Energieforschungsprogramm

Publizierbarer Endbericht

Programmsteuerung:
Klima- und Energiefonds

Programmabwicklung:
Österreichische Forschungsförderungsgesellschaft mbH (FFG)

Endbericht
erstellt am
29/05/2019

Projekttitel:

IES Austria

IES - Integrating the Energy System

Projektnummer: 853693

Ausschreibung	2. Ausschreibung Energieforschungsprogramm
Projektstart	01/03/2016
Projektende	31/05/2019
Gesamtprojektdauer (in Monaten)	39 Monate
ProjektnehmerIn (Institution)	Technologieplattform Smart Grids Austria
AnsprechpartnerIn	Dr. Angela Berger
Postadresse	Mariahilferstraße 37-39, 1060 Wien
Telefon	01/58839 58
Fax	
E-mail	Angela.berger@smartgrids.at
Website	http://www.iesaustria.at

IES Austria
IES - Integrating the Energy System

Authors[1]:

TP-SGA: Angela Berger
AICO: Gerald Franzl
FHTW: Matthias Frohner
OFFIS: Marion Gottschalk

[1] Please note that the contributions of the mentioned authors summarise the contributions from all active members if the IES Austria project team. Therefore, this report belongs to all team members and is licensed CC BY-SA.

1 Table of contents

2 Introduction

Task of the project

Interoperability is essential for the success of the energy transition and contributes to the investment protection for the users as well as the manufacturers. A normalized use of technical standards for interfaces and communication protocols is a central requirement for cost-effective system integration. Seamless interoperability in the energy system is important, because the change takes place gradually and new components must be integrated into an existing system. An example of a communication standard used within energy technologies is the IEC 61850. Due to its flexibility, only a normalized application of it can lead to interoperability. The objective of the project IES Austria was the design of a modular process chain to achieve interoperability, starting with the selection of use cases and the necessary standards for the realization, specification of a normalized use of these standards in interoperability profiles at different levels, their implementation, and ending with a demonstration of the test for interoperability.

Focus of the project

The aim of the project IES Austria was to foster interoperable smart energy systems via adopting an approved holistic methodology from the health care information technology sector established and maintained by the Integrating the Healthcare Enterprise (IHE) consortium. The IHE methodology is standardised in the draft technical report ISO DTR 28380-1.

<u>Implementation of a methodology for interoperability processes for data exchanges in the energy system</u>

The methodology was carefully adopted and adjusted to fit the demands and preferences of the energy sector. Operation engineers and physicians have in general different technical background and understanding. Building up by the experiences and the know-how of the IHE, the processes were applied for the production of (standard) profiles for the flow of information and data exchange in the Smart Grid and their tests on interoperability at different levels within the scope of the requirements of the CEN-CENELEC-ETSI Smart Grid Coordination Group (SGCG / M490).

<u>Building a test platform to ensure the interoperability of energy system components</u>

This project evaluated elements which allow setting up test procedures. The tests are described in Open Source elements to ensure a sustainable long term development within a cooperation of all stakeholders, preserving compatibility to a wide range of future applications, flexibility and open interfaces. Requirements of SGAM and existing IHE modules and functionalities were taken into consideration.
Gazelle is a test bed for interoperability of eHealth information systems. It is developed by IHE Europe with the support of several other IHE countries. For the IES project the test platform Gazelle was evaluated and adopted for the selected standards and technical specifications.

Classification in the program

The main areas of application addressed by the project IES Austria were in the thematic field “Intelligent Networks TF4 / 4.1 Power grids” of the “Energieforschungsprogramm - 2. Ausschreibung”.
There the focus lies on:

- System architectures for the integration of information and communication technologies (ICT) into future smart grids with a special focus on interoperability and security (security, safety, privacy and resilience, convergence of systems)
- open, interoperable ICT, regulatory and automation solutions for the integration of distributed energy resources and storage

- Methods and concepts to support the development process - from design to evaluation to validation - of smart grid components and systems to reduce time to market, such as: B. Model-based design concepts for smart grid automation systems, information models for system, application, control and communication aspects, etc .;

The project primarily addressed the following objectives:
Objective 2: Increase the affordability of sustainable energy and innovative energy and mobility technologies Cutting costs with highly innovative technologies is the key to accelerating market penetration.
Objective 3: To build and secure technology leadership and to strengthen the international competitiveness of Austrian companies and research institutes in the field of innovative energy and mobility technologies. Strengthening technological competence and competitiveness will strengthen Austria as a location for business and innovation and open up new opportunities for Austria's international climate protection policy.
The project IES Austria can also be classified in the three layers of the "Three Layer Research Model", which was used by ERA NET to locate the research projects.

Topic: Technology, Interoperability
The objective of the project was the establishment of efficient processes to guarantee interoperability as output by combining the experience of IHE (http://www.ihe.net/) and the results of M490 (SGAM). The proven practices from the health system, which were successfully established in Europe, led to a cross-sector knowledge exchange in the project. The experience of IHE was transferred into a demonstration for interoperability processes in the electricity domain, since today Smart Grid solutions have not completed this step yet.
Part of this process is the set-up of a testing platform for interoperability (related to IHE method). Some selected use cases were implemented and tested as a demonstration of the developed process for ensuring interoperability for communication and data exchange in Smart Grids

Topic: Market Place
The whole method serves as a service: Interoperability will help to create solutions for the participants of the energy market to leverage smart resources across national borders and to participate in changing energy market structures. Transparent methods to harmonise technical specifications and profiles with a clear focus on the needs of the customers will create a real European Market Place. The harmonised use of standards and profiles will lead to improved demand side management solutions, better prosumer interaction and faster integration of microgrids. Interoperability will foster competition and contribute to decreasing prices for better products. The marketplace for interoperable products and services will help to overcome dividing conditions.

Topic: Stakeholder / Adoption
Interoperability is the strongest precondition to overcome barriers to widespread user adoption. A result of interoperability targets all sectors: public community, stakeholders, society and industry.
Innovation through transition: Interoperability will increase consumer acceptance and prosumer interaction; it will push innovations, security, privacy and various interactions.
Interoperability will help to speed up the development of cross border and cross sector activities in communication, data exchange and trading.
All stakeholders will actively take part in the definition, development and use of an increasing number of innovative applications.
Decreased prices will motivate users to engage and accept the (necessary) change and the new processes that will support innovation in the energy business.

3 Content Presentation

The IES-approach

IES implements a transparent, vendor-neutral and cooperative modular process chain to specify interoperability profiles for ICT-systems in the energy sector (see Fig. 1). By initiating a cross-sector knowledge exchange, the initiative IES draws from 15 years of experience and know-how in the healthcare sector, where systems interoperability has been implemented for a long time. In the global organization Integrating the Healthcare Enterprise IHE, manufacturers and users work together in a participatory process to ensure the interoperability of relevant ICT systems. Experiences from the healthcare sector showed that the profiling approach harmonizes the use-cases that software products need to comply. Hence, vendors and customers need fewer resources to integrate new components into an existing IT-landscape.

The three pillars of the IES Interoperability Process

IES accompanies the process of developing "Technical Frameworks" containing the integration profiles (Pillar Profiles), software tools provide interoperability testing (Pillar Tests) and subsequently, the developed "Technical Frameworks" and the results of the successful tests are made publicly available (Pillar Results).

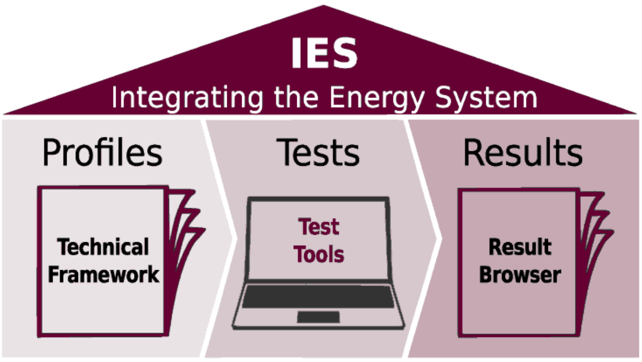

Figure 1: The three pillars of the IES methodology

***Pillar Profiles*: What is an IES integration profile?**

In a structured document called "Technical Framework", the so-called integration profiles specify on the one hand informative descriptions of the functions and on the other hand a normative specification of the data exchange with existing standards. The document structure is in line with the Smart Grid Architecture Model (SGAM) which was developed within the European Smart Grid Mandate M/490

***Pillar Tests*: What is a test event “Connectathon Energy”?**

IES provides a test environment for vendors to test their product interfaces on interoperability and conformity based on the Technical Frameworks. Part of the IES process is the regular organization of test events “Connectathon Energy”. There, the implemented integration profiles are tested by manufacturers peer to peer with other vendors. An open source software testbed Gazelle is used, providing test management and capabilities for participants supporting the interoperability testing.

***Pillar Results*: Who can benefit and what are the benefits?**

The jointly developed Technical Frameworks are publicly available. These can serve as references for tenders by users or procurers and used by manufacturers for implementation. The information about successfully tested products are made available in the online accessible Result Browser, which makes the manufacturer more visible. For users or procurers the Result Browser is an important source of information.

The specification of the Technical Framework is the centre of the IES Process (see Fig. 2)
In the first step of the process the Technical Framework is specified by experts starting with a concrete use case, the document structure suits to the Smart Grids Architecture Model (SGAM).
According to the process all the specifications are online accessible.
Therefore the Technical Framework is the specification for the implementation of the interfaces of ICT systems and for the interoperability testing it serves as basis for the specification of the test tools and the test case definitions.

