Interoperability-by-design framework

Deliverable D1.4

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Deliverable D1.4
Interoperability-by-design framework

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O	Software, technical diagram, etc.	

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More information on the project can be found at https://www.maesha.eu

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EXECUTIVE SUMMARY

This document presents the "interoperability-by-design" framework defined for the MAESHA solution. To be interoperable, the solution should indeed be designed with certain interoperability and reusability requirements in mind.

To define this framework, we first conducted an analysis of the system:

- We identified the "interoperability-critical" interfaces of the system architecture to identify the interfaces for the interoperability design and testing. From this analysis, we decided to focus mainly on System Operator (SO) level communication interfaces and to let the choice to partners to select the most relevant standard for asset level communication
- From the information exchanged section of the use cases' description, we derived some data exchange requirements to identify the most relevant standards for our solution

After identification of a dozen of standards and candidates for each interface, we conducted a literature review to compare them and assess their relevance with regards to the use cases' requirements:

- On the System Operator level, few standards meet most of the requirements: the Electricity Balancing Process, OpenADR, CIM Market, USEF/UFTP. To select a unique standard, we then looked at different criteria such as its maturity, its scalability and its acceptance in Europe. Our final choice for the Electricity Balancing Process was mostly driven by a sake of harmonization with continental France, homeland of MAESHA pilot site, Mayotte. Finally, as the selected standard does not support the Distribution System Operator (DSO) needs, we conducted a gap analysis to identify the adaptations and extensions needed for our project (e.g., adding the connection point of the asset in the Distribution network). We finally decided to rely on the CIM extension proposed by Enedis (main French DSO) in its E-Flex platform.
- On the asset level, we recommended to use OCPP to communicate with Electric Vehicles charging points, SunSpec over Modbus profile or the IEC 60870-5-104 to communicate with the Distributed Energy assets and EEBus for the communication with energy appliances deployed at home. However, and most importantly, we will have to take into account the capabilities of the assets available in Mayotte.

Last but not least, we defined an interoperability testing methodology that will be followed in Work Package 8 to ensure that the components developed in the project are interoperable before their integration in the final solution. First, we will prepare the interoperability testing by applying the Joint Research Centre (JRC) interoperability testing methodology on the SO level. Then, we will conduct connectivity and interoperability tests during a "plug-fest", gathering all the components suppliers.

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1. NOTATIONS, ABBREVIATIONS AND ACRONYMS

Table 1: Acronyms

Acronyms	
API	Application Programming Interface
BAIOP	Basic Application Interoperability Profile
BAP	Basic Application Profile
BESS	Battery Energy Storage System
BSP	Balancing Service Provider
CEM	Customer Energy Manager
CIM	Common Information Model
COSEM	Companion Specification for Energy Metering
CPMS	Charging Point Management System
CS	Control Space
CSMS	Charging Station Management System
DER	Distributed Energy Resource
DLMS	Device Language Message Specification
DoE	Design of Experiments
DR	Demand Response
DSO	Distribution System Operator
EDI	Electronic Data Interchange
EDM	Electricité de Mayotte

EFI	Energy Flexibility Interface
EMS	Energy Management System
ENTSO-E	European Network of Transmission System Operators
ERRP	ENTSO-E Reserve Resource Process
ETSI	European Telecommunication Standards Institute
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FAN	Flexible power Alliance Network
FCR	Frequency Containment Reserve
FMTP	Flexibility Management and Trading Platform
FRR	Frequency Restoration Reserve
FSP	Flexibility Service Provider
HTTP	HyperText Transfer Protocol
HV	High Voltage
HVAC	Heating, Ventilating and Air-Conditioning
LAN	Local Area Network
LEC	Local Energy Community
IEC	International Electrotechnical Commission
IEEE	Institute of Electronic and Electronic Engineers
IoT	Internet of Things
ISO	International Organization for Standardization

JRC	Joint Research Centre
JSON	JavaScript Object Notation
LV	Low Voltage
MV	Medium Voltage
NIST	National Institute of Standards and Technology
NFC	Near Field Communication
OCPP	Open Charge Point Protocol
OpenADR	Open Automated Demand Response
OSI	Open Systems Interconnection
P2H	Power to Hydrogen
PLC	Power Local Controller
PMS	Power Management System
PPP	Point-to-Point Protocol
PV	Photovoltaic
RES	Renewable Energy Source
RFID	Radio Frequency Identification
RTE	Réseau de Transport de l'Electricité
SAREF	Smart Anything REFerence
SCADA	Supervisory Control And Data Acquisition
SGAM	Smart Grid Architecture Model
SGILab	Smart Grid Interoperability Laboratory

SHIP	Smart Home Internet Protocol
SO	System Operator
SOAP	Simple Object Access Protocol
SPINE	Smart Premises Interoperable Neutral-message Exchange
TCP	Transmission Control Protocol
TSO	Transmission System Operator
UC	Use Case
UFTP	USEF Flexibility Trading Protocol
UML	Unified Modelling Language
USEF	Universal Smart Energy Framework
V1G	Smart Charging
V2G	Vehicle-to-Grid
VEN	Virtual End Node
VPP	Virtual Power Plant
VTN	Virtual Top Node
WAN	Wide Area Network
WP	Work package
XML	Extensible Markup Language
XMPP	Extensible Messaging and Presence Protocol
XSD	WML Schema Definition
XSLT	Extensible Stylesheet Language Transformation

2. Introduction

2.1. Definition and main concepts

The goal of this document is to present the "interoperability-by-design" framework defined for the MAESHA solution. To be interoperable, the solution should indeed be designed with certain interoperability and reusability requirements in mind. To improve the reusability of the solution in different geographical islands, a modular approach is to be preferred as all islands do not present the same context and assets on their territory. Although sustainable, this modular approach comes along with the challenge to make all the sub-systems work together as one system, the MAESHA solution. Successful integration of the various sub-systems is therefore a key factor for the success of MAESHA.

According to IEC TS 61850-2, interoperability can be defined as the ability of two or more devices to exchange information and use it for correct cooperation to perform the required functions. In other words, two or more systems (devices or components) are interoperable if they can perform a specific function cooperatively by using information that is exchanged.

Interoperability is a critical enabler of the smart grid potential. Because interoperability is a design consideration, it should be considered at the very beginning in the project development lifecycle to save money and time. Also, by defining the "interoperability-by-design" framework, involved partners and stakeholders have a better understanding of the automation interfaces, dependencies and expectations: communication is thus more effective and easier.

Two systems are considered interoperable if both present an interface and a data model that allow them to exchange some information to achieve a common goal together. According to the IEEE Standard Computer Dictionary, an interface is a shared boundary between two systems that work as a path that data takes for the communication between the systems. And a data model can be defined as an abstract model organizing the properties of the system along with their structure.

In order to ensure interoperability throughout all of MAESHA's subsystems, two complementary methods will be used:

- Relying on industry-ready standards providing open specifications that MAESHA's stakeholders must comply with.
- Developing an interoperability testing methodology specific to MAESHA that allows the proper testing of communication exchanges between each subsystem.

2.2. Structure

The structure of this document closely follows the methodology used to define MAESHA's "interoperability-by-design" framework. The first section presents the analysis of information extracted from deliverables D1.1 [1] and D1.2 [2] regarding the system's architecture as well as the use cases requirements for data exchange. It then defines the system's critical communication interfaces without which the system cannot properly operate.

The second section studies existing standards relevant to MAESHA. Those are considered based on their previous implementation in other European projects or following recommendations from stakeholders. The most suitable standards are then selected and analysed for possible adaptations in order to meet MAESHA's most specific needs.

The third and last section describes the testing methodology that will be used in WP8 to ensure the interoperability of all components of the MAESHA solution.

3. System architecture and use cases requirements analysis

To define the “interoperability-by-design” framework, we first conducted an analysis of the MAESHA solution. Primarily, we analysed the system architecture of the solution defined in Task 1.2 and presented in Deliverable D1.2 ([2]) to identify interoperability-critical interfaces. Those interfaces are the ones to look at in priority when designing the interoperability framework as they present potential risks for the future integration of the solution. Secondly, we derived some data exchange requirements from the use cases defined in Task 1.1 and presented in Deliverable D1.1 ([1]). Those requirements are indeed essential to identify relevant standards and to assess the relevance of those standards for the MAESHA solution. This section presents those two analyses and lists all relevant standards for the project.

3.1. Analysis of the system architecture

The system architecture of the MAESHA solution presented in D1.2 ([2]) was analysed to identify the interoperability-critical interfaces.

According to the H2020 European project InterFlex (Deliverable D3.3, [3]), the criteria for identifying an interface (between components) as critical from the interoperability perspective are detailed below:

- **The interface is between different actors**. In such cases, there is a risk of different understandings of the interface and therefore potential difficulties to align the implementations, possibly leading to interoperability issues.
- **No clear standard is identified in the industry for this interface.** In such cases, additional work is required to identify a good solution. Furthermore, the lack of maturity of the solution may lead to interoperability issues.

Please note that the second case was not identified for the MAESHA solution: in task 1.2, partners proposed standards for all interfaces. However, as most interfaces are between different actors, we decided to add an additional distinction in our analysis by using a 1-to-3 code to characterize each interface:

- A **3-interface** presents a high criticality from the interoperability perspective,
- A **2-interface** presents a medium criticality as a mitigation plan has already been identified for the potential risk linked to this interoperability-critical interface,
- A **1-interface** presents a low criticality from the interoperability perspective.

The analysis is available in Table 2. To ease the analysis, we schematically represented the MAESHA solution architecture with Figure 1 below.

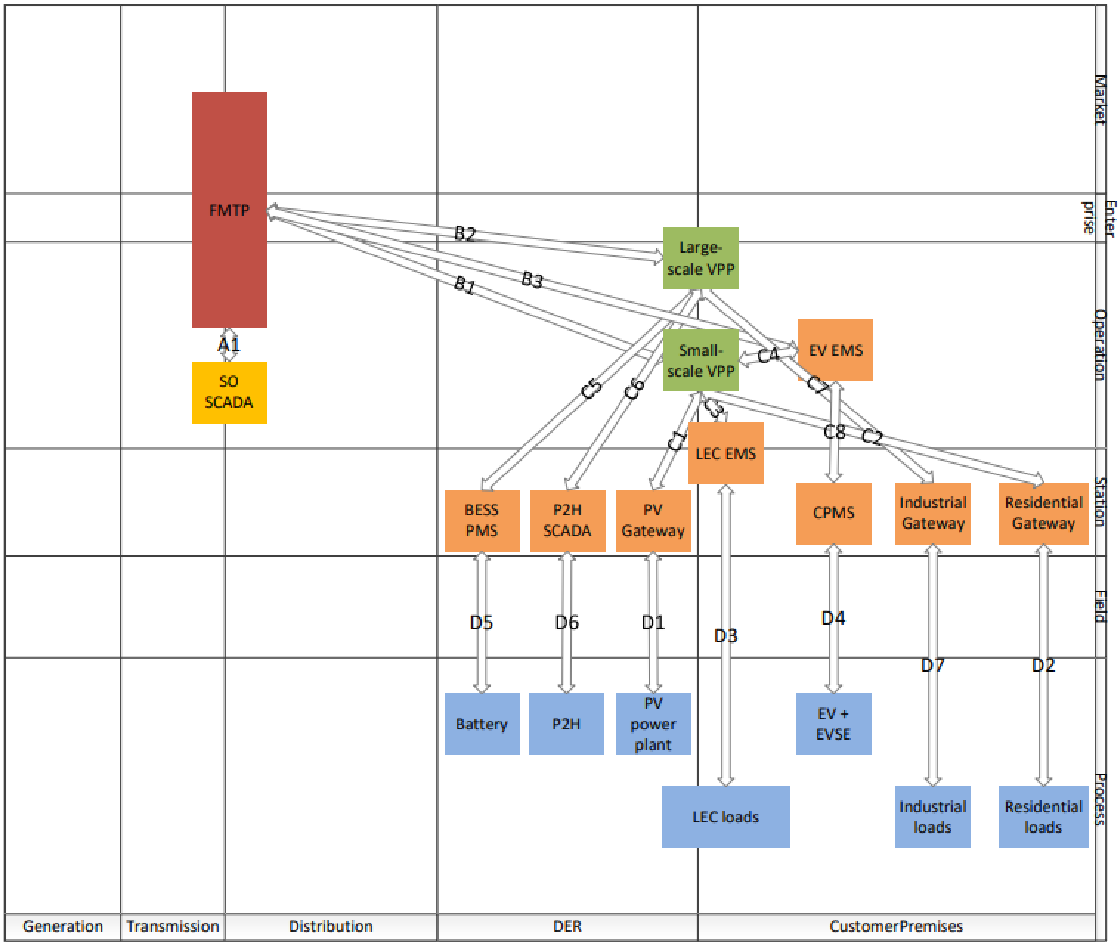

Figure 1: Schematic system architecture of the MAESHA solution

Table 2 below presents the result of our analysis with some justifications in the last column.

Table 2: Analysis of the interfaces from an interoperability perspective

Interface	Solution A and partners/actors		Solution B and partners/actors		Criticality from an interoperability perspective	Justification
A1	SO SCADA	EDM	FMTP	cyberGRID	**3**	This interface can be considered as critical from an interoperability perspective as several standards were identified in T1.2 (see D1.2 [2]) for the trading of flexibility: OpenADR, FlexOffer, ERRP, etc.
B1	FMTP	cyberGRID	Small-scale VPP	Centrica	**3**	This interface can be considered as critical from an interoperability perspective as several standards were identified in T1.2 (see D1.2 [2]) for the trading of flexibility: OpenADR, FlexOffer, ERRP, etc.
B2	FMTP	cyberGRID	Large-scale VPP	cyberGRID	**1**	Even if several standards have been identified in T1.2, once selected, there is lower risk linked to the standard interpretation as the same partner is in charge of developing the FMTP and the large-scale VPP
B3	FMTP	cyberGRID	EV EMS	Bovlabs	**3**	This interface can be considered as critical from an interoperability perspective as several standards were identified in T1.2 (see D1.2 [2]) for the trading of flexibility: OpenADR, FlexOffer, ERRP, etc.
C1	Small-scale VPP	Centrica	PV gateway	External actors	**2**	This interface can be considered as critical, but the risk is mitigated by the fact that Centrica will publish requirements and specifications that the

						asset's owners will have to comply with to enter the MAESHA project
C2	Small-scale VPP	Centrica	Residential gateway	Centrica, external actors	**3**	This interface can be considered as critical, especially as there is a lack of harmonization in standardization in the Smart Home domain. Several standards exist and it also mainly depends on the assets deployed in the territory of the demonstration site. Specific analysis is conducted in task 5.3.
C3	Small-scale VPP	Centrica	LEC EMS	Trialog	**2**	As Centrica has large expertise in Virtual Power Plants, they will push some specifications to partners that they will have to comply with for the proper communication of the system. Also, they can provide support for the implementation in the development phase
C4	Small-scale VPP	Centrica	EV EMS	Bovlabs	**2**	As Centrica has large expertise in Virtual Power Plants, they will push some specifications to partners that they will have to comply with for the proper communication of the system. Also, they can provide support for the implementation in the development phase
C5	Large-scale VPP	cyberGRID	BESS PMS	COBRA, EDM, external actors	**2**	As cyberGRID has large expertise in Virtual Power Plants, they will push some specifications to partners that they will have to comply with for the proper communication of the system. Also, they

						can provide support for the implementation in the development phase
C6	Large-scale VPP	cyberGRID	P2H SCADA	COBRA, EDM	**2**	As cyberGRID has large expertise in Virtual Power Plants, they will push some specifications to partners that they will have to comply with for the proper communication of the system. Also, they can provide support for the implementation in the development phase
C7	Large-scale VPP	cyberGRID	Industrial gateway	cyberGRID, external actors	**2**	This interface can be considered as critical, especially as there is a lack of standardization in this domain. However, cyberGRID has already identified relevant standard (IEC 60870-5-104) and can provide support to external actors for their implementation of the standard.
C8	EV EMS	Bovlabs	CPMS	Bovlabs	**1**	The two components are developed by the same partner and have already been successfully demonstrated
D1	PV gateway	External actors	PV power plant	External actors	**1**	Out of the scope of the MAESHA project. Also, the risk is mitigated by the fact that the installed PV power plants inverters are usually already coupled with a gateway
D2	Residential gateway	Centrica, external actors	Residential loads	External actors	**1**	Out of the scope of the MAESHA project
D3	LEC EMS	Trialog	LEC loads	External actors	**2**	High risks as the LEC EMS can interact with several loads (EV charging station, battery, PV, smart appliances etc.). Risks will be mitigated by the fact that the

						partner will impose a standard
D4	CPMS	Bovlabs	EVSE	CREARA	**2**	Risk mitigated by the fact that the two partners have already and successfully demonstrated the use of a common standard: OCPP 1.6
D5	BESS PMS	COBRA, EDM, external actors	Battery	EDM	**1**	No risk as the battery purchased will be provided with its PMS
D6	P2H SCADA	COBRA, EDM	P2H	EDM	**1**	No risk as the P2H system purchased will be provided with its SCADA
D7	Industrial gateway	cyberGRID, external actors	Industrial loads	External actors	**1**	Out of the scope of the MAESHA project
D8	EVSE	CREARA	EV	External actors	**1**	The risk is mitigated by the fact that the charging points purchased will be tested and approved by the manufacturer

From this analysis, it appears that several interfaces could be considered as interoperability-critical. However, most risks can be mitigated by the fact that some systems are already set up and already work well in their own environment: partners who developed them can thus provide support for the implementation of the communication protocol, by sharing some API specifications for instance.

