

Integrating the Energy System – IES

Technical Framework on
Local Energy Communities

TF-LEC

Vol. 2

Version 0.5

First trial ☕ — contains no mature profiles yet ☹️

February 14, 2023

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The work is since progressing, and partners from the ERA-Net SES projects SONDER, R2EC and UCERS have been invited to contribute. More to follow in the years to come.

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1 About the Document

This document comprises Vol. 2 of the Technical Framework on Local Energy Communities, i.e., the collection of Local Energy Communities related IES Integration Profiles released and here included at the date this document was last compiled, i.e., February 14, 2023.

1.1 Document structure

The concept of Technical Frameworks and Integration Profiles is based on the established IHE (Integrating the Healthcare Enterprise [www.ihe.net]) approach to *IT interoperability* in the medical technology sector, adopted to the area of smart energy systems 2016–2019 by the IES Austria project [www.iesaustria.at]. Technical Frameworks are embedded in a business domain each, but may be referred to across sectors. The approach to interoperability is holistic, advising adequate integration of all stakeholders in compiling and maintaining Technical Frameworks [1].

IES specifies Volume 1 to be entirely informative, presenting the big picture, i.e., a business case (the trunk) and required business functions (branches), and Volume 2 to cover all the normative and technical specifications, i.e., the IES Integration Profiles, which are the independent documents (technical specifications) that comprise the *leaves* of the document *tree* (structure) that emerges from the business description (being the *soil* all is based upon).

Vol. 2 covers the IES Integration Profiles on Local Energy Communities, i.e., introduces the normative specifications required to develop interoperable sub-systems capable to integrate energy consumers and distributed energy resources (DER) in short term predictive balancing and trading of local energy supply and demand.

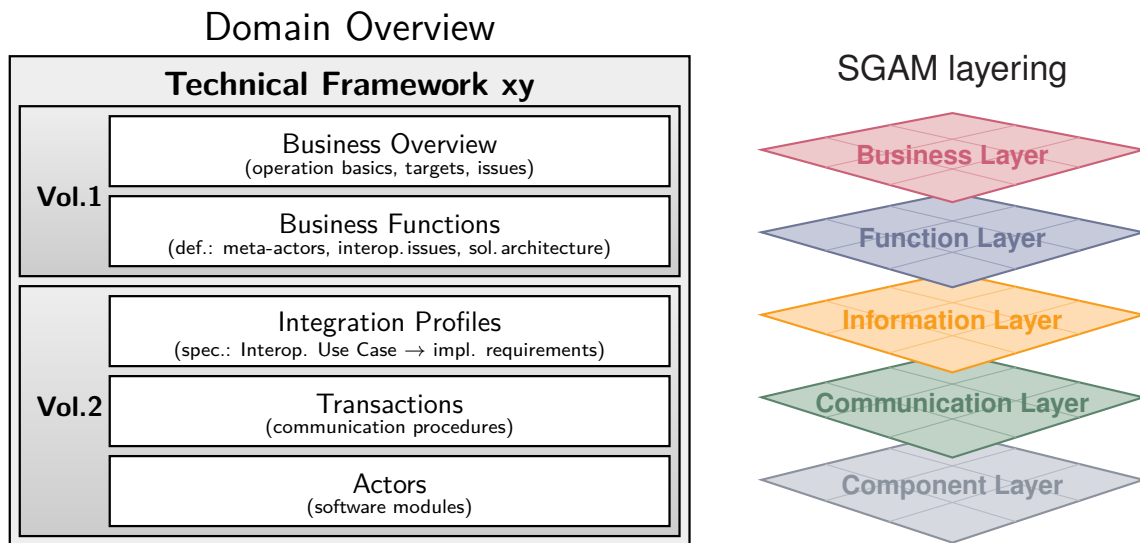


Figure 1.1.1: The IES Document Structure: roughly incorporating the five SGAM Layers [1].

Vol. 1 on Local Energy Communities closes with the informative specification of operational functionalities (*Business Functions*) and the naming of the independent IT systems that interact (*Meta-Actors*). Vol. 2 is a dynamic compilation, an open collection, of the normative IES Integration Profiles (IIPs) that state technical constraints and recommendations on how standards and good practice shall be harmoniously applied to achieve interoperability.

◇ Vol.1

- Business Case Overview (informative)
 - Typical applications
 - Relevant meta-actors
 - Related standards

- Business Functions (informative)
 - Describe interoperability issues (use IEC 62559 Use Case Methodology)
 - Use Case diagrams
 - Actor Transaction diagrams

◇ Vol.2

- Business Functions to Integration Profile mapping (normative)
 - Table(s) binding Integration Profiles to Business Functions
- Integration Profiles (normative)
 - Definition of Interoperability issue addressed (Use Case)
 - Definition of needed transactions
 - Definition of involved actors
- Transactions (normative)
 - Specification of individual steps and list of actors involved
 - Specification of used IT standards, options, variants, etc.
 - Specification of communication security and resiliency
- Actors (normative)
 - Specification of actors' interfaces
 - Specification of used IT standards, options, variants, etc.
 - Specification of actor safety and data security measures

The entire Technical Framework is embedded in a business domain overview, here on smart energy systems and Smart Grids in general. The structuring reflects the common approach to complex problems also underlying the V-model. The Smart Grid Architecture Model (SGAM) [2] uses this same layering approach to handle complexity by multi disciplinary separation.

↔ The structure of Technical Frameworks follows the *top-down* approach and the informatics tradition to first name items, than define them, and finally specify them. For example: name an algorithm, define what it does, and specify how to implement it, before actually coding it. The terms "*definition*" and "*specification*" are hence used accordingly. Writing a Technical Framework can be done in any order. Commonly, previous parts need amendment whenever later parts become changed or added because the context runs back-to-front.

↔ *Vol. 2* starts with assigning Integration Profiles to the Business Functions from Vol. 1. In this table also Integration Profiles from other Technical Frameworks may be assigned (*bundled*). Transactions and Actors are commonly specified profile-by-profile, but may as well be bundled from one Integration Profile into some other. Bundling shall prevent redundant specification. The bundling formalism is specified in [3] and further addressed next.

1.2 Composition of IES Integration Profiles

Vol. 1 covers the informative view, outlining business case(s) and potential functional requirements (Business Functions) of Local Energy Communities. Vol. 2 of the Technical Framework focuses on the *normative* specification of specific *technical features* (*Technical Use Cases*). Therefore, Vol. 2 is basically a collection of IES Integration Profiles that shall *harmonise* transactions and actor specifications (ABB_spec¹), covering profile specific *security considerations, naming conventions, response times, execution protocols, state machines, data models and formats, encoding schemes, transport channels and media, etc.*

¹According to TOGAF (The Open Group Architecture Framework) Architecture Building Blocks (ABB) approach [4]

These harmonised technical features shall be specified to the point required to interoperably implement (realise) required Business Functions. In general, such normative specifications (restrictions) are necessary only where involved Meta-Actors (sub-systems) may be developed and deployed by independent vendors.

In consequence, harmonised specification of interoperability relevant features (the IES Integration Profiles) shall be openly shared to achieve true interoperability. Therefore, IES Integration Profiles shall neither disclose Meta-Actor internal implementation details nor restrict vendors in their freedom to choose implementation means, as far as these are irrelevant for the interoperability of the deployed Meta-Actors.

◇ **IES Integration Profiles** result from strictly applying the Use Case Methodology specified in IEC 62559 [5]. Each IES Integration Profile shall be an individual document that can be used stand alone to interoperably implement a certain technical functionality. For example, how to remotely monitor the live measurements of a sensor in the field. Another IES Integration Profile could than specify how to record monitored data in a secure repository; and a third, how to implement secure authentication, authorisation and access control (AAA). All these exemplary profiles are per se independent but may be required together as (puzzle-)parts of some complex Business Function.

The examples for IES Integration Profiles given above are easy to understand and it should be clear that different flavours of these may be required for different Business Functions. For example, a simple sensor may not have the processing power to implement secure AAA, such that this feature may be needed server based and in the field can only be achieved by a securely barred hardware interface (e.g., a locked hatch).² Figure 1.2.1 shows this modular, still use case specific, composition of technical specifications supported by the IES document templates.³

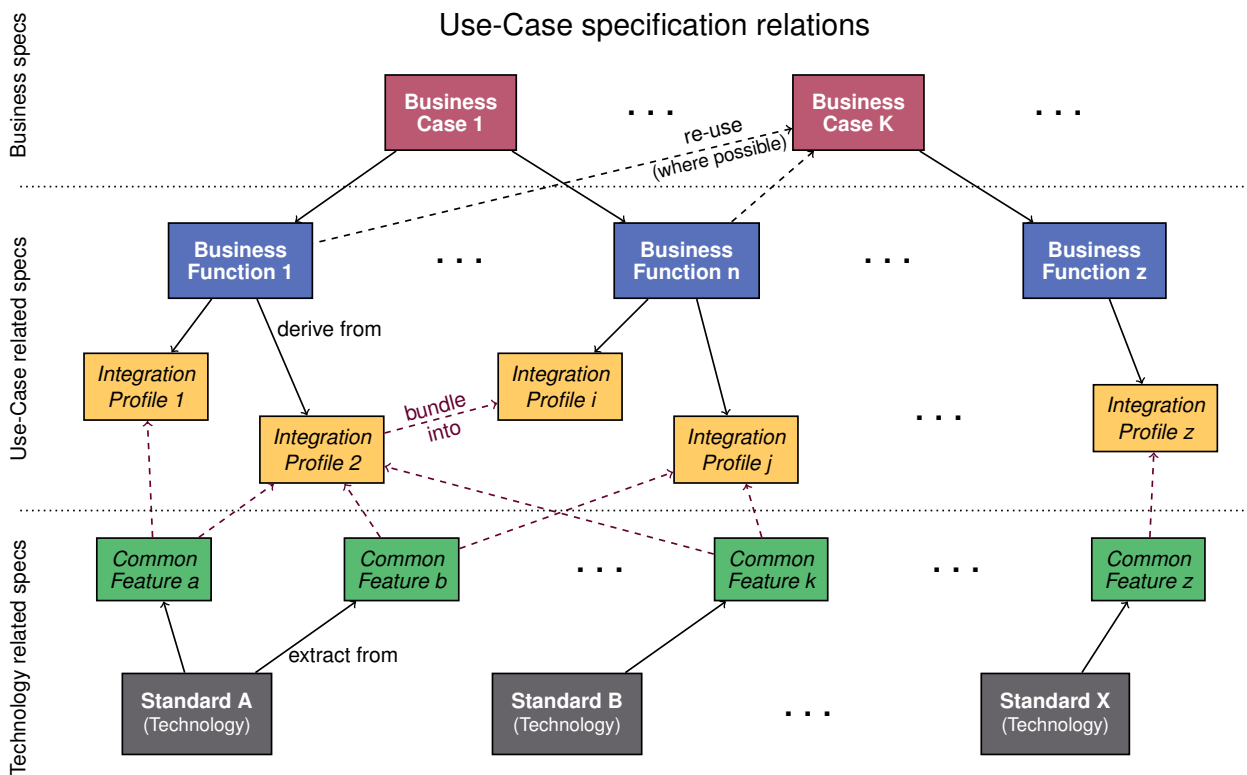


Figure 1.2.1: Use case centric still modular technical specifications composition supported by IES templates [6]

²Note that IES Integration Profiles are not restricted to software based solutions. Where necessary, interoperable hardware solutions shall as well be specified. Often the used hardware feature per se (here a hatch with a lock and a fitting key) is commonly known and needs no textual specification, such that a use case specific parametrisation in the IES Integration Profile is sufficient (e.g., specify the security class of the hatch and the lock). The same applies for commonly known software features. For example, the Internet Protocol (IP) needs not be specified, only the transport protocol (TCP, UDP, etc.) and if necessary also its flavour (Vegas, Reno, etc.) because latter implies the former.

³The use of *Common Features* is optional and not predefined in the document templates. Common Features are introduced to prevent repeated specification of manifold used, commonly well known, still mandatorily needed technical features.

In case a Technical Use Case to be specified is an extension or adoption of an existing one, the new IES Integration Profile (IIP) shall reference the original IIP, and shall only specify the added requirements and constraints, including potential deviations from specifications stated in the original IIP. Doing so is called *IIP bundling*.

If common practice or standards provide features that can be used in different flavours, than these features shall be specified once, as *Common Feature*, providing all the usage flexibility they offer. Common Features can be addressed by diverse IES Integration Profiles, which reduces the specification effort per profile to restricting the flexibility to the single harmonised usage that fits, i.e., best serves the business function to realise.

The modular approach shall minimise redundant, duplicate, and inconsistent specification of the same technical feature when used for different business functions. In return to the possibly added effort here, this approach reduces the implementation effort because a technical feature needs to be adopted to perform different tasks for different business functions only and not repeatedly understood and implemented in different flavours. The more modular Vol.2 is designed, the more consistent is the technical specification in the long term, and therefore, the easier to implement are the harmonised requirements that finally yield interoperability.

1.3 What is *interoperability*

According to dictionary: "*Ability of a system to work with or use the parts or equipment of another system*" [Merriam-Webster] the term *interoperability* refers to the ability of a system to work with parts and features provided by some other system. To do so, information is essential. First, to know how to use which parts, and second, how to address and control the used features of the other system.

To cooperate seamlessly the following five *interoperability levels* need to be considered:⁴

- **Legal:** common compliance with regulatory obligations and standards
- **Semantic:** uniform understanding and interpretation of information and operation means
- **Syntactical:** equal data formats, coding schemes, and encryption methods
- **Technical:** using the same communication means and protocols
- **Operational:** timely reliable provisioning of info/response

Orderly cooperation of systems is possibly where requirements are fulfilled layer by layer, and where all internal components of a device operate correctly, i.e., flawless. Imagine what happens if the unit of a metric differs (semantic issue): cooperation fails (e.g., the lander crashes) even though each system works perfectly to its specification. Malfunction of cooperation does not necessarily imply faulty implementation – internally everything may work fine. Consequently, *interoperability* cannot be assessed standalone without involving independent systems as test peers. Accordingly, INTEROPERABILITY CANNOT BE IMPLEMENTED.

Ad testing *interoperability* [ITU-T Z.450] says: "*Testing to assess the ability of two or more systems to exchange information and to make mutual use of the information that has been exchanged.*" Here *mutual use* is pronounced, i.e., all involved systems shall benefit. Thus, correct interpretation and trust in the correctness and beneficial use of exchanged information and provided features are likewise essential.

Other references, examples and notes

◇ **wikipedia.org:** "*Interoperability imply Open standards ab-initio, i.e., by definition. When a vendor is forced to adapt its system to a dominant system that is not based on Open standards, it is not interoperability but only compatibility.*"

◇ **interoperability-definition.info:** "*Interoperability is a characteristic of a product or system, whose interfaces are completely understood, to work with other products or systems, present or future, in either implementation or access, without any restrictions.*" Sadly this webpage proves itself semantic interoperability failure due to language complexity when definitions become translated. The German differs considerably: "*Interoperabilität ist die Fähigkeit*

⁴Five layers similar to the SGAM and the Technical Framework structure.

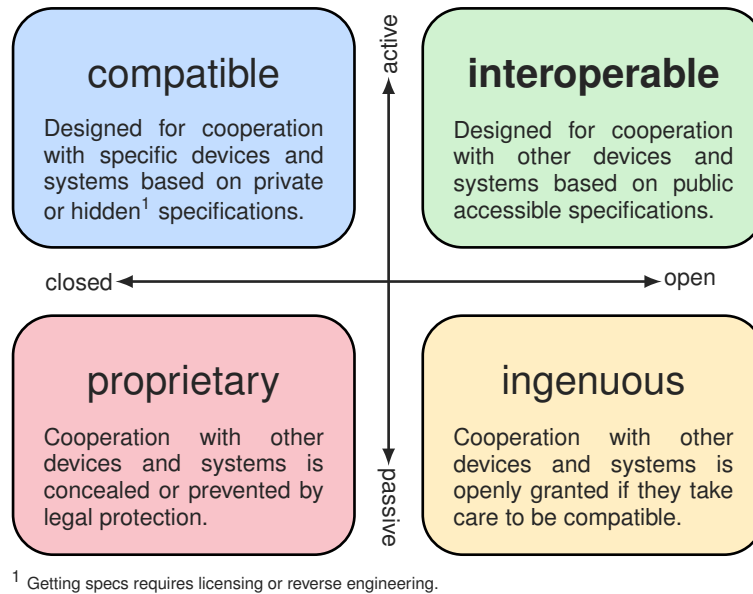


Figure 1.3.1: Matrix of cooperation options

eines Programms oder Systems (dessen Schnittstellen vollständig offengelegt sind) mit anderen gegenwärtigen oder zukünftigen Produkten oder Systemen ohne Einschränkungen hinsichtlich Zugriff oder Implementierung zusammen zu arbeiten bzw. zu interagieren."

↔ Only one definition in one language can be binding. No two or more, but all may be true and valid in their context. Not knowing how to interpret a particular definition it remains a rather unspecific composition of words, alike given names being composites of letters, basically. TERMS DESCRIBE CONTEXT ↔ CONTEXT SPECIFIES TERMS.

1.4 Brief introduction to the IES process

The dynamic interlinked IES document structure, especially prominent in Vol.2, results from TOGAF® (*The Open Group Architecture Framework*) sketched in Figure 1.4.1, and the IES relations to the EIRA© (*European Interoperability Reference Architecture*) sketched in Figure 1.4.2.

These approaches organise requirement management by decomposing the specification complexity into individually manageable chunks, and lead to the *IES methodology* outlined in [1] and the document templates based on the *Use Case Methodology* (IEC 62559).

The IES process (Figure 1.4.3) and its timing (Figure 1.4.4), centred on the peer-to-peer interoperability test-event called *Connectathon Energy*, yield the organisational framework to tackle these specification chunks in a cooperative manner (Figure 1.4.5) involving all relevant stakeholders as peers, contributing their individual expertise as needed in the course of the IES process.