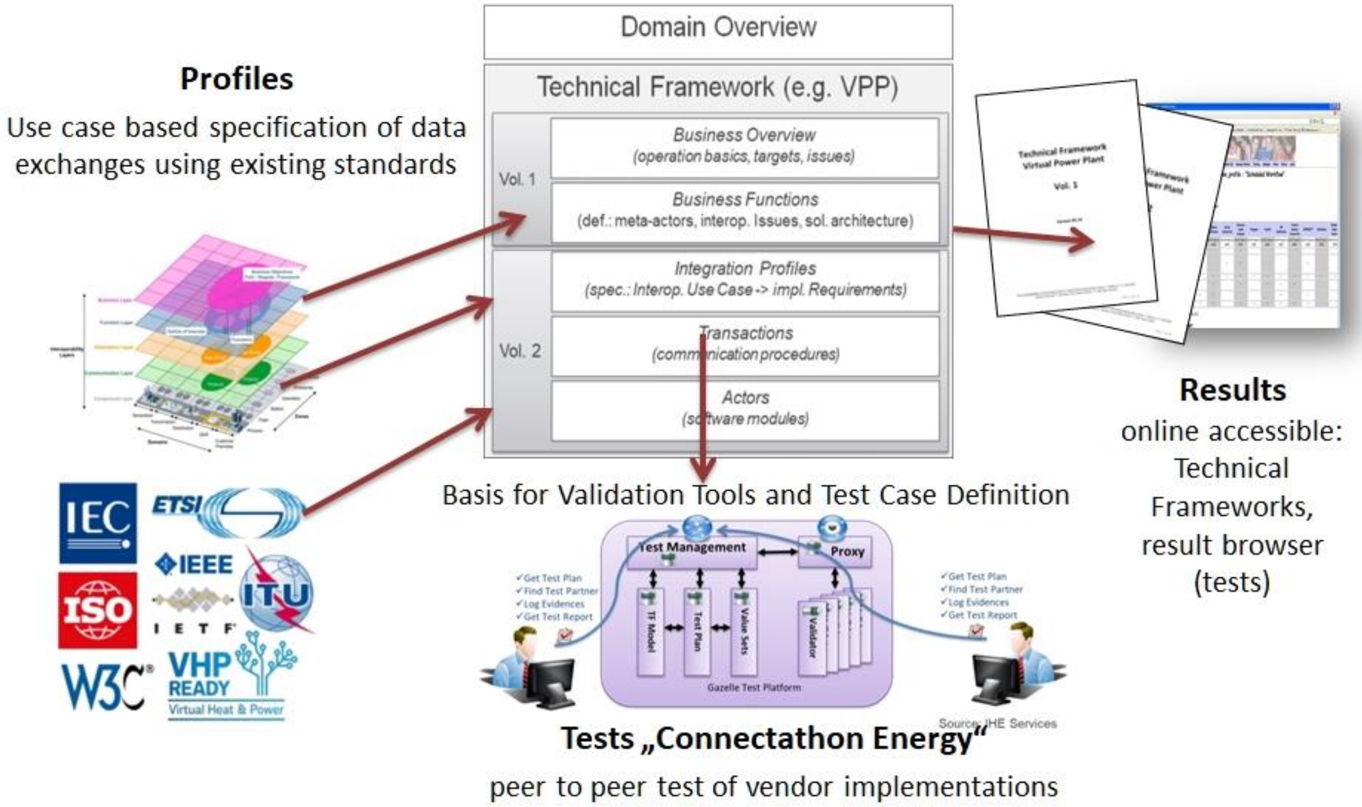

Figure 2: The IES Technical Framework is the centre of the IES process

3.1 Implementing the IES process

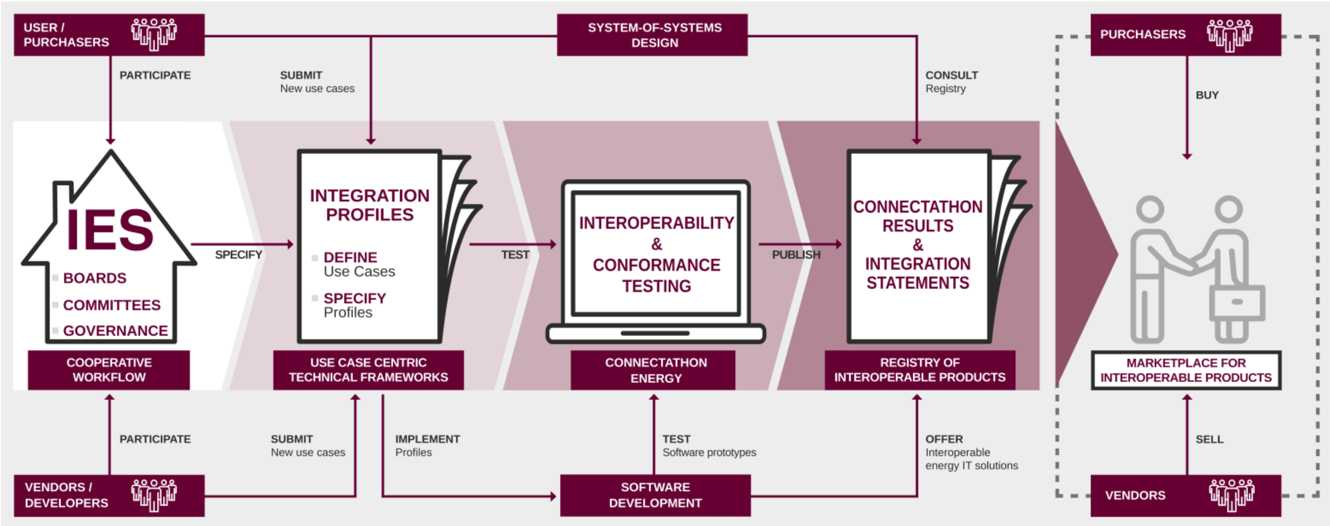

Figure 3: The IES process

The “actors” that realise the IES process outlined Figure 3 are experts working at manufactures or as operators of the systems. These people constitute the IES community which needs to be established for the method to become applied. Therefore, the IES approach to achieving interoperable solutions needs to become known as a reliable supportive tool for modernising the energy sector. To perform this, early adopters become domain experts that promote and monitor the application of the IES methodology in research projects and development endeavours where interoperability among independent systems is required.
If profiles are too complex to be specified within one cycle, their development may occur over two or more cycles. Effort is needed to change the traditional bottom-up thinking of engineers and the fear based call for over-specification and -regimentation.

Not included in the IES process is the actual implementation of the developed specifications. This is evident because IES does not manage the implementation. Every vendor is free to decide how to fulfil the specifications stated in the IES Integration profiles. Thereby, plurality of solutions and differentiation among products from different vendors remains alive while interoperability is still granted.

For successful testing of the profile implementation at the Connectathon Energy, passing the tests with three independent peers is required. It is therefore advantageous to establish a team that jointly writes the specifications. Implementing these is always performed individually, and at the Connectathon Energy only black-box testing of the individual prototypes is performed. Evidently, IES Integration Profiles specified by a team of renowned experts support faster acceptance in the community and more vendors to implement the requirements and test their systems at the Connectathon Energy.

To coordinate the development such that new implementations of IES Integration Profiles are ready for testing at the same time, IES proposes the timeline described in Chapter 3.5.

3.2 Specifying interoperability requirements

The IES requirements specification follows the Use Case Methodology (IEC 62559), and thereby uses the Smart Grid Architecture Model (SGAM) and The Open Group Architecture Framework (TOGAF) to structure the process, minimising the risk to overlook important requirements. According to TOGAF shown in Figure 4, several steps are required to get from the business case to the individual steps that can be technically specified. A use-case can be of any size and may summarise a complete hierarchy of smaller use-cases. Accordingly, Integration Profiles, where each shall refer to exactly one use-case only, can integrate other Integration Profiles and they may be integrated with others, interchangeably called bundling or grouping.

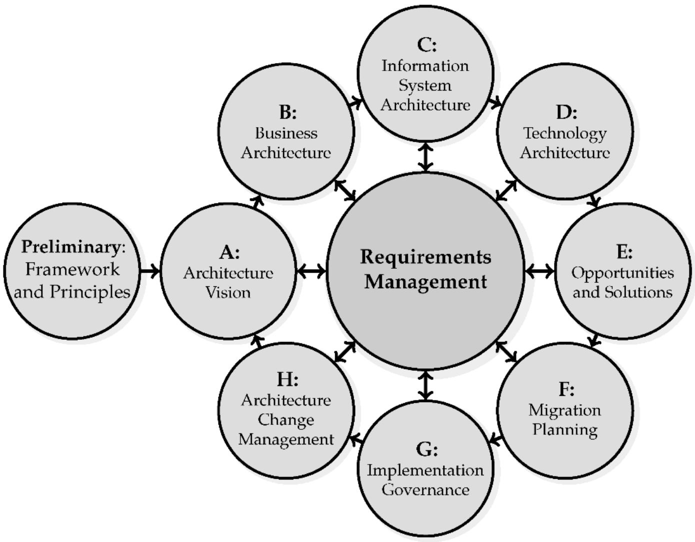

Figure 4: The Open Group Architecture Framework (TOGAF)

The document structure of IES Technical Frameworks shows parallels with the SGAM layering, as depicted in Figure 5. It is essential that the requirement development is performed top-down in order to assure use-case centric specification of interoperability requirements. Step-by-step the granularity is increased, and the covered features become less complex and more technical. Once a feature can no more be split into other features it becomes a use case in the sense of the Use Case Method. These features may consist of many steps, but no single step fulfils on its own a complete task required for the use case to work.

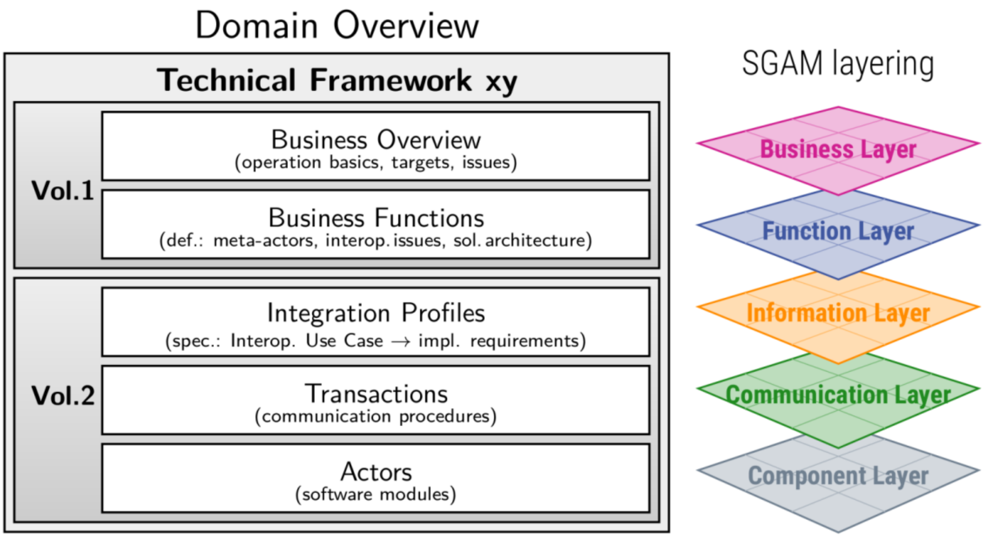

Figure 5: The IES document structure in relation to the SGAM layers

Specification of the first Technical Framework

For the exemplary IES Technical Framework and IES Integration Profiles we chose in the project the Virtual Power Plant (VPP) implementing data exchanges using the two standards IEC 61850 and IEC 60870. Positioning the features and functions in SGAM resulted in the localisation shown in Figure 6.

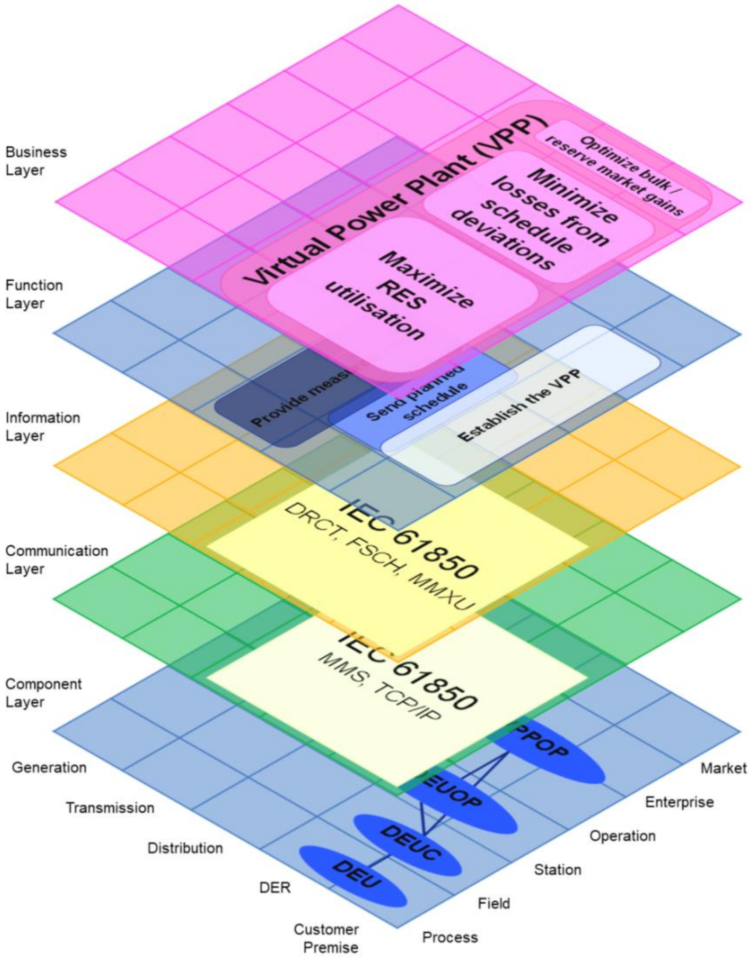

Figure 6: Positioning of tasks, features, data-objects, protocols and components using SGAM to identify their interfaces

Based thereon, we choose the apparently essential functionalities listed and outlined in section 4.2 and specified their requirements in the exemplary Integration Profiles.