In the definition of the "interoperability-by-design" framework, we thus decided to focus mainly on "System Operator (SO) level" communication interfaces (A1, B1, B2 and B3) and to let the choice to partners to select the most relevant standard for "asset level" communication. Also, most standards for downstream communication are technology-dependent (e.g., OCPP 1.6 or 2.0 for Electric Vehicles, SunSpec for PV inverter) and it is difficult to find a consensus for all assets, that would not limit the future expansion of the solutions.

3.2. Analysis of the use cases requirements

To identify the potential standards relevant for the MAESHA solution, we extracted the requirements related to data exchange from the MAESHA use cases (section 5 “Information Exchanged” of the IEC 62559-2 template) and based on the frequency of the information exchange as well as its utilization and scope, we categorized them, using a 1-to-5 priority for standardization scale – with a 5 symbolizing a high priority in terms of standardization.

Please note that, for this analysis, we only considered the following use cases:

- Frequency control
- Voltage control
- Minimization of the consumption peak

The two other use cases – maximization of the use of Renewable Energy Sources and energy access – are indeed not directly linked to the concept of flexibility.

Finally, to ease the standards assessment available in section 4, we linked each requirement to a service for flexibility markets. It thus allows us to only look at the coverage of the service by the standard, rather than looking for each individual information in the specifications of the standard. The services were extracted from the InterConnect flexibility market framework, available in Deliverable D4.1 ([4]) and depicted in Figure 2 below:

- **Registration** should take place once, when a flexibility provider requests to participate in the market. Information related to the assets (e.g., location, maximum flexibility range) should be provided,
- **Pre-qualification** may imply
  - Product pre-qualification, to verify that the resources are able to technically provide the flexibility according to the technical requirements of the services,
  - Grid pre-qualification, to verify that the resources can provide the flexibility considering the technical constraints and characteristics of the grid where they are connected to,
- The **Forecasting** phase corresponds to the use of forecasts to assess the flexibility needs,
- The **Market operation** corresponds to the processes of receiving the bids, selecting the bids or market clearing,
- The **Delivery** phase implies the activation of the selected flexibilities to deliver the product committed,
- The **Verification** phase consists of monitoring the grid operation to verify that the activated flexibilities have the expected result and of metering the resources providing flexibility to verify that the committed products are properly delivered. Please note that this phase is included in the previous one in InterConnect,
- Finally, based on the market results and on the verification process, the **Settlement** determines the final economic transactions to the flexibility provider.

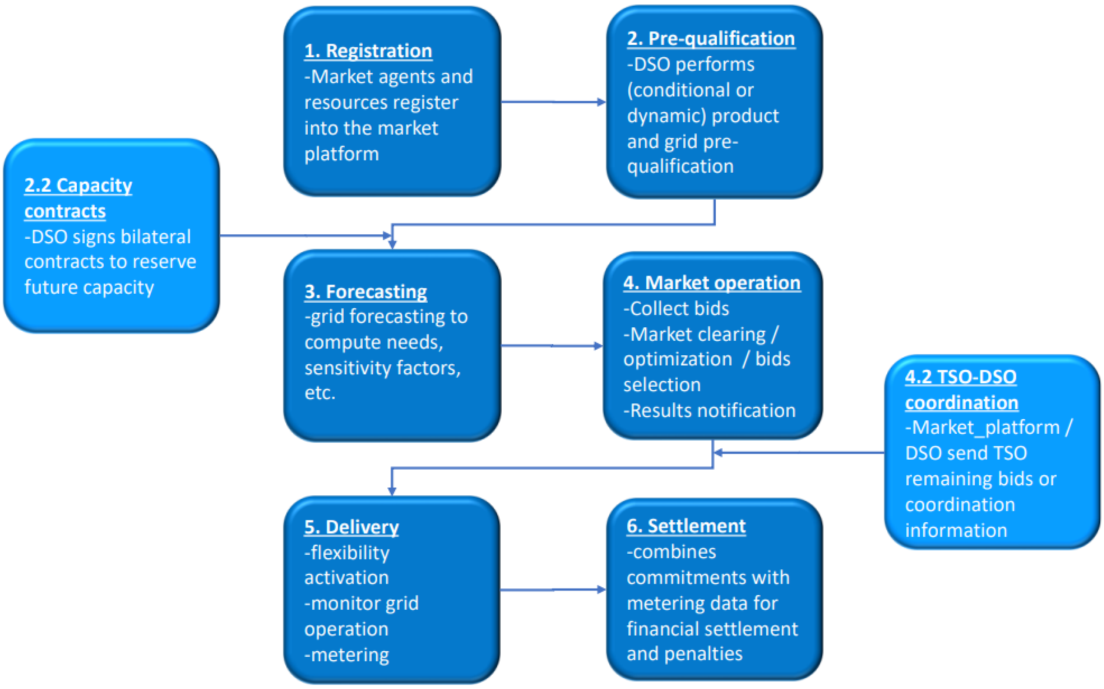

Figure 2: Market phases and functions to enable local flexibility markets (source: [4])

The following three tables presents the analysis conducted for each of the use cases.

Table 3: Frequency control use case requirements

Information exchange, ID	Name of information	Description of information exchanged	Frequency of information exchange	Utilization/range	Priority for standardization 1 = low priority 5 = high priority	Services
IE-01-01	Frequency bandwidth and emergency thresholds	Predefined bandwidth of allowed system frequency, including target value (50 Hz) and thresholds for initiating emergency measures	yearly	Public	1	-
IE-01-02	System model	Model of the power system supporting dynamic analyses	yearly	SO internal	2	-
IE-01-03	Historic measurements	Historic timeseries of measured generation, consumption and system frequency	yearly	internal or public	2	-
IE-01-04	Fault statistics	Statistics of faults in the power system that are relevant for balancing reserve dimensioning	yearly	SO internal	1	-
IE-01-05	Consumption forecasts	Mid-term (timeseries) of the total consumption	yearly	SO internal	2	Forecasting
IE-01-06	Design scenarios	Expected critical situations (e.g. yearly peak load, separation of parts of the grid, etc.) relevant for balancing reserve dimensioning	yearly	SO internal	2	Forecasting
IE-01-07	Required amount of balancing reserve	Required amount of balancing reserves to ensure a stable operation of the power system, (e.g. 99.975% reliability)	yearly	public	1	-
IE-01-08	Balancing products and requirements	Definition of balancing products and requirements comprising: products (duration, min. bid size, direction, tolerances)	yearly	public	1	Pre-qualification
IE-02-01	Network frequency	Actual measurements of network frequency measured on-site by DER	1s interval	DER internal	3	-
IE-02-02	Frequency deviation	Actual frequency deviation detected on-site at DER	1s interval	DER internal	3	-
IE-03-01	Grid Frequency	Actual measurements of grid frequency centrally acquired by SO	1s interval or faster	SO internal or public	4	-
IE-03-02	Frequency deviation	Actual frequency deviation detected centrally by SO	1s interval or faster	SO internal or public	4	-
IE-03-03	Updated FRR setpoint	Actual FRR setpoint calculated by AGC, sum for all	2s interval	SO internal	4	-

		assets participating in FRR service provision				
IE-04-01	Balancing services rules	The document describing the rules for participation in balancing services, their technical and administrative requirements and tendered products, as well as the prequalification procedure	onetime or yearly	public	1	Pre-qualification
IE-04-02	Request for prequalification of DER	The flexibility provider (DER operator) applies for the prequalification for the balancing service participation.	onetime or 3 years	SO, BSP	3	Pre-qualification
IE-04-03	Request for prequalification of platform	The aggregator (intermediate platform operator) applies for the prequalification for the balancing service participation.	onetime or 3 years	SO, BSP	3	Pre-qualification
IE-04-04	Confirmation of prequalification	The SO confirms the successful prequalification of a DER or platform. Confirmation may need to be renewed after an expiry period.	onetime or 3 years	SO, BSP	3	Pre-qualification
IE-04-05	Rules and schedules of balancing service tender	The SO publishes the rules and schedules of balancing service tender, including description of tendered balancing service products.	Rules: onetime or yearly Schedules: weekly	public	4	Market operation
IE-04-06	Balancing service bid document	The aggregator or flexibility provider participates in the tender for balancing services by submitting one or multiple binding bids. Bids contains ID of bidder, date, timespan, product ID, power, capacity price, energy price.	weekly or daily	BSP, SO	5	Market operation
IE-04-07	Balancing service bid acceptance	The SO informs the bidders about acceptance or rejection of the bids submitted in the tender.	weekly or daily	BSP, SO	5	Delivery
IE-05-01	FCR provision enabled	The (PLC of the) DER enabled the FCR functionality and starts detecting the frequency deviations.	daily	DER internal	3	-
IE-05-02	FCR setpoint	FCR setpoint calculated on-site by PLC (DER)	2s interval	DER internal	2	-
IE-05-03	FCR monitoring data	The FCR monitoring data includes local measurements of frequency, active power, calculated setpoint, actual FCR provision. It is submitted in short intervals (e.g. of 2 s).	2s interval	BSP, SO	5	Validation
IE-05-04	FCR validation report	The FCR validation report summarizes the quality of FCR service provision of a flexibility provider.	yearly	SO, BSP	2	Validation
IE-06-01	FRR provision enabled	The (PLC of the) DER enabled the FCR functionality	2s interval	BSP, DER	3	-

		and starts listening for incoming setpoints.				
IE-06-02	FRR setpoints for central balancing assets	FRR setpoints for central balancing assets (controlled by the SO)	2s interval	SO internal	4	-
IE-06-03	FRR setpoint for DER	FRR setpoints for FMTP	2s interval	SO internal	5	Delivery
IE-06-04	FRR Activation requests	FRR setpoints for VPPs or large DER (controlled by 3rd party flexibility providers) send from FMTP	2s interval	SO, BSP	5	Delivery
IE-06-05	Individual FRR setpoints	Individual FRR setpoints for DER controlled via an intermedia platform	2s interval	BSP, DER	3	Delivery
IE-06-06	Individual FRR monitoring data	Monitoring data of individual DER, which is sent to an intermediate platform Datapoints: active power, baseline, setpoint, FRR activation, control bandwidth	2s interval	BSP, DER	3	Validation
IE-06-07	Aggregated FRR monitoring data	Aggregated monitoring data of a pool of DER (managed by an intermediary platform), which is sent to the FMTP. Datapoints: active power, baseline, setpoint, FRR activation, control bandwidth	2s interval	SO, BSP	5	Validation
IE-06-08	FRR validation report	The FRR validation report summarizes the quality of FRR service provision of a flexibility provider.	yearly or weekly?	SO, BSP	2	Validation
IE-07-01	Daily balancing service accounting	Accounting of provided balancing energy and related costs (according to balancing service bid document), created on d+1	daily	SO, BSP	4	Settlement
IE-07-02	Monthly balancing service accounting and remuneration report	Monthly sum of Daily balancing service accounting positions, which are used for remuneration of the flexibility provider	monthly	SO, BSP	4	Settlement
IE-08-01	Forecast of flexible capacity and costs	The forecast of flexible capacity and costs of a DER is generated for the entire upcoming product duration, that is tendered.	daily or weekly	DER, BSP	3	Registration
IE-08-02	Flexibility merit order	The flexibility merit order sorts the DER's flexibility forecasts according to their costs (from cheapest to most expensive).	daily or weekly	BSP internal	3	Market operation
IE-08-03	Actual flexibility of DER	The actual flexibility bandwidth of a DER	2s interval	BSP, DER	3	-

Table 4: Voltage control use case requirements

Information exchange, ID	Name of information	Description of information exchanged	Frequency of information exchange	Utilization/range	Priority for standardization 1 = low priority 5 = high priority	Services
IE-01-01	Request for connection or participation in voltage control services	Document requesting a connection of the asset to the grid or requesting the participation of the asset in voltage control services	One time	SO + DER	1	Registration
ServiceIE-01-02	Capabilities curve	This curve represents the capabilities of individual assets as represented in Q-U-ranges	One time	SO + DER	2	Registration
IE-01-03	Static voltage droop curve	This curve is a voltage-to-power response curve that translates local voltage measurements to active and reactive power response. This curve is specific to an individual asset.	One time and in case of significant topology changes	SO + DER	2	Registration/Pre-qualification
IE-02-01	Voltage data	Local voltage level measured at the asset level	Continuously 1 minute	DER internal	3	-
IE-02-02	Reactive power setpoint	This setpoint is the reactive power response calculated by the gateway in charge of the control logic based on the static voltage droop curve of the asset	Continuously 1 minute	DER internal	3	Delivery
IE-03-01	Validation data	Those data is needed for the validation process. It includes the baseline, power and voltage measurements and is submitted in a format predefined by the SO	15 min interval	SO internal	4	Validation
IE-03-02	Request for validation data	A formal request of the SO to submit the validation data	Daily (or weekly, monthly)	SO internal	5	Validation
IE-03-03	Validation report	A document issued by the SO reporting the result of the validation process	Yearly or on request	SO, FSP	2	Validation

Table 5: Minimization of the consumption peak use case requirements

Information exchange, ID	Name of information	Description of information exchanged	Frequency of information exchange	Utilization/range	Priority for standardization 1 = low priority 5 = high priority	Services
IE-01-01	Flexibility market description	Public document describing the flexibility market, the products and the related requirements	One time or yearly	SO public	1	Pre-qualification
IE-01-02	Participation in flexibility market approval	Document certifying that a specific flexibility provider is allowed to participate in the flexibility market described in IE-01-01	One time or yearly	SO, FSP	2	Registration/Pre-qualification
IE-02-01	Consumption data	Various consumption data collected from the assets involved in the flexibility market for minimizing the consumption peak.	Continuously 1 min interval	DER, FSP (flex platform)	4	-
IE-02-02	Baseline forecast	Estimate of the future demand that is based on the historical demand	Hourly, daily (depends on the asset considered)	EMS, flex platform internal	3	Market operation
IE-02-03	Flexibility potential forecast	Estimate of the flexibility potential of the asset (by load shedding or load shifting)	Hourly, daily (depends on the asset considered)	EMS, flex platform internal	3	Market operation
IE-02-04	Flexibility bid	Consists of the aggregation of the flexibility potentials of the different assets connected to an intermediate platform.	**Daily** (hourly might be supported)	flex platform, SO	5	Market operation
IE-02-05	Flexibility activation request	A flexibility activation is a request from the SO to modify the load profile at a specific location by reducing the consumption	**Daily** (hourly might be supported)	flex platform, SO	5	Delivery
IE-02-06	Disaggregated flexibility activation	Flexibility activation request is disaggregated for control dispatching of the different assets connected to the intermediate platforms	After reception of an activation request	DER, FSP (flex platform)	4	Delivery
IE-02-07	Consumption profile	Consumption profile of the assets involved in the flexibility market	Continuously 1 min or 15 min	DER, SO	5	Validation
IE-02-08	Flexibility reward	Reward of the flexibility providers for its participation if the flexibility market	Monthly, daily	SO, FSP	3	Settlement
IE-04-01	ID Tag	Authentication of EV using RFID/NFC tag	Event-based (new	EV system internal	4	-

			connection)			
IE-04-02	New EV connection signal	The charging point management system communicates with EV EMS information about connected charger and EV driver data	Event-based (new connection)	EV system internal	4	-
IE-04-03	EV driver's preferences	Through the mobile app, the EV driver indicates its preferences for the EV parking statis, such as desired state of charge, departure time, etc. and if he wants to engage in smart charging	Event-based (new connection)	EV system internal	3	-
IE-04-04	Smart charging profile	Charging/discharging profile to be performed by an individual EV connected to the EVSE	Every 15'	EV system internal	4	-

From this analysis, it appears that there is a strong need for standardization for the three services **Market Operation, Delivery and Validation**. They are indeed redundantly coupled with the highest priority for standardization. Specific focus has thus been set on those services for the standards assessment.