The brain of the approach toward achieving interoperability are the *IES Integration Profiles*, which normatively state how to combine and implement established standards and good practice. The heart is the peer-to-peer testing activity at an event called *Connectathon Energy* because interoperability is about connectivity. The arms that get things going are on one hand the experts that formulate the requirements and on the other hand the developers (implementers) that test their prototypes among each other to assess their implementation of the requirements specified in profiles, and implicitly reveal ambiguities. The legs that shall get interoperable products to the market, are the *Results Browser* and the *Integration Statements* issued to state that a vendor can do profile compliant IT solutions, no more no less.

Independent whether a profile is new, revised, or stable, it can only be offered for testing at the *Connectathon Energy* if the required number and type of peers register systems for the testing of a particular profile. Unannounced ad-hoc testing of trial profiles may be possible, if the test plans and procedures (the test cases) are available on site. Inofficial tests may also be performed independent of the event on a pure peer-to-peer basis, however logging and test documentation by a neutral third party are in that case not possible and thus, integration statements cannot be issued based on such testing.

Jointly specifying the user requirements and technical necessities may be cumbersome, but can save some fundamental revisions induced by experts and professionals not included right from the start. It also helps to assure that a sufficient number of test candidates is available for interoperability testing at the *Connectathon Energy*.

◇ **Connectathon Energy:** The IES testing event is such entitled to highlight that it is about connecting systems and that nothing is hacked. The software modules tested are handled as black-boxes, i.e., as systems A and B in Figure 1.4.6, only the data exchange happening between these systems is monitored and analysed, not the features implemented within these systems.

The prime testing aim is to identify misunderstandings as early in the development process as possible, and to sort out any apparent specification ambiguities. Typically, early prototypes are tested at the event, often running in some development environment only, i.e., operational though still far from finished. These prototypes are commonly operated by the developers themselves because they are the onyl ones that know how to use the snippets at hand and what to expect.

In case problems pop up while executing the test cases and procedures, the developers (implementers) may fix them on site and repeat the test until they succeed. This particular detail makes the event extremely productive and at the same time forces a multi-day event and multi-day presence of the developers. Ample problem identification and fixing time fuels the vivid on-site enthusiasm that thrives on the protected/secured test floor. This maximises productivity and solution finding creativity, the learning of alternative fault detection and correction approaches from test peers, and general system understanding beyond company boundaries.

Because no final products are tested, the testing at a *Connectathon Energy* must not be mistaken with any kind of certification tests. The aim is complementary: testing at a *Connectathon Energy* shall prevent sunken development costs by revealing misunderstood requirements as early as possible and not at the end of the development process when products are handed over to accredited testing facilities for product certification. Thus, participating early in a *Connectathon Energy* will in general pay back by reducing the in average required number of certification

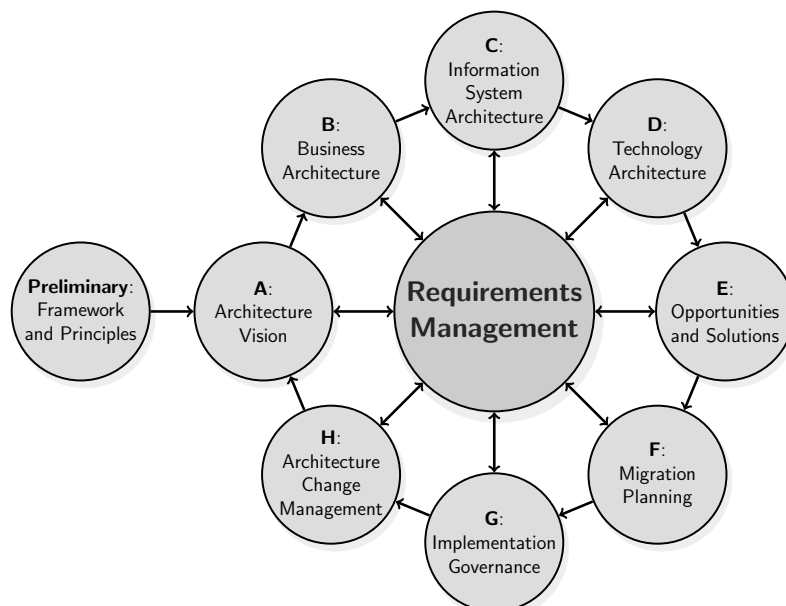


Figure 1.4.1: The Open Group Architecture Framework (TOGAF® ↔ www.opengroup.org/togaf)

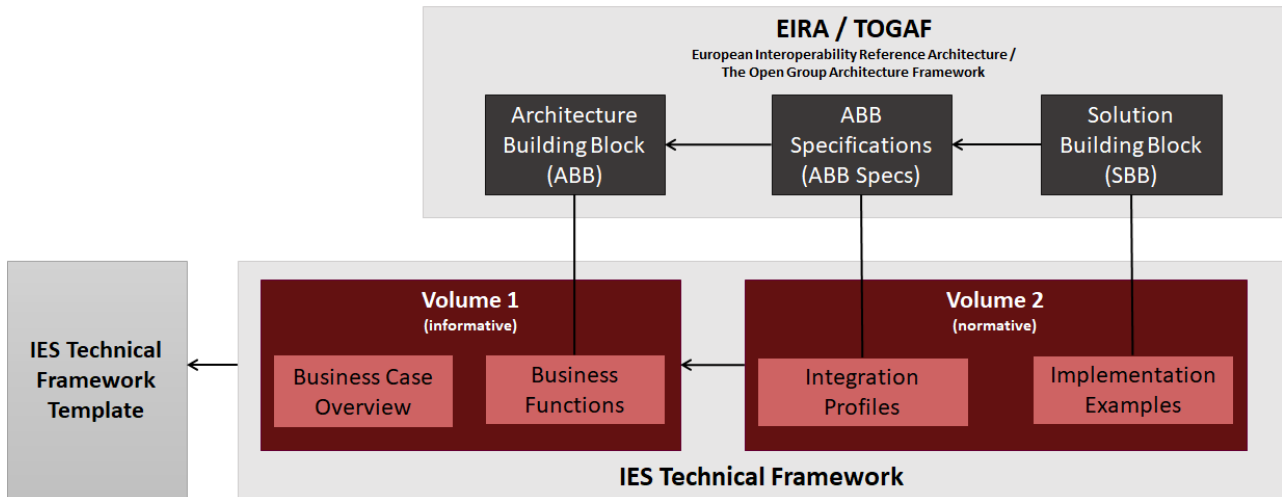


Figure 1.4.2: IES relations to the European Interoperability Reference Architecture [7]
 (EIRA© ↔ <https://joinup.ec.europa.eu/collection/european-interoperability-reference-architecture-eira>)

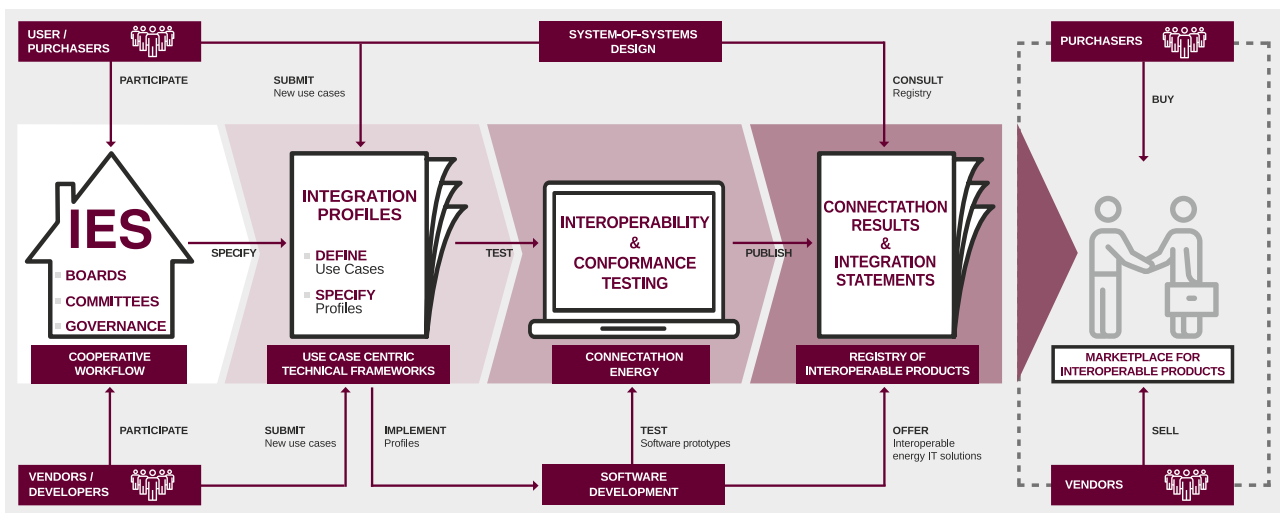


Figure 1.4.3: The IES Process [1]

attempts due to less misinterpretation of requirements, and also by reducing the requirements uncertainty that always challenges, and sometimes can paralyse, entire development departments.

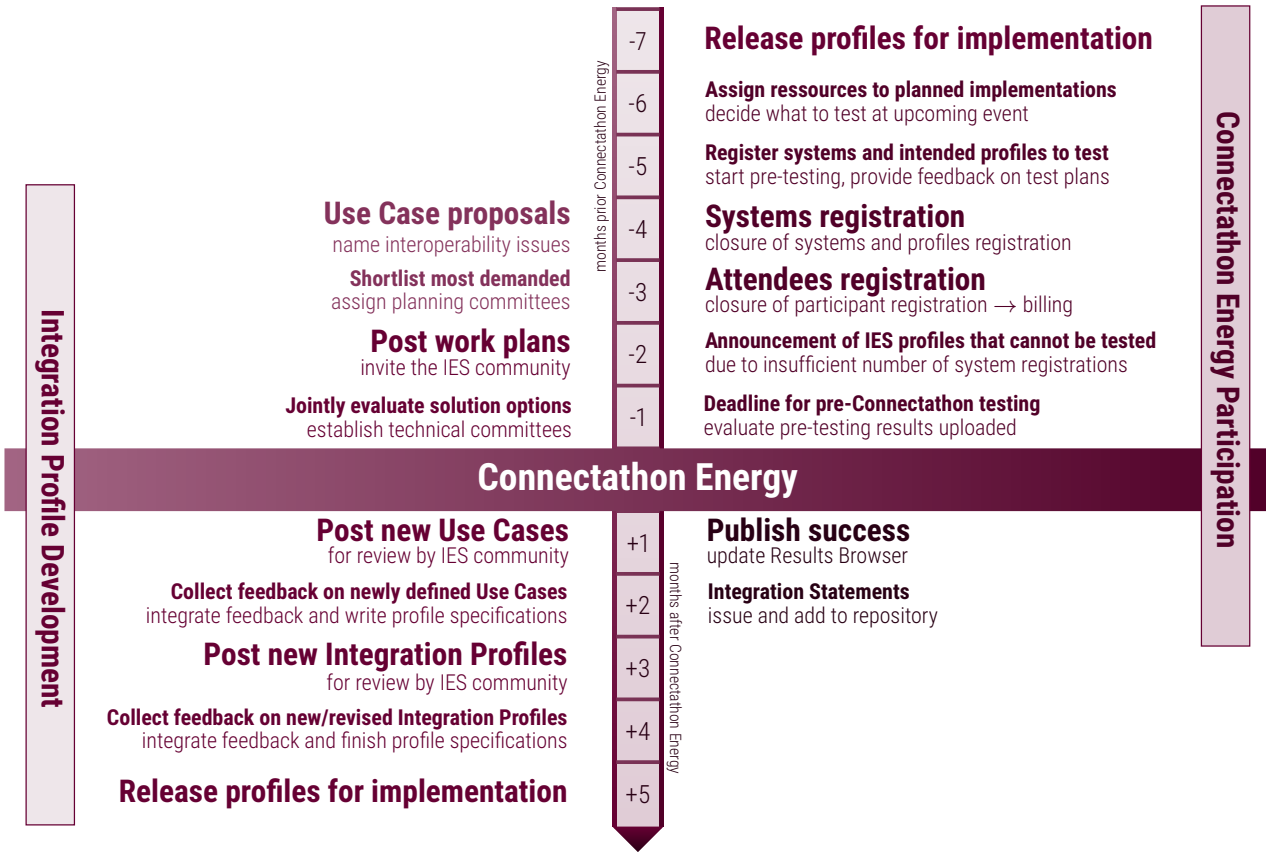


Figure 1.4.4: The timing of the IES Process [1]



Figure 1.4.5: Cooperation and co-creation fostered by the IES Process [1]

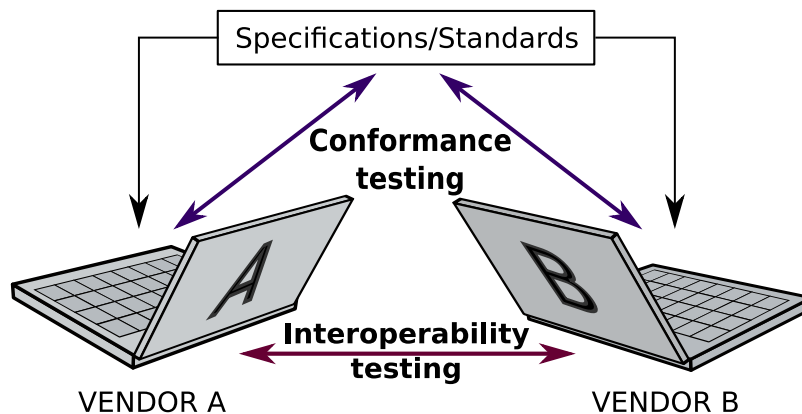


Figure 1.4.6: Interoperability testing at Connectathon Energy [1]

1.5 Definitions

Active customer is a final electricity customer, or a group of jointly acting final customers, that may produce, use, sell and store electricity, commonly self-generated within their premises (within confined boundaries), for whom these activities do not constitute a primary commercial or professional aim.

Actor is here a functional component of an IT system that executes operational tasks commonly in cooperation and/or coordination with other actors.

Aggregation refers to a function performed by a natural or legal person (an *Aggregator*) that combines multiple customer loads or their generated electricity for sale, purchase or auction in some *electricity market*.

Ancillary service means a service necessary for the operation of a transmission or distribution system, including balancing, steady state voltage control, fast reactive current injection, inertia for local grid stability, short-circuit current, black start capability and island operation capability, but is not including any congestion management.

Business Case is the economic viable application of an idea or technology.

Business Function is a feature required to be realised for a Business Case to work.

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

Demand response means the change of electricity load by a customer, in respect to the normal or current consumption pattern, in response to market signals, including in response to time-variable electricity prices, incentive payments, or other options for reimbursement.

Distribution refers to the transport of electricity at different voltage levels towards the delivery to customers, but does not include supply.

Distribution System Operator is the legal entity that is responsible for energy grid safety and persistent power supply.

Electricity consumer is a technical asset that consumes electric power when operated. In a market centric view, the natural or legal person that operates electricity consuming assets is often referred to as energy consumer.

Electricity customer is a natural or legal person that purchases electricity service, i.e., the provisioning and on demand delivery of electric energy.

Electricity generation refers to the physical production of electricity.

Electricity markets are markets for electricity, including over-the-counter markets and electricity exchanges, markets for the trading of energy, capacity, balancing and ancillary services, in all time-frames, including forward, day-ahead and intra-day markets.

Electricity producer refers to a natural or legal person that operates assets to generate and sell electricity.

Electricity supply refers to the sale of electricity to customers; i.e., assuring and billing of the supply with the contracted amount of electric power.

Energy storage is an electric asset that allows to defer the final use of electricity to a moment later than when it was generated. This may (and often does) include the conversion of electrical energy into a better storable form of energy, its storing, and subsequent reconversion into electrical energy or use as another energy carrier.

Grid Codes are regulations, typically specifying technical requirements that need to be fulfilled to connect devices to the electricity grid or to participate different electricity markets.

Household customer purchase electricity service to operate electric assets within the own household. Non-household customer purchase electricity not for own household use, including producer, industry, small and medium-sized enterprises, general business, and wholesale customer (i.e., energy trader).

Integration Profile is the specification required to realise a part of a Business Function (or combination thereof) in an interoperable fashion (normalised).

Interoperability Level refers to the abstraction level of interoperability requirements. We consider five levels: Legal, Semantic, Syntactic, Technical, and Operational.

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

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

Meta-Actor joins functional components (actors) in order to fulfil all the functionalities required for a Business Function (IHE grouping). For the Use Case description, it could be a human operator, but typically it is a software component embedded in some device that provides an interface to some communication infrastructure.

Network Codes see *Grid Codes*.

Safety refers to maintaining a proper state of systems such that neither persons operating assets nor the electricity system itself, i.e., the seamless power supply to all customers, is undue endangered.

Security refers to both, security of supply and provision of electricity, and colloquially may also include technical safety. Primarily, security aims at the protection of the system's operation to assure system safety, including restricted physical and digital access to system assets.

Smart Grid Architecture Model (SGAM) refers to the reference architecture model developed by the M/490 for the European Commission [8]. It provides a normative approach to position (locate) the different components, services, and sub-systems of a smart grid, among each other and to identify required interfaces.

Synchronverter – also called virtual synchronous generator – is a power inverter that mimics a synchronous generator to provide "synthetic inertia" as ancillary service.

Transaction is the execution of sending, receiving and reacting to a message or set of messages (1..n) exchanged between a pair or more actors. Transactions realise Use Case specific information exchanges (in one or both directions, in a strict or loose order) as specified by an Integration Profile.

Transmission refers to the (long distance) transport of electricity across the extra high-voltage and high-voltage grid with a view towards delivery to customers or distributors, but does not include supply.

Operational Use Case is a part of a Business Function that describes a task not involving any data exchange between actors. Such internal use cases are mentioned in the IES Technical Framework, but not considered as Integration Profiles because they do not cause interoperability issues.

Use Case is a well defined functionality in a well specified environment. Use Cases can be defined and specified on every SGAM Layer.

2 Overview and mapping of IIPs to Business Functions defined in TF-LEC Vol. 1

↔ *The Technical Framework Vol. 2 Introduction* shall summarise Vol.1 to the point required for implementation experts (i.e., software engineers) to roughly understand the general Energy Community aims followed by a brief description of Business Functions and their potential interoperability issues. The introduction closes with a table (or some other textual tool) that relates the Business Functions from Technical Framework on Local Energy Communities Vol. 1 with the IES Integration Profiles that Vol. 2 is composed of.