3.3 Deriving test cases and required test-tools

Test scenarios and sequences are based on the use-case and the specifications defined in an Integrating Profile. In total, they shall cover all aspects specified, but no more. Especially for security and safety requirements, it is important to design a sufficient number of negative tests. For example, tests are passed if the system does not respond to erroneous and malicious requests. Not all possible attacks can be tested, it is therefore important to choose the most critical and those that cover a broad attack spectrum. All test definitions and reports shall be made available to the testing peers by Gazelle Test Management, in accordance to their role in the test.

For defining and maintaining test cases, test participants (System under tests SUTs), and test steps the test framework Gazelle is used. This tool originates from the healthcare IT domain and is used during the IHE Connectathon to test and document conformance to IHE specifications and interoperability between software systems developed by different software manufacturers. For the IES project a Gazelle instance was used that is hosted by the University of Applied Sciences Technikum Wien. This Gazelle instance was adapted and configured to fit the requirements for testing interoperability and conformance that is demanded by the IES profile definitions.

The bases for the test cases are the IES profile specifications. Therefor the implementation of the test cases was aligned with the profile development process. The single test cases where specified in the Gazelle test management tool. In addition, the roles of the SUTs were configured in Gazelle and these roles where linked to the corresponding test cases. Beside the definitions of the needed test roles (the SUTs), each test cases shorty describes the key aspects (starting conditions, targeted outcome, test method) and the single test steps. The latter is depicted in form of sequence diagrams (as shown in Figure 7) with additional information and test criteria for each message exchange. The single sequence stops correspond to single test steps that need to be conducted and documented (provide link to validation result) within Gazelle.

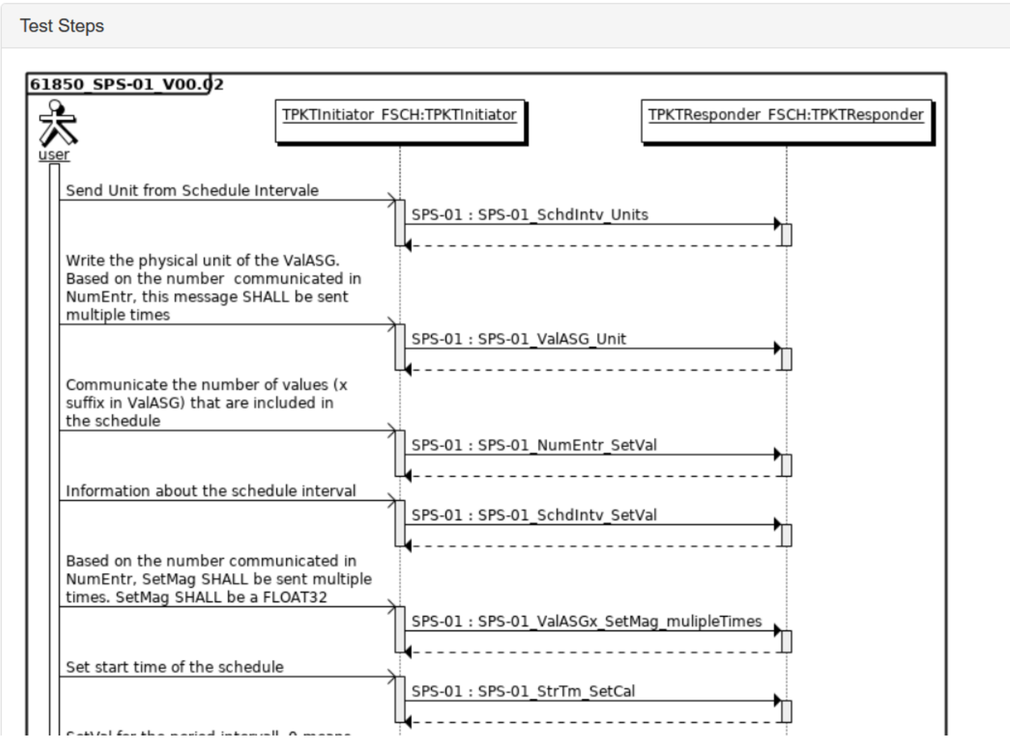

Figure 7: Screenshot of the sequence diagram

In order to enable the validation of the exchanged binary-coded messages a transformation process was specified how to gain an XML-representation out of the binary data. This step was necessary since Gazelle's validation tools for conformance testing of the messages expects XML coded data. This circumstance is based on the requirements for exchanging medical information – and the field of medical IT is the origin of Gazelle. For this transformation a mapping syntax is used (Daffodil). This syntax is based on XML-schema definitions and enriches this information (about the structure and data types of an XML) by specification how binary data needs to be interpreted. In a nutshell, this transformation rule says, for example, that "the next 8 bit should be considered as an integer value with a valid range of 0…255, where the least significant bit is on the very right side, and that this integer value should be interpreted and named in the targeted XML file as 'invokeID'". For each message such a transformation rule needs to be specified and these rules are included within Gazelle. For the validation of a binary-coded message, Gazelle will trigger the transformation automatically and after the XML was generated, it will be handed over to the existing XML-validation engines. For the XML-validations, rules were defined likewise, i.e. for each message to be tested an XML-schema file and an XML-Schematron file were

implemented. The first is used to validate the correct structure of the transformed XML files and the latter is used to validate the business rules, i.e. the Schematron checks if a certain XML-content-element holds a valid data value as specified by the IES profiles.
In order to enable this validation step, Gazelle was configured that once a message validation is started, the binary message will (1) first be transformed into an XML-representation and checked for well-formatted-ness, (2) the structure of the XML is validated using the schema definition, and (3) the contents of the XML elements is validated using the Schematron file. As a result, a user will find the outcome of these single three steps at Gazelle's validation services, as depicted in Figure 8.

Figure 8: Screenshot of the validation result

As mentioned in the begin, negative tests are a mean to investigate and test the stability of systems. However, till the end of the project the focus laid on the specification, implementation and evaluation of communication test cases and not on the test cases to test the robustness of the participating systems. In the end, all interoperability issues shall be considered together to finally exploit the key advantage of profiles over standards and to ensure safe and secure overall functionality, even if one of the components gets compromised or shows malfunctioning.

3.4 Executing peer-to-peer testing

Once the IES Test Definitions are established the communication among systems can be tested. To approve that the test tools perform as they should it is recommended to test the communication among Reference Implementations for which correct operation has been assured before.

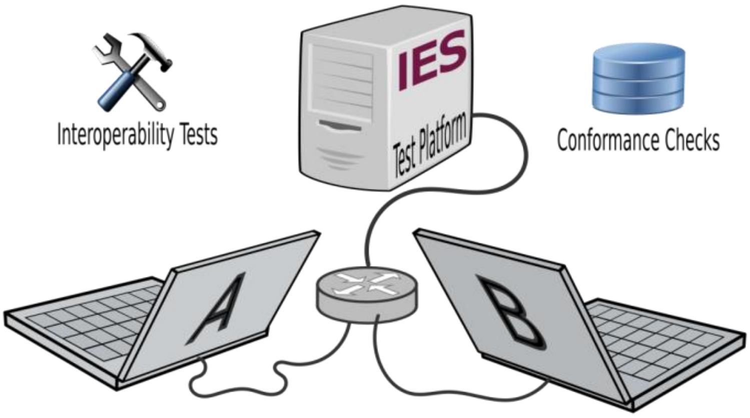

Figure 9: Peer-to-peer black-box testing managed and monitored via test-platform

The peer-to-peer testing shall be performed in accordance with the following recommendations:

- Follow testing schedule: Test scenarios and cases shall be performed with the foreseen peers according to the testing schedule announced by the test management.
  - The schedule assures that if all peers pass all tests, all peers are successful with the tests foreseen in the schedule. A sufficient number of repetitions with different peers is in all cases scheduled.
- Execute test sequences: The sequence of test cases and steps per test case are provided by Gazelle. In general, they may be executed in any order.
  - Note that sometimes the system state needed for test cases and steps may be bound to the previous tests. Either follow the recommended sequence or make sure that the system is ready to correctly execute tests.
- Record test results: In general, test results are to be manually confirmed by the peers participating in test cases. Recorded message flows are commonly automatically assigned and provided for verification tools.
  - External verification: If foreseen by the test case, use an external verification tool. How to perform the validation should be explained in the information on the test case within Gazelle.
- Repeat test cases: If something went wrong, i.e., a test or message verification failed, the peers can repeat test cases (steps) as often as needed to sort out the problem.
  - System state: When repeating test cases and steps be aware that some tests may require specific initial system states to be successfully executable.
  - Arrange new testing time with your peers if testing shall be postponed to a later time because you need to make changes that cannot be performed on-the-fly.
- Ad-hoc testing sessions: Commonly, the planned testing schedule leaves gaps for on demand testing. This is arranged peer-to-peer on the floor, and provides the option to find alternative peers to pass the planned tests.
  - Ad-hoc testing draft implementations in a state most likely not good enough to pass test cases is an option to check the current implementation among friends.

3.5 Timing of tasks and events

Figure 10 shows the timing of the recurring IES process, centred around the Connectathon Energy. The organization of the annual Connectathon Energy determines the timing of all other events during the year. The timeline in Figure 10 refers to the established practice from IHE.

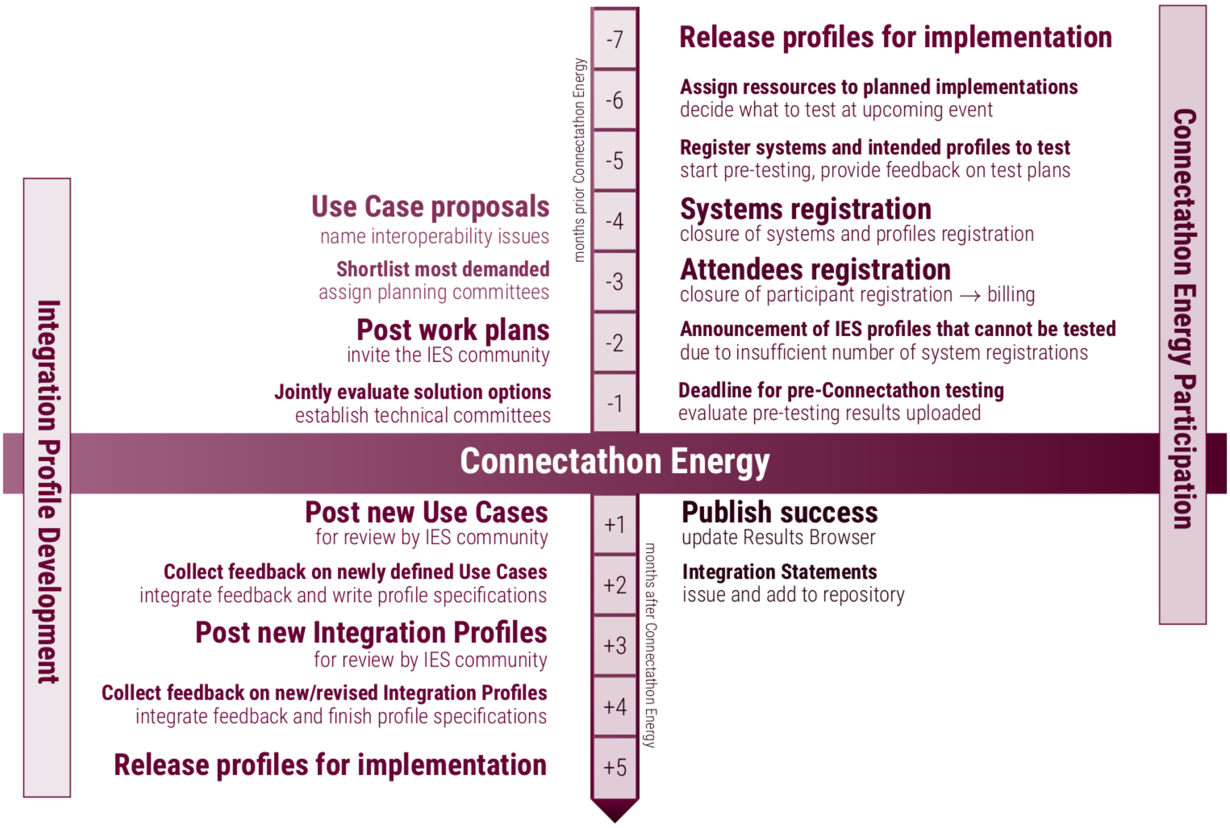

Figure 10: IES timing

At first, the IES community collects and rates interoperability issues. When a core team of experts agreed to contribute towards solving one of these, the intended endeavour (work plan) shall be disclosed to the IES community two months in advance of the upcoming Connectathon Energy. Until the Connectathon Energy, the contributing partners survey ideas for solutions by collecting options, standards and good practice examples. Potential solution concepts for the most interesting profile ideas can be presented at Connectathon Energy side-events to engage and involve more experts.