3.3. IDENTIFICATION OF RELEVANT STANDARDS

This section lists the standards that have been identified as potentially applicable for the MAESHA solution. To identify them, we screened the EU-SysFlex Deliverable 5.5 ([5]) to identify the relevant potential standards describing data models[1], the catalogue of standards initiated by the BRIDGE initiative in its Data Management Working Group (Action #3) ([6]), the InterConnect Deliverable 4.1 "Functional Specification of DSO Standard Interface Application" ([4]), the Merlon Deliverable 4.1 "Analysis of EU-wide interoperability standards and data models and harmonization requirements" ([7]) and the SENDER Deliverable D3.1 "Interoperable architecture report" ([16]).

Table 6: Relevant standards for MAESHA

Level	Category	Standard
SO level (SO, FMTP and VPPs)	**Real-time operations of the grid**	• IEC 61970, 61968, 62325, also known as the Common Information Model (CIM) • IEC 60870-5-104
	Smart meter	• IEC 62056, also known as the DLMS/COSEM suite
	Flexibility trading	• IEC 62325 (CIM for energy market) • Electricity Balancing Market (ex ERRP) • EQUIGY • OpenADR • UFTP/USEF • FlexOffer
Assets level (Gateways, EMS and assets)	**Electric Vehicles**	• OCPP (1.6 and 2.0) • IEC 63110 • ISO 15118
	Battery and DER	• IEC 60870-5-104 • Modbus TCP • SunSpec
	Residential and industrial Demand Response	• EEBus • IEEE 2030.5 • KNX • EFI • SAREF4ENER

[1] We only focused on standards describing data models. Eu-SysFlex deliverable 5.5 indeed identifies several standards presenting also use cases, requirements and communication protocols. As those were already defined in MAESHA, we decided to focus on the information layer and on the data models.

4. State-of-the-art of relevant standards

This section provides an overview of the standards identified as relevant for MAESHA as well as the standard analysis conducted by the MAESHA partners regarding their service coverage and other criteria such as maturity, scalability and acceptance in Europe. Based on this analysis, some recommendations and needs for adaptations are proposed to fully meet the requirements of the MAESHA solution.

4.1. Literature review

This section provides an overview of the standards identified as relevant for MAESHA.

4.1.1. SO level

4.1.1.1. Common Information Model (IEC 61970/61968/62325)

Originally developed in the mid-1990s by the Electric Power Research Institute in the USA, the Common Information Model (CIM) was handed over to the IEC in 1996, which continued the work at international level. The CIM standard family is particularly important in the area of standardization of system interfaces and data models for network management as well as the integration of applications into the IT system landscape of an energy supply company.

The CIM standard family [8] is composed of the IEC 61970, the IEC 61968 and the IEC 62325 standards that promote interoperability in electric power systems:

- IEC 61970 Energy management system application program interface:
  - IEC 61970 is the series of standards that provide a solution by defining a common information model to describe the electrotechnical relationships between different systems and components of power grid management,
  - It standardizes a set of interfaces that provide access to all applications and systems,
  - It defines an application program interface (API) for the integration of internal EMS applications from different manufacturers.
- IEC 61968 Application integration at electric utilities - System interfaces for distribution management:
  - The IEC 61968 standard is an extension of the information model defined in the IEC 61970 standard to cover aspects of management and operation of the distribution of electrical networks (e.g. monitoring of operations, work planning, customer invoicing, etc.).
- IEC 62325 Framework for Energy market communications
  - A series of standards that describes a framework for communications relating to the deregulated energy market,
  - The main objective of IEC 62325 is to facilitate the integration of application software for the market, developed independently by different vendors. Message exchanges are defined to allow these applications or systems to access public data and exchange information regardless of how that information is represented internally.

The aim of CIM is to minimize costs and reduce time expenditure in the integration of applications in and with energy management systems (EMS). In addition, investment protection for systems is provided by standardization and effective operation is ensured.

CIM is a domain model based on electronic exchange standards to describe concepts such as topology, asset descriptions and component descriptions. It is an abstract model that represents all the major objects in power systems and market operations. It facilitates interoperability in power systems namely in outage management, customer information management and exchanges between utilities/DSO. CIM is used at least since 2007 by TSOs and is being implemented for the Balancing Code, Operational Planning & Scheduling to guarantee the "interoperability" between the actor's participating to these processes.

CIM standardizes also interoperability in energy management functionalities, such as network operations, and electricity markets, power system distribution, and information exchange between them ([8]).

The European Network of Transmission System Operators for Electricity (ENTSO-E) provides tests to check the syntax of the latest ENTSO-E XML schema to ease the translation between ENTSO-E XML instances and IEC CIM XML instances (using XSLT transformation). The IEC TC 57 series IEC 62325 covers the needs for market exchanges, scheduling for balancing and transparency, and IEC 62325-301 184 describes the CIM-Market.

CIM is used as an enabler by more than 100 companies in the world (about 42 TSOs from 34 countries). The main advantages of CIM are:

- Time saving when creating a new interface (the information to be exchanged being defined elsewhere in the shared exchange model)
- Reduction of total data administration and IT development costs by limiting the number of specific interfaces to be developed
- Better control and readability of the information exchanged
- Increased guarantee of the overall consistency of data
- Easier learning and reduction in training time

The CIM is currently maintained in UML, but standardized documentation with UML diagrams is not freely available. The implementation of CIM is dependent on the interpretation of the standard, consisting in one of the main barriers for the integration of new applications and systems.

4.1.1.2. IEC 60870 (focus on IEC 60870-5-104)

In electrical engineering and power system automation, IEC 60870 standard defines systems used for telecontrol (supervisory control and data acquisition, also known as SCADA). Such systems are used for controlling electric power transmission grids and other geographically widespread control systems. By use of standardised protocols, equipment from many different suppliers can be made to interoperate. The IEC 60870 standard has six parts, defining general information related to the standard, operating conditions, electrical interfaces, performance requirements and data transmission protocols.

The areas of application of the standard are: monitoring of plants, substations and DERs and data exchanges between energy management systems.

IEC 60870 part 5 provides a communication profile for sending basic telecontrol messages between two systems using permanent directly connected data circuits. IEC 60870-5-104 (also known as the IEC 104) protocol is an extension of IEC 60870-5-101 protocol with changes in transport, network, link & physical layer services to suit the complete network access. The standard IEC 60870-5-104 uses an open TCP/IP interface to the network to have connectivity to the LAN (Local Area

Network) and routers with different facility can be used to connect to the WAN (Wide Area Network). The standard defines two separate link layers, which is suitable for data transfer over Ethernet & serial line (PPP - Point-to-Point Protocol). The control field data of IEC 104 contains various types of mechanisms for effective handling of network data synchronization. IEC 60870 part 5 is used mainly to communicate data points but is not well suited to communicate timeseries, which is of increasing importance in the power industry.

4.1.1.3. IEC 62056 (DLMS/COSEM)

DLMS/COSEM is a series of standards specifying a language for data exchange with smart (meter) devices. Such meters have increasing number of functionalities, including consumption management, near-real-time measurements, and therefore their communication capabilities become increasingly critical to ensure interoperability and secure data exchange.

COSEM (Companion Specification for Energy Metering) is the object model of smart meters. DLMS (Device Language Message Specification) is the application layer protocol of smart meter messages. Though the IEC 62056 standards have been developed for electricity metering, some parts of it like the COSEM data model are and can also be used for non-electricity metering. DLMS/COSEM does not cover collecting data into and storing in central data hubs/warehouses (except communication and data model part), nor does it cover head-end systems at data platforms or data brokers, nor does it cover centralised consent-based access to data. However, it does support gateways and soon services via Simple Object Access Protocol (SOAP). DLMS/COSEM has a very complete set of interface classes for handling data users' authorisation, and various levels of cyber security.

4.1.1.4. Electricity Balancing Process (ex ERRP)

The Electricity Balancing Process (derived from the ENTSO-E Reserve Resource Process, ERRP (see [22]) is defined in the Electronic Data Interchange (EDI) library of ENTSO-E. It is a set of conceptual and assembly models, based on the IEC 62325 series (CIM) and developed for reserve resource tendering, planning and activation within the balance management process, as displayed in Figure 3 below. IEC 62325-451-7 defines the Balancing processes, contextual and assembly models for European style market. The system implementation is based on the following ENTSO-E documents:

- ENTSO-E Reserve Resource Process (ERRP) Implementation Guide v5r0 or later versions
- IEC 62325-451-1: Acknowledgement business process and contextual model for CIM European Market
- ENTSO-E Code lists v50 and later versions
- ENTSO-E CIM XSD Schemas

The Electricity Balancing Process defines schemas for:

- Historical activation
- Planned resource schedule
- Redispatch
- Reserve allocation result
- Resource schedule anomaly report
- Resource schedule confirmation
- Bid availability

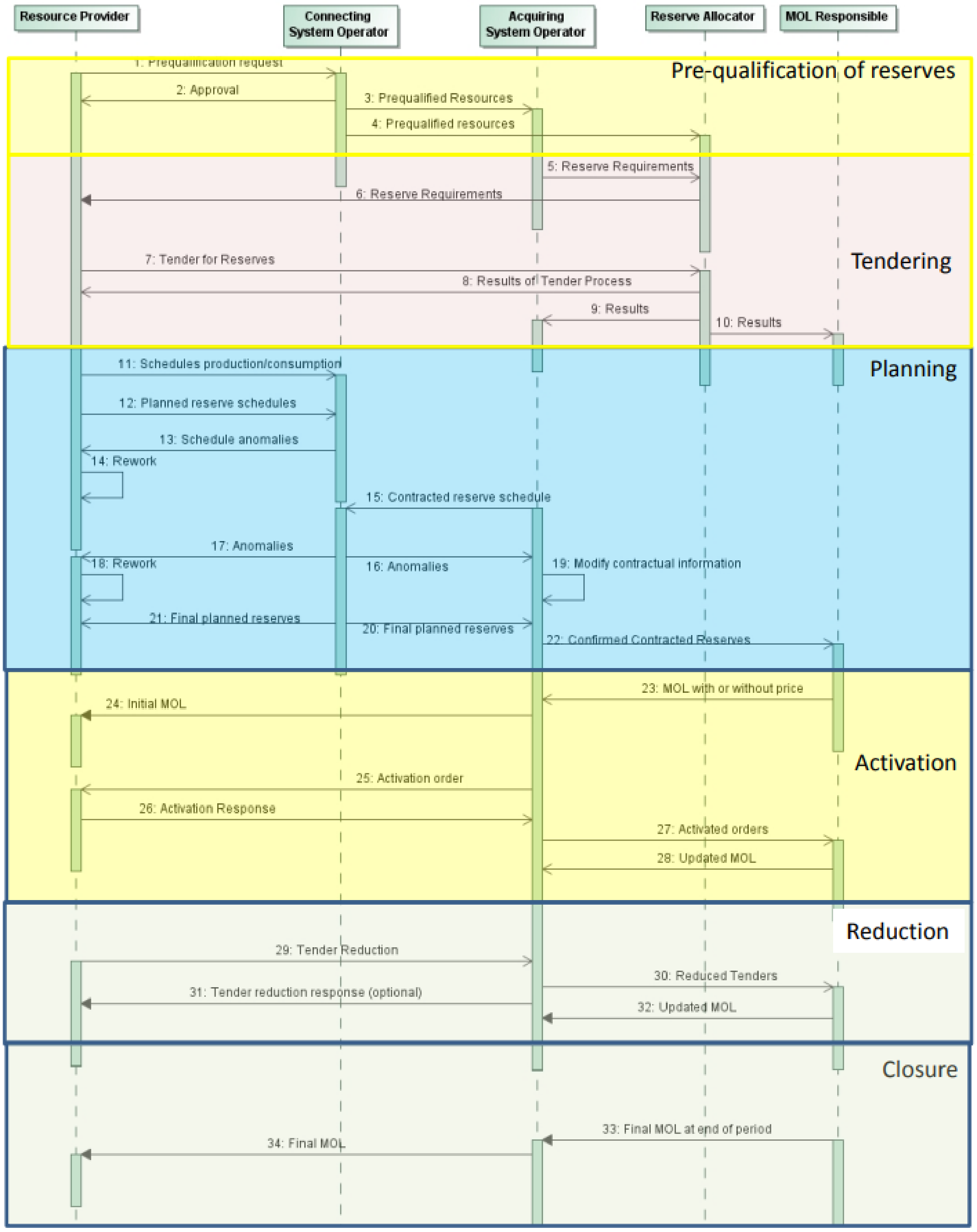

Figure 3: Reserve resource activation sequence (source: [22])

In 2022, the Electricity Balancing Process will be implemented as communication standard for the platforms for procurement procedures of automatic Frequency Restoration Reserve (aFRR) (PICASSO project), manual Frequency Restoration Reserve (mFRR) (MARI project), and Replacement Reserves (RR) (TERRE project) by most European TSOs, and some TSOs will also extend the application to Frequency Containment Reserve (FCR) procurement. This fact makes it to the most relevant standard for ancillary services procurement in the European Union. The ENTSO-E has published several implementation guides to define the data exchanges with those European platforms for the exchange of balancing energy ([34]).

On the other hand, there are some market participants that criticize the Electricity Balancing Process for the following reasons:

- The Electricity Balancing Process causes high effort to implement which may be an entry barrier for smaller BSP.
- As for now, the application focuses on ancillary services procurement for TSOs but other use cases shown in Figure 3, like registration and prequalification, but also monitoring and settlement have not been applied in practice so far or are not even available at all.
- The standard represents the use cases of the TSOs, but DSO have not been involved in the standardization process.
- The utilization of XML formats creates much overhead and simpler format like JSON gain importance in internet communication.

As such, the Electricity Balancing Process alone cannot cover all use cases of ancillary services provision and needs to be combined with other CIM based standards to cover the entire workflow. If ENTSO-E maintains the pace of developing and implementing the Electricity Balancing Process, it is very likely that the standard will be further developed in the following years.

4.1.1.5. EQUIGY

The Electricity Balancing Process has developed towards the de-facto standard for balancing markets communications in the European Union. While the data model is applied consistently in different countries, the transport layers are not harmonized between the control zones and each European country can implement its own solution. Further critics are based on the use of XML formats, which may introduce too much communication overhead and limit the future development of applications for very fast services like real-time monitoring for aFRR.