2.1 Summary of TF-LEC Vol. 1

The introductory Vol. 1 of this Technical Framework compiles the needs of users and stakeholders involved in Local Energy Communities. The technical aspects refer mainly to the operation of Energy Communities, as sketched in Figure 2.1.1.

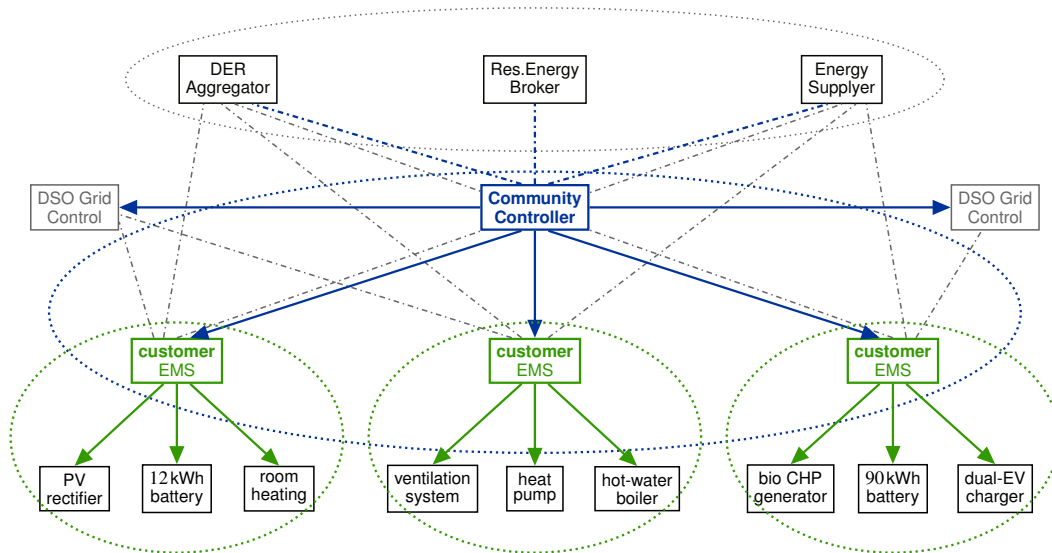


Figure 2.1.1: Energy management levels and realms [9, Figure 2.2]

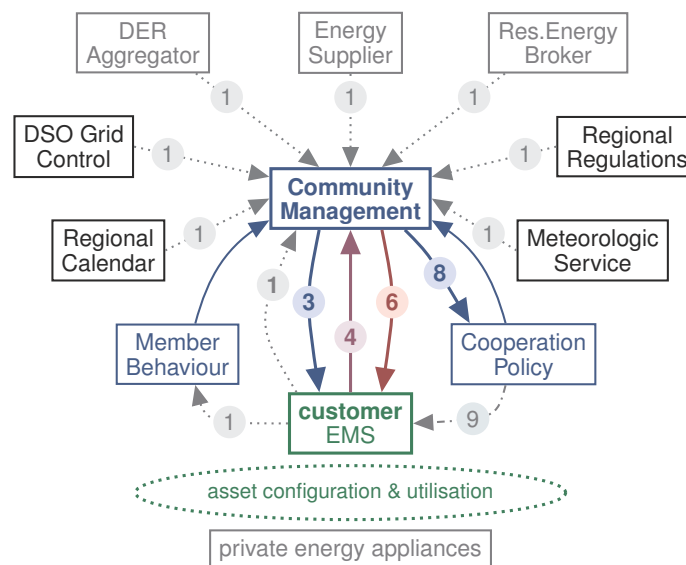


Figure 2.1.2: Community Energy Management System (C/EMS) operation [9, Figure 2.3]

The operation cycle to manage and control the future energy flows among the peers participating in an Energy Community is sketched in Figure 2.1.2.

The identified sequence of actions contains:

- | | | |
|------------------------------------|----------------------------------|--------------------------------|
| 1. Collect asset & env. conditions | 4. Monitor power & energy flow | 7. Accumulate energy budgets |
| 2. Predict demand & generation | 5. Calculate deviation from plan | 8. Adjust fulfilment weighting |
| 3. Distribute planned schedules | 6. Trigger schedule corrections | 9. Distr. benefits & compens. |

Based thereon, different functional needs (Business Functions) and inter-system interfacing needs among systems and stakeholders have been identified, as shown in Figure 2.1.3.

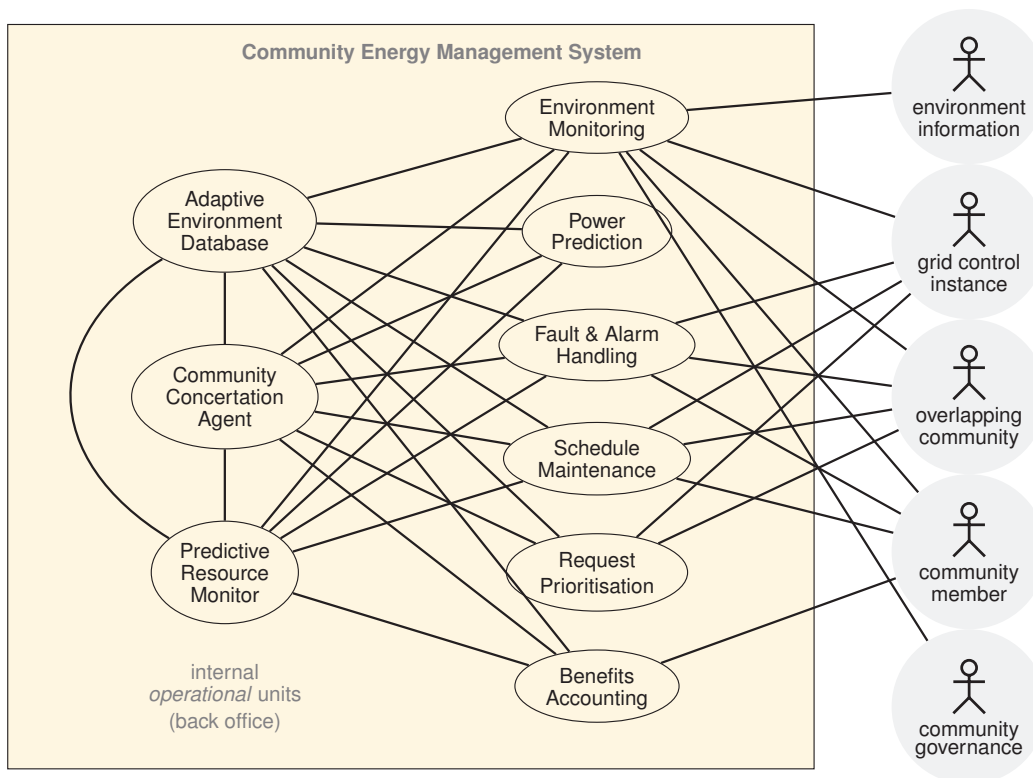


Figure 2.1.3: Local Energy Community Meta Use Case Diagram [9, Figure 3.0.2]

The Business Functions involving the Community Energy Management System (C/EMS), also referred to as Community Controller, have been assigned to communications with Meta Actors as shown in Figure 2.1.4.

The identified Business Functions are:

- | | |
|--|--|
| 1. Get Info from Assets and Environment (GIAE) | 6. Trigger On-demand Schedule Corrections (TOSC) |
| 2. Predict Demand and Generation Profiles (PDGP) | 7. Accumulate Member Energy Budgets (AMEB) |
| 3. Distrib. Planned Schedules for Execution (DPSE) | 8. Adjust Share Fulfilment Weighting (ASFW) |
| 4. Monitor Power and Energy Flows (MPEF) | 9. Distrib. Member Benefits & Compens. (DMBC) |
| 5. Calculate Current Deviation from Plan (CCDP) | 10. Coord. Overlapping Community Actions (COCA) |

Based thereon the development of IES Integration Profiles has started by identifying the most challenging and most needed functionalities where interoperability is at risk. The developed technical requirements are compiled one-by-one into this Vol. 2 of the Technical Framework.

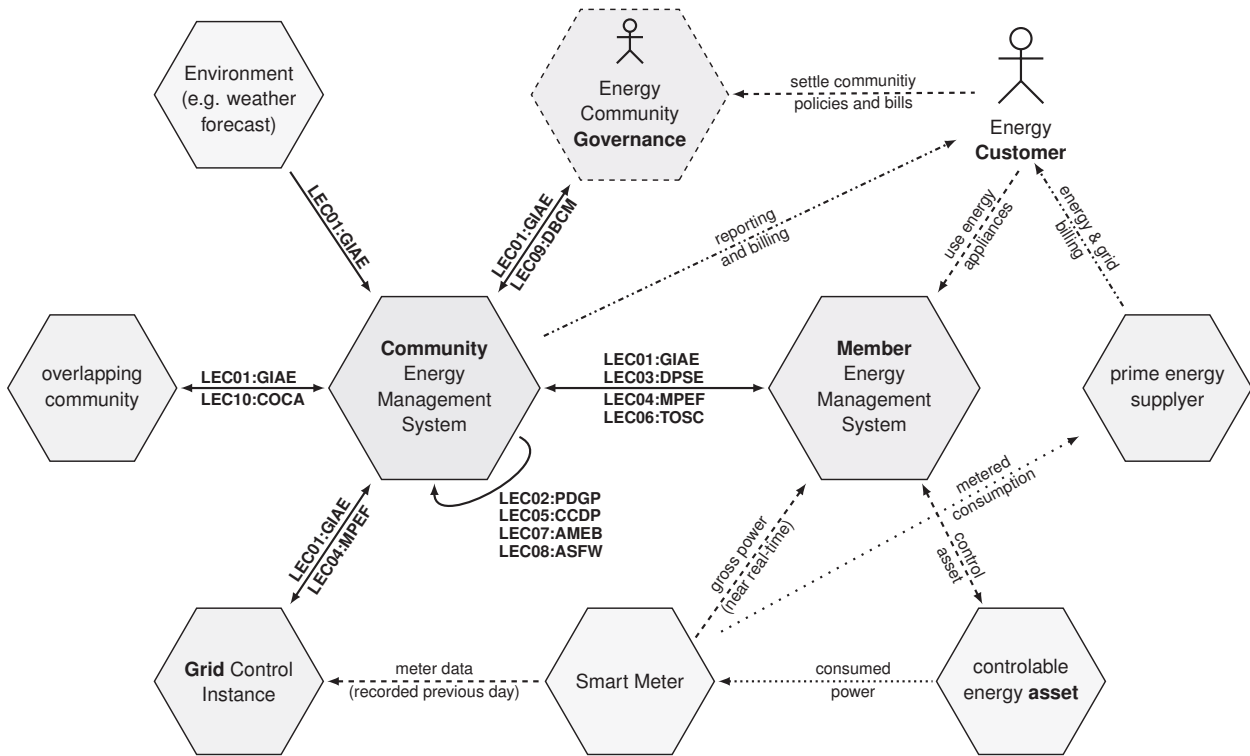


Figure 2.1.4: Local Energy Community Business Functions overview [9, Figure 3.0.1]

2.2 Business Functions to Integration Profile mapping (normative)

Business Function (Vol. 1)	IES Integration Profile (Vol. 2)
1. Get Info from Assets and Environment (GIAE)	LEC-DSO-TLS, LEC-61850-Storage
2. Predict Demand and Generation Profiles (PDGP)	internal → no interoperability issue
3. Distrib. Planned Schedules for Execution (DPSE)	LEC-61850-Storage
4. Monitor Power and Energy Flows (MPEF)	LEC-AMI-Data (not yet ready)
5. Calculate Current Deviation from Plan (CCDP)	internal → no interoperability issue
6. Trigger On-demand Schedule Corrections (TOSC)	LEC-61850-Storage, LEC-DSO-TLS
7. Accumulate Member Energy Budgets (AMEB)	internal → no interoperability issue
8. Adjust Share Fulfilment Weighting (ASFW)	internal → no interoperability issue
9. Distrib. Member Benefits & Compens. (DMBC)	not yet available
10. Coord. Overlapping Community Actions (COCA)	LEC-DSO-TLS, not yet available

3 IES Integration Profiles (IIPs) for Local Energy Communities

IES Integration Profiles are specified in the very informatics, i.e., programming language, oriented "*definition prior specification*" pattern. First any items are named and their relations stated, before their functionality and usage is specified. This *header-file* oriented approach is followed throughout IIP specification.⁵

Hence, this chapter starts with a table showing which IES Integration Profiles are available and which Business Functions and Meta-Actors from Vol. 1 these address, i.e., the table shown in 2.2 only reversed.

Table 3.0.0.1: TF-LEC Vol. 2 IES Integration Profiles to Vol. 1 Business Functions mapping

IES Integration Profile (Vol. 2)	associated Business Functions (Vol. 1)
LEC-DSO-TLS (Section 3.1) DSO based RGB Traffic Light Signals (rgbDSOtlS)	1. Get Info from Assets and Environment (GIAE) 6. Trigger On-demand Schedule Corrections (TOSC) 10. Coord. Overlapping Community Actions (COCA)
LEC-61850-Storage (Section 3.2) Remote Access to Energy Storage Flexibilities	1. Get Info from Assets and Environment (GIAE) 3. Distrib. Planned Schedules for Execution (DPSE) 6. Trigger On-demand Schedule Corrections (TOSC)
LEC-AMI-Data (not yet finished) Energy flow data from Smart Meter operator	4. Monitor Power and Energy Flows (MPEF) which is internally needed to roughly do 2. Predict Demand and Generation Profiles (PDGP) 5. Calculate Current Deviation from Plan (CCDP) 7. Accumulate Member Energy Budgets (AMEB) 8. Adjust Share Fulfilment Weighting (ASFW) 9. Distrib. Member Benefits & Compens. (DMBC)

Table 3.0.0.2: TF-LEC Vol. 1 Meta-Actor mapping to IES Integration Profiles of Vol. 2

IES Integration Profile (Vol. 2)	involved Meta Actors (Vol. 1)
LEC-DSO-TLS (Section 3.1) DSO based RGB Traffic Light Signals (rgbDSOtlS)	Environment Information (grid codes & power limits) Grid Control Instance (grid state signalling) and indirectly Community Member (demand response) Overlapping Community (cellular balancing)
LEC-61850-Storage (Section 3.2) Remote Access to Energy Storage Flexibilities	Community Governance (self-balancing) Environment Information (DER state & features) Community Member (demand side management)
LEC-AMI-Data (not yet finished) Energy flow data from Smart Meter operator	Grid Control Instance (DSO as AMI operator) Community Member (meter data access approval) Community Governance (meter data processing)

⁵If meaningful item naming and relations cannot be achieved beforehand, it is recommended to compose IIPs in reverse, doing the headers (naming and relations) in the end to save repetitive revision effort.

3.1 LEC-DSO-TLS: DSO based RGB Traffic Light Signals (rgbDSOTls)

DRAFT

This IES Integration Profile specifies the essential functionality, procedurs, and features required for interoperability among independent profile conform realised components and systems, in respect to the outlined Use Case.

◇ Use Case: Distribution of Signals that indicate the local Grid State


If active customers, i.e., their home, building, or micro-grid energy management systems (EMS) shall be actively grid friendly (responsive & supportive), they apparently need to know something about the current grid state.

A simple signalling scheme shall provide a kind of *traffic light signal* (TLS), communicating the state of the local grid (e.g., from a region covered by a local transformer down to single feeders) as it is expected to be for the near future (e.g., 15 minutes). This spatial and temporal horizon enables some foresight and a broader scope than achievable by responding to the voltage and frequency at the grid connection point, to which grid code based (emergency) behaviours commonly react isolated and perfectly autonomous.

Independent of the signalling system itself, the response to the TLS can be manifold. Instead of cutting back local renewable energy production (curtailment) the local demand may be risen, yielding the same result, a kind of micro-balancing on the low voltage (LV) level. Equally, adjusting the parameters of grid code based mechanisms is conceivable. Adequate responses to signalled grid states yield more renewable power being produced from existing assets and the potential to connect more RES to the existing distribution grid capacities, a win-win solution.

The actual color communicated is irrelevant because digital signalling anyhow translates it into a bit pattern. Here, we use red, blue and green as base colours, and all combinations thereof to represent different grid states, implicitly indicating also where the locally consumed power apparently comes from. Table 3.1.0.1 shows also potential

Table 3.1.0.1: Interpretation of alight traffic light colors

color	red	green	blue	Interpretation	Response
	0	0	0	No light ⇒ no signal received	act as usual
red	1	0	0	Load dropping is enforced	lower local load
violet	1	0	1	Power mostly from grid	lower local load
blue	0	0	1	Average local coverage	act as usual
teal	0	1	1	High local power share	act as usual
green	0	1	0	Surplus local production	raise local load
yellow	1	1	0	RES curtailment is enforced	raise local load
white	1	1	1	Ambiguous signal ⇒ ignore it	act as usual

interpretation of colors and the expected response. Note: Interpreting of combinations shall be intrinsically optional; any response adequate for any of the base colors is a valid response, even though it may not be the best choice. The only exception is the yellow state where red and green indicate opposing demands. In that case, ignore and act as usual would be viable (safety-by-design). However, red and yellow refer to emergency states that hardly ever shall occur for well designed and managed distribution grids, at least not for prolonged times.

Communicating the *self-sufficiency rate* $r_s = \frac{\text{local production}}{\text{local demand}}$ instead of colors would be appealing, but that cannot be calculated by the DSO. What the DSO can measure and communicate is the *grid-resource utilisation* $r_g = \frac{\text{grid-load}}{\text{grid-capacity}}$, where $r_g > 1$ demands red color, and $r_g < -1$ yellow color, assuming energy flow from lower to higher grid levels is expressed by negative numbers. For $|r_g| \leq 1$, we get a continuous color drift from red ($r_g \geq 1$), via blue and green, to yellow ($r_g \leq -1$). The intermediate colors defined in Table 3.1.0.1 represent a discretisation thereof.