One month later, the Use Case shall be completely formulated and posted for an open review. At this time the task force working on the specifications can go into specification details and shall post the resultant Integration Profile two months later, again for open review. Another two months later, the profile shall be published and is thereby announced ready for implementation.

If a sufficient number of Connectathon Energy participants register systems for testing the new profile, the testing becomes scheduled. Commonly, trial profiles need to be revised based on the feedback collected. If only minor adjustments are needed, the profile becomes announced mature and is offered for regular testing and subsequent Integration Statements.

Independent whether a profile is new, revised, or stable, it can only be offered for testing at the Connectathon Energy if the required number and type of peers registered systems for testing a particular profile. However, unannounced ad-hoc testing of trial profiles may be possible, if the test plans are available on site (in Gazelle).

At the end of the process the results are published.

3.6 Feedback and revision of specifications

Once an Integration Profile has been written to the likes of all participating experts, it needs to be published and in consequence tested at a Connectathon Energy. Commonly, four independent peers need to bring prototypes or (sub-)systems supporting a new/revised profile to a Connectathon Energy for successful testing. This three-independent-peers constraint is in place to implicitly prevent any proprietary solutions that would compromise the aim of IES for open interoperable systems-of-systems in the energy domain, not hindering any vendor from proposing an idea.

According to the timeline, the specification is a two-step approach. First agreement on use cases shall be achieved before the interoperability requirements are specified. Former shall be performed by application experts, latter by implementation experts. To eliminate minor faults and short-sighted specifications, both, new Use Case descriptions and Integration Profile specifications shall be posted for an open review process. Only registered users from the IES community shall see drafts and are allowed to comment. All comments and recommendations shall be signed; no anonymous access granted.

If a new Integration Profile is first released, it is released for trial implementation only. In that case, the documents shall be conclusive, but need not have the rigour of mature profiles. Also the timing is more flexible if the peers from the technical committee are sufficient to do successful testing among them. Note, Integration Statements may not be issued for Integration Profiles in trial state. Trial testing is performed aiming at testing the profile, not the preliminary implementation.

To achieve maturity, the implementation experts forward the revised Integration Profile to the framework and domain management, which decides if the revised profile has sufficiently considered the feedback that made the revision necessary. Application experts decide if the specifications achieved maturity and either release it for mature testing or call for another trial testing cycle. The release of a revision triggers the test preparation and announcement of the renewed profile in the IES community and beyond.

4 Results and Conclusio

The core idea of the IES methodology is agile cooperation between stakeholders: among users and technicians, scientists and engineers, managers, etc. All shall participate as peers and contribute jointly to the development of demand oriented solutions. Interoperability may be achieved reliably with simple means that work for many.

The IES approach foresees that the implementer from different vendors test their solutions among each other, in a safe environment and in an early development stage. All peers participating in a test case have a common goal: eventually they all want to pass the test. A multi-day plugfest provides the environment and time to track down errors and make corrections prior the decisive test.

4.1 Identified benefits – implicit and explicit

The IES approach to interoperability has several advantages over plain standardisation, proprietary solutions and infinite requirement management:

- Public Integration Profiles yield increased development efficiency and market access:
    - profiles provide clear answers to questions on possible options
    - profile conformity allows small companies to offer sub-systems to integrate
    - vendors need only one interface/solution to make their product interoperable
- Contributing to Integration Profile development yields individual advantages:
    - contributing parties can influence the solution design
    - customers can make sure that profiles match their needs
    - knowing specifications early enables foresighted development
    - trust and respect among peers from working together on solutions
- Testing solution prototypes at a Connectathon Energy yields these benefits:
    - testing with peers helps to identify and solve interpretation problems early
    - test partners help each other to pass the tests eventually (common goal)
    - ambiguous specifications are jointly identified and reported for correction
    - public testing success can convince customers (Results Browser)
    - profile compliance listing for products (Integration Statements – on demand)
- Integration Statements optionally added to the public Products Registry:
    - a shared, neutral and valuable marketing and advertisement option
    - system purchasers can find matching components by comparing listed products

4.2 Specifications developed

The specifications developed in the course of the project IES Austria shall serve as exemplary IES Technical Framework and IES Integration Profiles. Perfectly in line with the evolving process developed, these documents are the first published, intended for trial implementation and testing among external peers at the second Connectathon Energy. Based on the feedback from test-peers and our learnings from the implementation of the reference systems reported next in section 4.3, these exemplary profiles now need to be refined by experts contributing more field and customer needs than available in the course of the project.

As interesting technical challenge that covers a wide range of requirements and novel challenges we have chosen the operation of a distributed Virtual Power Plant where communication over an operator owned communication infrastructure is not economically viable. In this application environment we showcased the usage of IES Integration Profiles for specifying the communication among technical energy sub-systems. A technical core feature of VPPs are the so called schedules, which specify a power curve including changing points over some time interval, commonly a day separated into 15 minutes slots during which no changes occur. These schedules can be used for prognosed production/load schedules (offers), planned schedules (requests), executed schedules (delivery), and alike. In the example we assume remote controlled VPP assets that can at least execute a schedule, i.e., receive a planned schedule and execute it as good as possible.

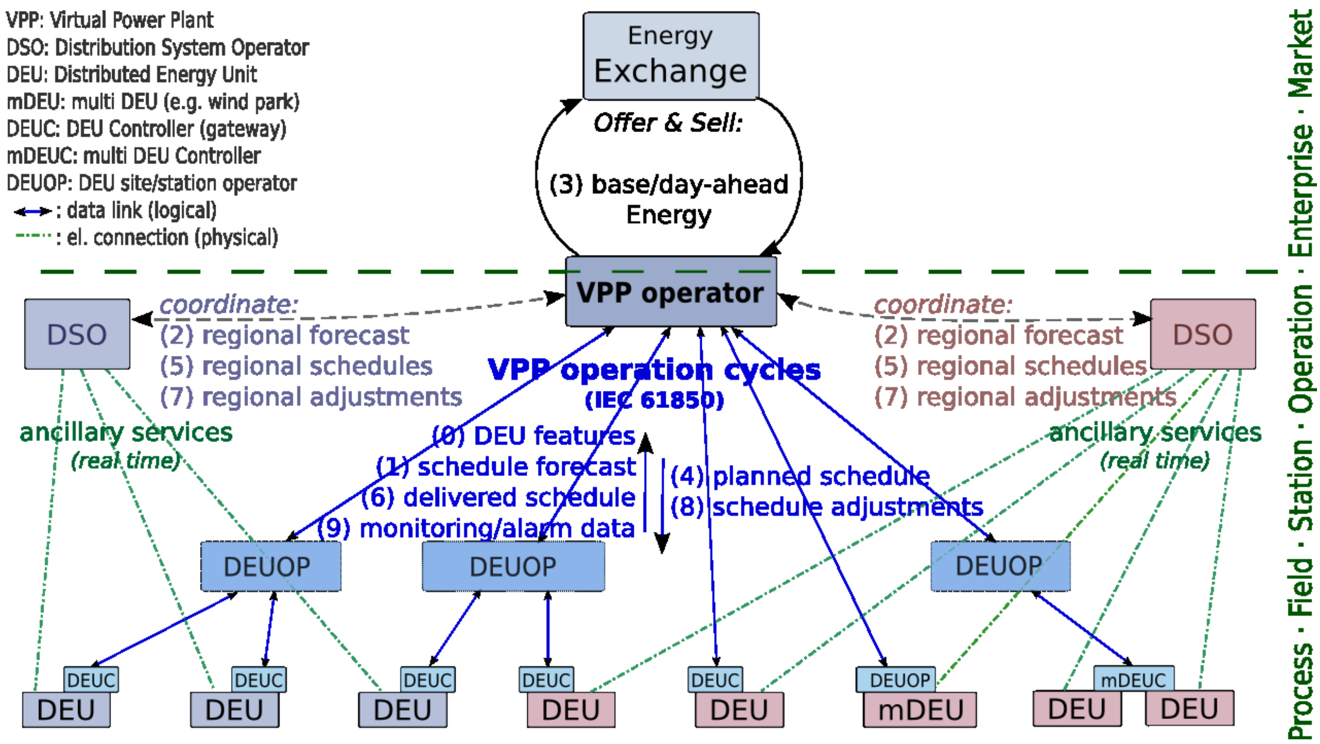

Figure 11: Remote Controlled VPP Operation Cycles

The assumed operation is sketched in Figure 11. This is the most complex VPP operation mode. Simpler VPP variants result from a reduced set of commands, which makes this the best candidate to specify because it includes all other. For more information on VPPs please refer to the Business Case Overview, being the first part of the Technical Framework on VPPs [TF-VPP Vol.1].

We note that Renewable Energy Source (RES) may not be able to always execute a schedule precisely as planned. We therefore choose to also define and implement a VPPOP driven DEU monitoring. Therefore, we assume that every DEUC offers the measured total power parameter, which the VPPOP can read any time using some 'get-measured-value' command.

4.2.1 TF-VPP-61850-SMV: Send Measured Value

This use case covers the on-demand transfer of a measured value, e.g., the data from a sensor. According to the specified Actor-Transaction-Diagram, an IEC 61850 compliant client triggers the transaction by sending a request that identifies the MMXU data element the client wishes to get from the

server. The server responds by transferring the requested MMXU data element to the client. A typical application of this use case is to monitor the total power (totW) currently generated by a power source. This MMXU is therefore specified as required feature for the VPP use case.
It is essential to note here that an IES Integration Profile needs to specify the actual minimal set of MMXU data-objects required for the use case to perform the related business function within the according technical framework. Interoperability is not granted if peers can correctly transfer MMXU values but do not provide the same set of MMXU values required to operate a VPP.

4.2.2 TF-VPP-61850-SPS: Send Planned Schedule

This use case covers the management of the power inserted and/or drained by a VPP asset for a time interval in the future, typically a day ahead. According to the specified Actor-Transaction-Diagram, an IEC 61850 compliant client tells the asset in the field when to produce/consume how much power by transferring the intended (planned) schedule to the IEC 61850 compliant server. According to the IEC 61850 specific state machine, the server is not allowed to execute a schedule prior it has been verified and enabled. Both these actions need to be triggered by the client in exactly this order via sending according operator messages to the server. The first, the validation operator, triggers the validation of the schedule by the server. The server is expected to internally verify if it is capable and allowed to execute the planned schedule. The second, the enable operator, changes the schedule-state to executable and thereby prevents any further modification. To modify an enabled schedule a client first needs to send the disable operator, and after the modification needs to trigger the validate and enable operation again. Aside from that, schedules may have a priority assigned, such that after the end of a schedule, or when the currently executed schedule becomes disabled, the server falls back to executing the next lower prioritised schedule. Presumable, every server needs a base operation mode that is executed if schedule execution is not enabled or no readily enabled schedule is available.