EQUIGY ([35]) is a recent initiative driven by four European TSOs to combine the benefits of the data model of the Electricity Balancing Process with a widely applied state-of-the-art way for internet communication. The XML format is replaced by a JSON format, and the messages are exchanged by means of REST web services. It is intended to extend the application to the entire reserve resource process including registration on a “Crowd Balancing Platform”, trading like in the original Electricity Balancing Process, online monitoring and DSO flexibility markets. EQUIGY aims at providing a platform that can also integrate small flexibilities due to its rather lean protocol and simple implementation on the side of the Flexibility Service Provider.

EQUIGY is in the pilot stage, with ongoing pilots to develop and demonstrate Minimum Viable Product in five European countries. The initiative looks very promising, but because of its still early stage there is no publicly available information about the data model or protocol which limits the application independent from the key actors at the moment.

4.1.1.6. OpenADR

The Open Automated Demand Response (OpenADR) is an open-source smart grid communications standard used for demand response applications ([9]). The protocol has been developed by the United Stated Department of Energy’s Lawrence Berkeley National Laboratory in 2002. It is typically used in demand response scenarios when specific signals are sent to devices to be turned off during periods of higher demand. The OpenADR standard, currently at version 2.0b, prescribes the information exchange between utilities and energy management control systems.

OpenADR uses a service-oriented architecture in which all interactions occur between entities called virtual top nodes (VTNs) and virtual end nodes (VENs), as shown in Figure 4 below.

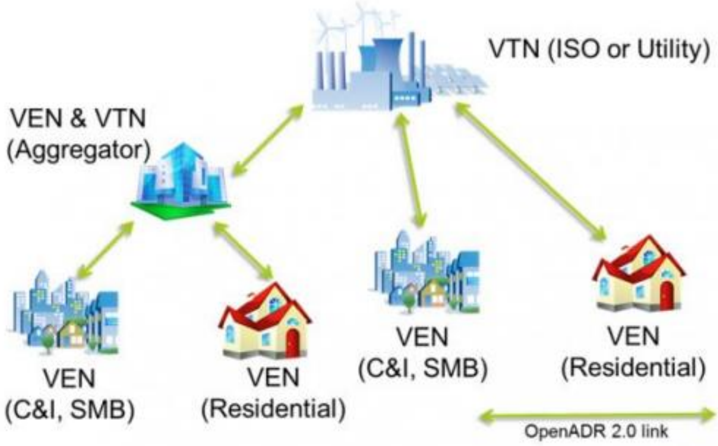

Figure 4: OpenADR service-oriented architecture (source: [36])

In general, the VTNs send demand response signals to the VENs and there is a hierarchical relationship between VTNs and VENs, where in some cases a node can be a VEN and a VTN at the same time. This model therefore supports the notion of intermediaries such as aggregators, which are common within existing demand response implementations.

Up to now, two profiles of OpenADR 2.0 have been developed. Profile A is targeted towards low-end devices and is limited to a simple implementation of OpenADR enabling only the notification of the VEN of upcoming DR events and sending the demand response signals from the VTN to the VEN. Profile B is targeted toward fully functional control systems and devices and enables feedback and additional services. It includes the opt out of the VEN from DR events and the information reporting to the VTN. This information is typically used by the VTN to both predict and monitor the behaviour of the demand-side loads associated with the VEN.

The standard allows a response signal to the DR event to travel back from VENs to the VTNs, and, in addition, other information can also be exchanged related to DR events, such as event name and identification, event status, operating mode, various enumerations characterizing the event, reliability and emergency signals, renewable generation status, market participation data and test signals ([10]). The implementation of the services is based on standard-based IP communications such as HTTP and XML Messaging and Presence Protocol (XMPP).

The demand-response signals are the means by which a VTN interacts with a VEN in order to influence or change the load profiles of the demand-side loads associated with the VEN. The OpenADR specification supports a wide range of different types of demand-response signals such as direct load control, or price incentives.

From the security perspective, OpenADR 2.0 aims to conform with the NIST Cyber Security requirements and follows the guidelines provided by the “Security Profile for OpenADR”. At the moment OpenADR 2.0 is limited to electrical DR. It would be important to consider the relation to other energy sources used e.g. for heating and cooling in a cross-carrier energy context to apply DR also to other energy sources.

Please note that in January 2019, the OpenADR Profile Specification was named as the IEC 62746-10-1 ED1 getting an international recognition as the standard for the implementation of automated demand response strategies. The IEC 62746 standard is fully named “Systems interface between customer energy management system and the power management system”.

In Europe, OpenADR has been implemented in several projects, such as the ELBE project, which goal is to install in Hamburg 7000+ intelligently controlled charging stations (see [32]). OpenADR is also used in the Intertrust Platform by E.ON, one of the largest utilities in Europe, for load balancing for efficient EV charging management in Germany and Western Europe (see [33]).

4.1.1.7. USEF Flexibility Trading Protocol (UFTP)

USEF Flexibility Trading Protocol (UFTP) is a subset of the Universal Smart Energy Framework (USEF). Focused specifically on the exchange of flexibility between Aggregators and DSOs, it describes the corresponding market interactions between them. It can also be used as a stand-alone protocol for flexibility forecasting, offering, ordering and settlement processes. The USEF framework as well as the UFTP specifications (v1.01) are open and accessible to all in the USEF website (usef.energy).

USEF was founded in 2014 by seven key players, active across the smart energy industry: Alliander, Stedin, ICT Group, DNV GL, ABB, IBM and Essent. It grew out of the Smart Energy Collective, a Dutch multi-partner collaboration, developing smart energy technologies and services. The foundation aimed to contribute to the development of a common smart energy standard and shared EU framework to maximize the value of flexibility to all market stakeholders.

The framework describes some roles, responsibilities and agreements, with very clear processes for effective interaction. The main processes of contracting, planning, validation, operation and settlement are described in Figure 5 below.

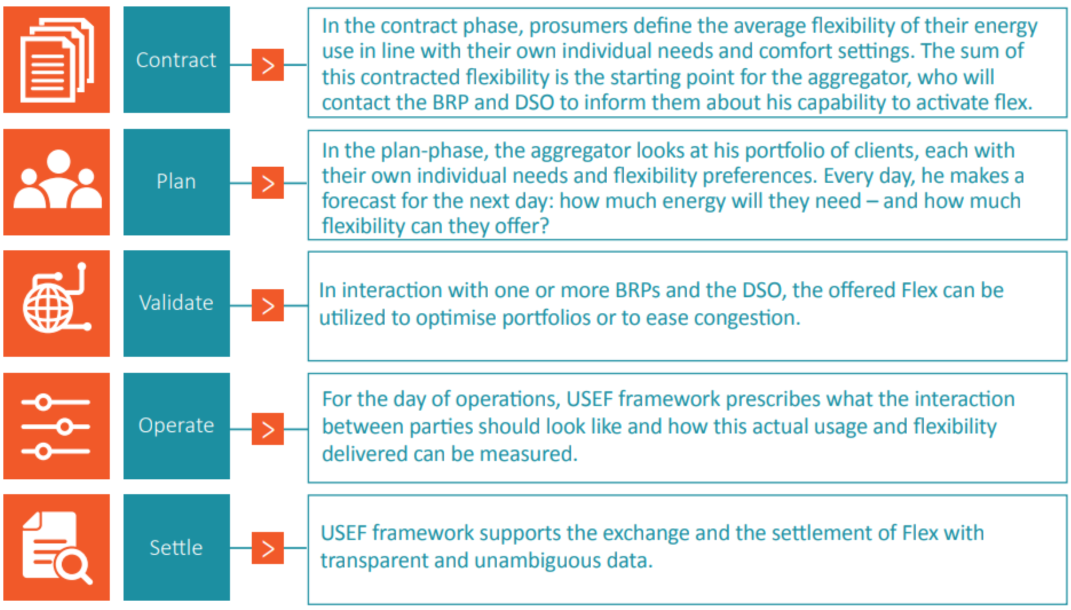

Figure 5: Description of the main processes of the USEF framework (source: [23])

Initially, the protocol has been developed to resolve grid constraints by applying congestion management or grid-capacity management. However, the protocol has been selected and extended for the use of some European projects (e.g., X-FLEX and MERLON) as described in [6].

All interactions between the Aggregator and the SO in the five different processes are described in the open specification (see [24]), as well as the description of each XML message. As an example, the XML representation of the FlexOffer messages used by aggregators to make DSOs an offer for provision of flexibility is proposed in Figure 6.

XML representation summary

```
<FlexOffer
  Metadata…
  Period                   =  Period
  CongestionPoint          =  EntityAddress
  ExpirationDateTime       =  DateTime
  FlexRequestMessageID     =  UUID (mandatory if and only if solicited)
  ContractID               =  Text (only if this offer refers to a bilateral
                              contract)
  D-PrognosisMessageID     =  UUID (mandatory if and only if unsolicited and if it
                              has been agreed that the baseline is based on D-
                              prognoses)
  BaselineReference        =  Text (only if another baseline methodology is used)
  Currency                 =  ISO4217Currency
  <OfferOption                (1...n)
    OptionReference        =  String (only if there are multiple OfferOptions)
    Price                  =  ISO4217Currency
    MinActivationFactor    =  Number (optional [0.01-1.00])
    <ISP                      (1...n)
      Power                =  Integer
      Start                =  Integer
      Duration             =  Integer (optional, default = 1)
    />
  />
/>
```

Figure 6: XML representation of the FlexOffer message (UFTP, source: [24])

4.1.1.8. FlexOffer

FlexOffer is an application-level communication protocol for flexibility trading between prosumers, aggregators and DSOs. This protocol helps in defining and transmitting flexibility offers extracted from various assets (e.g., heat pumps, EVs and HVAC systems). In simple cases, it is an offer from a prosumer to an aggregator, but in more complex cases, a flexibility offer can represent a production, a mix between production and consumption (balancing, self-consumption) or a constraint on the electricity network. It thus offers a unified way of representing or modelling flexibilities and is relatively adaptable as it details the messages used and not the use cases. It also allows the aggregation of flexibility offers between different types of prosumers and different aggregators.

A visual representation of a (simple) flex-offer is shown Figure 7 below. Each bar in the graph corresponds to a time slice of energy consumption, with the lower part representing the minimum amount of energy that a flexible resource needs to provide its service, and the upper part an interval within which it can adjust its consumption, while still satisfying functional constraints (e.g., comfort temperature). This is called an (energy) amount flexibility. Another type of flexibility is time flexibility as shown in Figure 7. Time flexibility is provided when an energy load can be shifted within a time interval, defined by an earliest start time at which the flexible resource can start its consumption, and a latest end time at which it should be done. When created, a flex-offer is assigned a baseline schedule that corresponds to the consumption pattern that the associated flexible resource prefers to follow.

Updated schedules can be assigned to the flex-offers to modify the consumption behaviour of the flexible resource, utilizing its provided flexibility. More advanced forms of the flex-offer exist and are described in [11] and [12].

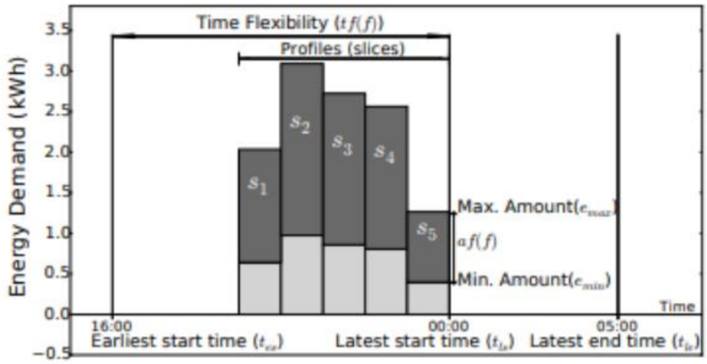

Figure 7: A visual representation of the simple flex-offer

FlexOffer has been used in several innovation projects (Mirabel, Totalflex, Arrowhead, DiCyps, Goflex, GIFT, and Fever) since 2010. More recently (2022), a FlexCommunity initiative has been created to gain a comprehensive understanding of the similarities and differences of the technical approaches developed in the projects, to strengthen cooperation in the development and implementation of advanced organisational structures and business models like energy communities and to align terminology and communication efforts. Additionally, a FlexOffer User Group, a technical community gathering implementers, adopters and promoters of the FlexOffer technology has been created.

4.1.2. Assets level

4.1.2.1. Electric Vehicles

Open Charge Point Protocol (1.6 and 2.0)

Open Charge Point Protocol (OCPP) has been designed and developed to standardize the communications between an Electric Vehicle Charging Station and a Charging Station Management System (CSMS), which is used for operating and managing charging stations. OCPP is an international open standard, which was developed in 2009, and now it is supported by majority of stakeholders in the EV industry such as utilities, EV charger manufacturers and back-office software suppliers ([14]).

As such, the OCPP is designed to be vendor independent, thereby creating the freedom for infrastructure operators in choosing EV chargers and for vendors to supply EV chargers to any infrastructure operators. Thus, it shall allow charging stations and central systems from different vendors to easily communicate with each other ([15]).

Until now, several OCPP versions have been released that include OCPP 1.2, OCPP 1.5, OCPP 1.6, and OCPP 2.0 ([13], [14]). OCPP 1.5 is designed to be implemented with SOAP which uses XML information set for its message format, and relies on application layer protocols such as HTTP for message negotiation and transmission.

OCPP 1.6 is based on OCPP 1.5, with some new functionalities and considerable textual improvements. It introduces new features to accommodate the market. These features include smart charging, OCPP using JSON over web sockets, better diagnostics possibilities, and more charge point statuses, etc. Due to improvements and new features, OCPP 1.6 is not backward compatible with OCPP 1.5. It can be observed that OCPP 1.6 has two different variants, namely OCPP-S for SOAP and OCPP-J for JSON. If a system supports both JSON and SOAP variant, it should be labelled as OCPP 1.6-JS or simply OCPP 1.6.

Furthermore, OCPP 2.0 introduces new functionalities such as device management compared to OCPP 1.6. Due to improvements and some new features, OCPP 2.0 will not be backward compatible with old versions such as OCPP 1.6 or OCPP 1.5.

The OCPP standard is a strict protocol: it does not only describe messages, but also the related behaviour of the CSMS and charging station, under the form of use cases, with the detail of the exact sequence of messages that is to be used.

Note that to pilot V2G (Vehicle To Grid, i.e. the discharging of the EV battery in the grid), OCPP 2.0 is preferred, even if the feature is not standardized in this version of the protocol (it will most probably be in version 2.1). However, the extension of the protocol is feasible through the creation of custom messages (DataTransfer).

ISO/IEC 15118

The ISO/IEC 15118, entitled “Road vehicles – Vehicles to grid communication interface”, is one of the standards enhancing communication between electric vehicles and the recharging infrastructure. It will soon enable bi-directional charging/discharging of electric vehicles. The user-convenient and secure “Plug & Charge” feature that comes with ISO 15118 enables the electric vehicle to automatically identify (id and charging contract) and authorise itself to the charging station on behalf of the driver to receive energy for recharging its battery. The only action required by the driver is to plug the charging cable into the EV and charging station. ISO 15118 will enable smart charging: optimization of charge planning taking into account constraints of electric vehicles (V1G or unidirectional power flow), charging stations and power grid and the needs of the driver. ISO 15118 will soon become an international standard defining a Vehicle to Grid (V2G) communication interface for bi-directional charging/discharging of electric vehicles (ISO 15118-20).

ISO 15118 defines a digital, IP-based protocol applied in the communication between EV and charging station. The idea is to enable a user-friendly mechanism for authentication, authorisation and billing without the need for further user interaction (Plug and Charge). Technically ISO15118 uses XSD schema files to define the messages structure (XML and JSON messages) and describes security concepts needed to ensure confidentiality, integrity and authenticity: 256 bits keys cryptography, Hash function SHA-256, X500 digital certificates and more.

IEC 63110

The IEC 63110 is an international standard defining a protocol for the management of electric vehicles charging and discharging infrastructures, which is currently under development by the International Electrotechnical Commission (IEC). It will address the requirements and information exchange for the establishment of an e-mobility ecosystem, therefore covering the communication flows between the different e-mobility actors as well as data flows with the Electric Power System.