Anyway, the TLS cannot replace (emergency) grid codes. Grid codes implement the prime mechanisms to maintain customer safety and to prevent serious harm to customer resources and the energy system as a whole. Responding to TLS is an add-on feature intended to increase local renewable energy production and the LV grids' hosting capacity for local RES by mitigating the impact of the introduced volatility on local grid stability.

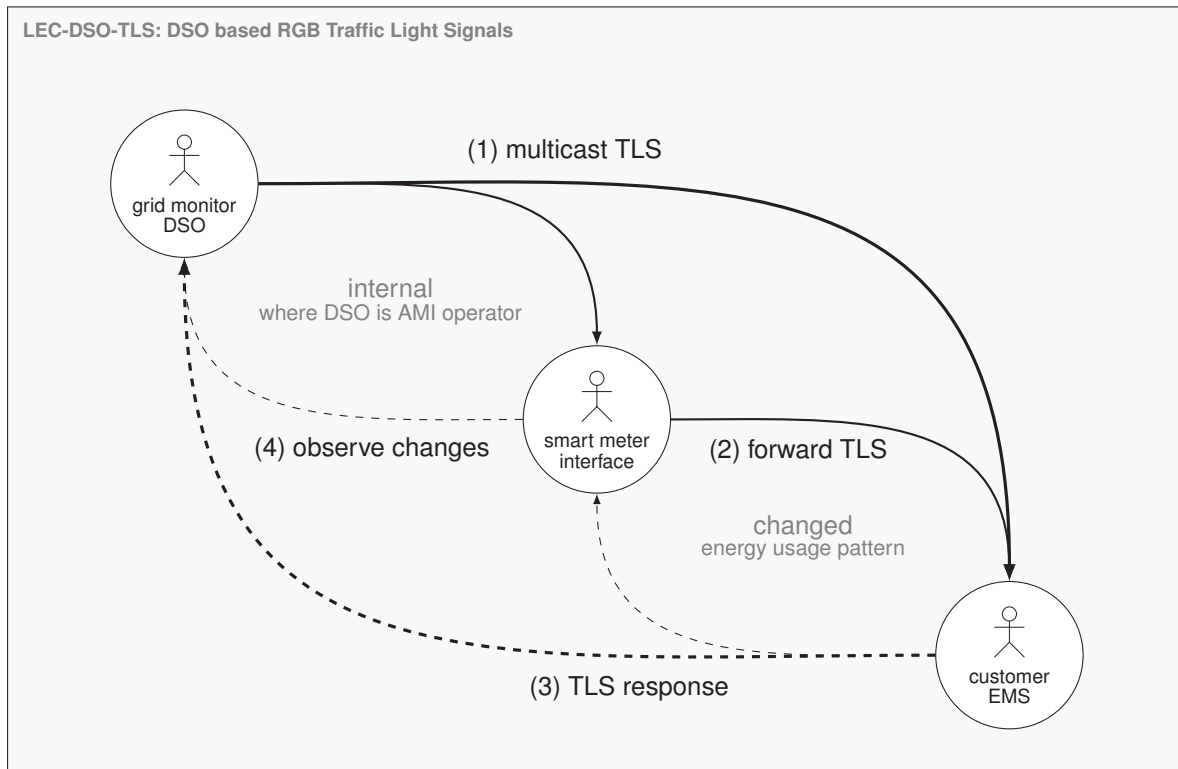


Figure 3.1.1: LEC-DSO-TLS Actors-Transactions Diagram

◇ **Actors-Transactions Diagram:** The actors-transactions diagram shown in figure 3.1.1 reveals how simple a TLS is technically to implement.⁶ It is a broadcast signal that reaches the customer EMS either directly via public IT infrastructure (1) or forwarded by the local smart meter via local IT infrastructure (2). The customer EMS shall receive the TLS info via its IP-address irrespective whether it is relayed by the smart meter or not. The content transported (i.e., the three-bit signal) and its encapsulation above IP/TCP (i.e., encoding and encryption) shall be identical.

Because a TLS should be universal, it is very important that the format and the meaning of colors is perfectly clear to all parties (systems) involved. To achieve an accordingly universal and reliable interoperability of participating systems the means for TLS reception shall be easily accessible and easy to implement (i.e., based on anywhere available and commonly used technology), such that interoperability on the device and communication level should not be an issue.

↔ *The interpretation of, and the consequential response to, TLS messages, are the critical interoperability levels to address in detail, i.e., the information (semantics) and the functional (operational) level of the SGAM.*

Please note that every *active customer* is also an EMS. With every decision to switch an appliance on/off and on how to configure assets, the customer manages the energy consumption and production, where available. However, humans cannot process digital signals without the help of some HMI (human machine interface). Here, a three-color RGB-LED can do the trick, i.e., converts the received bit-pattern into the according color. The colors are chosen to be intuitively understood: Red is bad, blue is the grid, green are the local RES, and yellow represents the alert triggered by too much green power.

3.1.1 LEC-DSO-TLS Transactions

The sequence of actions and transactions is evident: Whenever the grid state changes beyond some threshold the DSO shall broadcast the color change.

⁶The challenge of TLS resides in actually achieving the intended and expected response within time. Sending the signal is most trivial, deciding when to set which signal is not.

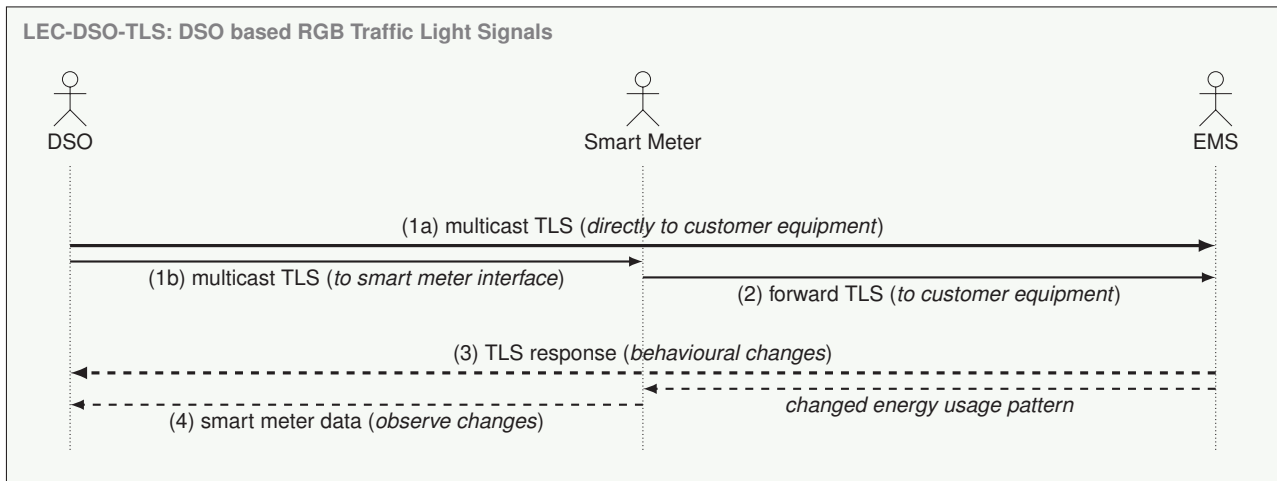


Figure 3.1.2: LEC-DSO-TLS Sequence Diagram

◇ LEC-DSO-TLS Multicast the TLS Color (T-1a | T-1b & T-2):

These transactions tell the receiving systems the current grid state. The signal shall be triggered whenever the state changed from one color to some other. Newly connected recipients shall get the signal initially, which applies likewise for recipients that rejoin after a connection loss.

The DSO may decide to trigger the color change spatially focused and/or slightly offset in time to prevent excessive simultaneous response. Therefore, a multicast solution shall be implemented. A broadcast solution may be used where multicast is not feasible.

The communication channel itself needs not be perfectly secure because the signal itself does not reveal sensitive or any personal information. But, TLS info shall be signed by the sender, and received TLS info shall always be checked on sender authentication, to prevent spoofing and man-in-the-middle attacks.

↪ *A common IP based multi-casting technology* shall be used to transfer the TLS from the DSO to the EMS, with and without a Smart Meter in between.⁷ To spare lower layer specification of IT standards, options, and variants, it is mandatory to use plug-and-play connection technology that does not require any configuration.

↪ *IEC 61850-7-420:2021* offers the logical nodes DECP (electric connection point) and DPCC (point of common coupling) for power sources, which cover grid connection related features, i.e., information.⁸

The DECP provides the optional *Health* data object (DO) that offers only **ok**, **warning** and **alarm** state. For a three color TLS that might suffice, but neither is the physical nor the electricity state thereby indicated. A supportive electricity wise response cannot be derived from *Health* information. No other utile DO could be identified. Also the option to link-in a sensor node and to calculate the state is only relevant for executing grid codes because it does not support communicating regional predictions provided by a stakeholder; i.e., the DSO.

If there is no specified solution yet, the indication for expected grid states shall be added to the DECP. The new DO is named TLScolor, is of enumeration type (TSLcolorEnumKind), and shall provide enums according to Table 3.1.1.1.

↪ *Presentation of TLS colors* shall be realised as specified in Table 3.1.1.1 only, irrespective of the recipients and the technology used to transfer the color information.

Where individual bits are used, e.g., three on-off wires, the bit-pattern transports the color information, where integer numbers are communicated the three least significant bits carry the information, and where RGB colors are transferred the individual red, green and blue intensity (>0) carries the information.

⁷The technology underneath the presentation layer may be different for the DSO–EMS, DSO–SmartMeter, and SmartMeter–EMS connections; e.g., copper/fibre/radio, 5G/WDM/PLC/DSL, TCP/UDP/QUIC/MQTT/RPC/XMPP, TLS/SSH, and so on.

⁸The logical node DVER (virtual electrical reference point) is used where an aggregate of physical connection points is managed. It contains references to the individual physical ECPs of assets and some joint features. If a DVER is the recipient of a TLS signal, it shall forward the TLS signal to the linked DECPs and DPCCs; i.e., relay TLS info like a smart meter does.

⁹ The 1st bit shall be the LSB (least significant bit); the 2nd the next significant bit, and so on.

Table 3.1.1.1: TLScolorEnumKind

3-bit integer	red 1 st bit ⁹	green 2 nd bit	blue 3 rd bit	color
0	0	0	0	black
1	1	0	0	red
2	0	1	0	green
3	1	1	0	yellow
4	0	0	1	blue
5	1	0	1	violet
6	0	1	1	teal
7	1	1	1	white

◇ **LEC-DSO-TLS Respond to TLS Colors (T-3):**

This transaction specifies the principal response to grid traffic lights, but there is no direct answer to the sender of the TLS information. What actually can be executed is not specified because that depends on the conditions and capabilities on site. Not all recipients of a TLS change will respond in the precise same way. Table 3.1.1.2 shall harmonise the direction in which electric behaviour shall change in response to the TLS received.

Table 3.1.1.2: Expected behavioural responses to TLS colors

color	red 1 st bit ⁹	green 2 nd bit	blue 3 rd bit	3-bit integer	expected response
black	0	0	0	0	continue (TLS not available)
red	1	0	0	1	reduce load ∪ increase insertion (demand)
violet	1	0	1	5	reduce load ∪ increase insertion (advice)
blue	0	0	1	4	continue (default)
teal	0	1	1	6	continue (default)
green	0	1	0	2	increase load ∪ reduce insertion (advice)
yellow	1	1	0	3	increase load ∪ reduce insertion (demand)
white	1	1	1	7	continue (no conclusive TLS available)

The basic responses are to reduce or increase either the load or the insertion of power. While a *demand* sent by the DSO shall be obeyed as good as possible, i.e., for the good of all connected customers with temporary side-effects possibly disadvantageous for the individual responder, is the response to an *advice* clearly in the TLS recipient's discretion, i.e., for the recipients good with side-effects possibly beneficial to all.

If all TLS recipients interpret the received information in the same way, their response should accumulate. To avoid excessive simultaneous behaviour changes the recipients shall not be constraint in their response time. Quite contrary, randomised response delaying may be enforced if needed:

$$\Delta T_{\min}^{\text{wait}}(\text{dithering}) = \text{rand}[0..3] \text{ minutes} \quad (3.1.1.1)$$

↔ *A TLS change shall be considered only after it remained stable for some time to avoid oscillating adjustments.* Basically, the DSO could implement this prior communicating changes, but that introduces a central point of failure. It is more robust to implement this distributed, i.e., on the TLS recipient side:

$$T_{\min}^{\text{wait}}(\text{stable TLS}) = [1..5] \text{ minutes} \quad (3.1.1.2)$$

The minimal time the TLS has to be stable before recipients may respond to TLS changes shall be announced by the local DSO to assure that any reactive measures (i.e., grid code based responses) converged. Still, the TLS responses shall kick-in before any market mechanisms (e.g., re-dispatching) counteract. Latter shall take effect after the local response potentials have become utilised as good as momentary possible.

Finally, if both measures are implemented, we get the sum of the two

$$T_{\min}^{\text{wait}}(\text{prior response}) = T_{\min}(\text{stable TLS}) + \Delta T_{\min}(\text{dithering}) \tag{3.1.1.3}$$

as the required waiting time before a recipient may respond. Any TLS change while waiting shall reset the waiting time T_{\min}^{wait} and triggers re-calculation.

◇ **LEC-DSO-TLS Smart Meter Feedback (T-4):**

This transaction covers the feedback intrinsically contained in the metered electricity flows, and provided by the smart meter to AMI operator and DSO. Where the DSO is also the AMI operator that is an internal issue. But also where AMI operator and DSO are independent, the DSO readily gets the smart meter data to evaluate the load along the operated distribution grid.

↔ *The transaction T-4 is already established as a part of the AMI.* There is no use in specifying an IES Integration Profile where other demands prevail and already yield the required interaction of actors and systems.

3.1.2 LEC-DSO-TLS Actors

To realise this IES Integration Profile two actors are mandatory: a **TLS sender** that provides TLS colors, and a **TLS recipient** that receives TLS colors and possible responds to these. The third actor foreseen, a **TLS relaying** actor shall forward TLS information, bridging communication means as needed.

◇ **LEC-DSO-TLS Sender:**

Commonly, the role of this actor will be performed by the local DSO, in particular where the TLS shall improve the local grid resources' capacity to host volatile RES (renewable energy sources). Aside from the evident need to send TLS colors to a group of recipients, the TLS sender also needs to determine the TLS color and time when to best multi-cast the color information to a group of recipients.

The TLS color and the group of recipient that shall receive it at a certain time, will be determined based on predicted local grid states and expected recipient responses. A simple "prediction" might be assuming that the current grid state persists and that all clients shall receive the TLS information as soon as possible. Actually, this poor "prediction" leads to responsive control based on the current state, i.e., the domain of grid codes. More sophisticated approaches are advisable, potentially involving AI (artificial intelligence) methods, to optimally consider long term experience, recently observed patterns, and local weather forecasts where relevant.

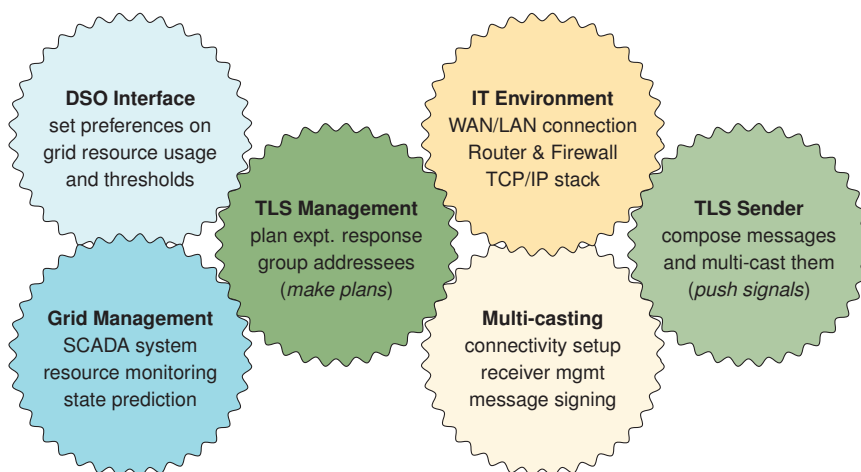


Figure 3.1.3: TLS Sender components required for DSO based RGB Traffic Light Signals

We notice that the functional features shown in Figure 3.1.3 are required but we shall not restrict how these may be realised and implemented.¹⁰ To specify and test the interoperability needs, we can simply assume that the DSO knows the TLS color, the group of relevant recipients, and the best time to send TLS color changes.

¹⁰The method to determine the TLS color, the group of recipients, and the optimal timing, is irrelevant for achieving interoperability.

◇ **LEC-DSO-TLS Recipient:**

Commonly, the role of this actor will be performed by a local EMS; i.e., a *home energy management system* (HEMS) or a *building energy management system* (BEMS). Where smart DER (distributed energy resources) shall respond individually, these need to implement the TLS recipient actor within their individual control logic. Whereas in case DERs located at different sites behind different grid connection points and smart meters are managed by an overarching EMS, for example a community EMS (CEMS), only that EMS shall implement the TLS Recipient actor to avoid contradicting messages to individual DERs.

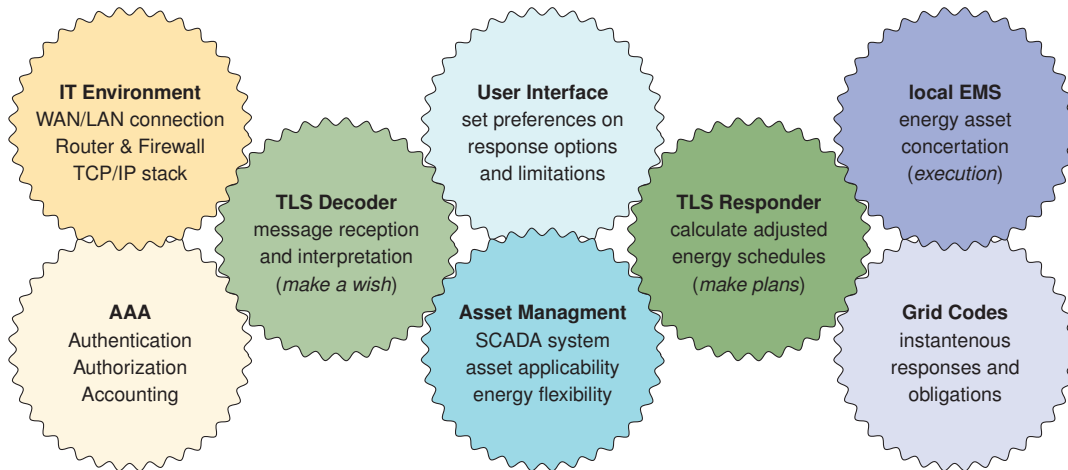


Figure 3.1.4: TLS Recipient components required for DSO based RGB Traffic Light Signals

We note that the IT Environment shown in 3.1.4 needs to support the connection set up by the TLS Sender. If the IT Environments of sender and recipient are incompatible, a message parser is required to establish a bridge between sender and receiver. This shall be achieved the the TLS Relaying actor sketched next.