4.2.3 TF-VPP-61850-SAC: Send Asset Configuration

This use case covers the on-demand transfer of an asset's configuration. Because IEC 61850 specifies the exact data-model to cover all the configuration data of an IED (intelligent electrical device) the transaction represents a file transfer. This can be achieved by exchanging an XML file electronically or stored on some medium. Because the file structure is precisely specified by IEC 61850 there is formally no interoperability problem. But interoperability is at risk if the file does not contain data objects and elements required for the specific use case, as we experienced when testing market ready devices.
The on-demand configuration transfer specified in this profile utilises an IEC 61850 compliant data-link (e.g., IP connection), and does not transfer an XML-file. Instead, all the configuration information specifying an IED is transferred one-by-one in any order that allows the client to locally set up the data-structure received. In practice, this use case for on-demand configuration transfer is widely deferred for security concerns and good tradition. The ongoing digitalisation of the energy system will change this eventually, when robust security measures and trustworthy redundancy become integrated.

4.2.4 TF-VPP-60870-TMV: Get Transfer Measured Value

This use case covers the same functionality as specified in TF-VPP-61850-SMV. However, IEC 60870-5-104 does not support the pulling of a measured value. The here specified work-around uses the monitoring feature provided by IEC 60870, where the 60870 Slave is told to regularly send measured values to the 60870 Master. Thus, the transaction starts with enabling the monitoring, setting the monitoring interval, and specifying the values to be enclosed in the message regularly pushed to the Master. To optimally match the operation with its 61850 pendant and in accordance to VHPready specification, the transfer of the totW value was specified to be sent as sole value enclosed in the message. After the reception on the value the monitoring would have needed to be stopped, to perfectly match the IEC61850 functionality, but that has been identified contrary to common practice and a waste of resources in case the measured value becomes regularly requested by the 60870 Master.

4.2.5 TF-VPP-60870-SPS: Send Planned Schedule

This use case covers the same functionality as specified in TF-VPP-61850-SPS. However, IEC 60870-5-104 does not support schedules per se. IEC 60870 is a control standard optimised for time critical messaging not considering features to tell assets anything ahead of time, and a schedule always covers a lengthy interval of time. With 60870 schedules are traditionally executed by the 60870 Master via sending the 60870 Slave the required changes just in time, one after the other. Luckily, VHPready specified an option to transfer schedules using communication based on IEC 60870-5-104. For details please refer to the IES Integration Profile [TF-VPP-60870-SPS] and VHPready [www.vhpready.com].

The decision to specify an alternative means to perform the same functionality revealed that both communication standards, IEC 61860 and IEC 60870-5-104, can be specified in parallel within the same technical framework. But it is necessary to define individual IES Integration Profiles for each standard used. This is essential to assure that successfully tested systems are actually interoperable with all peer systems that passed the same test, at least as far as specified by the respective IES Integration Profile. The only alternative would be forcing all systems to support both standards in full, which in most practical situations would not be required so generally, thus would represent an obvious over-regulation issue.

4.3 Reference Implementations

Example Use Cases have been specified as outlined in section 4.2. The first and most challenging was the distribution of schedules, i.e., step 4 in Figure 11. The less strenuous Use Case was the monitoring case, i.e. step 6 in Figure 11, which we assumed to be driven by the VPPOP doing regular checks on the delivered power (reading TotW currently inserted). Another Use Case has been selected for implementation, step 0, the integration of a DEU asset into the VPP control. Because that is in practice preferably done manually, as far as we were told by stakeholders from the industry, we ranked that one optional. However, IEC 61850 provides the means for plug-and-play integration via automated configuration data exchange. These three constitute the example Use Cases from the TF-VPP to be implemented.

Please see the IES Technical Framework on VPPs to find the detailed IES Integration Profiles specifying what needs to be implemented to achieve reference prototypes. The actual implementation of different Architecture Building Blocks (ABBs) as reference Prototype Solution Building Blocks (SBBs) was distributed among project partners and accompanied by bi-weekly tele conferences, and controlled using the commonly agreed to-do-list shown in Table 1.

TF	ABB	Integration Profile (ABB_spec)	Completion			Notes
			Start	End	%	
Virtual Power Plant (VPP)	DEUC1-EE (FHTW-EE)	SMV, SPS, (SAC)	06/17	03/18	95%	MMXU server provides live TotW measurements of PV@energyBASE
	DEUC2-EE (FHTW-EE)	SMV, SPS, (SAC)	10/17	03/18	85%	FSCH receiver displays received TotW target via multi-colour LED (RaspberryPi)
	DEUC-SA (Sprecon)	SMV, SPS, (SAC)	--	03/18	60%	Adopted market ready product, FSCH is not supported by the OEM software purchased – maximum 67% achievable
	DEUOP-AS (AICO)	SMV, SPS, (SAC)	--	--	0%	No adequate personnel resources available, implementation postponed
	VPPOP-TS (Tiani)	SMV, SPS, (SAC)	12/17	03/18	80%	SMV works, SPS partly, SAC optional

Table 1: Reference Implementation – work plan / to-do-list (example from CAT'18 preparation phase)

The actually developed reference prototype implementations of the SBBs are described next partner by partner, highlighting specific issues and their role in the course of the project IES.

Sprecher Automation GmbH provided an IEC 61850 Server and IEC 60870 Slave mounted into a transport box together with a third party control centre (in the upper shell), as depicted in Figure 12. The SPRECON-E-T3 supports multiple communication standards (IEC 61850, IEC 60870-5-103, IEC 60870-5-104) as common and required in practice to maximise the customer share addressable. This system was not developed in the course of the project IES Austria and is therefore not a reference implementation specifically developed. Still, it was adapted and configured to match the IES Integration Profile specifications. For the other prototypes developed solely based on the specified IES Integration profiles it served as test peer representing an established market ready product.

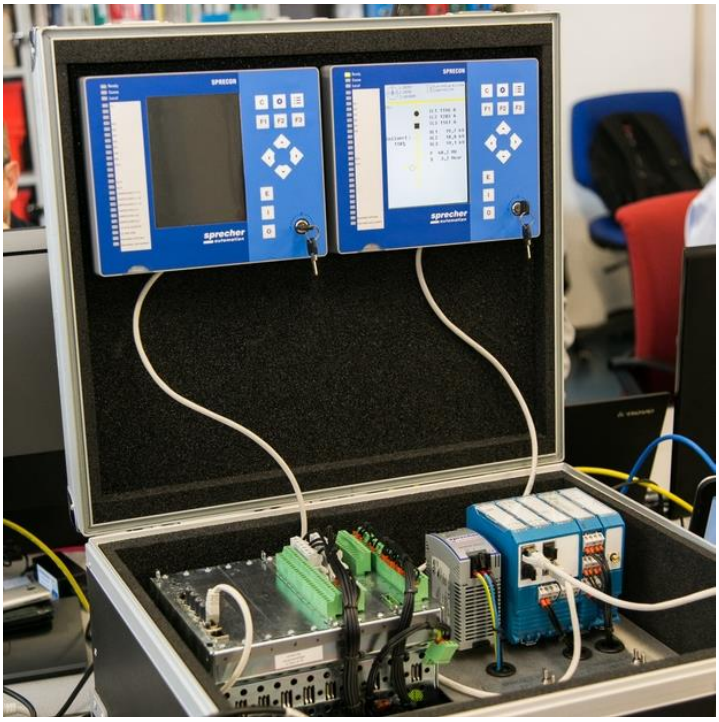

Figure 12: Sprecher Automation GmbH prototype set-up in a transport box featuring the SPRECON-E-T3 DEUC.

The third party communication stack implemented in the SPRECON-E-T3 could not be configured to support schedules, i.e. the logical node FSCH, because that was only recently added to the IEC 61850 standard. Therefore, this market ready system could only support the following IES Integration Profiles:

- TF-VPP-61850-SMV: Send Measured Value, and
- TF-VPP-60870-TMV: Transfer Measured Value.

FH Technikum Wien - FHTW implemented several DEUC prototypes, which were partially provided as remote test-peers with publicly accessible IP-address to perform Pre-Connectathon tests. This feature compensated the lack of true simulators, which would have been integrated in the Gazelle test-platform. In total these reference implementations on Linux based Raspberry-Pi micro-computers covered the following Server/Slave/Provider SBBs of the transactions specified in the TF-VPP:

- TF-VPP-61850-SMV: Send Measured Values,
- TF-VPP-61850-SPS: Send Planned Schedule,
- TF-VPP-61850-SAC: Send Asset Configuration,
- TF-VPP-60870-TMV: Transfer Measured Value, and
- TF-VPP-60870-SPS: Send Planned Schedule according to VHPready specification.

Technikum Wien also implemented VPPOP prototypes that run on Microsoft Windows Laptops. Figure 13 shows the two GUIs required to depict a FSCH schedule (left) and a repeatedly polled MMXU value (totW). Earlier VPPOP clients based on the versatile Felix GUI (provided for OpenMUC in general) were intensely used to enable the development of the Wireshark extension to identify and display MMS messages spoofed while travelling from the DEUC server to the VPPOP client, and to be independent of the progress of other project partners developing their prototype using the FHTW DEUCs already available. All the FHTW VPPOP prototypes supported the same, i.e., entire, set of TF-VPP Integration Profiles specified in the course of the project IES Austria.

Figure 13: FHTW VPPOP reference prototype GUIs

Tiani Spirit GmbH implemented each a VPPOP prototype which in total also implemented and supported the entire set of SBBs according to the IES Integration Profiles specified in the course of the project IES Austria:

- TF-VPP-61850-SMV: Send Measured Values,
- TF-VPP-61850-SPS: Send Planned Schedule,
- TF-VPP-61850-SAC: Send Asset Configuration,
- TF-VPP-60870-TMV: Transfer Measured Value, and
- TF-VPP-60870-SPS: Send Planned Schedule according to VHPready specification.

Notably, the implementation of these reference prototypes was entirely based on the available IES Integration Profile specifications.
Tiani Spirit is an expert on IHE profile implementation, and so their feedback supported the IES team very much on achieving complete profiles and the essential test procedures required for compliant implementation and testing. The resultant Tiani Spirit VPPOP GUI shown in Figure 14 displays a received measured value (totW) and the GUI in Figure 15 provides the features required to configure and manage a power schedule (FSCH).

As common with engineering of novel systems, many prototypes were finished last minute for the testing at the Connectathon Energy event. Last features and bugs were mended at the event, mostly on the initial set-up day utilising the feedback and support from the peers in the room. This may seem unprofessional, but is a perfect example of agile development and highlights the positive impact that the Connectathon Energy event has on the implementation progress.