The standard will cover many different features, such as the management of energy transfer (e.g., charge session), the asset management of EV supply equipment and the authentication, authorization and payment of charging and discharging sessions. The business use cases developed in IEC 63110-1 ("Basic Definitions, Use Cases and architectures") are shown in Figure 8.

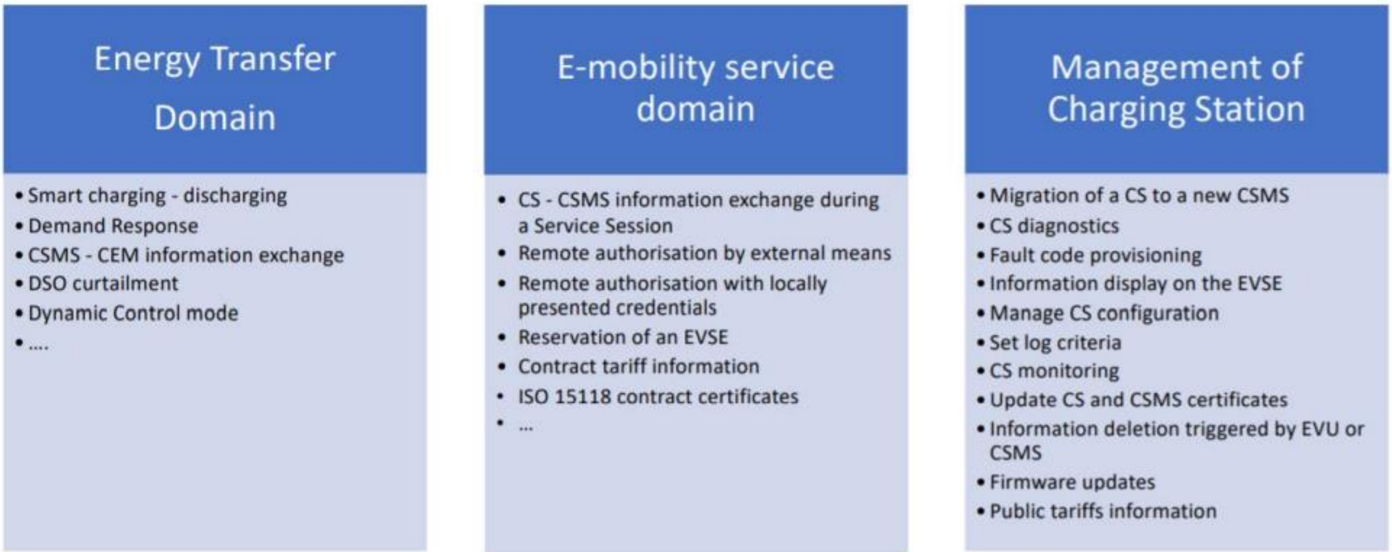

Figure 8: Business use cases developed in IEC 63110-1

IEC 63110-part 1 is currently under development (release planned in July 2022), but some information can be found in [17].

4.1.2.2. Battery and DER

IEC 60870-5-104

The IEC 60870-5-104 protocol is explained in section 4.1.1.2.

Modbus (focus on Modbus TCP)

The Modbus protocol is a messaging structure developed by Modicon (Schneider Electric) in 1979. It is used to establish master-slave/client-server communication between various devices connected to the same network. It is a request/reply protocol. A device exposes services via Modbus registers and function codes. Function codes are predefined and registers are free to be filled in by the manufacturer.

Each device communicating (transferring data) on a Modbus network is given a unique address. There's many variants of the Modbus protocol available. Most common are:

- Modbus RTU: this variant is used in serial communication and makes use of a compact, binary representation of the data. Binary is machine readable.
- Modbus ASCII: this variant is used in serial communication and makes use of an ASCII representation of the data. ASCII is human readable and less efficient (in communication between devices) than binary/machine readable.
- Modbus TCP: this variant is used for communication over IP (Internet Protocol). TCP/IP provides a reliable data transport mechanism (better than the above) between devices.

Data model and function calls are identical for all these three variants. However, the variants are not interoperable, nor are the messages.

Every device has its own way of expressing functionality via Modbus registers and function codes. There's not a common way to express for instance a 'set limit' or 'read power measurement' command. Every manufacturer can choose which services are made available (which registers and functions should be used) and what those registers mean. Besides the fact that all Modbus devices 'speak' the same language it is still to be determined which 'messages' should be used and what their meaning is. Because every device has its own way of expressing its functionalities, interaction between Modbus devices always requires a device specific coupling. Finally, it is important to mention that the Modbus protocol defines a strict data model that can't be extended and that it requires hardwired connections.

SunSpec

SunSpec is a suite of information standards for the Distributed Energy industry produced by the SunSpec Alliance ([25]). It is a U.S. based association with 150+ international members from the Distributed Energy industry in order to address the main shortcoming of the last decay impeding the broad deployment of solar PV systems, i.e. the lack of interoperable and standard-based renewable energy products in the market. The little flexibility provided by the current solar installations regarding how solar plants are managed, monitored and controlled has made evident the increasing need of a standardization effort between solar component manufacturers and operators. This has led to the idea of SunSpec as described in the SunSpec Alliance White Paper ([26]).

From that moment, the mission of SunSpec Alliance has been to accelerate the growth of the DER industry, reduce cost, promote innovation and expand the market for renewable power. For that reason, de facto standards (information models, data formats, communication protocols, system interfaces, best practices and other artifacts) have been specified by SunSpec Alliance which enable solar components and energy storage DER power plants to interoperate transparently with system components, software applications, financial systems, and the Smart Grid.

An overview of SunSpec Alliance technology is given in [27], where the SunSpec Alliance Interoperability Specifications are described.

Figure 9 depicts the areas of standardization that SunSpec standards address. As shown thereby, solar PV plants consist of the aggregation of the devices in a system and other information associated with the system. Devices are represented by a collection of Information Models (SunSpec Device Models), which can be used to convey device data between any two communicating entities by mapping them to the appropriate communication protocol (e.g., Modbus, HTTP, etc.). Currently supported device categories include inverters, meters, panels, environmental sensors, string combiners, trackers, energy storage and charge controllers. Generally, PV plants have one or more gateways (SunSpec Loggers) which communicate with devices such as inverters and meters, and relay the information gathered to Servers, which store data permanently and perform various analytics. Servers also communicate with other servers for regulatory reporting, grid operations, data acquisition (SCADA) and other customized applications.

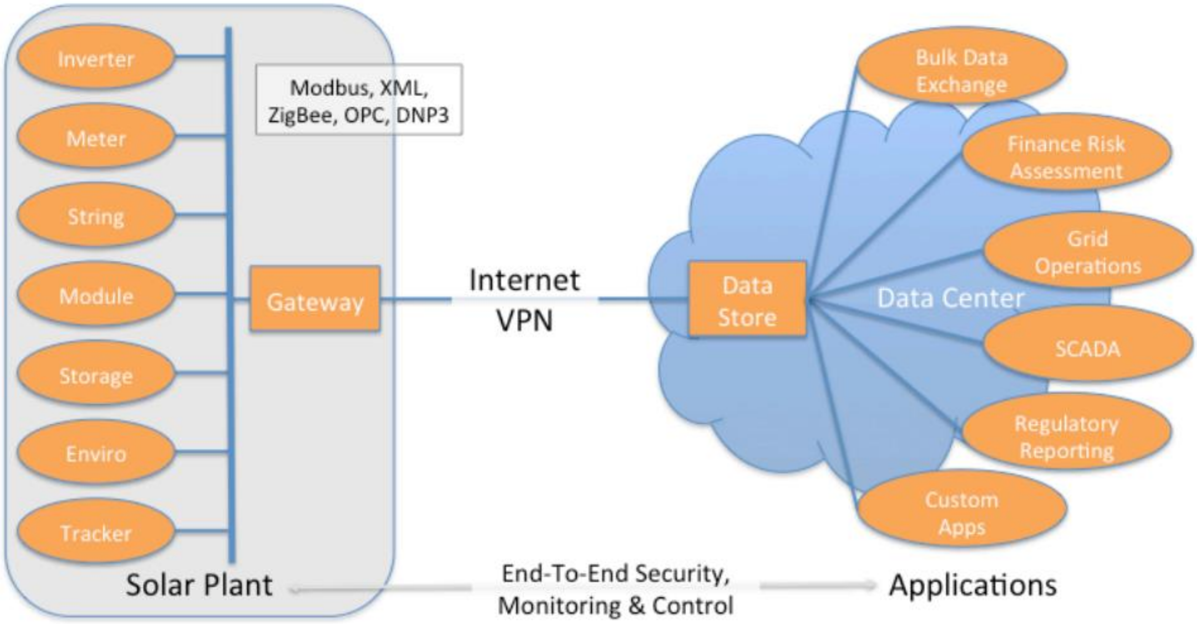

Figure 9: SunSpec architecture (source: [27])

The communication between devices and gateways is governed by the "SunSpec Information Model Specifications" ([28]), which regulate the information flow in SunSpec through a set of Information Models, representing functionalities implemented by devices or plants.

SunSpec Information Models are communication protocol agnostic: they have been mapped to Modbus TCP/RTU, HTPP/XML, OPC and other protocols.

On the other hand, the communication between gateways (Loggers) and Servers as well as Servers and other Servers is typically on the Internet, running standard internet protocols such as HTTP. This communication is governed by the SunSpec Model Data Exchange ([29]) and Plant Information Exchange specifications, to which the reader may reference for further details.

It is finally important to mention that in April 2018, the Institute of Electrical and Electronic Engineers (IEEE) revised the standard for interconnecting Distributed Energy Resource (DER) systems. The updated standard, IEEE 1547-2018, introduces a communications requirement for SunSpec Modbus or another standard interface. Once state and local jurisdictions adopt the IEEE 1547 revision, all DERs are required to provide a standard communications interface as a condition of grid interconnection.

4.1.2.3. Residential and Industrial Demand Response

EEBus

The EEBus protocol is developed by the EEBus Initiative e.V, which is a non-profit organisation with manufacturers from the sectors of networked building technology, electromobility and energy. The protocol enables the information exchange to coordinate and shift the energy between an intelligent power grid and the individual components in the households and buildings (e.g., photovoltaic system, battery storage, heating and electric vehicle).

The EEBus protocol is publicly available at no cost from the EEbus website. It has been used in the European project REnnovates, which ended in 2018, and is used in innovation projects from several automotive manufacturers, such as Audi or Volkswagen. It is now mainly adopted by German actors, but tends to spread.

EEBus is divided in 3 subparts, as shown in Figure 10:

- The Smart Home Internet Protocol (SHIP) handles everything related to the SGAM Communication layer
- The Smart Premises Interoperable Neural-message Exchange (SPINE) defines data model for the SGAM Information layer
- The use-cases are designed separately

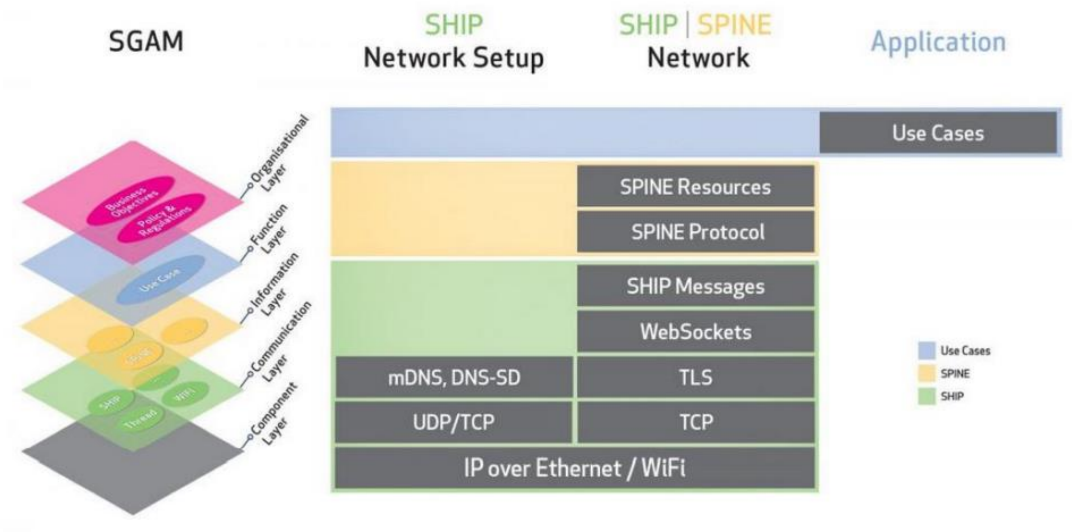

Figure 10: EEBus SGAM architecture

The protocol is quite generic and can be used in a wide range of areas, as shown in Figure 11. Many use cases implementing EEBus have been developed in the Smart Home and Smart Grid domains, in order to limit the variability of the scenarios implementation. In particular, E-mobility Use Case Specifications were published in 2019 ([19]):

- Coordinated EV charging
- Overload protection by EV charging curtailment
- Optimization of self-consumption during EV charging
- EV charging electricity measurement
- EV and EVSE commissioning and configuration

The same year, the EEBus Initiative E.V. releases HVAC use cases specifications:

- Configuration of room cooling temperature and system function
- Configuration of room heating temperature and system function
- Monitoring of outdoor temperature
- Monitoring of room temperature
- Monitoring of room cooling system function
- Monitoring of room heating system function

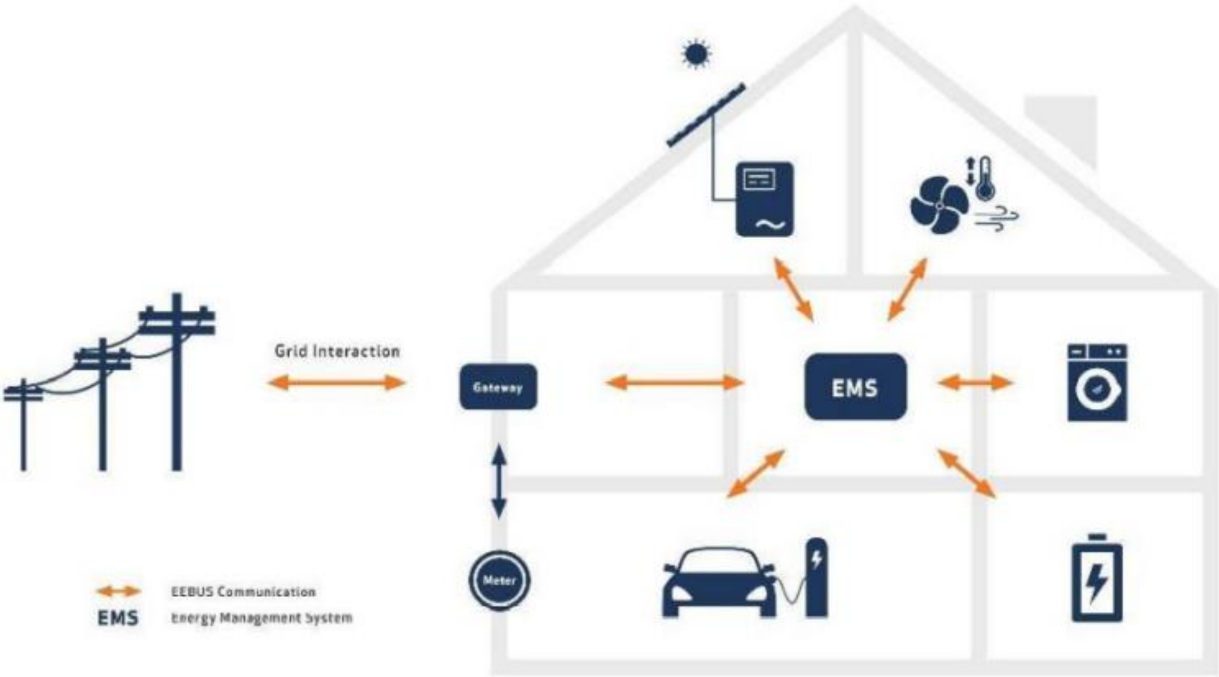

Figure 11: Interfaces covered by EEBus

IEEE 2030.5 / SEP 2.0

The SEP 2.0 protocol or IEEE 2030.5 standard formalizes the requirements for many aspects of the smart energy ecosystem including device communication, connectivity and information sharing requirements. It provides the guidelines on how devices should communicate with one another. The protocol is based on the IEC 61968 Common Information Model and the IEC 61850 information model for DER. It follows a RESTful architecture utilizing widely adopted protocols such as TCP/IP and HTTP. SEP 2.0 originates from the ZigBee Alliance and is a successor to the Zigbee Smart Energy Protocol v1.

