data like max output power, maximum voltage, and time delays for starting and stopping assets.

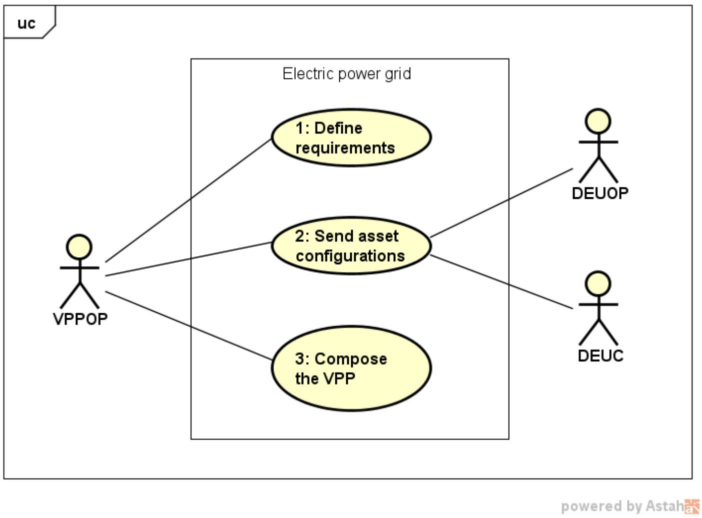

Figure 6: VPP-00 Use Case Diagram

In Figure 6, the Use Case Diagram shows the activities and connections between actors for establishing a VPP. The ovals show steps to fulfil the Business Function for creating a VPP. Steps where data is exchanged between different actors are described as Interoperability Use Cases in Volume 2 by the Transactions. Steps with no data exchange are Operational Use Cases, which are not considered in the IES Technical Frameworks, but they are part of the Business Function view. As you can see only the second step depicts an Interoperable Use Case that will be defined later on.

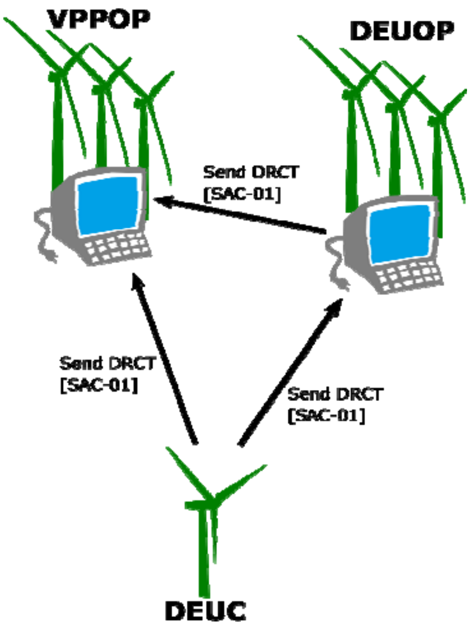

Figure 7: VPP-00 - Schematic drawing of the actors involved and their interactions

Figure 7 shows the schematic view of the interoperability issue in the Business Function. It visualizes the connection between the DEUC, DEUOP and VPPOP to provide asset configurations for the VPPOP to establish the VPP. The related Integration Profile is described in Volume 2.

Transaction	Name	Description
SAC-01	Send DRCT	This transaction is used to send asset configurations from the DEUC to the DEUOP and VPPOP with the Logical Nodes LLN0 and LHPD from the IEC 61850-7-4.

4.2 VPP-04: Send planned schedule

Based on the agreement achieved on the market (committed schedule sold), the VPPOP splits the schedules into feasible regional schedules, which may be coordinated with the involved DSOs (cf. Use Case VPP-02). However, the market communication is not part of this profile. The VPPOP transmits individual schedules to the DEUOPs and DEUCs involved. In case a DEUOP is involved, the DEUOP splits the received regional schedule further into individual schedules per managed energy asset, and sends these to the DEUCs controlling the different DEUs. Depending on the features of the DEUCs these schedules may be sent as a complete schedule by the VPPOP or as a sequence of adjustment messages by the DEUOP, such that the connected DEUs execute the individual schedules. A DEUOP merges individual local DEUs into one and adds local flexibility (smartness) by enabling the DEUOP to decide locally when which asset shall produce or consume how much energy. Local fluctuations and short-term demands can be compensated/fulfilled locally, without involving the VPPOP, as it is required where the VPPOP communicates directly with the DEUC. Regarding normative operation, no difference is made between direct and indirect control.

Note: The introduction of local DEUOPs increases the scalability and allows the owners of multiple DEUs to decide themselves how to fulfil a requested schedule. In principle could DEUOPs be cascaded (introducing regional DEUOPs), which make the control architecture infinitely scalable.
The DEUC manages the execution of the individual schedule, adjusted to the features of the respective DEU. Solutions for the communication between DEUC and DEU are essential, yet commonly custom-built or based on established control system solution, e.g. based on Fieldbus technology and alike. Interoperability issues of this interconnection are outside the focus of the VPP operation, which this Use Case addresses. A High-Level Use Case “Local Control of DEUs” may be defined elsewhere, whereas “Integrate a DEU in a VPP” is another Business Issue for each vendor to be considered within the VPP Use Case (if an interoperability issue exists).