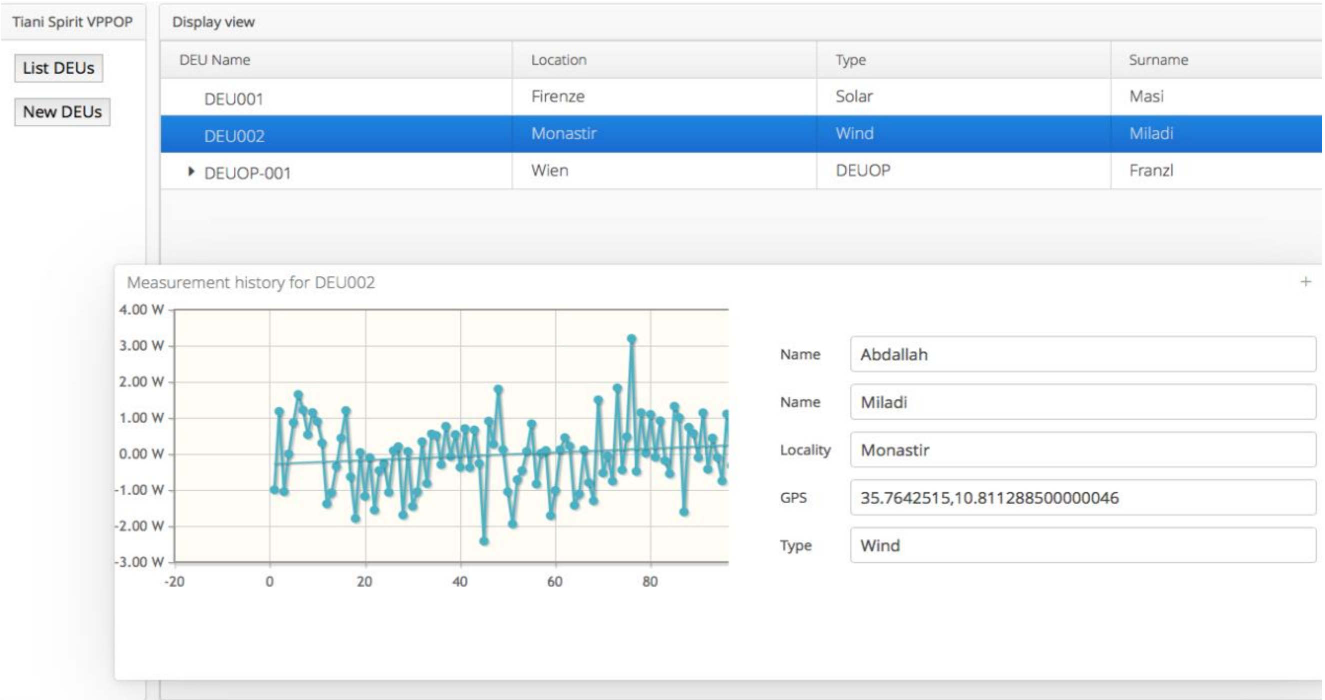

Figure 14: Tiani Spirit prototype GUI to present a monitored measurement value (MMXU)

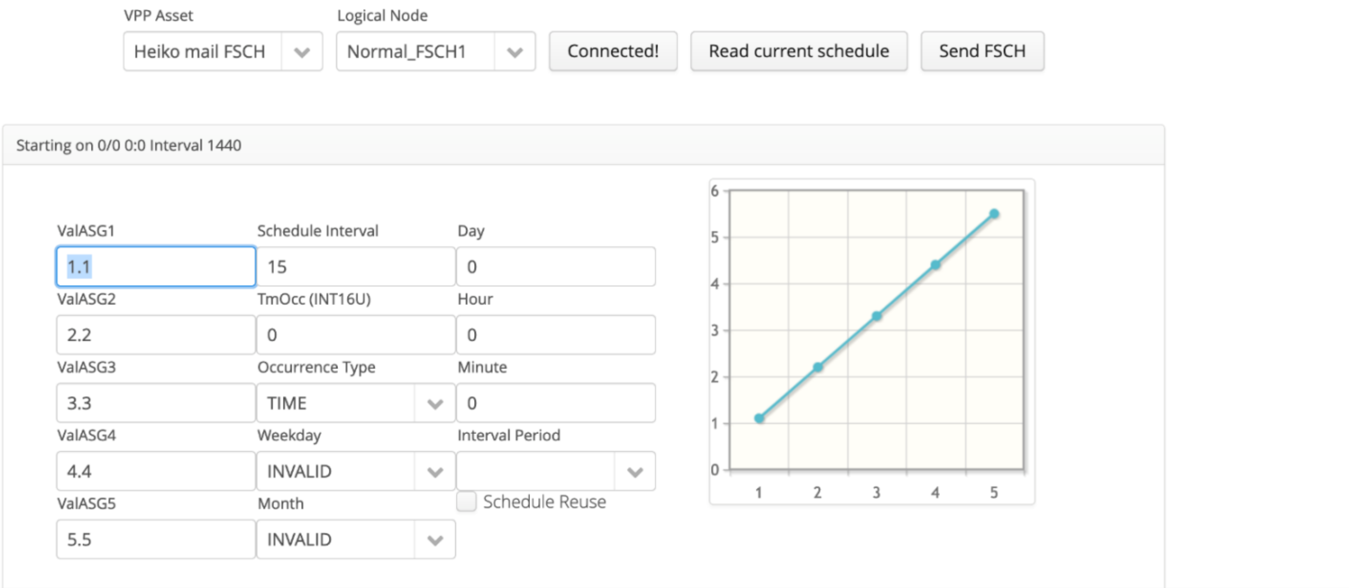

Figure 15: Tiani Spirit FSCH prototype GUI to specify/modify and manage a power schedule (FSCH)

4.4 Peer-to-peer testing

Interoperability testing between independently developed systems is necessary to overcome specification interpretation issues. This kind of software test is most effective when a system from vendor A is tested directly against a system from an independent vendor B, as shown in Figure 16. To perform this, the IES initiative is to host the annual Connectathon Energy test events, which have proven in the medicine IT sector to be an utile approach to ensure the interoperability of systems beyond company boundaries.

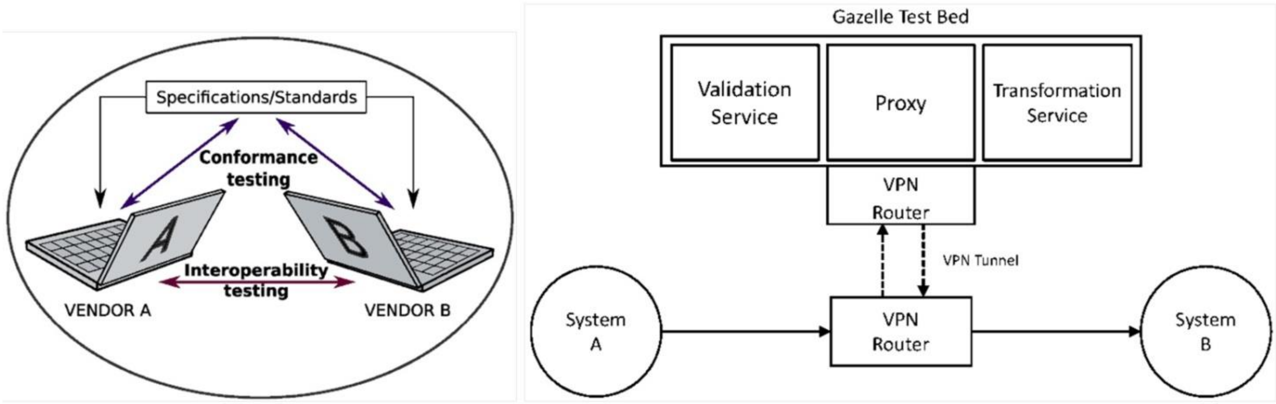

Figure 16: Peer-to-peer interoperability testing: independent implementations get connected and their cooperation is evaluated, including verification of exchanged messages (formats and contents)

Gazelle's validation uses primary XML validation methodologies, i.e., the validation services check the XML payload: if it is well-formed, whether the payload adheres to specifications specified in XML schema files, and if additional formatting rules are fulfilled, using XML-Schematron validation. Since the example VPP profiles specify the use of IEC 61850 compliant data objects exchanged using MMS to generate and transport data, here the payload is binary encoded. To validate the exchanged messages using Gazelle's validation services, the binary encoded data need to be transferred into an XML representation. Therefore, the Data Format Description Language (DFDL) [35] and a Daffodil-Transformation [36] are used for the example. DFDL is an XML schema like a definition language extending classics schema file with additional information on how single bytes, and even bits, shall be interpreted in a form of annotations (an example is shown in Figure 17). Daffodil-Transformation is an open source tool that processes the binary data and generates XML files based on the specifications stated in a DFDL file. Gazelle already includes capabilities for this transformation step and, therefore, only the DFDL files need to be defined to create XML files from the logged messages containing binary encoded information. The resulting XML files can be further validated with the common Gazelle tools. In this example the binary pattern for the message's *invokeId* will be transformed into a XML-element. The shown XML-attributes from the "dfdl"-namespace define, beside other things, the length and the representation of a number of bits that will be transformed into XML content.

```
<xs:complexType name="InvokeId">
  <xs:sequence>
      <xs:element name="type" type="xs:byte" dfdl:alignment="implicit" dfdl:hUnits="bytes"/>
      <xs:element name="length" type="xs:unsignedByte" dfdl:alignment="implicit" dfdl:hUnits="bytes"/>
      <xs:element name="value" type="xs:byte" dfdl:lengthKind="explicit" dfdl:alignment="implicit"
          dfdl:length="{(xs:unsignedInt(../length))}" />
  </xs:sequence>
</xs:complexType>
```

Figure 17: Example of a Daffodil transformation specification.

An essential feature of the test-bed Gazelle is its capability to record messages that are exchanged between the systems under test (SUT). To use this feature called Proxy, the SUT needs to be configured to communicate with test partners indirectly via the Proxy, as shown in Figure 18.

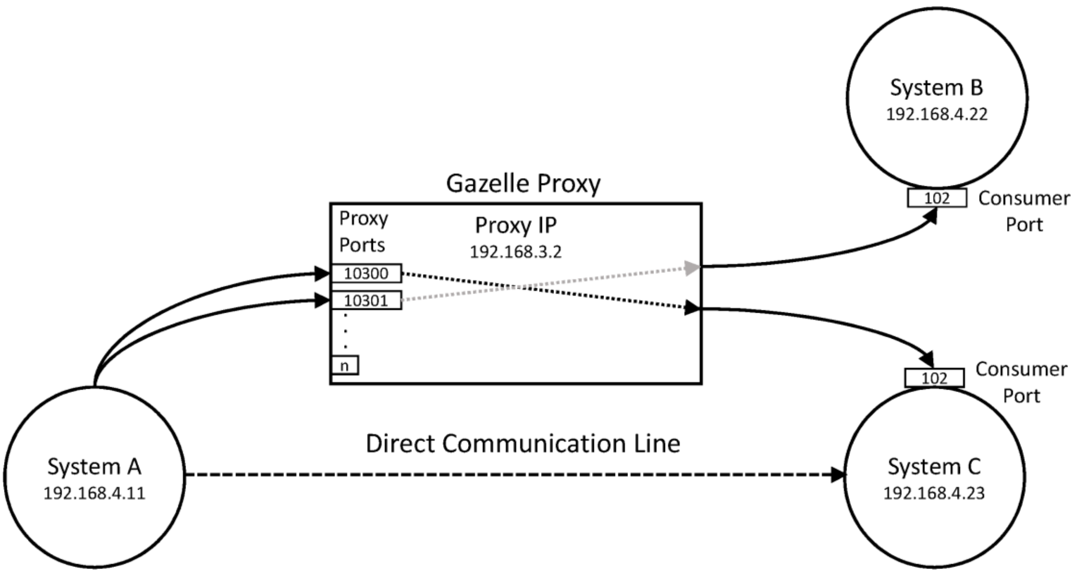

Figure 18: Derailing communication via Gazelle proxy service

The proxy needs to be configured to assign all the corresponding endpoints to test instances and SUTs, such that messages received from a SUT are logged and in parallel forwarded to the correct receiving SUT. Logged messages can be forwarded to Gazelle's validation tools (or external validation options). Only during this last step, the Daffodil-Transformation stated above is applied to gain an XML representation of the message content for the actual validation. Derailing communication via Gazelle proxy service: port numbers are assigned to the systems prior testing, transferred messages are captured to undergo validation.