The protocol defines various device properties that can be manipulated. These properties (also known as "resources") work together in logical groups to implement SEP 2.0 functionalities (called the "function sets"). A metering system, or pricing system, is an example of an application-specific function set. The protocol is quite broad and the function sets are defined in a generic way (client can be a thermostat, but also an EV) which means that it can be used in a wide range of areas.

KNX

KNX is a worldwide standard for home and building control, developed and promoted by the KNX Association. It provides energy efficiency by controlling heating/cooling and lighting. KNX is an OSI layer based communication standard for building automation. KNX is largely used in the commercial sector but nowadays it is implemented into many residential properties as well.

KNX provides energy management to control for example when to start charging the EV. Within a KNX system each device can be programmed, for example to read information from solar panels or other renewables to know how much energy those devices are generating.

In contrast to a standard electric installation, there is no hardwired connection between the control units and the power supply, for example a light switch is not directly connected with the respective light. Instead, devices and electric assets are connected via the KNX BUS. Both star and tree network topologies are supported. This enables setting it up as a completely decentralized system, but also supports a setup with an EMS (closest to the direct approach).

KNX is however quite complex/has a steep learning curve, requiring courses to use it. Furthermore, when it comes to connecting the KNX system to the internet, there are some security challenges that should be taken into consideration to avoid any attacks from outside the house.

EFI

The Energy Flexibility Interface (EFI) ([20]) is a communication protocol developed and maintained by the non-profit Flexible power Alliance Network (FAN) aiming at the interoperable control of various smart appliances that can offer flexibility (e.g., solar panels, heating, air-conditioning units and electric vehicle).

The EFI protocol is publicly available at no cost from the FAN GitHub.

The interface is part of the so-called Energy Flexibility Platform. Both components together form a runtime environment enabling the interaction of various smart grid applications on one side and with smart appliances on the other side. Figure 12 illustrates the high-level design of the Energy Flexibility Platform & Interface (EF-Pi).

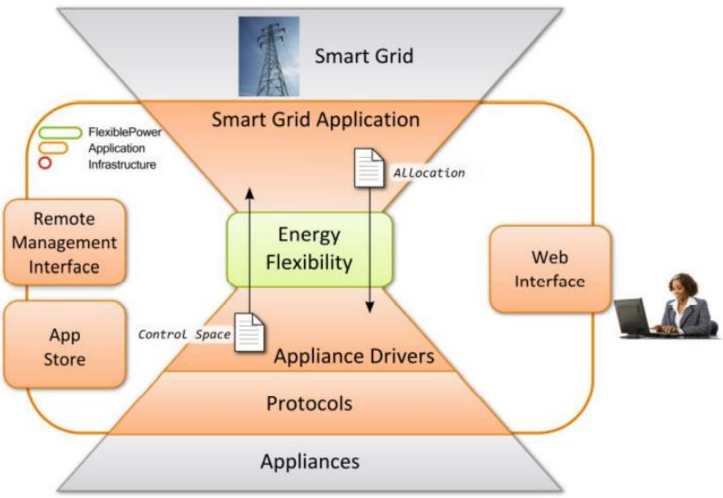

Figure 12: Energy Flexibility Platform and Interface Architecture Overview ([21])

A key functionality of the Energy Flexibility Platform & Interface is its ability to abstract energy flexibilities from vendor dependent implementations, by relying on vendor specific appliance drivers. These drivers can be connected to their respective appliances by any physical layer protocols such as Zigbee, Z-Wave, PLC, WiFi, Ethernet or a proprietary protocol. To the upper layers, the appliance drivers provide abstract models of the underlying energy flexibility (flexibility potential) by means of so-called control space (CS) elements. EFI distinguishes four different control spaces ([21]):

- Uncontrollable CSs that do not offer flexibility but are measurable
- Time-shiftable CSs that support flexible scheduling but are constrained by a deadline
- Buffer/Storage CSs offering flexible production or consumption but are bounded to a buffer limit

- Unconstrained CSs offering flexible production and not bound to a buffer, e.g., gas generators.

On the upper layers, Demand-Side Management solutions such as OpenADR, can use the control space elements to determine a suitable usage profile of the device. Based on the usage profile, the upper layer can request an abstract device behaviour, e.g. turning it on or off, by means of so-called allocations. Upon allocation, the appliance drivers translate the abstract allocation to a device specific control sequence and send it to appliances.

The Energy Flexibility Platform & Interface are open source in order to encourage the development of further appliance drivers and the development of new applications ([20]).

SAREF4ENER

The Smart Anything REFerence ontology (SAREF) is a reference ontology defining a set of concept and categories defined by their properties and relations (see Figure 13). Its aim is to help achieve interoperability among IoT projects. Its development started in 2013, backed by the European Commission in collaboration with the European Telecommunication Standardization Institute (ETSI). SAREF is published as a series of ETSI technical specifications, consisting of a modular framework that comprises a generic core ontology for IoT and 10 domain-specific extensions (ETSI TS 103 410, parts 1–10), such as SAREF for Energy, Buildings and Cities, amongst others.

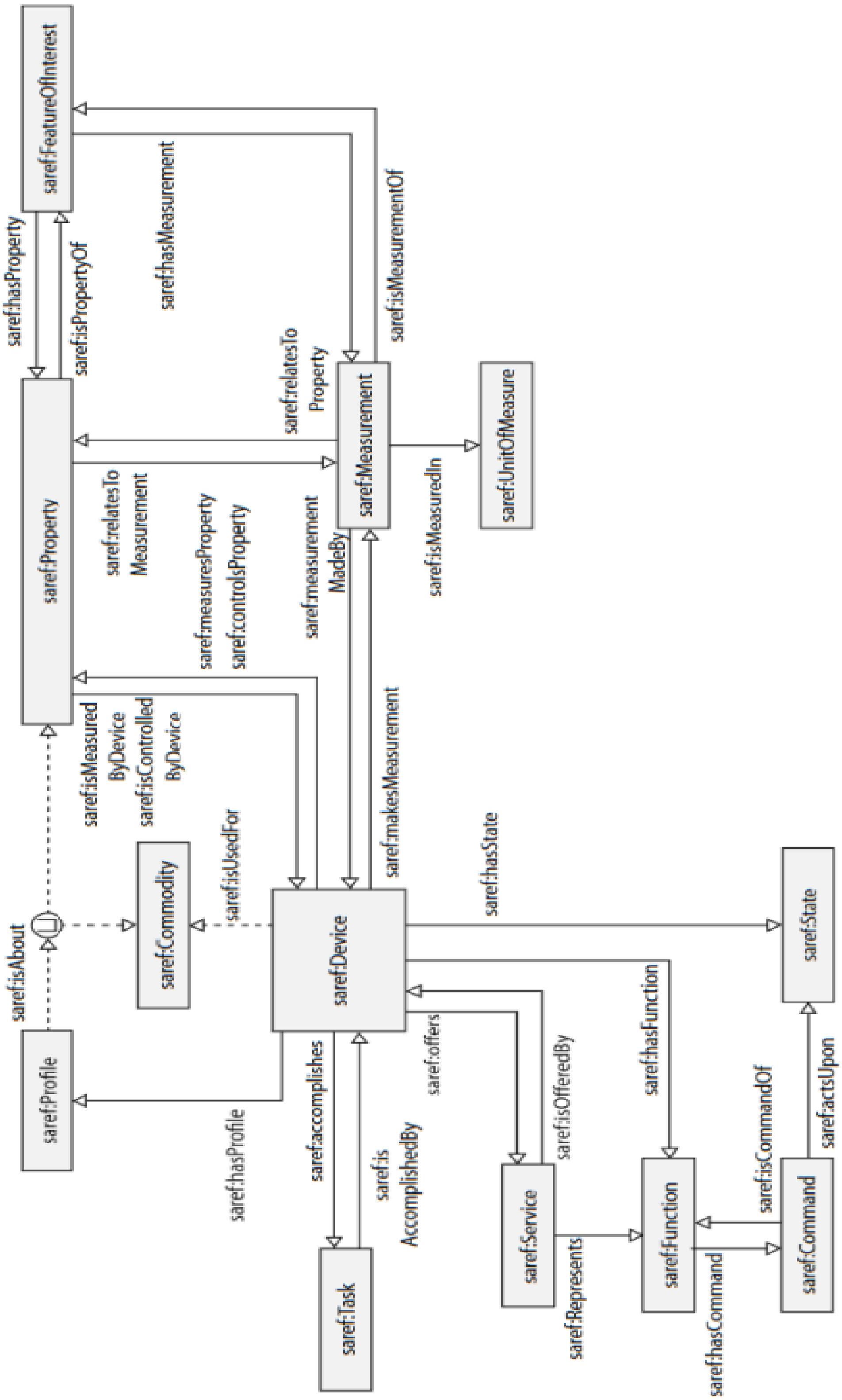

Figure 13: Overview of the SAREF ontology

In total, SAREF contains 81 classes, 35 object properties and 5 data properties. Most important is the concept of ***Device***, which is defined as a tangible object designed to accomplish a particular ***Task***. In order to accomplish this task, the device performs a ***Function***. For example, a temperature sensor is a device of type saref:Sensor, designed for tasks such as saref:Comfort, saref:WellBeing or saref:EnergyEfficiency, and performs a saref:SensingFunction. A ***Command*** is a directive that a device needs to support to perform a certain function. Depending on the function(s) it performs, a device can be found in a corresponding ***State***. A device that wants its function(s) to be discoverable, registerable, and remotely controllable by other devices in the network can expose these functions as a Service. A device can also have a ***Profile***, which is a specification to collect information about a certain ***Property*** or ***Commodity*** (e.g. Energy or Water) for optimizing their usage in the home/building in which the device is located. A ***Property*** is defined as anything that can be sensed, measured or controlled by a device, and is associated to measurements. For example, a temperature sensor measures a property of type saref:Temperature. A ***Measurement*** is the measured value made over a property and must be associated to a unit of measure and a timestamp.

SAREF4ENER (previously called SAREF4EE) is an extension of SAREF that was created in collaboration with EEBus and Energy@Home to enable the interconnection of their different data models, Energy@Home developing and promoting technologies and services for energy efficiency in smart homes, based upon the interaction between user devices and the energy infrastructure. SAREF4ENER is thus meant to enable the (currently missing) interoperability among various proprietary solutions developed by different consortia in the smart home domain. By using SAREF4ENER, smart appliances from manufacturers that support the EEBus or E@H data models will easily communicate with each other using any energy management system at home or in the cloud.

SAREF4ENER extends SAREF with 63 classes, 17 object properties and 40 data type properties. It focuses on demand response scenarios, in which customers can offer flexibility to the Smart Grid to manage their smart home devices by means of a Customer Energy Manager (CEM). In the ETSI specification (see [18]), the SAREF4ENER is illustrated with four use cases:

- Use case 1: configuration of devices that want to connect to each other in the home network, for example, to register a new dishwasher to the list of devices managed by the CEM
- Use case 2: smart energy management/ (re-)scheduling appliances in certain modes and preferred times using power profiles to optimize energy efficiency and accommodate the customer's preferences
- Use case 3: monitoring and control of the start and status of the appliances
- Use case 4: reaction to special requests from the Smart Grid, for example, incentives to consume more or less depending on current energy availability, or emergency situations that require temporary reduction of the power consumption

4.2. Standards analysis

First, it is important to mention that the communication at the asset level will depend on the technologies already deployed on the territory of Mayotte. Thus, even if we will recommend some standards in section 4.3, the final choice will be driven by:

- The EVs available in Mayotte. For further information, please refer to Task 6.1
- The PVs and inverters installed in Mayotte. For further information, please refer to the Annex and section 8.1 detailing the current practice in Mayotte
- The household's devices that can be piloted and already installed in Mayotte. For further information, please refer to Task 5.3

In this section, we will thus exclusively assess the standards relevant for communication at SO level. First, we assessed the standards in terms of services supported (registration, pre-qualification, forecasting, market operation, delivery, validation and settlement – see section 3.2 for details). Then, as most considered standards were covering the same services, we decided to extend our analysis by assessing other criteria such as:

- Its maturity – according to our own assessment, a mature standard is a standard widely accepted, available on the market, implemented in many projects and with massive roll-out for feedback.
- Its acceptability in Europe and in France – as the MAESHA solution is intended to be replicated on many European islands (St Barth, Gran Canaria, Favignana, Wallis & Futuna, Gozo), it is important to ensure the acceptability of the standard at the European level to ensure an easier integration of the solution by other SOs.
- Its scalability – the MAESHA solution is being developed to support five use cases specifically designed for Mayotte. However, follower islands might have other needs and the solution, and hence the standard, should be capable to support other use cases with minor adaptations.
- The access to open specifications – to ensure replication and allow external stakeholders to use the MAESHA solution, it is preferrable to select a standard with open specifications that is easily accessible.
- The data format – as the MAESHA solution will support frequency control, it is important to have quick data interchange: JSON is thus to be preferred as it is specifically designed for such applications. Mind that with increasing communication bandwidth the disadvantages of more complex data formats like XML diminish.
- Security aspects – as individual data will be collected, cybersecurity and security concerns should be considered at early stages. Please refer to Task 7.3 for details.
- Other identified limitations – based on their experiences, partners have identified potential limitations to the use of the standard in MAESHA.
- Other identified benefits – based on their experiences, partners have identified potential benefits to the use of the standard in MAESHA.