◇ **LEC-DSO-TLS Relaying:**

Commonly, the role of this actor will be performed by the local Smart Meter where direct communication between the DSO and the EMS of a customer or the local smart DERs is not possible.

Similarly, community energy management systems (CEMSs) shall relay the TLS color to the EMSs of their members, but only in case these cannot receive the TLS information directly from the DSO. If the received TLS color is relevant for a subset of members only, the TLS information may be forwarded to only these.¹¹

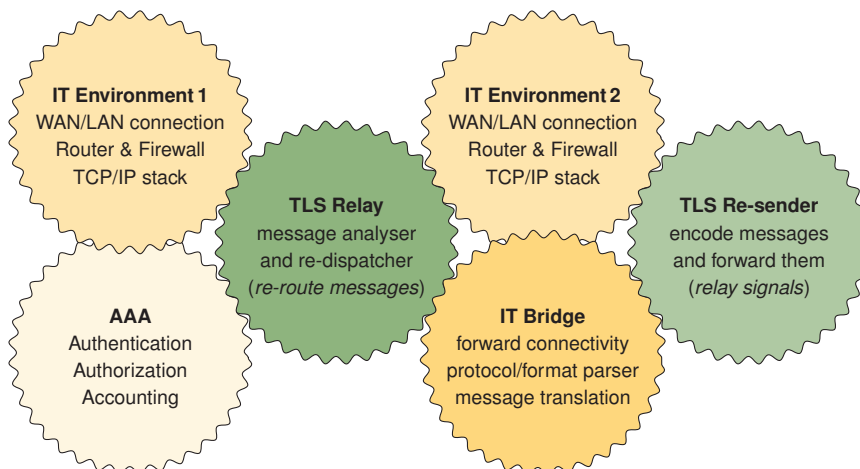


Figure 3.1.5: TLS Relaying components required for DSO based RGB Traffic Light Signals

¹¹Note the difference to the case where the CEMS directly controls DERs at customer premises, i.e., where no EMS is present at customer premises, where the CEMS takes the TLS Recipient role on behalves of the local customer.

This actor needs to receive TLS messages on behalf of one or more recipients, and shall re-address and forward them unaltered to the final recipients. It needs a receiver part, a message re-routing part (the TLS Relay) and sending parts that support all connection types required by the final TLS recipients.¹²

3.1.3 LEC-DSO-TLS Security & Safety measures

AAA is mandatory and sufficient to achieve communication security. However, the TLS Relaying actor is critical. On one hand shall it forward credentials of the TLS sender to the TLS recipient, on the other it needs to be trusted not to manipulate the messages relayed. Thus, the connection set-up process between TLS Relaying actor and TLS Recipients needs to be secured. The same measures shall apply for all connections, both for the connection set-up (AAA) and for the protection of transmitted messages (end-to-end encryption and signing, e.g., PGP).

3.1.4 LEC-DSO-TLS Notes

↪ *Optional information utile for an interoperable implementation of the above specified actors and transactions, i.e., utile but not essential to realise the specified procedures and features.*¹³

3.1.5 LEC-DSO-TLS Solution Building Blocks (SBBs)

The building blocks outlined next are basically examples on how features may be implemented.¹⁴ Whether they are normative or not depends on their content. For example, an XML schema shall be used as specified, but possibly some features may be skipped if not needed for a particular transaction. Likewise may a decision logic be implemented differently, as long as the chosen realisation yields precisely the decisions specified by the profile.

◇ LEC-DSO-TLSdecision SBB

Figure 3.1.6 shows an exemplary decision logic to derive the required actions from the three TLS bits specified (red, green, and blue).

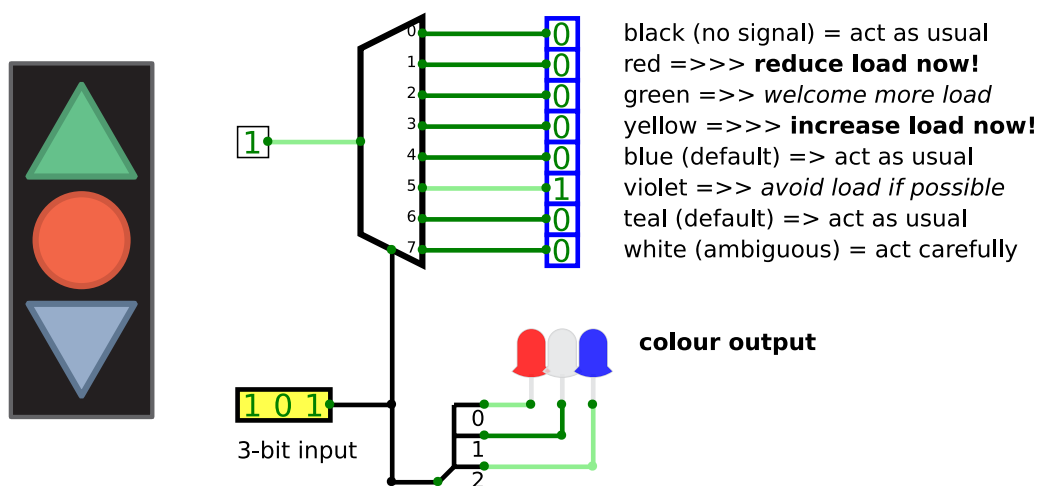


Figure 3.1.6: TLS logic example for deciphering the DSO based RGB Traffic Light Signals

The example circuit shown is based on a demultiplexer. A logic circuit using binary gates or a micro-processor might be used as well. Actually, any realisation of the deciphering supports interoperability as long as it triggers a response in the correct direction.

¹²If not all connection types can be supported by one TLS Relaying actor, several may be cascaded to achieve it (with some delay).

¹³If the information is essential for the realisation it shall be included in the subsections before and not here in the notes subsection.

¹⁴More SBBs may be added, i.e., on secure connection set-up, TLS message signing, secure key exchange, connection types, etc.

3.2 LEC-61850-Storage: Remote Access to Energy Storage Flexibilities

Trial

This IES Integration Profile specifies the essential functionality, i.e., procedures and features required for interoperability among profile compliant designed systems in respect to the outlined LEC-61850-Storage Use Case.

LEC-61850-Storage includes the following bundled specifications:

- IP VPP 61850-Send-asset-configurations (from IES Austria project)
- IP VPP 61850-Send-Planned-Schedule (from IES Austria project)

◇ **Narrative:** Energy storage assets provide flexibilities that shall be made available to mitigate the volatility of renewable energy sources (RES) on a local scale, for example within a grid section to maximise the RES hosting capacity, or within an energy community to maximise the utilisation of shared RES.

The IEC 61850 standards family adopts the modern information technology (IT) paradigms of being intrinsically *modular* (structured into logical objects/nodes) and *open by design* (easily extendable). The consequential specification complexity may appear strange and disturbing when compared to traditional operation technology (OT) standards, which commonly focus on *simplicity* (ease of implementation) and *resource efficiency* (minimal computation and bandwidth demand).

To achieve the digitalisation of energy systems we need to integrate OT with IT systems. Latter have a far shorter life-cycle and system turn-over times in the range of 2 to 5 years, whereas OT systems might remain operational up to 50 years. The modularity and openness of IEC 61850 provides the bridge to sustainable digitalisation, in other words a path to operationally link distributed energy resources (DER), i.e., the envisaged smart grid. Therefore, we focus on the current IEC 61850, i.e., IEC 61850-7-4:2020 and 61850-7-420:2021. We note that due to the OSI layering of data-exchange mechanisms (ITU-T X.200) other than those specified in IEC 61850-8-1 may likewise work with this IES Integration Profile; i.e., can equally achieve interoperability in case the same transport media, physical connectors, transmission technology, data encoding and encryption means, etc. are used by communicating instances involved.

The LEC-61850-Storage specifies mainly the *Information Layer* of the SGAM (Smart Grid Architecture Model). It specifies the logical nodes (LNs) and data objects (DOs) from IEC 61850 that shall be used, and the information exchange procedures and protocols (transactions) that need to be executed jointly and in a coordinated fashion by the communicating entities (software modules). Parameters and features of a specified Intelligent Electronic Device (IED), like a storage unit, are defined by an ICD file. These configuration files are usually provided by the IED vendor, already specifying the respective server's features and control needs. ICD files are XML based [<http://www.iec.ch/61850/2003/SCL>] and need to be adapted to client needs, either manually by editing and merging the provided server files directly, or supported by IEC 61850 system configuration software tools.

◇ **Use Case: Access energy storage flexibilities using the IEC 61850 standard** Energy storage provides both, generation and demand flexibility from dis-/charging respectively. Available energy volumes (\pm Wh) depend on the current state of charge (SoC), whereas the peak dis-/charging power (\pm W) is bounded by the conversion process, lastly by the inverter's power rating. In addition, both may be dynamically limited by the current SoC if we consider SoC dependent dis-/charging capacity (e.g., slow conversion process when close to empty/full).

In general we can control three operation parameters of storage assets:

- P_{\max}^{out} peak discharging power [$-$ W]
- P_{\max}^{in} peak charging power [$+$ W]
- $P(t)$ dis-/charge power over time [\pm W([time-interval/unit])] (schedule)

We use load centric signs, where positive power represents used power drawn from the grid, and negative power indicates inserted power given away into the grid. This sign convention also matches with adding energy to the battery (add positive to SoC) and removing energy from the storage (add negative, i.e., subtract from SoC), where SoC is a positive number up to 100% storage capacity.

A principal decision is whether we manage energy chunks $E(t_i) = \int_{t_{i-1}}^{t_i} P(t) dt$ or the instantaneous dis-/charging power $\pm P(t)$ directly. Given the common 15-minute smart metering intervals t_i , energy per quarter of an hour $E^{\frac{h}{4}}(t_i)$ appears handy. However, as listed above, we need to control the dis-/charging power $\pm P(t)$ to achieve an energy target $\pm E(t_i)$ set by some energy management system (EMS) for the time interval t_{i-1} to t_i .

In case the SoC $Q(t)$ approaches the lower or upper threshold Q_{\min} or Q_{\max} , the available $\pm P_{\max}$ ¹⁵ needs to be appropriately reduced in order not to violate the SoC bounds, i.e.,

$$\bar{P}(t_i) = \text{absmin}[\pm P_{\max}, 4 \cdot (Q_{\min} - Q(t_{i-1})), 4 \cdot (Q_{\max} - Q(t_{i-1}))] \quad (3.2.0.1)$$

where *absmin* shall be the minimum of the absolute (sign-less) values, the SoC is given in Wh, and 15-minute time intervals t_i are used, i.e., $t_{i+1} - t_i = \frac{1}{4}$. The according $\pm P_{\max}$ results in case the threshold is not in reach, as shown in figure 3.2.1.

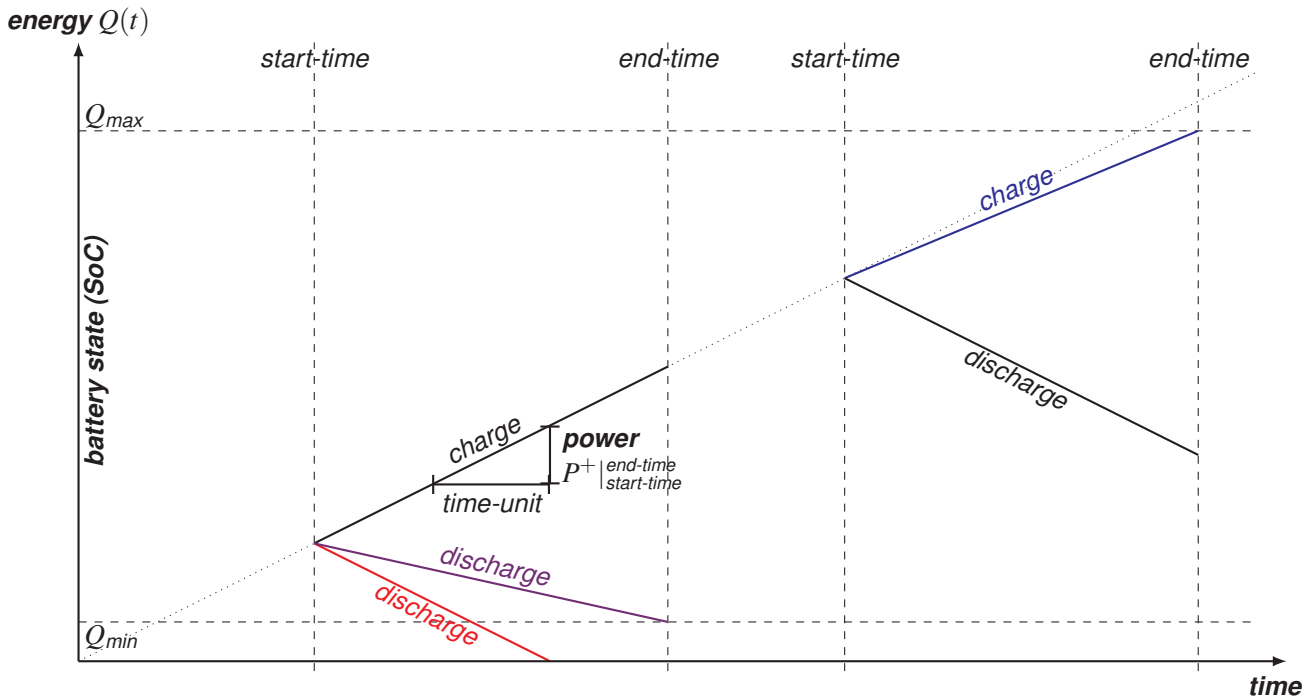


Figure 3.2.1: Bounded dis-/charging power for time intervals in case of hard SoC bounds

Commonly, the properties of the storage medium and the energy conversion raise additional constraints and dependencies to consider. While the ramp-up time may be long for a hydroelectric pump storage compared to a super-capacitor, show chemical storage media temperature dependence as well as saturation and depletion effects well before the SoC thresholds are reached. The state of power (SoP), i.e., the instantly available $\pm P(t)$, will in general depend on several external as well as system immanent parameters, including temperature, energy conversion state, the current SoC $Q(t)$, and evidently any performance degradation caused by usage stress or age.

Considering typical battery power ratings (dis-/charge power) we notice that in many cases several batteries may be needed in parallel to match peak power generation ratings. For example provide household PV inverters up to 20 kW per prosumer on the community level and modern wind-turbines up to ~5 MW on the grid section level. At least on latter scale, secure communication using an application specific and international established standard appears evident, e.g., IEC 61850.

Using IEC 61850, a group of storage assets operated in parallel can be represented by a virtual LN that represents the whole aggregate of physically existing LNs. On the information layer, communicating with either LN is the same, i.e., no need to separate 'virtual' from 'real' LNs, even though the actual communication channels to connect the individual assets of an aggregate may be different. This approach also separates the challenge to equalise the strain put on individual resources from using them jointly.

¹⁵Insert the correct P_{\max} depending on whether charging or discharging is intended in case the two absolute values are not the same.

◇ **Actors-Transactions Diagram:**

Based on the representation of storage assets according to IEC 61850-7-420:2021, i.e., the logical node DSTO and its data objects sketched in Table 3.2.3.1 in the SBBs section (3.2.3), we identify the available parameters and functions required to access and make use of energy storage flexibilities.

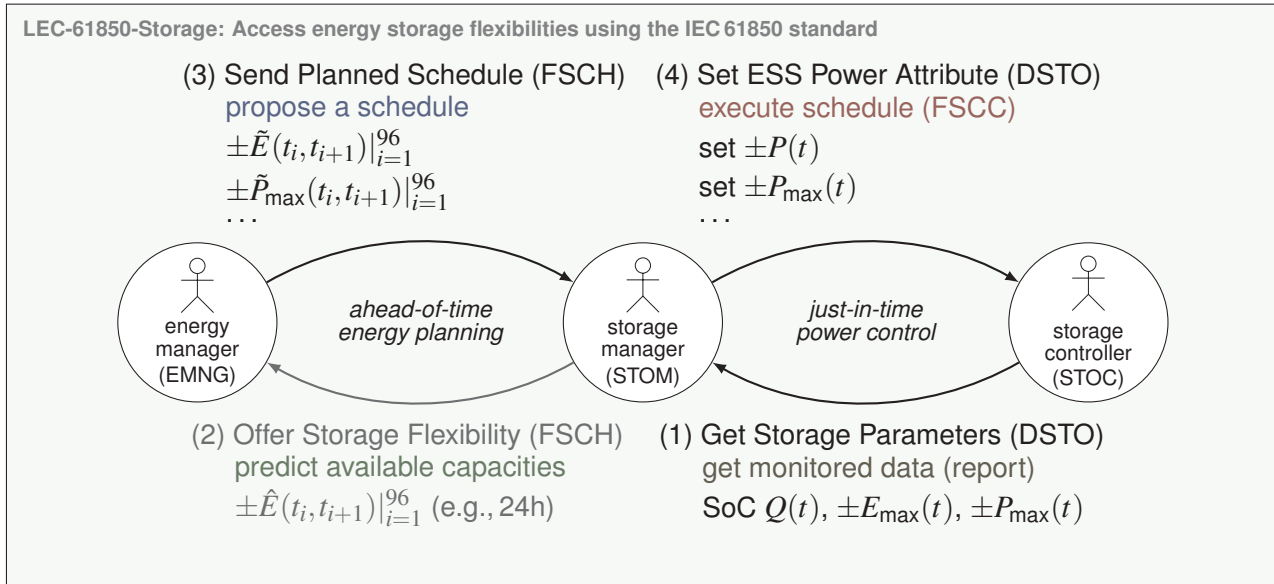


Figure 3.2.2: LEC-61850-Storage Actors-Transactions Diagram

To execute a sequence of planned settings/changes that shall be applied at some time in the future, commonly called a schedule and required to perform the core task of actively managing an energy storage system (ESS), the parameter that shall be affected needs to be linked to an FSCH (functional schedule LN), as detailed in the SBBs section (3.2.3) on page 40. An FSCC LN is also mandatorily needed to manage potentially overlapping schedules with different priorities, as detailed in the same SBBs paragraph because this functional LN is complementary to using FSCH LNs.