The Use Case Diagram shown in Figure 8 visualises the schedule exchanges among a VPPOP and the DEUCs actually controlling the DEUs constituting the VPP. The ovals show the steps in the Business Function for sending the operative schedule from the VPPOP to a DEUC. Steps where data is exchanged between different actors are described in Section in the transactions of Volume 2 that specify Interoperability Use Cases. Steps with no data exchange are Operational Use Cases, which are not considered in the IES Technical Frameworks, but they are part of the Business Function view.

Note that the step “2a: Adjust schedule” is not considered since these tasks are executed by an actor internally, i.e., these steps are only informative and not yet tested.

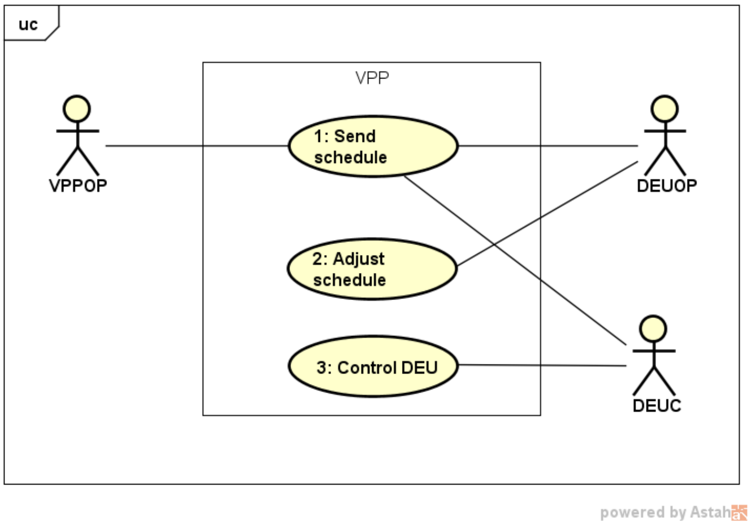

Figure 8: VPP-04 - Use Case Diagram

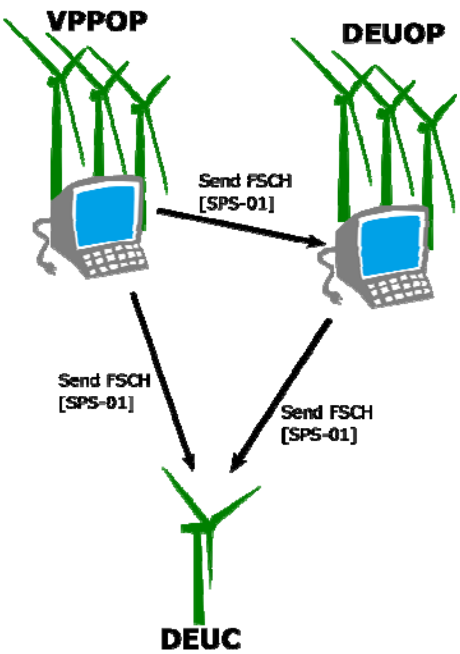

Figure 9: VPP-04 - Schematic drawing of the actors involved and their interactions

Figure 9 displays the actors that are involved during the exchange of planned schedules together with the transactions between them. This figure only shows the interoperability viewpoint of the Business Function and establishes the connection to the following technical specification, the transactions in the integration profile "Send Planned Schedule" (cf. Volume 2).

Transaction	Name	Description
SPS-01	Send FSCH	This transaction is used to exchange a "functional schedule" (FSCH). The FSCH is a Logical Node (LN) defined in IEC 61850.

4.3 VPP-09: Provide measured values by the DEUC

The DEUC has measuring instruments that record data about the voltage, power, apparent power, reactive power, cos-phi-values, and frequency. The DEUCs shall provide these data as live data for the DEUOP, the VPPOP and the DSO to manage the VPP and to control the electric power grid. Therefore, measured data are requested from the client side and reported from the DEUC. For the VPPOP and the DEUOP, these data are important to organize the outcome of the VPP and to check if the schedule is fulfilled. The DSO needs the data to check the electric power grid stability, and based on that, to decide if further interactions are needed to keep the grid stable. Figure 10 shows the connections between actors and their functions. The ovals show the steps in the Business Function for sending measured values from the DEUC to the VPPOP, DEUOP or DSO. The second step describes the collection of the measured values by the DEUC; it is an Operational Use Case. The first and third steps are interoperability Use Cases. The VPPOP, DEUOP or DSO requests the data from the DEUC, and the DEUC sends these data; it is considered in the integration profile “Provide Measured Values”.