4.5 Testing results and participants feedback

Figure 19 shows the result of the second Connectathon Energy which took place in the end of January 2019 in Vienna in the Energy Lab of the University of Applied Sciences Technikum Wien. The figure represents the companies (first column) that took part at this peer-to-peer test event and the outcomes of the SUT, based on the tested IES profiles. Each x-mark represents a successful test, where the SUT was tested successfully three times with a different test-setup, i.e. the test partners must be different for each test case. This repetition of test cases should demonstrate that a certain software module (or product) is interoperable with the other available software products. When a single test case could not be repeated three times, due to the fact that no additional test parties where available, this fact was considered by the test management and finally those tests were considered as successfully as well.

The feedback of the test participants showed that such a test event is a perfect opportunity to get in contact with other implementers in order to share knowledge and to find solutions. This cooperation between implementers is of interest for the software producing companies and also improves the quality of the specifications since feedback is provided. The feedback showed that, although the provided IES profile specification are understandable and provide a sufficient level of technical details, some formulation needs to be adapted to strengthen mandatory subjects. It was discussed that, especially used *optional* conformance criteria, lack clarity whether an data point needs to implemented and supported optionally or that the use is optional but the implementation needs to consider optional elements.

Results from the 2nd IES Connectathon Energy - 2019 Vienna

	Meta Actor DEUC					Meta Actor VPPOP				
Profile	TMV	SMV	SPS		SAC	TMV	SMV	SPS		SAC
Standard (Option)	104	61850	104	61850	61850	104	61850	104	61850	61850
CyberGrid						X				
Hochschule Ulm		X								
Hochschule Ulm - Remote System		X								
Sprecher Automation GmbH		X								
SSV Software Systems GmbH	X		X							
Tiani Spirit	X					X	X	X	X	X
TU Wien							X			
FH Technikum Wien	X	X	X	X	X	X	X	X		
WAGO			X							

Profiles:
TMV: Transfer Measured Value TotW
SMV: Send Measured Values
SPS: Send Planned Schedule
SAC: Send Asset Configurations

Standards:
104: IEC 60870-5-104
61850 : IEC 61850

Figure 19: Connectathon Energy results 2019, Vienna

Concerning the usability of Gazelle it was noted that the manual validation of messages needs to be improved. This issue arose due to the primary intended use of Gazelle in the medical context, where transferred message are text-based and not, like in the energy domain, based on binary data. The provided solution, in terms of the Daffodil transformation into a text-based (XML) representation enables the validation of the messages, but the proxy, as source of the messages to be validated, displays the binary recorded messages only in an ASCII representation. This makes it difficult, sometimes impossible, to find the correct message for validation on the proxy, and additional time and effort is needed to identify the recorded messages. This issue, as the time being, can only be address by additional implementation effort of IHE services. When a critical mass is identified by IHE services, they reported that this functionality might be implemented. Nonetheless, a Connectathon Energy and the use of the Gazelle platform is an appropriate way to test, to document and to promote interoperability testing in upcoming fields within the energy domain where interoperability of systems is a core requirement to fulfill recent, and especially up-to-come, use cases.

5 Outlook and Recommendations

The team was very active in disseminating the IES idea because our own problems with understanding the genius showed clearly that it is not that easily understood. Especially, in an environment where traditional certification dominates the market access, a scheme that supports the development in an early prototype state is very novel and the value difficult to assess because it is a little revolutionary, requiring a shift in the mindset of stakeholders.
Therefore the team used the message about the worldwide reference of the methodology ant the synergies of the combination of proofed concepts, as illustrated in

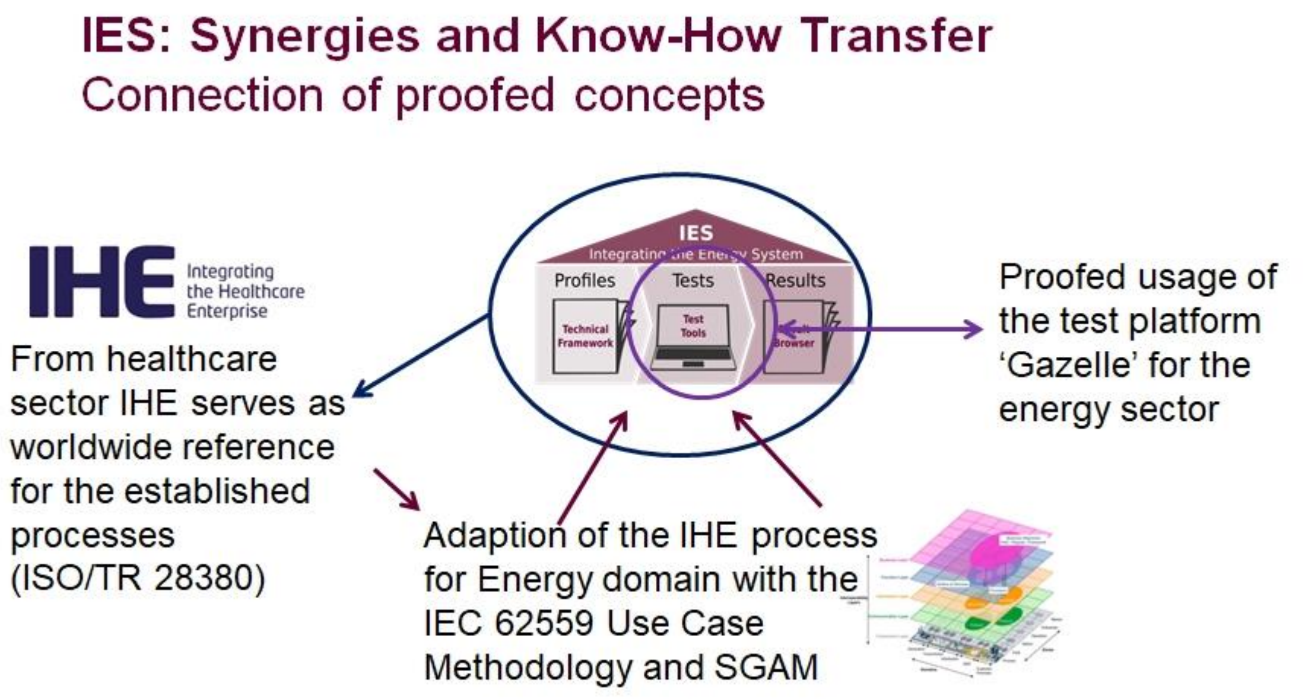

Figure 20: Illustration of the synergies and Know How transfer used for the IES Process

5.1 IES Europe and beyond (long term)

At the IHE Connectathon Europe 2018 in Den Hague 70 vendors from the healthcare sector tested more than 3.000 transactions among 84 systems in reference to their interoperability. It would be great if IES can achieve similar numbers in not too long time. However, to perform tests we first need to specify IES Technical Frameworks for the different business cases in the energy sector where interaction among independent systems and stakeholders occurs. These Frameworks than need to be filled with IES Integration Profiles, because only these specifications can be transferred into test cases that Connectathon Energy participants can execute to assess the interoperability and conformance to the IES Integration Profiles of their prototype implementations and later on their products on the market.

The greater vision: IES Europe

It is important that these harmonization processes take place on an international level to ease implementation and facilitate the required communication of decentralised energy components as demanded by the transition of the energy system.

The Vision IES Europe is already anchored in the SET-Plan Action 4 Implementation Plan 2018, Activity A4-IA0-5 PROCESS CHAIN FOR INTEROPERABILITY OF ICT SYSTEMS. (Download here)

To further expand the IES Idea, the following points need to be addressed next:

- Setup of a transnational organisational structure to coordinate the operative work of the IES process
- Deployment of an annually recurring process that brings together vendors and users of ICT technologies to ensure interoperability in the energy sector
- Start the development of first integration profiles which are relevant on an European level
- Hosting of annual European interoperability test events “Connectathon Energy”, where vendors can test their software on interoperability and conformity with the relevant integration profiles

5.2 IES Dissemination Success (short term)

The project team started in an early stage of the project to disseminate the idea and to integrate the IES approach as tool in roadmaps, funding programs, and directly in R&D proposals.

The project team's good contacts with the IHE health sector experts and the organizers of the IHE Connectathons enabled the first 'Connectathon Energy' to be held in April 2018 in The Hague during the annual European IHE Connectathon. This achieved a first international visibility of the IES activities.

During a presentation at the ETIP-SNET Working Group 4 in Vienna in November 2018, valuable contacts could be made with other platforms such as AITOI and ENTSO-E, which promise further follow-up activities beyond the end of the project.

At the German SINTEG conference in June 2018 a presentation of the IES methodology could be placed. The presentation was very well received and follow-up with the BMWi after the project is planned.

At the same time as final event of the project, the 2nd Connectathon Energy was held in Vienna in January 2019. International companies already participated in the tests, which were not project partners. The test event was a great success and the participating companies were able to confirm the importance of the test events.

The vision of an IES Europe could be placed in the European SET Plan Implementation Plan 'Increase the resilience and security of the energy system'. Therefore, in the course of the 2nd Connectathon Energy an international Set-Plan “Symposium on Interoperability” was held. This was an information session on IES and other activities related to the interoperability of Smart Grid components and, in general, current developments in the modernization and digitization of electricity grids. For this purpose, international experts were invited, key notes held and a panel discussion moderated. Finally, the kick-off of the IES-Europe initiative took place.

The integration of the IES methodology into new international R & D projects has succeeded in ERA-Net SES RegSys Call1 projects and will be pursued further.

In H2020, R&D projects could still be submitted, which could implement the IES methodology and lead to new technical framework conditions and integration profiles.

However, the true success of the project would be the adoption of the IES process by the industry, which could be measured by the number and market relevance of the systems tested at the Connectathon Energy plugfest, the definition of new IES Technical Frameworks, and also the number of IES Integration Profiles annually tested at the Connectathon Energy events. This KPI is today beyond reach.

5.3 IES Recommendations

Aside from the mandatory extension of the IES initiative to a broader, at least European, scale (IES Europe), the engineers and researchers developing the solutions shall be addressed and invited to contribute their experience and findings in specifying good concise recommendations in the form of IES Integration Profiles. Vendors shall be convinced that with interoperable products their practical value is increased and in the long term more profit achievable. In that respect it is also necessary to pronounce that IES specifications only refer to the information that leaves/enters their black-box; how the requirements are fulfilled, i.e., the intellectual property of the implementation itself inside the box, shall not be disclosed.

To all engineers in the field and in R&D projects, you already need to document what you invent if you want it applied elsewhere outside your bubble. Consider to make those parts where functionality requires the cooperation of some other system more public by specifying these requirements as IES profile. If you are already a vibrant team of diverse experts you have the best chances to succeed.
To the vendors that today still trust in customer lock-in and ignore open cooperation, participate or wait until regulation makes you participate. To the customers, take the responsibility in your hands and build the system-of-systems you need and want to have using interoperable components. Cooperate in the specification writing to make sure that your practical needs are considered in the recommendations specified in IES Integration Profiles. Only together we can get what we really want and need to realise the modernisation of the energy system required to enable 100% renewable sources.

6 Bibliography

The IES project team used many sources to learn about the IHE method, new approaches and their requirements in the energy system, and use case based specification management in general. Every partner contributed his or her specific expertise. The following list of referenced literature only covers the literature we refer to in most of our publications. Far more is available and could be recommended here.