Both these LNs may be implemented either within the storage controller (STOC) provided by the ESS vendor, or within the energy managing actor (EMNG) of an energy management system (EMS).¹⁶ The ESS and EMS systems are commonly developed and provided by different vendors, which raises an interoperability challenge if the LNs selected by different vendors are not compatible.¹⁷

To preserve some design freedom we specify a dedicated actor in between, i.e., the storage manager (STOM), that may be bundled into either system. Aside from hosting FSCHs and the FSCC, at this position an actor may in addition manage a whole group of ESS or even a mixed energy resource (a DMDR LN), i.e., an aggregation of diverse distributed energy resource (DERs), which would recommend positioning it in the EMS, as may be advantageous in case the STOM actor is also used as message parser bridging the interoperability gap between different communication means, e.g., IEC 61850 between EMNGs and STOMs, and Modbus, ZigBee, etc. between a STOM and the STOCs it manages.

To achieve interoperability, different vendors shall support all the required LNs equally. Mutual understanding of the STOM actor with either the EMNG or the STOC actor is required, depending on which actors are not provided within the same system, e.g., at the EMS's or the ESS's side, respectively. The following section specifies the transactions sketched in figure 3.2.2. The used LNs, DOs and DAs are thereby specified and become mandatory to pass any profile conformity and system interoperability testing.

¹⁶To clearly separate the actor role (task) from the acting system (device) we deliberately use different acronyms where expedient.

¹⁷Compatible LNs need to be designed on each side to work with respective LNs on the far side. This is not solved by sharing individual configurations, i.e., the ICD, CID, IID, SCD, or SED files according to IEC 61850-6; it requires coordinated design (fitting LN and DO selection).

3.2.1 LEC-61850-Storage: Transactions

The different transactions specified next may appear like a logical sequence of information exchanges, as shown in figure 3.2.3. As already figure 3.2.2 indicates, this order is driven by the plain information demand logic and that there are two control cycles: one on managing energy flows involving EMNG and STOM, and another controlling actual power involving STOM and STOC. In practice, the two control cycles operate uncoupled. Get Storage

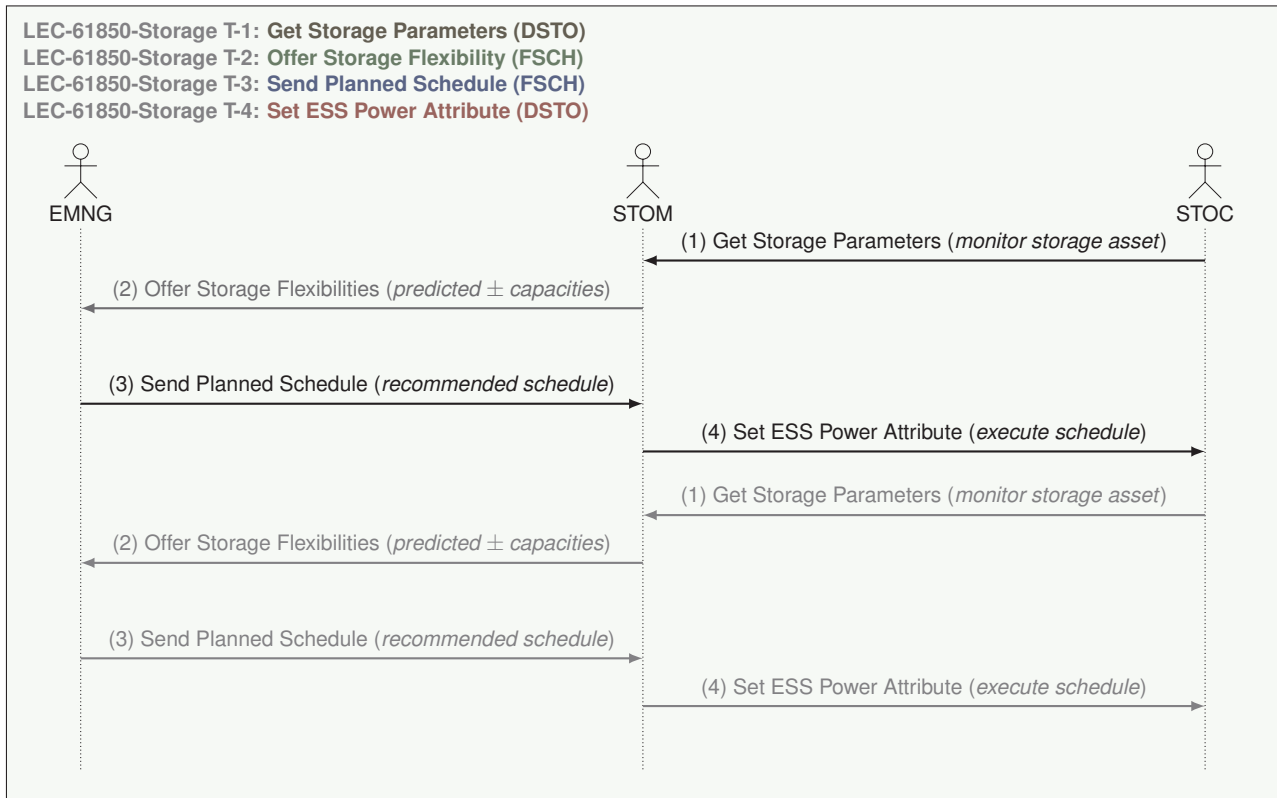


Figure 3.2.3: LEC-61850-Storage Information Flow Diagram

Parameters (1) and Offer Storage Flexibilities (2) are best implemented on an on-demand push basis, where only the changed parameters require being reported. Send Planned Schedule (3) shall be a recurring process assuring that at least one executable schedule is available at any time. In general, schedules shall be updated and extended to maintain a sufficient management horizon (e.g., 24 hours in 96 intervals). Finally, Set ESS Power Attribute (4) is not correlated to the occurrence of any other transaction; it is set just in time by the schedule controller (FSCC).

Message formats, encoding, and means of transport are generally specified in IEC 61850-7-1/2. In the energy sector it appears that the MMS (ISO 9506: Manufacturing Message Specification) based communication option is the only preferred/recommended over public infrastructures. Within confined LANs, the GOOSE (Generic Object Oriented Substation Events) option is well established, in particular where reliably short transport delays are essential. How to initiate and set-up an MMS or GOOSE connection is specified in the according SBB in section 4.1.4 on page 58 ff.

◇ Get Storage Parameters (DSTO) (LEC-61850-Storage T-1):

Initially, all relevant parameters of an ESS shall be made available to the STOM. Immutable nameplate ratings shall be transferred by exchanging the configuration file. This can be performed manually or automated. Being an initialisation task, this initial one-time exchange of information is not covered here. The automated procedure is specified in the Technical Framework on virtual power plants (TF-VPP) by the IES Integration Profile IP VPP 61850-Send-asset-configurations. Here, we focus on the variable and changeable ESS parameters listed below, which need to be known by the STOM to perform its tasks.

IEC 61850 provides two basic methods: (a) monitoring a single DO or DA, and (b) compiling and forwarding *reports* that contain a defined set of DOs and DAs. Both methods are explained in detail as an SBB in section 4.1. Either

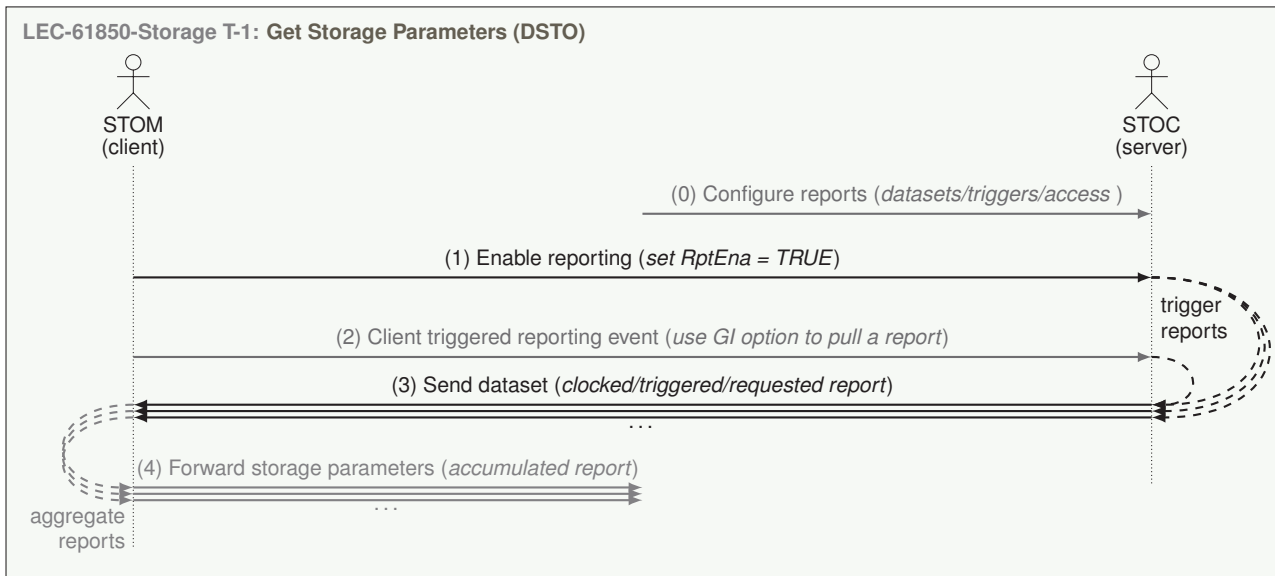


Figure 3.2.4: LEC-61850-Storage T-1: Sequence Diagram

method is eligible and shall be provided because every IEC 61850 compliant IED (intelligent energy device) supports both.

Trigger events:

- the time that passed since the last transmission (periodic update)
- a critical parameter has changed by a certain amount/percentage (update on demand)
- report request by operator (GI – General Interrogation)

DOs and DAs to monitor (individually or jointly in a report):

- \$WSpt\$mxVal: set active power target [W] *
- \$SocWh: state of charge [Wh] *
- \$OutWh: available discharging capacity [Wh] *
- \$InWh: available charging capacity [Wh] *
- \$AvIDschW: available discharging power [W] (→ FSCH validation)
- \$AvIChaW: available charging power [W] (→ FSCH validation)
- \$AvIUpW: available capacity for increasing active power output [W] (→ flexibility offer)
- \$AvIDnW: available capacity for increasing active power consumption [W] (→ flexibility offer)
- \$UseWh: usable energy storage capacity [Wh]
- \$UseWhMinPct: lower energy storage capacity reserve level (customised discharging limit) [%]
- \$UseWhMaxPct: upper energy storage capacity reserve level (customised charging limit) [%]

↔ a trailing * marks the DOs that shall trigger an update when changed

↔ the marks the DOs identified as essentially needed – questionable DOs are *grayed*

Any change of a DA can be specified to trigger the reporting of the whole dataset. Therefore, two datasets should be considered and pre-defined by the ICD file of the IED, here the STOCs (the digital twins of distributed ESSs) shall send reports. The SBB outlined in section 4.1.3 describes the Report Control Block (RCB) procedure in detail. Commonly, reports should be triggered by quality change, data update/change, and when polled by the client (General Interrogation). In addition, thereto, reports used to continuously monitor the server shall be pushed regularly (periodic) to provide a *heartbeat / still-alive* signal and not to miss changes that themselves do not trigger the reporting.

The *config/status* dataset(s) could include rarely changing information (DOs and DAs) and shall not be pushed too frequently but configured as *Buffered Report* to assure no changes are lost due to temporarily lost connections e.g.:

- \$Health: state of the logical node [ENS (HealthKind)]
- \$UseWhMinPct: lower energy storage capacity reserve level (discharging limit) [%]
- \$UseWhMaxPct: upper energy storage capacity reserve level (charging limit) [%]

One *dynamic/runtime* dataset shall include all the frequently changing DOs and DAs of importance that accordingly shall be jointly pushed to the client limiting the frequency of updates and configured as *Unbuffered Report* if sent sufficiently frequent and where losing past samples of the reported dataset causes no harm, e.g.:

- \$WSpt\$mxVal: set active power target [W]
- \$SocWh: state of charge [Wh]
- \$OutWh: available discharging capacity [Wh]
- \$InWh: available charging capacity [Wh]

↔ The following IED configuration file excerpt (Listing 1) specifies an example report control block configuration of the *Get Storage Parameters* transaction.

Listing 1: Transaction T-1 reporting control example

```
<IED>
<LDevice inst="STOC" desc="Storage Controller" IdName="STOC">
  <LN0 InClass="LLNO" InType="LLN01" inst="">
    <DataSet name="ConfDat" desc="configuration data">
      <FCDA IdInst="STOC" InClass="LLNO" fc="ST" doName="Health" daName="stVal"/>
      <FCDA IdInst="STOC" InClass="DSTO" fc="SP" InInst="1" doName="UseWhMinPct" daName="setMag.f"/>
      <FCDA IdInst="STOC" InClass="DSTO" fc="SP" InInst="1" doName="UseWhMaxPct" daName="setMag.f"/>
    </DataSet>
    <DataSet name="DynDat" desc="dynamic data">
      <FCDA IdInst="STOC" InClass="DSTO" fc="MX" InInst="1" doName="WSpt" daName="mxVal.f"/>
      <FCDA IdInst="STOC" InClass="DSTO" fc="MX" InInst="1" doName="SocWh" daName="mag.f"/>
      <FCDA IdInst="STOC" InClass="DSTO" fc="MX" InInst="1" doName="OutWh" daName="mag.f"/>
      <FCDA IdInst="STOC" InClass="DSTO" fc="MX" InInst="1" doName="InWh" daName="mag.f"/>
      <FCDA IdInst="STOC" InClass="DPMC" fc="MX" InInst="1" doName="WSpt" daName="mxVal.f"/>
      <FCDA IdInst="STOC" InClass="DWGC" fc="MX" InInst="1" doName="WSpt" daName="mxVal.f"/>
    </DataSet>
    <ReportControl name="config" confRev="0" dataSet="ConfDat" rptID="STOCSTOC/LLN0.rcb1" buffered="true" intgPd="60000" bufTime="2" desc="
configuration data">
      <TrgOps dchg="true" qchg="true" dupd="true" period="false" gi="true"/>
      <OptFields seqNum="true" timeStamp="true" dataSet="true" reasonCode="true" dataRef="true" bufOvfl="true" entryID="true" configRef="true"/>
      <RptEnabled max="2" desc=""/>
    </ReportControl>
    <ReportControl name="dynamic" confRev="0" dataSet="DynDat" rptID="STOCSTOC/LLN0.rcb1" buffered="false" intgPd="15000" bufTime="2" desc="
dynamic data">
      <TrgOps dchg="true" qchg="true" dupd="true" period="true" gi="true"/>
      <OptFields seqNum="true" timeStamp="true" dataSet="true" reasonCode="true" dataRef="true" bufOvfl="true" entryID="true" configRef="true"/>
      <RptEnabled max="2" desc=""/>
    </ReportControl>
  </LN0>
</LDevice>
</IED>
```

This example report configuration shown in Listing 1 is configured according to the SBB section 4.1.3. The parameters named rptID, buffered/unbuffered and number of allowed clients (RptEnabled) need to be pre-defined in the ICD file. All other parameters like the dataset reference (datSet), trigger options (TrgOps), and optional field (OptFields) could be set during runtime. Since not every IEC61850 stack supports dynamic creation of datasets, all optional parameters are also pre-defined. A report control block (RCB) can be reserved for a specific ClientLN (see Listing 9). Nevertheless, for the sake of simplicity, no pre-defined clients are defined here. After the initial server-client connection, the client can accomplish the reservation by setting the Resv/ResTms flag of the RCB.

Communication security and resiliency (i.e., encryption and data flow integrity protection):

- According to IEC 61850 shall all communication via public infrastructure using the MMS communication stack be encrypted end-to-end and protected by physical isolation, i.e., a serial connection between the IT interface and the component actually controlled shall prevent malicious intrusion.
- Resilience is achieved by the MMS stack. IP realises hop-by-hop routing and thus, dynamic path recovery for the virtual circuit used to transport data using MMS. TCP assures that no data is lost unnoticed, in contrast to UDP where the sender and receiver are responsible for detecting any lost data, e.g., by consecutively numbering the messages exchanged.
- We assume these issues are solved by the communication stack, which shall not be a topic of this integration profile because any serious stack is exchangeable according to the layering principle specified in ITU-T X.200 [10] for modern digital communication.
- How to correctly set-up and use an IEC 61850 conform data connection is outlined in the SBB "*IEC 61850 — MMS based communication:*" in section 4.1.4.

◇ **Offer Storage Flexibility (DSTO→FSCH) (LEC-61850-Storage T-2):**

Flexibility can be assured in the moment only, i.e., not for all times in the future. Therefore, flexibility offers should include a metric assessing the reliability. Like flexibility itself, the reliability metric may depend on time, such that a complete offer shall contain two correlated curves over time: expected energy/power flexibility and correlated reliability over time. Actually, latter will be a distribution function and no scalar value, but that might be too complex to handle in practice and therefore, shall be substituted by assuming a likely distribution, i.e., the normal distribution.