Table 7: Comparison of standards - supported services

Services	CIM extension for markets (IEC 62325)	Electricity Balancing Process	EQUIGY	OpenADR	USEF/UFTP	FlexOffer
Registration	Yes, the registration service has been added in IEC 62325-301:2018	Yes, the registration of the Reserve Object is done during the pre-qualification phase. (It also entails the identification of all its characteristics, such as capacity, rate of response, activation time, etc.)	Yes	Yes RegisterService is a service covered by OpenADR 2.0	Yes	No
Pre-qualification	Available, but not much used at the moment	Yes, the pre-qualification of reserves is part of the process	No	No	No	No
Market operation (flexibility bids management)	Yes	Yes	Yes	Yes Part of the EventService	Yes Part of the Validate phase	Yes
Delivery (flexibility activation management)	Yes	Yes	Yes	Yes Part of the EventService	Yes Part of the Operate phase	Yes
Validation	Covered by the IEC 62325-451-4: Settlement and Reconciliation Business Process, Contextual and Assembly Models for	Yes (daily)	Yes	Yes Validation data can be exchanged through the ReportService	Yes, the validation is performed by both SO and aggregator and is part of the Settle phase	No

	European Market					
Settlement	Covered by the IEC 62325-451-4: Settlement and Reconciliation Business Process, Contextual and Assembly Models for European Market	Yes	No	Yes	Yes, the standard proposes settlement calculation over a one-month period	No

Table 8: Comparison of standards – other criteria

Criteria	CIM extension for markets (IEC 62325)	Electricity Balancing Process	EQUIGY	OpenADR	USEF/UFTP	FlexOffer
Maturity	High	Medium	Low	High – Mature and widely used in the industry (100+ appliances are already OpenADR certified)	Medium	Medium
Acceptability in Europe, in France	Widely accepted in Europe. Used also by ENEDIS, main French DSO, in its E-flex platform	Widely accepted in Europe. The standard is used in the ongoing European projects PICASSO, TERRE and MARI, in which RTE, the French continental TSO is involved	Start to be accepted in Europe (the Netherlands, Italy, Switzerland, etc.). Not used in France so far	Has been used in several European projects (e.g., ELBE, GGIP) but stakeholders highlight the US-centred vision of the standard, despite its IEC standardization in 2019	Has been used in several energy projects across Europe (InterFlex, Fusion, etc.)	Has been used in several European projects (Mirabel, Totalflex, Arrowhead, DiCyps, Goflex, GIFT, and Fever)

Scalability	High – some working groups are still making the standard evolve	High - the standard has been updated lately to support more services (2022)	High	Medium	Medium – the USEF foundation ceased to exist on July 1st, 2021 as their mission was accomplished. No evolutions of the standards are thus expected. However, the standard seem easy to extend as adaptations and modifications were proposed in the European projects X-FLEX and MERLON	High – the FlexCommunity was founded recently and their ambition is to build on past experiences to propose a robust and future-proof standard
Open specifications available?	Yes, in the ENTSO-E EDI library	Yes, in the ENTSO-E EDI library	No	Yes	Yes, in the USEF website	Not yet, but planned for 2022
Data format	XML	XML	JSON	XML	XML	XML
Identified limitations	• Represents primarily the perspective of the TSOs and needs (minor) extensions for DSO's purposes – the current CIM coverage for other flexibility services/products besides balancing is not necessarily	• Limited feedback	• Limited feedback • No specifications available	• US-oriented – the notion of opt-out is not accepted in Europe	• Represents primarily the perspective of the DSOs	• Flexibility needs are not supported

	sufficient • Is so large that it requires a relative large amount of time and effort to understand					
Identified benefits	• Supported by ENTSO-E • Covers all needs for flexibility trading and flexibility provision • Used by ENEDIS, the main continental French DSO, for its flexibility platform and for some data exchanges between information systems (e.g., load curves) • Already implemented by cyberGRID (commercially and tested for	• Used by RTE, the continental French TSO • Implementation guides are available for RR, aFRR and mFRR	-	• Suitable to be used in multiple places in the EV chain	• Public standards freely available	• Used in innovation projects (Mirabel, Totalflex, Arrowhead, Goflex, GIFT and Fever)

	DSO flexibility provision in H2020 InteGrid)					
Security aspects	• Yes	• Yes	• No information available	• Cybersecurity mechanisms for risk mitigation are described - From the security perspective, OpenADR 2.0 aims to conform with the NIST Cyber Security requirements and follows the guidelines provided by the “Security Profile for OpenADR”.	• USEF follows the principle of privacy and security by design. Privacy-value creation trade-offs, data management, data communication, confidentiality, integrity, availability, disaster recovery, identification-authentication-authorization and risk assessment are explored in the USEF Privacy and Security Guideline (see [30])	• Not considered so far

4.3. RECOMMENDATIONS

4.3.1. On the SO level

On the SO level, first conclusions can be drawn from the analysis on services supported (see Table 7):

- Considered standards cover approximately the same services, with the exception of FlexOffer, which only covers the market operation and delivery services. For that reason, this protocol was quickly disregarded.
- The EQUIGY protocol seems really promising, as it looks similar to the Electricity Balancing Process standard with some adaptations already identified as needed by MAESHA partners (e.g., JSON rather than XML). However, with little information on it and no public specifications available, it was quite difficult to progress on the assessment of the standard. For those reasons, EQUIGY was also disregarded.
- OpenADR and UFTP do not consider the pre-qualification process. However, considering the data exchanged requirements presented in section 3.2, this process has a low priority for standardization in MAESHA and can be done manually. The two standards were thus further considered for the rest of the analysis.

To further assess the relevance of CIM Market, Electricity Balancing Process, OpenADR and UFTP for MAESHA, we looked at two other criteria, particularly important for the project: the maturity of the standard as well as its acceptance in Europe:

- CIM and OpenADR are the most mature standards, widely used in Europe and in the US respectively
- All four standards are quite well accepted in Europe. OpenADR is sometimes criticized to be too US-centric (with the notion of opt-out, for instance) but its IEC standardization in 2019 should help in its deployment in Europe.

The previous analysis did not allow us to select one standard in particular, as most of them were performing quite well. However, as the MAESHA solution will be demonstrated in Mayotte and will be used by its System Operator, Electricité de Mayotte (EDM), we decided to look at potential harmonization with continental France. EDM has indeed, among other roles, a role equivalent to the one of RTE, the continental French Transmission System Operator and interacts with the main continental French Distribution System Operator, Enedis. As an example, EDM purchased the same modelling tool as Enedis (PowerFactory) and will deploy, in the near future, the smart meters developed by the DSO (Linky) on the territory of Mayotte. Our analysis showed us that RTE and Enedis will or were already using CIM-based protocols:

- RTE will connect to the MARI, PICASSO and TERRE European platforms, mentioned in section 4.1.1.4 and will use the Electricity Balancing Process protocol.
- Enedis is using a CIM-based data model in its E-Flex platform, as described in [4] (see section 3.2 of the document). The platform enables the exchange of information needed to match the supply and demand of a local flexibility mechanism and has thus introduced the notion of location in the CIM Market v2 data model.

To harmonize with continental France, we thus decided to also consider a CIM-based protocol for the MAESHA solution: the Electricity Balancing Process with some adaptations to consider the DSO needs and to fully meet the requirements of our solution. Please refer to section 4.4 for further details on the adaptations needed.

4.3.2. On the asset level

On the asset level, we recommend the following:

- For the communication with EV charging points, we would recommend OCPP as it is currently the main standard used for communicating with EVSEs, the IEC 63110 being still under development. OCPP 1.6 is already supported by several EVSEs manufacturers but OCPP 2.0 better supports V2G than OCPP 1.6. Please note that V2G will be fully supported by OCPP 2.1, which is under development.
- For the communication with the Distributed Energy assets, we would recommend the SunSpec over Modbus profile or the IEC 60870-5-104, as these solutions are widely used.
- For the communication with energy appliances deployed at home, we would recommend EEbus as it supports relevant use cases and has a good support from the industry.

Again, on the asset level, those standards are recommended based on the analysis detailed in this document but, most importantly, we will have to take into account the capabilities of the assets available in Mayotte.

4.4. Needs for adaptations

As mentioned in its name, the Electricity Balancing Process is a solution dedicated to balancing and frequency control. It thus perfectly covers the project's needs related to UC1 "Frequency control".

The Electricity Balancing Process however does not support the DSO needs. DSO challenges are indeed local and the notion of location is lacking in the standard. An extension of the standard is thus required, by, at least, adding the connection point of the asset in the Distribution network. To not reinvent the wheel, we will rely on the CIM extension proposed by Enedis in its E-Flex platform and detailed in InterConnect Deliverable 4.1 (see section 3.2 of [4]), that adds the following items:

- The solicitation or flexibility request issued by the distributor to ask aggregators for offers for a given location and period to meet a grid constraint identified by the distributor. The request is created using the data model described in Table 9 below.
- The flexibility offer from the aggregation platform to the distributor represents the possibilities of modulating the consumption/production of customers belonging to the entity over a given period. Please note that an entity can be a MV/LV substation or a set of client sites. The parameters of the flexibility offer are represented in Figure 14 below.

Figure 14: E-Flex flexibility offer parameters (source: [4])

- The request for activation of a flexibility offer, sent by the DSO to the aggregation platform, relates to an existing offer.

Table 9: Flexibility request message structure (source: [4])

MarketDocument	Description
mRID	Unique object identification number
revisionNumber	Version number of the object (incremented for each transmission of the same document)
createdDateTime	Date and time the document was created
type	= *"Operator Flexibility Offer Request"* By convention, the type field contains the name of the transaction
Subject	= *"Offer Request"* By convention, the subject field contains the name of the main object Business dealt with in the transaction
<Sender_marketParticipant> **mRID**	DSO ID
<Sender_marketParticipant> **name**	DSO name (optional)
<Sender_marketParticipant> **roleType**	= *"DistributionSystemOperator"*
<Receiver_marketParticipant> **mRID**	Aggregator ID
<Receiver_marketParticipant> **name**	Aggregator's name (optional)
<Receiver_marketParticipant> **roleType**	= *"DistributionFlexibilityOperator"*
Domain	**Flexibility entity on which an offer is expected to be made** **Rule:** **- a solicitation may designate more than one entity** **- a solicitation sent to an offeror includes at least one entity**
mRID	The code of the structure (e.g., the MV/LV substation, MV client substation) on which the DSO expresses a need for flexibility

Name	Name of the structure (optional)
TimeSeries	**Object describing the desired power differences**
BusinessType	= *“aggregatedRequestPower”*
Measurement_Unit.**name**	= *”KWT”*
FlowDirection.**direction**	= *“A01” or “A02”*
Period	**Object representing the chronicle of power**
Resolution	= *PT30M*
Point	**Each point describes the time step of the chronicle** **Rule:** **- The number of points entered must be equal to the resolution**
Position	Sequential value (starting with 1)
Quantity	Required power differential

5. Interoperability testing methodology

The MAESHA solution is characterized by multiple components. For the proper operation of the MAESHA solution, it is important to test that all components correctly interact with each other. Once connectivity between all components is checked, we will verify that the communication between interfaces works as intended in terms of correct forming of data messages, interpretation of received information and security. This section details the interoperability testing methodology to apply in MAESHA.

5.1. Interoperability testing strategy

As described in section 3.1, the MAESHA solution is composed of 20 different interfaces that will support several communication standards (Electricity Balancing Process, OCPP, SunSpec etc.). Testing the full implementation of all standards being effort- and time-consuming, we decided to adopt the following strategy for the interoperability testing of the solution that will be performed in Task 8.3:

- On the asset level, we will rely on industrial certifications when available. For instance, the Open Charge Alliance proposes an OCPP 1.6 certification program to certify the compliance of products to the OCPP 1.6 specifications. Similarly, the SunSpec alliance proposes certifications for Distributed Energy assets. Those certification programs are indeed complete, up-to-date and the certification is provided by a neutral third party that can be trusted.
- On the SO level, the interfaces A1, B1, B2 and B3 are much more critical from an interoperability point of view. The standard used to exchange flexibility data has been chosen but some adaptations are needed (see 4.4). Special focus should thus be put on those interfaces during the interoperability testing process to ensure a good communication between all involved stakeholders. For that reason, we decided to rely on the Joint Research Centre (JRC) interoperability methodology and to apply it to MAESHA.

5.1.1. JRC methodology

The Smart Grid Interoperability Laboratory (SGILab) at the Joint Research Centre (JRC) of the European Commission has produced in 2018 a unified approach towards a European framework for developing interoperability testing specifications (see [31]). A successful development and deployment of the future smart grid requires indeed a better understanding of how components interoperate and how the proposed standards ensure interoperability among those components.

The JRC SGILab methodology could be seen as a set of best practices the developer could follow to complete the interoperability test in a smooth way. The methodology helps the user through a step by step process to create smart grid interoperability testing objects, namely the Use Cases (UC), the Basic Application Profiles (BAP) and the Basic Application Interoperability Profiles (BAIOP). It keeps track of the testing specifications along the development of the testing process from conception to realization.

The flowchart of the JRC methodology is depicted in Figure 15 below. It is composed of six steps:

1. Use case elaboration
2. Basic Application Profiles (BAP) creation
3. Basic Application Interoperability Profiles (BAIOP) creation
4. Statistical Design of Experiments (DoE)
5. Testing

6. Statistical analysis of experiments

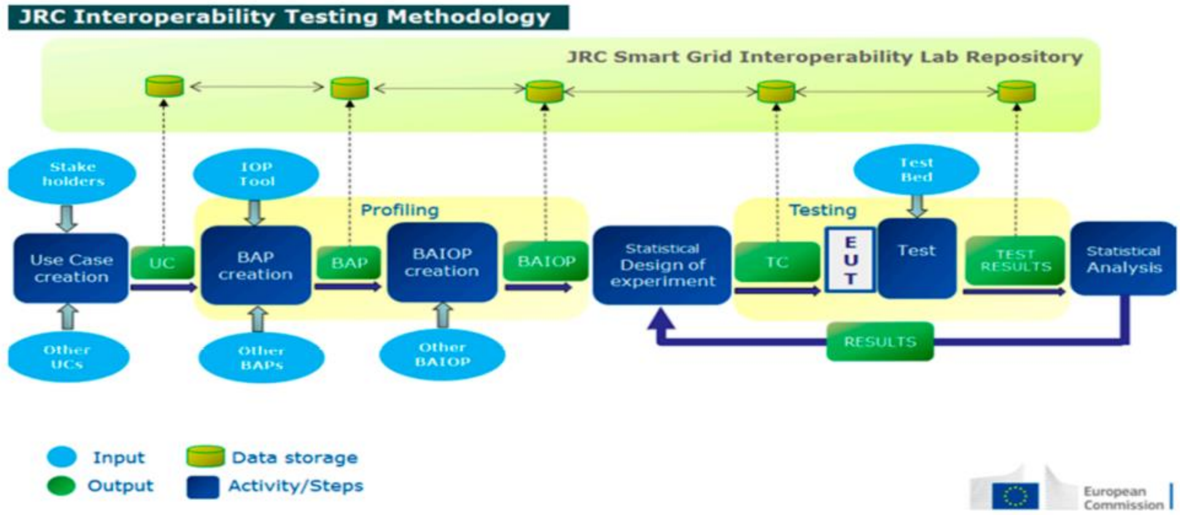

Figure 15: JRC proposed methodology flowchart (source: [31])

BAPs and BAIOPs creation is part of the profiling phase. Those profiles should describe:

- How a standard can be used to support the requirements of a specific function (described in the use case)
- The way the standard will be used and its options fixed
- All information that is required for a producer to create payload instances, for a consumer to interpret payload instances and for an impartial party to judge compliance of payload instances.

BAPs and BAIOPs for the interfaces A1, B1, B2 and B3 will be detailed in Deliverable 8.3 in a later phase of the MAESHA project, however a first BAP was defined to assimilate the JRC methodology.

5.1.2. First Basic Application Profile (BAP) for MAESHA

First, it is important to mention that the interfaces of interest (A1, B1, B2 and B3) are only used in UC1 “Frequency control” and UC3 “Minimization of the consumption peak” (see [1]). We will thus focus on those two use cases for the creation of the BAPs and BAIOPs for MAESHA.

To define the first BAP for MAESHA, we used the BAP template provided by the JRC in its technical report (see [31]).

5.1.2.1. BAP Identifiers

BAPs ID	***USE CASE ID***	***Standards***
BAP 1	UC3 – Minimization of the consumption peak	IEC 62325-301 (CIM Market) extended

5.1.2.2. Referenced documents, terms and definitions

Source(s) / Literature	***Link***	***Conditions (limitations) of Use***

ENTSO-E EDI Library	https://www.entsoe.eu/publications/electronic-data-interchange-edi-library/	Public
ENTSO-E code list (v81)	https://www.entsoe.eu/publications/electronic-data-interchange-edi-library/	Public
IEC 61968-100:2022 "IEC Implementation profiles for application integration"	https://webstore.iec.ch/publication/67766	Not freely accessible
MAESHA D1.1	Published in https://www.maesha.eu/deliverables/	Public
MAESHA D1.4, section 4.4	Will be published in https://www.maesha.eu/deliverables/ once approved by the EC	Public
InterConnect D4.1, section 3.2	https://interconnectproject.eu/wp-content/uploads/2022/02/InterConnect_D41_revJan2022_v0.pdf	Public

5.1.2.3. Functionality

Scope and Objectives of Functionality
The goal of the present study is to test the communication between the Flexibility Management and Trading Platform (FMTP) and the Virtual Power Plants (VPPs), considering a flexibility market for minimizing the consumption peak (see UC3 description, in MAESHA Deliverable 1.1). It is assumed that the registration as well as the pre-qualification processes have been performed. The interface and relevant communications to be tested are highlighted in red in Figure 16.