6.1 Referenced Literature

- Uslar, M.; Specht, M.; Daenekas, C.; Trefke, J.; Rohjans, S.; Gonzalez, J.M.; Rosinger, C.; Bleiker, R. Standardization in Smart Grids; Springer: Berlin/Heidelberg, Germany, 2013.
- Ramchurn, S.D.; Vytelingum, P.; Rogers, A.; Jennings, N.R. Putting the ‘Smarts’ into the Smart Grid: A Grand Challenge for Artificial Intelligence. ACM 2012, 55, 86–97. [CrossRef]
- Kroposki, B.; Johnson, B.; Zhang, Y.; Gevorgian, V.; Denholm, P.; Hodge, B.M.; Hannegan, B. Achieving a 100% Renewable Grid: Operating Electric Power Systems with Extremely High Levels of Variable Renewable Energy. IEEE Power Energy Mag. 2017, 15, 61–73. [CrossRef]
- Steg, L.; Shwom, R.; Dietz, T. What Drives Energy Consumers? Engaging People in a Sustainable Energy Transition. IEEE Power Energy Mag. 2018, 16, 20–28. [CrossRef]
- IEEE Standards Board. IEEE Standard Glossary of Software Engineering Terminology; Technical Report; Standards Coordinating Committee of the Computer Society of the IEEE: Los Alamitos, CA, USA, 1990.
- Merriam-Webster Incorporated. Definition of Interoperability. https://www.merriam-webster.com/dictionary/interoperability .
- IES Team. IES—Integrating the Energy System. www.iesaustria.at
- European Commission. Digital Single Market. Available online: https://ec.europa.eu/commission/priorities/digital-single-market_en .
- IEC 62559-2:2015. Use Case Methodology—Part 2: Definition of the Templates for Use Cases, Actor List and Requirements List; IEC TC8 Standard; IEC: Geneva, Switzerland, 2015.
- M. Gottschalk, M. Uslar, and C. Delfs, The Use Case and Smart Grid Architecture Model Approach: The IEC 62559-2 Use Case Template and the SGAM applied in various domains. SpringerBriefs in Energy, Springer, 2017. http://dx.doi.org/10.1007/978-3-319-49229-2 .
- CEN-CENELEC-ETSI Smart Grid Coordination Group. First Set of Standards; Technical Report;
- CEN-CENELEC-ETSI Smart Grid Coordination Group: Brussels, Belgium, 2012.
- Englert, H.; Uslar, M. Europäisches Architekturmodell für Smart Grids-Methodik und Anwendung der Ergebnisse der Arbeitsgruppe Referenzarchitektur des EU Normungsmandats M/490. In Proceedings of the Tagungsband VDE-Kongress, Stuttgart, Deutschland, 5–6 November 2012; Technical Report.
- SG-CG/RA. Smart Grid Reference Architecture; Technical Report; CEN-CENELEC-ETSI Smart Grid Coordination Group: Brussels, Belgium, 2012.
- The Open Group. TOGAF Version 9—The Open Group Architecture Framework (TOGAF), 9th ed.; The Open Group: San Francisco, CA, USA, 2009.
- Urbauer, P.; Sauermann, S.; Frohner, M.; Forjan, M.; Pohn, B.; Mense, A. Applicability of IHE/Continua components for PHR systems: Learning from experiences. Comput. Biol. Med. 2015, 59, 186–193.

- Noumeir, R. Integrating the healthcare enterprise process. Int. J. Healthc. Technol. Manag. 2008, 9, 167.
- IHE International, “Gazelle - eHealth test framework for interoperability.” https://gazelle.ihe.net/.
- Smart Grid Mandate. Methodologies to Facilitate Smart Grid System Interoperability through Standardization, System Design and Testing. Available online: https://www.google.com.tw/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=2ahUKEwie3vD7__3eAhXCEnAKHRGNCyoQFjAAegQIAxAB&url=https%3A%2F%2Fwww.researchgate.net%2Fpublication%2F322752190_Smart_Grid_Interoperability_Testing_Methodology_A_Unified_Approach_Towards_a_European_Framework_for_Developing_Interoperability_Testing_Specifications&usg=AOvVaw1MICQd3PD5VnSUZxHksKpy (accessed on 30 October 2018).
- Wolfgang, B.; Heiko, E. Basic Application Profiles for IEC 61850. 2013. Available online: https://docstore.entsoe.eu/Documents/RDCdocuments/BAP_concept_TC57WG10.pdf (accessed on 30 October 2018).
- Masera, Marcelo. The Role of Interoperability in the Digital Energy Vision. 2017. Available online: https://www.etip-snet.eu/wp-content/uploads/2017/06/2.-The-role-of-Interoperability-Marcelo-Masera.pdf (accessed on 30 October 2018).
- Forsberg, K.; Mooz, H.; Cotterman, H. Visualizing Project Management—Models and Frameworks for Mastering Complex Systems, 3rd ed.; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2005; pp. 108–116, 242–248, 341–360.
- Industry Alliance VHPready e.V. VHPready. https://www.vhpready.com/
- IEC 60870-5-104—Telecontrol Equipment and Systems—Part5-104: Transmission Protocols—Network Access for IEC 60870-5-101 Using Standard Transport Profiles. Available online: https://www.google.com.tw/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=2ahUKEwj81rL6_v3eAhUJfnAKHSfIBgYQFjABegQIBhAB&url=https%3A%2F%2Fwebstore.iec.ch%2Fpublication%2F3746&usg=AOvVaw2LLUacS4XK_It0q8rsKXnt (accessed on 30 October 2018).
- IEC 61850-7-420:2009—Communication Networks and Systems for Power Utility Automation—Part 7-420: Basic Communication Structure—Distributed eNergy Resources Logical Nodes. Available online: https://www.google.com.tw/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=2ahUKEwiZo4jE_v3eAhXYQd4KHX35Ab4QFjAAegQIBRAB&url=https%3A%2F%2Fwebstore.iec.ch%2Fpublication%2F6019&usg=AOvVaw2BLqlPG9vYoFh7SuXlbmGj (accessed on 30 October 2018).
- Eisl, Hubert. ELGA Erfolgreich Gestartet. 2016. Available online: http://ihe-austria.at/elga-erfolgreich-gestartet/ (accessed on 30 October 2018).
- IHE Europe. Whitepaper on Connectathon. The IHE Connectathon. What Is It? How Is It Done? Version 004. Available online: https://www.google.com.tw/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&cad=rja&uact=8&ved=2ahUKEwjU-t_q_f3eAhWI62EKHT46BAsQFjACegQICBAC&url=https%3A%2F%2Fwww.ihe-europe.net%2Fsites%2Fdefault%2Ffiles%2FWhitePaper_Connectathon_2016.pdf&usg=AOvVaw3vNVAnPQmRWdfV5aSS8e5h (accessed on 30 October 2018).
- “ISO DTR 28380-1: Health Informatics - IHE Global Standards Adoption - Part 1: Process.” https://www.iso.org/obp/ui/#iso:std:63383:en .
- M. Masi, T. Pavleska, and H. Aranha, “Automating smart grid solution architecture design,” in 2018 IEEE International Conference on Communications, Control, and Computing Technologies for Smart Grids (SmartGridComm), pp. 1–6, Oct 2018. http://dx.doi.org/10.1109/SmartGridComm.2018.8587457 .
- The Open Group. Introduction to Building Blocks. http://www.opengroup.org/public/arch/p4/bbs/bbs_intro.htm

- IHE Europe. Gazelle | IHE Europe. 2018. https://www.ihe-europe.net/testing-IHE/gazelle
- Open Grid Forum. Data Format Description Language (DFDL) v1.0 Specification. https://www.ogf.org/documents/GFD.207.pdf
- The Apache Software Foundation. Apache Daffodil (Incubating) | Getting Started. https://daffodil.apache.org/getting-started/
- Hevner, A.; Chatterjee, S. Design Research in Information Systems; Integrated Series in Information Systems 22; Springer: Berlin/Heidelberg, Germany, 2010; pp. 9–21.
- Temporary Working Group 4—Increase the Resilience and Security of The Energy System. Strategic Energy Technology Plan—Implementation Plan—Final Version—15.01.2018; Technical Report; European Commission—SETIS: Brussels, Belgium, 2018.
- C. Carr, "IHE international, incorporated principles of governance." https://www.ihe.net/wp-content/uploads/2018/07/IHE-International-Principles-of-Governance.pdf .
- "IHE profile design principles and conventions." https://wiki.ihe.net/index.php/IHE_Profile_Design_Principles_and_Conventions .

6.2 IES Publications

- G. Franzl, M. Gottschalk, M. Frohner, R. Pasteka, „IES Cookbook", Jan 2019, https://www.smartgrids.at/files/smartgrids/Dateien/Dokumente/Dokumente/IES_cookbook.pdf
- M. Gottschalk, G. Franzl, M. Frohner, R. Pasteka, M. Uslar, "From integration profiles to interoperability testing for smart energy systems at connectathon energy," Energies, vol. 11, p. 3375, Dec 2018. https://dx.doi.org/10.3390/en11123375
- M. Gottschalk, G. Franzl, M. Frohner, R. Pasteka, M. Uslar, „Structured workflow achieving interoperable smart energy systems", Energy Inform. Okt 2018, https://doi.org/10.1186/s42162-018-0039-x
- G. Franzl, M. Frohner, M. Gottschalk, V. Reif, G. Koch, A. Berger, „Interoperabilität im Datenaustausch in der Energiewirtschaft—Vom Use Case zum Test der Integrationsprofile", in Proceedings of the Symposium Energieinnovation 2018, Graz, Austria, 14–16 Feb 2018.
- European Strategic Energy Technology Plan Implementation Plan: Increase the resilience and security of the energy system, Crosscutting Activity A4-IA0-5 Process chain for interoperability of ICT systems, https://setis.ec.europa.eu/system/files/set_plan_esystem_implementation_plan.pdf, 15 Jan 2018
- ETIP SNET Webinar on Integrating the Energy System, https://www.etip-snet.eu/events/etipsnet-webinars/national-webinars/, https://www.youtube.com/watch?v=30betao4ZDg, Jan 2018
- V. Reif, A. Berger, M. Frohner, S. Sauermann, „IES Prozess - Entwicklung von Integrationsprofilen und Durchführung von Interoperabilitätstests basierend auf IHE-Methodik", https://www.klimafonds.gv.at/assets/Uploads/Science-Brunch-Broschuere-Smart-Grids-2018.pdf
- M. Frohner, M. Gottschalk, G. Franzl, R. Pasteka, M. Uslar, S. Sauermann, "Smart grid interoperability profiles development," in 2017 IEEE International Conference on Smart Grid Communications (SmartGrid-Comm), pp. 189–194, Oct 2017, https://dx.doi.org/10.1109/SmartGridComm.2017.8340674

7 Attachments/ Homepage

All documents created during the project are available for download on the IES project homepage www.iesaustria.at.
Since the activities for the IES initiative is ongoing even after the end of the project, the structure of the homepage and the corresponding links might change. Therefore no links to specific documents are published in this document.

8 Contact

Project Lead:
Dr. Angela Berger
Technologieplattform Smart Grids Austria
Mariahilfer Straße 37-39, 1060 Wien
angela.berger@smartgrids.at, www.smartgrids.at

Webpage Project: www.iesaustria.at

Further Project Team:
Valerie Reif, Marcel Schweitzer / TP Smart Grids Austria
Georg Koch, Massimiliano Masi, Abdallah Miladi / Tiani Spirit GmbH
Stefan Sauermann, Matthias Frohner, Richard Pasteka / FH Technikum Wien, IHE
Karl Knöbl, Simon Dimitriadis / FH Technikum Wien, EE
Marion Gottschalk, Mathias Uslar / OFFIS e.V.
Gerald Franzl / AICO EDV-Beratung GmbH
Stephan Hutterer, Markus Schicklgruber / Sprecher Automation GmbH