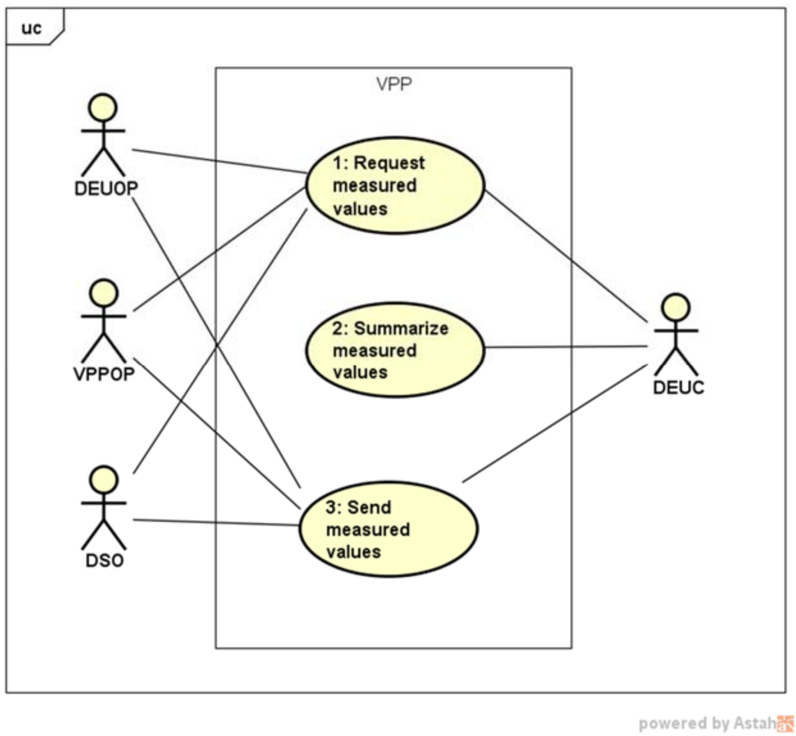

Figure 10: VPP-09 Use Case Diagram

Figure 11 shows the involved Meta-Actors and their connection with the transactions between them. This figure only shows the interoperability viewpoint of the Business Function and establishes the connection to the following technical specification, the transactions in the integration profile “Provide Measured Values” (cf. Volume 2).

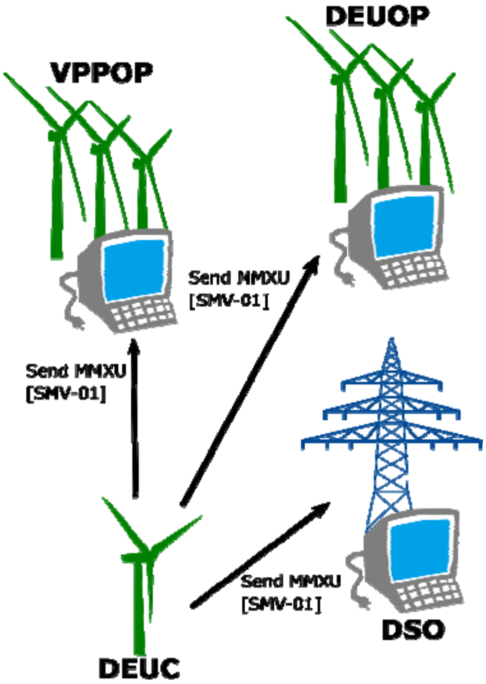

Figure 11: VPP-09 - Schematic drawing of the actors involved and their interactions

Transaction	Name	Description
SMV-01	Send Measured Values	This transaction is used to send measured data from the DEUC to the DEUOP, VPPOP and DSO with the Logical Node MMXU (Measurement) from the IEC 61850-7-4.

5 Content of Volume 2

The informative view about the business case and functional description of the VPP is specified in this volume; the second volume of the technical framework includes the normative description of these with the IHE methodology. This includes the description of integration profiles and transactions, which specify actors, security considerations, and data models for implementing the business cases.

6 Abbreviations

BER	Basic Encoding Rules
CHP	Combined Heat and Power generators
CIM	Common Information Model
cVPP	commercial VPP
DER	Distributed Energy Resource
DEU	Distributed Energy Unit
DEUC	Distributed Energy Unit Controller
DEUOP	Distributed Energy Unit Operator
DR	Demand Response
DSO	Distributed system operator
EEX	Energy Exchange
e-Sens	Electronic Simple European Networked Services
FFG	Austria Research Promotion Agency
FSCC	LN: Schedule Controller
FSCH	LN: Schedule
IDE	Intelligent Electronic Device

IEC	International Electrotechnical Commission
IES	Integrating the Energy System
ISO	International Organization for Standardization
IT	Information Technology
LAN	Local Area Network
LD	Logical Device
LN	Logical Node
PV	Photovoltaic Plants
SCSM	Specific Communication Service Mapping
SGAM	Smart Grid Architecture Model
SO	System Operator
TCP/IP	Transmission Control Protocol/Internet Protocol
TLS	Transport Layer Security
tVPP	technical VPP
UCMR	Use Case Management Repository
VPP	Virtual Power Plant
VPPOP	VPP Operator

7 References

[1] IEC, “IEC 61850-7-420 -Communication networks and systems for power utility automation - Part 7-420: Basic communication structure - Distributed energy resources logical nodes.” .

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