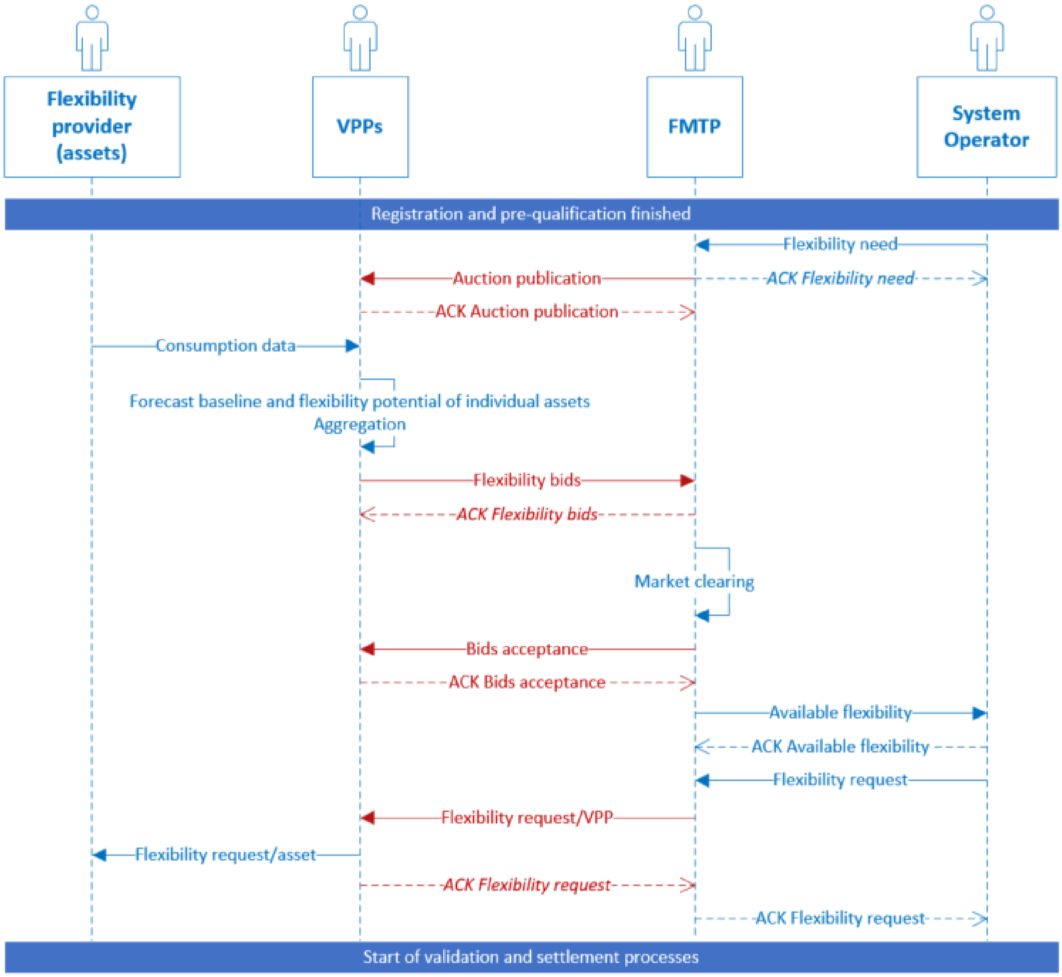

Figure 16: MAESHA local flexibility market workflow (source: internal)

First, the System Operator issues a request to ask aggregators for flexibility offers for a given location (entity) and period to meet a grid constraint identified. This equals the flexibility need. This flexibility need is forwarded to the VPPs.

Once the VPPs have collected various data from the customers belonging to the entity (MV/LV substation), the VPPs send the flexibility bids to the main platform. The main platform orders the bids and sends the flexibility offer to the SO. It represents the possibilities of modulating the consumption/production of customers belonging to the entity over a given period.

Finally, the DSO sends a request for the activation of a flexibility offer to the aggregator, relating to an existing offer. The aggregator must then contact the VPPs to comply with this request.

In MAESHA, flexibility needs, bids, offers and requests will be modelled following the CIM extension for the markets data model, extended to support the DSO needs (see section 4.4 of this document and section 3.2 of InterConnect Deliverable 4.1 ([4]).

5.1.2.4. Analysis of the standard

Analysis
For the analysis of the standard, every operation must be analysed separately. This means identifying the messages involved in the operation as well as the name, type and description of all fields comprehended in that operation.

Please note that, at the moment, only the flexibility need as well as the linked acknowledgement message are detailed in this BAP. This BAP is a draft and a final version of those specifications will be provided in future WPs.

Those messages follow the request/response message exchange pattern as described in IEC 61968-100. Flexibility need is a request message, structured as depicted in Figure 17. The acknowledgement message is a response messaged, structured as depicted in Figure 18.

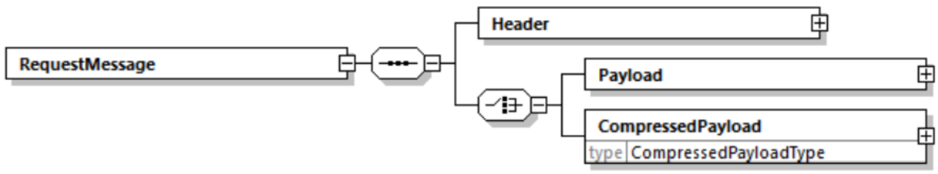

Figure 17: Structure of a Request Message

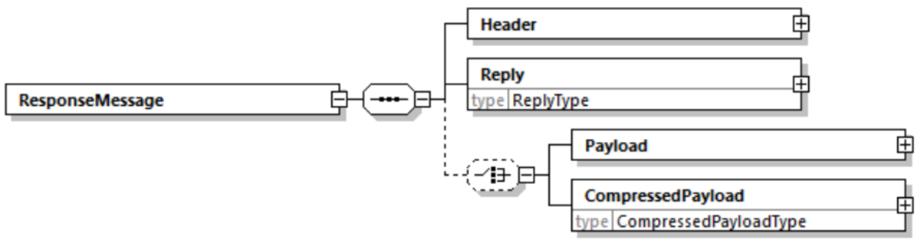

Figure 18: Structure of a Response Message

Flexibility need

The header of the flexibility need has the following structure:

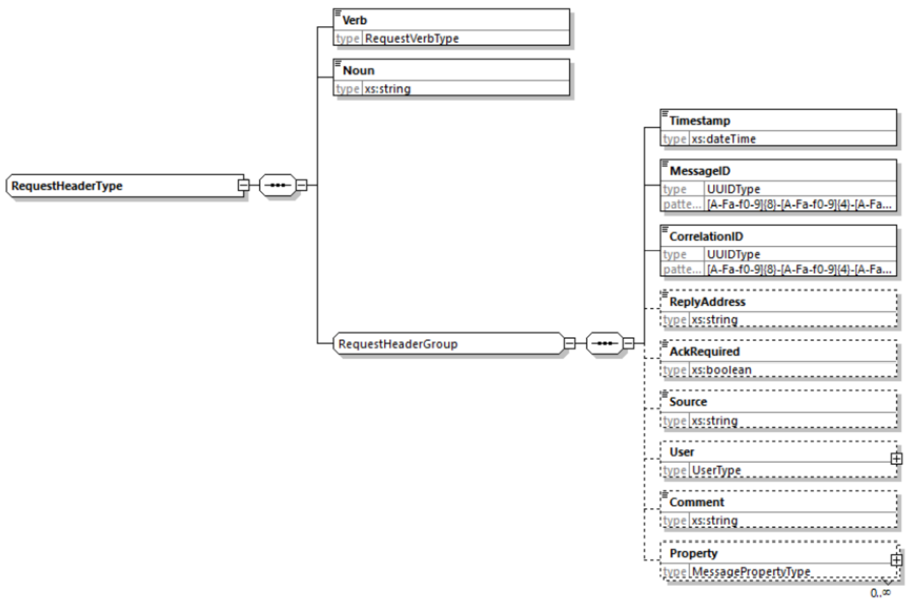

Figure 19: Structure of the <Header> element for request messages

For the details of the attributes, please refer to the section describing the <Header> element in the IEC 61968-100:2022.

The payload of the flexibility need is composed of the following fields:

Table 10: Payload elements of a flexibility need

Field Name	Field Type	Description
MarketDocument	Complex type (see below)	This identifies the flexibility request and the parties involved
Domain	Complex type (see below)	Flexibility entity on which an offer is expected to be made
TimeSeries	Complex type (see below)	Object describing the desired power differences
Period	Complex type (see below)	Object representing the chronicle of power
Point	Complex type (see below)	Each point describes the time step of the chronicle

Each field is of complex type and is composed of several subfields. For MAESHA, only the most relevant ones are required and described here.

Table 11: Details of payload elements of a flexibility need

Field Name	Subfield	Type	Values
MarketDocument	mRID	String	UUID
	revisionNumber	String	Coded value restricted to digits Pattern([1-9]([0-9]){0,2})
	createdDateTime	DateTime	Expressed in UTC: AAAA-MM-JJThh:mm:ssZ
	type	String	*"Operator Flexibility Offer Request"*
	subject	String	*"Offer request"*
	<Sender_marketParticipant> mRID	String	UUID DSO ID
	<Sender_marketParticipant> name	String	DSO name (opt)
	<Sender_marketParticipant> roleType	MarketRole	Composed of type, aliasName, description, mRID and name *"DistributionSystemOperator"*
	<Receiver_marketParticipant> mRID	String	UUID Aggregator ID
	<Receiver_marketParticipant> name	String	Aggregator name (opt)
	<Receiver_marketParticipant> roleType	MarketRole	Composed of type, aliasName, description, mRID and name *"DistributionFlexibilityOperator"*
Domain	mRID	String	UUID – code of the structure
	name	String	Name of the structure (opt)
TimeSeries	businessType	String	*"aggregatedRequestPower"*
	Measurement_Unit.name	String	Coded representation of the unit *"KWT"*
	FlowDirection.direction	String	Coded identification of the direction of energy flow *"A01" or "A02"*
Period	Resolution	Duration	Number of units of time that compose an individual step within a period

			"PT30M"
Point	position	Integer	Sequential value representing the relative position within a given time interval
	quantity	Decimal	Principal quantity identified for a point

Acknowledgement flexibility need message

The acknowledgement message is composed of the following elements:

- The <Header><Verb> shall be reply
- The <Header><Noun> shall have the same value as that of the original message for which the simple acknowledgement is being sent.
- A single <Reply><Status> element shall be included in the simple acknowledgement message:
    - <Reply><Status><Level> shall be fixed to OK
    - <Reply><Status><Code> shall be fixed to 0.3
- It may also contain an optional <Reply><Status><Reasons> element containing some arbitrary text.

No application-specific data shall be conveyed inside a simple acknowledgement message

5.2. Interoperability testing process

The interoperability testing process of MAESHA is made up of six steps:

Figure 20: Interoperability testing process

The interoperability testing process starts with a preparation phase:

- The first step consists of identifying the interfaces to be tested. In MAESHA, we have decided to preferentially test the 12 interfaces characterized as interoperability-critical (interfaces with criticality 2 or 3 in section 3.1).
- Secondly, the test coverage is identified - mostly by selecting the functions to be tested and the relevant valid and invalid behaviours to be considered. The test coverage is thus highly dependent on the use cases defined in [1] and on the scenarios description proposed in the IEC 62559-2 template.
- Then, partners will characterize each interface by detailing which components are involved, what data is exchanged and what protocol is used. For interfaces A1, B1, B2 and B3, the characterization will be done using the Basic Application Profiles developed by the JRC.
- Once interfaces are characterized, tests will be described. On a test template (like the BAIOPs proposed by the JRC), we will detail the test objectives, the test requirements, the initial state, the preconditions, the test body (i.e., action to be done, expected behaviour) and the postconditions.

Once prepared, the tests can be performed:

- First, we will conduct connectivity tests to check that the connection can be established between the components involved in each interface,
- Then, we will perform the proper interoperability tests, based on the test descriptions, resulting in PASS or FAIL verdicts. Every time a failure is encountered, it will be discussed if it is due to a bug of one of the components or to an ambiguity of the interface specification. Depending on that, either the component of the specification will be updated, and the tests will be run again with updated components. This process is performed iteratively until all the tests are set to PASS.

Note: these tests are usually performed together during a “plug-fest”, gathering all the components suppliers and allowing them to “plug” into each other.

Once this interoperability testing process will be completed, the integration tests, covering also functional behaviours, will be conducted in task T8.4.

6. Conclusions

This document reports the results of the Task 1.4 activities within the MAESHA project and presents the "interoperability-by-design" framework defined for the solution.

First, the analysis of the system architecture allowed us to identify the critical interfaces from an interoperability point of view - those interfaces will be the ones to consider in priority during our interoperability tests. Then, the analysis of the use cases enabled us to define data exchange requirements and to identify standard candidates for the communication of those data between components.

After reviewing potential standards for MAESHA, we compared the standards relevant for communication at SO level in terms of services supported. As the considered standards are approximately supporting the same services, we compared other criteria such as their maturity and their level of acceptance in Europe. Based on this assessment, we decided to implement the Electricity Balancing Process, a CIM-based standard, and to extend it to support DSO's needs. On the asset level, we recommended the most mature standards but the final choice will mostly be driven by the capabilities of the assets already deployed on the island.

Finally, we defined an interoperability testing strategy that we will implement in WP8 to validate the proper connection between each component. On that topic, we will rely on the JRC interoperability testing methodology.

The next steps are:

- As part of WP4: to define the exact specifications of the Electricity Balancing Process and its extension – specifications that partners will have to comply with to support the use cases defined for Mayotte,
- As part of WP8:
    - to define the missing BAPs and BAIOPs for the solution,
    - to test the interoperability of the solution, once all components will be available and ready.

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8. ANNEX

8.1. PV INSTALLATIONS IN MAYOTTE AND THEIR LINK TO EDM

In Mayotte, any newly-installed medium-voltage PV site producing more than 100kWp apparent power must be equipped with an ENSTO 2012 device and a high-speed internet connection (4G or optic cable). The ENSTO 2012 device allows for automatic exchange of measurement information between EDM and the PV site. The goal of EDM is to use the ENSTO 2012 device to send commands to reduce or even switch off the PV power production according to its needs in order to maintain grid stability. To ensure this stability, EDM is currently limiting the share of PV production below 36% of the total power production. At the moment, there are 7 PV sites with ENSTO 2012 devices installed, for a total peak power of more than 4.5MW.

The ENSTO 2012 devices use the IEC 60870-5-104 communication protocol. Data from all PV sites is uploaded to the EDM tool, ACE VISION. This software platform receives and stores measurements, monitors the operations, sends specific controls and is used for invoicing purposes. Eventually, PV sites equipped with an ENSTO 2012 will have a dedicated API on the EDM SCADA.

Furthermore, a few hundred low-voltage PV installations and old medium-voltage PV installations are equipped with SL 7000 devices which are used for remote reading and, if needed, switching the installation on/off. They are also connected to the EDM software platform, ACE VISION, via public switched telephone networks provided by France Telecom. The SL 7000 devices use HNZ protocol developed by Électricité de France.

Finally, in the future, EDM plans to use Chauvin Arnoux ALTYS electrometers with the EURIDIS protocol for the HV installations.

Table 12 summarizes the current practice depending on the installation, while Figure 21 provides a high-level overview on the MV installations with ENSTO 2012 together with the two electrometers.

Table 12: MV & HV Installations

MV installations	**HV installations**	
	Old configuration	**New configuration**
SL7000: used as remote reading and can also switch on/off installations	• SL7000: only used as remote reading • ENSTO 2012: allows automatic exchange of information between the DSO and the PV site. Therefore can reduce or increase production. Can also switch on/off installations	• ALTYS - Chauvin Arnoux: Will be use as remote reading as SL7000 is not compatible with ENSTO 2012 • ENSTO 2012: allows automatic exchange of information between the DSO and the PV site. Therefore can reduce or increase production. Can also switch on/off installations

Figure 21: High-level overview on the MV installations with ENSTO 2012 together with the two electrometers