The logical storage node DSTO does not offer a DO that may be used to handle the reliability of predicted State-of-Charge (SocWh) or available dis-/charging capacity (OutWh/InWh). And the functional node FSCH does not provide an option to handle value-pairs, e.g., $[x, \delta_x](t)$, either.

In consequence, the STOM shall assess the reliability of potential flexibilities in the future and conservatively reduce it to achieve an offer with constant reliability, e.g., 97.5%. For example, if InWh(t) at time t is known to vary with a standard deviation $\sigma = 25\%$ of the mean μ , the STOM can offer only $\sim 50\%$ of the expected mean InWh(t) $E(X)$ with $\sim 97.5\%$ reliability, according to the one-sided 3-sigma rule (assuming a normal distribution):

$$P(X < \mu - 1\sigma) = 15.8655\% \quad P(X < \mu - 2\sigma) = 2.2750\% \quad P(X < \mu - 3\sigma) = 0.135\%$$

In practice, where the reliability of predictions tends to drop considerably the further we look into the future, this conservative approach will result in flexibility offers that severely decline toward the future. Therefore, it is important to repeat the prediction periodically within the prediction horizon.

Actually, repeated predictions offer by themselves an approach to assess the reliability in an empiric fashion (independent of the actual distribution): If the prediction for a certain time interval within the horizon does not vary much across successive prediction attempts, it may be assumed to be primarily determined by data and day-time and less by correlation to events that occur prior the particular time-span. However, that's yet a guess only.

Communication security and resiliency (i.e., encryption and data flow integrity protection):

- IEC 61850 specifies general security and resiliency demands that can be assumed implemented by the communication stack as outlined above with the first transaction specified.

◇ **Send Planned Schedule (FSCH) (LEC-61850-Storage T-3):**

This transaction is already specified in the Technical Framework on VPPs as dedicated use case using either IEC 61850 or IEC 60870-5-104 to transport them. The IES Integration Profiles "*61850 Send Planned Schedule*" and "*60870 Send Planned Schedule*" specify it, respectively. To implement transferring a Schedule using the logical node FSCH from IEC 61850, refer to the IES Integration Profile for VPPs bundled into this profile, as stated on page 22.

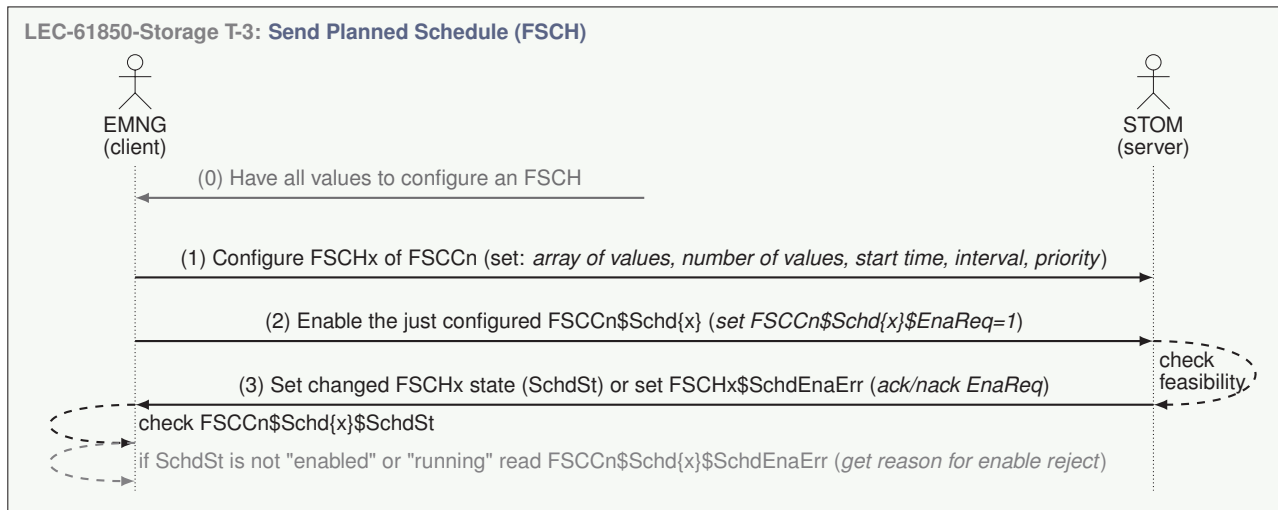


Figure 3.2.5: LEC-61850-Storage T-3: Sequence Diagram

Aside from transferring a schedule, i.e., configuring an FSCHLN, and realising its execution by its FSCCLN, we need to know which DO of the DSTON shall be controlled by the FSCCLN¹⁸ for the here addressed transaction, and which constraints shall be considered when calculating a schedule, i.e., a series of 96 ValASG values.¹⁹ For the example, and probably in practice as well, the *Set Active Power* set-point (WSpt) is used to control the active power drawn or inserted, depending on the sign of the set value. The distributed device (a DERResourceLN), here the DSTO, will then try to reach the set active power at the DECP assigned to it.

→ The DO that shall be controlled by $FSCHn\$ValASG$ values is the **DSTON\$WSpt**, the active power setpoint.²⁰

When calculating schedule values ($FSCHn\$ValASG$), and essentially at the responder side when checking the eligibility of a received schedule, i.e., when executing the <Enable> operator ($FSCHn\$EnaReq$), the following limitations shall be considered:

$$-DSTON\$AvidschW \leq FSCHn\$ValASG(i) \leq DSTON\$AvidChaW \quad \forall_i \quad (3.2.1.1)$$

$$Time-Horizon \leq FSCHn\$NumEntr \cdot FSCHn\$SchdIntv \quad (3.2.1.2)$$

And dynamically per 15 minutes time-slot (if required):

$$-DSTON\$InWh \leq \sum_{k=i}^{i+j} FSCHn\$ValASG(k) \cdot FSCHn\$SchdIntv \leq DSTON\$OutWh \quad \forall_{(i,j)|(i+j) \leq FSCHn\$NumEntr} \quad (3.2.1.3)$$

Note that some grid codes, e.g., dynamic P(U) insertion bounds, respond to the momentary state of the electricity connection point (ECP) and thus, cannot be considered ahead of time. Whereas grid codes that state a behaviour independent of the current ECP state, e.g., a power angle $\cos\phi(P)$ agreement, may be considered. However, the use case of this IES Integration Profile addresses primarily energy, i.e., only effective power P shall be scheduled. For scheduling reactive power Q look out for according profiles on providing *ancillary services* to grid operators.

Communication security and resiliency (i.e., encryption and data flow integrity protection):

→ IEC 61850 specifies general security and resiliency demands that can be assumed implemented by the communication stack as outlined above with the first transaction specified.

¹⁸According to common naming convention, present logical nodes are addressed by LN name and an attached integer number. Here, 'n' substitutes any integer number attached. The DO of an LN is addressed by attaching the DO name separated by a \$ character. If a particular DA shall be addressed, the DA name is subsequently attached, again separated by another \$ character.

¹⁹In regions where daylight saving time is applied and power scheduling is adjusted to the changing wall-clock-time, we find 92 and 100 15-minute intervals on the days the day-time is changed one hour forward and backward, respectively.

²⁰As stated earlier, we would like to assign an energy (Wh) set-point instead, but such is yet not available for either the DSTO or the ECP (electricity connection point).

◇ **Set ESS Power Attribute (DSTO) (LEC-61850-Storage T-4):**

This transaction refers to just-in-time setting the active power of the DSTO at the assigned DECP via the WSpt DO, either directly or indirectly via a DPMC and DWGC LN.²¹

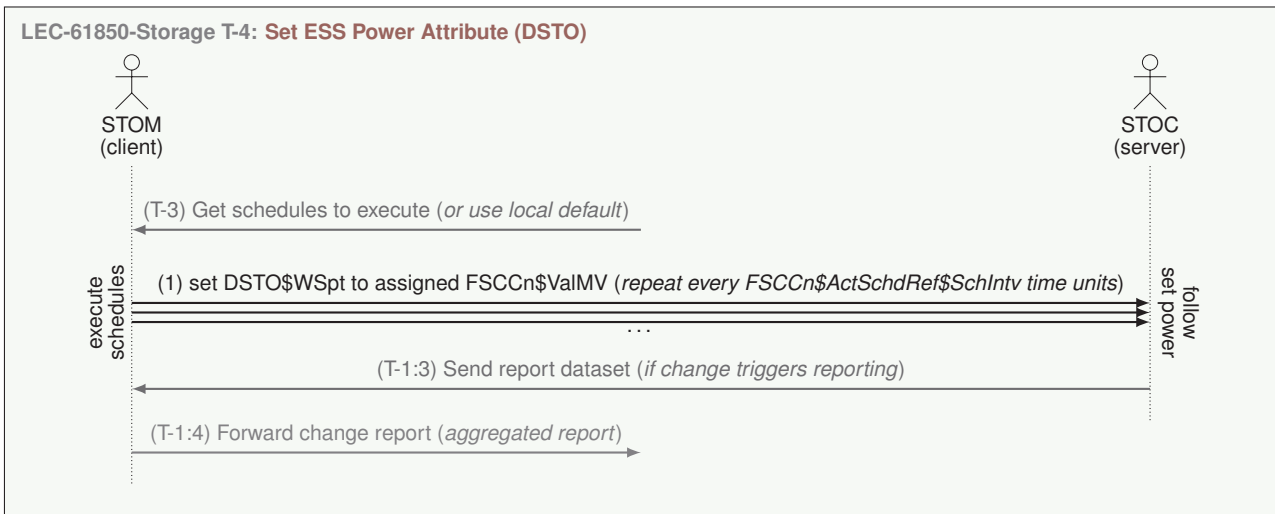


Figure 3.2.6: LEC-61850-Storage T-4: Sequence Diagram

The functional node FSCHn provides the DSTOn\$WSpt values that become set when the schedule is executed by the functional node FSCCn (Functional Schedule Controller). As every FSCH assigned to a DA is executed by exactly one FSCC determining which value shall actually be set, the operation is straightforward and automatically performed by the 61850 LN structure once client and server are connected. The data protocol used to link the STOM with the STOC has no impact on setting the value, only on the achievable timing performance.

In practice, the following options shall be supported (as sketched in Vol.1):

- Modbus (different variants, particularly those based on serial connections and TPC based variants)
- GOOSE (Real-time Ethernet without IP layer, with pre-reserved bandwidth yielding deterministic delays)

Many of the options cannot be tested by monitoring exchanged IP packets. Thus, supporting Modbus/TCP communication is mandatory for participating in IES interoperability testing.

Note: To set the WSpt value perfectly timed, any processing and transmission delays need to be compensated by triggering the parameter-change-process accordingly ahead of time. Any non-deterministic data transport mechanism would ruin/prevent the precise timing intended. Thus, for asynchronous data transmission, the component itself needs a precise clock and received values need to be accompanied by some info telling when to be executed, e.g., a schedule. In that case, the STOM is merged into the STOC, such that this transaction becomes internal as the local FSCH execution by the local FSCC achieves the required execution timing.

Communication security and resiliency (i.e., encryption and data flow integrity protection):

- IEC 61850 specifies general security and resiliency demands that can be assumed implemented by the communication stack as outlined above with the first transaction specified.
- In particular can this transaction be realised over the required physical isolation from IP via a serial 'last-mile' connection between STOM and STOC, are necessary even if STOM and STOC are integrated in one box.

3.2.2 LEC-61850-Storage: Actors

Here, the term *actor* commonly refers to one or more software modules, where each executes one side of a transaction specified above, i.e., the initiator, the responder, or a listener, repeater, or message parser part. IES

²¹Technically, the server in the field might be reduced to setting the charging or discharging of each battery-block via dynamic voltage and current limits of the battery protection circuits. However, the DBAT LN offers no DOs to set dynamic current limits and voltages. Accordingly, the DSTO has to be provided by the server in the field as depicted in Figure 3.2.7.

Integration Profiles are not intended to specify the actor implementation itself, only what the actors shall provide and how they shall execute their part, and finally, the stack of software modules that are required.

The IEC 61850 standards series specifies all kinds of features required to remotely monitor and control the components of 'intelligent' (*digitally transparent*) electricity generation and distribution systems. Edition 2.0 of the IEC 61850-7-420 standard adds features to include any kind of distributed electrical resource/asset, i.e., loads, storage, generation, behind the grid connection point. Intelligent energy devices (IEDs) are composed of logical nodes (LNs) that can be linked to other IEDs. Such 'linked-in' LNs provide directly accessible *digital twins*, irrespective of whether hard-linked or bidirectionally mirrored. Thus, a central control office, e.g., a SCADA system, may be digitally linked to every single entity in the field, yielding a locally accessible data-structure that contains all and everything. There exist also logical nodes to model functionalities and properties, e.g., representing the power-flow to/from an asset, for which only a logical/operational localisation in the electric system exists.

↪ *The linking of actors in this section 3.2.2* is achieved by the operational function LN "Set Active Power" (DWGC), being a 'virtual' LN that refers to setting a controllable power to the value specified by the "WSpt" DO of the DWGC LN linked to a unique 'virtual' DECP LN (electricity connection point), which itself is linked to a distributed load, generator or storage instance (DLOD, DGEN, DSTO) or a mixed DER (DMDR) where the individual units are not independently made accessible for being remote controlled.

↪ *Additional information for the following actor listings:*

The following actor listings are syntactically correct but not fully completed/valid at the application level. LNs/DOs like LLN0/Beh are excluded in the following listing to reduce overhead but per default included.

The DA WSpt.ctlModel needs to be set from "Status Only" to at least "direct-with-normal-security" to enable the controllable setpoint DA WSpt.ctlVal with the Functional Constraint CO.

Only required LNs, their DOs and DAs with necessary default values are mentioned. Example configurations for parameters like system structure, supported services and access points are further explained in the SBB Substation Configuration Language Model.

◇ **Storage Control Instance (STOC):**

This is the local instance that controls the storage asset, i.e., whether and how it consumes or delivers power. According to IEC 61850-7-420:2021 the DSTO LN is solely responsive and cannot store any requests that shall be executed at a later time (e.g., future set-point changes). Received requests are executed on reception (instantly).²²

↪ *The STOC actor needs to support specified transactions as listen in Table 3.2.2.1.*

Table 3.2.2.1: Transactions related to the STOC actor

TF-LEC-61850-Storage Transaction	stand-alone STOC	with integrated STOM
T1: Get Storage Parameters (DSTO)	⊗	⊗
T2: Offer Storage Flexibility (FSCH)		x
T3: Send Planned Schedule (FSCH)		o
T4: Set ESS Power Attribute (DSTO)	o	

'x' indicates the *initiator* role, 'o' the *responder* role, '⊗' where both applies.

²²This is in line with traditional (non-smart) generators and loads that are operated either independently, based on static parameterisation, or remote controlled by some centralised asset management (control centre). Smart assets, e.g., an FSTO (functional StorageLN), capable to be integrated as self-contained system in a system-of-systems architecture, will obliterate this deficiency.

The STOC shall integrate the following LNs and shall provide access to the following DOs and their DAs to perform the required transactions:

- LNs: DSTO, BRCB, URCB, DECP, DWGC, DWMX, DPMC, DBAT, and LNs needed for regular operation
- DOs: WSpt, SocWh, OutWh, InWh, AvlDschW, AvlChaW, OutEcpRef, DERUnit, AvlUpW, AvlDnW, capacity usage restrictions UseWh, UseWhMaxPct, UseWhMinPct, grid access constraints, etc.

Actually, the architecture of the STOC actor shall be tuned to the hardware available. Thus, Figure 3.2.7 shows components commonly required for the integration of a storage asset according to the use case and transactions considered in this IES Integration Profile so far. However, the transactions can be achieved likewise with less LNs using according to DOs of the actually present LNs.

More LNs and DOs, in particular functional nodes, are probably required to pass grid conformance certification according to the locally applied laws and regulations. See the note below on LD composition to jointly manage interrelated DER components.

LEC-61850-Storage: STORage Control (STOC) modules
 LNs required for the IED to provide the necessary functionality

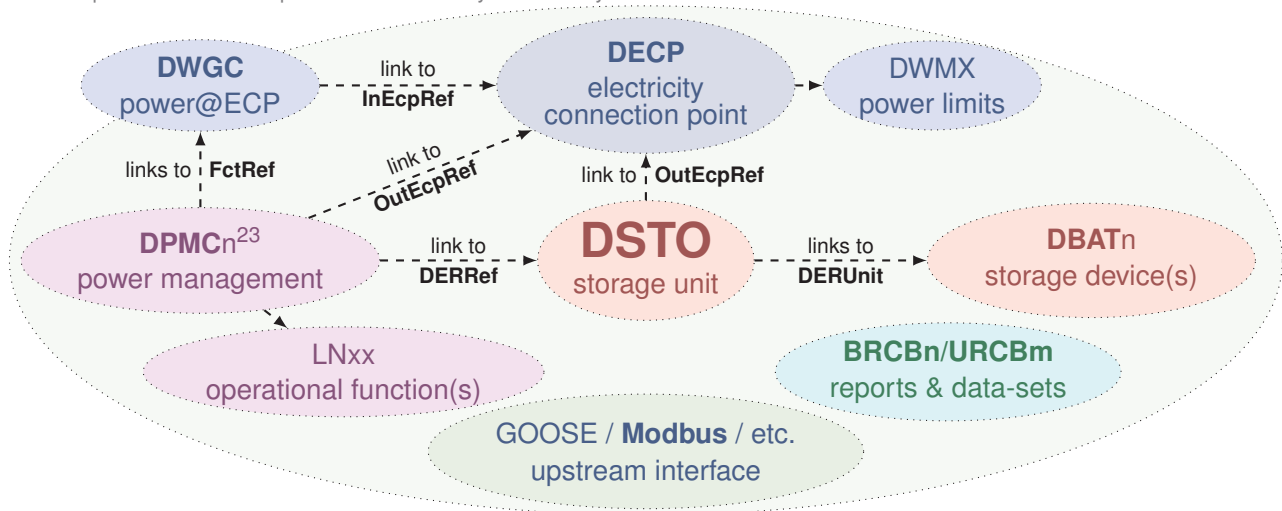


Figure 3.2.7: STOC components required for LEC-61850-Storage transactions, based on [11, Figure 48 and B.2]

Figure 3.2.7 sketches a possible²³ LN composition required to perform the transactions specified in Table 3.2.2.1. However, these transactions can be likewise performed with different actor compositions, as long as all the DOs required to perform the specified transactions are available from present LNs.

↔ The following IED configuration file excerpt (Listing 2) specifies example LD/IED components as shown in Figure 3.2.7.

Listing 2: STOC example configuration

```

<LDevice inst="STOC" desc="Storage Controller" IdName="STOC">
  <LN InClass="DSTO" InType="DSTO1" inst="1" prefix="">
    <DOI name="OutEcpRef" desc="">
      <DAI name="setSrcRef" desc="">
        <Val>STOC/DECP1</Val>
      </DAI>
    </DOI>
    <DOI name="WSpt" desc="">
      <DAI name="ctlModel" vallmport="false">
        <Val>direct-with-normal-security</Val>
      </DAI>
    </DOI>
    <DOI name="DERUnit" desc="">
      <DAI name="setSrcRef" desc="">
        <Val>STOC/DBAT1</Val>
      </DAI>
    </DOI>
  </LN>
  <LN InClass="DPMC" InType="DPMC1" inst="1" prefix="">
    <DOI name="WSpt" desc="">
      <DAI name="ctlModel" vallmport="false">
        <Val>direct-with-normal-security</Val>
      </DAI>
    </DOI>
    <DOI name="DERRef" desc="">
      <DAI name="setSrcRef" desc="">
        <Val>STOC/DSTO1</Val>
      </DAI>
    </DOI>
    <DOI name="OutEcpRef" desc="">
      <DAI name="setSrcRef" desc="">
        <Val>STOC/DECP1</Val>
      </DAI>
    </DOI>
    <DOI name="FctRef" desc="">
      <DAI name="setSrcRef" desc="">
        <Val>STOC/DWGC1</Val>
      </DAI>
    </DOI>
  </LN>

```

²³The DPMCn is evidently required where different DER components, e.g., controllable loads, generators, and storage, need to be jointly managed to achieve DWGC settings and to obey ECP constraints (DWMX) as noted in the end of the actor specification. Whether a DPMC LN is required even if only a single DER component is managed, here a single DSTO, is yet not known. Once the IEC TR 61850-7-520 guidelines are eventually published, the issue should be solved; until then, feedback from professionals is pending.

```

<LN InClass="DWGC" InType="DWGC1" inst="1" prefix="">
  <DOI name="InEcpRef" desc="">
    <DAI name="setSrcRef" desc="">
      <Val>STOC/DECP1</Val>
    </DAI>
  </DOI>
  <DOI name="WSpt" desc="">
    <DAI name="ctlModel">
      <Val>direct-with-normal-security</Val>
    </DAI>
  </DOI>
</LN>
</LDevice>
<DataTypeTemplates>
  <LNNodeType id="DSTO1" InClass="DSTO">
    <DO name="InWh" type="MV_1_Vol"/>
    <DO name="OutWh" type="MV_1_Vol"/>
    <DO name="SocWh" type="MV_1_Vol"/>
    <DO name="AvlDschW" type="MV_1_Vol"/>
    <DO name="AvlChaW" type="MV_1_Vol"/>
    <DO name="AvlUpW" type="MV_1_Vol"/>
    <DO name="AvlDnW" type="MV_1_Vol"/>
    <DO name="UseWhMinPct" type="ASG_1_ValASG"/>
    <DO name="UseWhMaxPct" type="ASG_1_ValASG"/>
    <DO name="OutEcpRef" type="ORG_1_InclSto"/>
    <DO name="DERUnit" type="ORG_1_InclSto"/>
    <DO name="WSpt" type="APC_1_WSpt"/>
  </LNNodeType>
  <LNNodeType id="DPMC1" InClass="DPMC">
    <DO name="DERref" type="ORG_1_InclSto"/>
    <DO name="OutEcpRef" type="ORG_1_InclSto"/>
    <DO name="FctRef" type="ORG_1_InclSto"/>
    <DO name="WSpt" type="APC_1_WSpt"/>
  </LNNodeType>
  <LNNodeType id="DWGC1" InClass="DWGC">
    <DO name="WSpt" type="APC_1_WSpt"/>
    <DO name="InEcpRef" type="ORG_1_InclSto"/>
  </LNNodeType>
  <LNNodeType id="DECP1" InClass="DECP">
    <LNNodeType>
    <LNNodeType id="DBAT1" InClass="DBAT">
      <LNNodeType>
      <DOType id="MV_1_Vol" cdc="MV">
        <DA name="mag" type="AnalogueValue_1" bType="Struct" fc="MX" dchg="true" dupd="true"/>
        <DA name="q" bType="Quality" fc="MX" qchg="true"/>
        <DA name="t" bType="Timestamp" fc="MX"/>
      </DOType>
      <DOType id="ASG_1_ValASG" cdc="ASG">
        <DA name="setMag" type="AnalogueValue_1" bType="Struct" count="5" fc="SP" dchg="true"/>
      </DOType>
      <DOType id="ORG_1_InclSto" cdc="ORG">
        <DA name="setSrcRef" bType="VisString129" fc="SP" dchg="true"/>
      </DOType>
      <DOType id="APC_1_WSpt" cdc="APC">
        <DA name="Oper" type="APCOperate_8" bType="Struct" fc="CO"/>
        <DA name="mxVal" type="AnalogueValue_1" bType="Struct" fc="MX" dchg="true"/>
        <DA name="q" bType="Quality" fc="MX" qchg="true"/>
        <DA name="t" bType="Timestamp" fc="MX"/>
        <DA name="ctlModel" type="ctlModel" bType="Enum" fc="CF"/>
      </DOType>
      <DAType id="AnalogueValue_1">
        <BDA name="f" bType="FLOAT32" desc="The value of f shall be the FLOAT representation of the measured value. f shall represent the technological value in SI units."/>
      </DAType>
      <DAType id="APCOperate_8">
        <BDA name="ctlVal" type="AnalogueValue_1" bType="Struct"/>
        <BDA name="origin" type="Originator_1" bType="Struct"/>
        <BDA name="ctlNum" bType="INT8U"/>
        <BDA name="t" bType="Timestamp"/>
        <BDA name="Test" bType="BOOLEAN"/>
        <BDA name="Check" bType="Check"/>
      </DAType>
      <DAType id="Originator_1">
        <BDA name="orCat" type="orCategory" bType="Enum"/>
        <BDA name="orIdnt" bType="Octet64"/>
      </DAType>
    </DataTemplates>
  </DataTemplates>

```

The core LN is the DSTO LN that provides the management of a group of similar storage devices (DBAT1..n). Being a DER component, it is mandatorily linked to specific electricity connection points (DECP), which introduce local power flow control (DWGC) and constraints (DWMX). To manage set-able DOs of the DSTO in coordination with other DER components, i.e., controllable loads and generation units, power management LNs (DPMC1..n) are required to jointly manage a DWGC.²⁴ Where only a single controllable DER unit is present we assume that DPMC LNs may be skipped and DOs/DAs of the DSTO may directly be linked to the functional schedule controllers (FSCC1..n) handled by the STOM actor specified next. Implementing grid codes and obeying limits then becomes a task performed by the EMNG (see below) for all the virtual DECPs physically connected by copper wires.

While the communication between STOC and STOM may be achieved using different technologies and protocols in accordance to local requirements, the interaction on the information layer is achieved by linking a set-able DO/DA of the DSTO LN to the schedule controller (FSCC) embedded in the STOM actor specified next. Linking a set-able DSTO-DO to an FSCC LN is specified in the configuration file as exemplarily shown in listing 2. The Data Attribute Watt Setpoint (DSTO/WSpt.ctVal) can either be directly modified from the FSCC or over the DPMC.

In addition thereto, the STOC needs to provide access to the DOs and DAs required for transaction LEC-61850-Storage T-1: Get Storage Parameters (DSTO). All listed transaction parameters shall be accessible on demand and also included in reports as specified with LEC-61850-Storage T-1.

Where the STOC and STOM actors are realised as separate units, only the STOM(s) linked to this STOC via FSCC-links shall have read and/or write access to local DOs/DAs and configured reports because in that case the STOM(s) shall be the sole interface (relay) to the outside world and a serial data connection between STOM and STOC can be used to isolate the local hardware components from public access, e.g., denial of service attacks.

⇒ *If STOC and STOM are realised within the same unit*, the safety and security demands outlined for the STOM actor prevail, i.e., full features AAA (authentication, authorisation, and admission control) is required.

Note: IEC 61850 offers free allocation of LNs in logical device (LDs). The recommendation to host locally related DERs, e.g., DLODs, DGENS, DSTOs with their specific DOs, in the same LD, is a standard way of ensuring that their operating modes are managed in a consistent way by operating the set of LNs at LD level. The DPMC is then applied to manage the entire set of DER LNs jointly, considering different DWMX²³ and implementing diverse grid

²⁴DPMCs can be used to implement locally enforced grid codes (LNxx) linked to the local DPCC (Point of Common Coupling), being the DECP at the edge to the area EPS (Electric Power System) also known as the distribution grid.

codes (LNxx)²⁴. Thus, the sketched STOC represents only the DSTO related fraction of a complete LD representing an interactive building or home energy management system, yielding a smart IED covering whole *active customer* sites in its entirety. However, to test the interoperability in respect to the use case the integration profile is focused on, the presented fraction should be sufficient.

Finally: Due to the integrated DWGC and DWMX LNs, setting parameters depending on the current state of the local DECP (distributed electricity connection point) is possible. Thus, local LDs can implement the state responsive grid codes enforced by local legislation (policies/regulations). These grid codes interfere only when the local DPCC, a special DECP called "point of common coupling", is in a boundary condition, i.e., in a state that requires a deterministic response (precisely known) to prevent harm beyond the DPCC. Thus, any settings that result from grid codes always excel any scheduled settings, until normal operation (no interference from grid codes) is regained. This behaviour is difficult to test and not relevant in respect to interoperability on the semantic, syntactic and communication layer, although essential for legal and operational interoperability. Latter is in most legislative environments enforced by mandatory device certification for grid connected devices that might cause any trouble.²⁵ Hence, the testing of responsive features related to the local grid state is yet excluded from prototype interoperability testing and relayed to the regionally enforced device certification.

◇ **Storage Management Instance (STOM):**

This instance acts as middleman; it buffers timed requests (i.e., schedules) and converts them into the instantaneous executable requests forwarded to the STOC just-in-time. This software module is required in case the storage control instance cannot handle schedules, e.g., cannot store and execute set-points that shall not become effective instantly.

↪ *The STOM actor needs to support specified transactions as listed in Table 3.2.2.2.*

Table 3.2.2.2: Transactions related to the STOM actor

TF-LEC-61850-Storage Transaction	integrated in STOC	stand-alone STOM	integrated in EMNG
T1: Get Storage Parameters (DSTO)		⊗	⊗
T2: Offer Storage Flexibility (FSCH)	x	x	
T3: Send Planned Schedule (FSCH)	o	o	
T4: Set ESS Power Attribute (DSTO)		x	x

'x' indicates the *initiator* role, 'o' the *responder* role, ⊗ where both applies.

The STOM shall integrate as many scheduler (FSCC) and related schedule (FSCH) LN instances as required for the use case, and all the LNs needed for regular operation. The STOM may be realised as part of a central energy management system (EMS), e.g., placed in the local station control centre (SCC), e.g., a HEMS, or in the central control office (CCO), e.g. a BEMS, integrating the EMNG actor. If the STOM is integrated as part of the device controller, i.e., together with the STOC, the STOM functionality converts a dumb storage asset into a smart energy storage system (ESS) ready for digital integration (digitalisation).

The STOM is composed by the FSCC LN instances that manage the different FSCH LNs associated to different DOs of DEResourceLNs (DGEN/DLOD/DSTO/DMDR) or powers at ECPs via DWGC/DWMX LNs, i.e., their *WSpt* DO, potentially managed by local power managers (DPMC), as shown in Figure 3.2.8. Every FSCC is linked to exactly one entity (*CtlEnt*) and all schedules (FSCH) present to realise the scheduled control of that entity.

The different FSCH groups per controlled entity (*CtlEnt*) are (a) those to be executed FSCHa 1..n, and (b,c) the flexibilities assumed available, i.e., schedule variation capacities for each direction, (b) plus/up and (c) minus/down. Here, flexibility is the potential variation of the scheduled charging and discharging of the DBATs managed by a

²⁵Smart energy devices become an active part of a digitally interlinked system-of-systems. Thus, compliance certification shall include semantic, syntactic and communication interoperability verification to assure safe integration in the digital system-of-systems management domain on top of the safe integration in the physical (electric) domain.

²⁶Whether FSCH LNs can and will be used to store, manage and communicate capacity schedules that contain predicted values somehow calculated from measured and set values of the managed DER components, is yet unclear. Feedback from professionals pending.

LEC-61850-Storage: STORage Management (STOM) modules
 LNs required for the IED to provide the necessary functionality

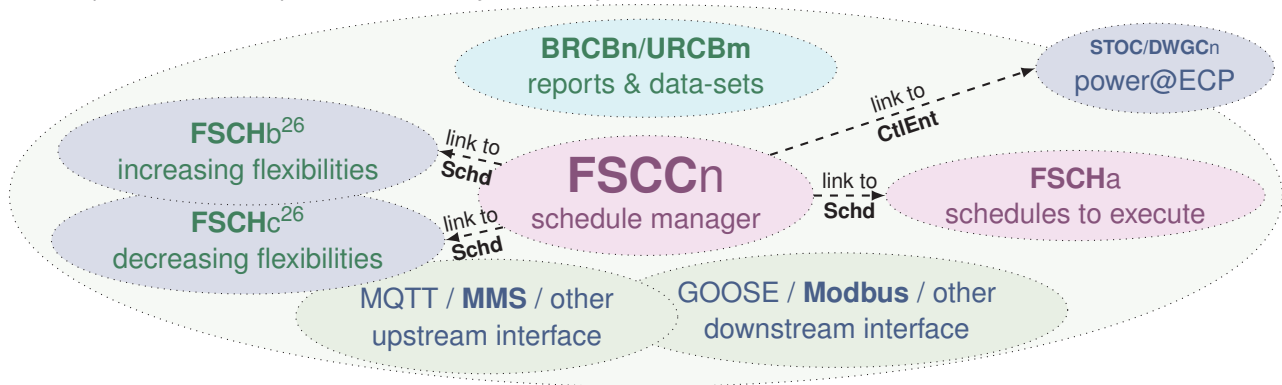


Figure 3.2.8: STOM components required for LEC-61850-Storage transactions, based on [11, Figure 47 and 48]

DSTO, which yields FSCHb 1..n and FSCHc 1..n respectively, actually the predicted AvlUpW and AvlDnW DOs²⁷ of the DSTO. How to compose and use FSCC and FSCH LNs is outlined in section 3.2.3 on page 40. Predicting and offering flexibility is out of the scope here. The presence of FSCHa and FSCHb dummies is yet sufficient, only FSCHa instances need to be correctly communicated, managed and executed to pass the interoperability testing. Accordingly is transaction T2 grayed-out in Table 3.2.2.2 and shall be added in a future revision, once good practice for communicating ±flexibilities is established.

↪ Exemplary FSCC specification and linking to the DSTO DOs used for testing, as well as the dummy FSCH specification to be used, are sketched in Listing 3.

Listing 3: STOM example configuration

```
<LDevice inst="STOM" desc="Storage Manager" IdName="STOM">
  <LN InClass="FSCC" InType="FSCC1" inst="1" prefix="">
    <DOI name="CtlEnt" desc="">
      <DAI name="setSrcRef" desc="" valImport="false">
        <Val>STOC/DWGC1</Val>
      </DAI>
    </DOI>
    <DOI name="Schd1" desc="">
      <DAI name="setSrcRef" desc="">
        <Val>STOM/FSCH1</Val>
      </DAI>
    </DOI>
    <DOI name="Schd2" desc="">
      ...
    </DOI>
  </LN>
  <LN InClass="FSCH" InType="FSCH1" inst="1" prefix="">
    <DOI name="DsaReq" desc="">
      <DAI name="ctlModel" valImport="false">
        <Val>direct-with-normal-security</Val>
      </DAI>
    </DOI>
    <DOI name="EnaReq" desc="">
      <DAI name="ctlModel">
        <Val>direct-with-normal-security</Val>
      </DAI>
    </DOI>
  </LN>
  <LN InClass="FSCH" InType="FSCH1" inst="2" prefix="">
    <DOI name="DsaReq" desc="">
      <DAI name="ctlModel">
        <Val>direct-with-normal-security</Val>
      </DAI>
    </DOI>
    <DOI name="EnaReq" desc="">
      <DAI name="ctlModel">
        <Val>direct-with-normal-security</Val>
      </DAI>
    </DOI>
  </LN>
  <LN InClass="FSCH" InType="FSCH1" inst="3" prefix="">
    <DOI name="DsaReq" desc="">
      <DAI name="ctlModel">
        <Val>direct-with-normal-security</Val>
      </DAI>
    </DOI>
    <DOI name="EnaReq" desc="">
      <DAI name="ctlModel">

```

```
<Val>direct-with-normal-security</Val>
  </DAI>
</DOI>
</LN>
</LDevice>
<DataTypeTemplates>
  <LNodeType id="FSCC1" InClass="FSCC">
    <DO name="ActSchdRef" type="ORS_2_ActSchdRef"/>
    <DO name="ValMV" type="MV_1_Val"/>
    <DO name="CtlEnt" type="ORG_1_InclSto"/>
    <DO name="Schd1" type="ORG_1_InclSto"/>
    <DO name="Schd2" type="ORG_1_InclSto"/>
    <DO name="Schd3" type="ORG_1_InclSto"/>
  </LNodeType>
  <LNodeType id="FSCH1" InClass="FSCH">
    <DO name="SchdSt" type="ENS_1_SchdSt"/>
    <DO name="EnaReq" type="SPC_1_EnaReq"/>
    <DO name="DsaReq" type="SPC_1_EnaReq"/>
    <DO name="SchdEnaErr" type="ENS_1_SchdSt"/>
    <DO name="NumEntr" type="ING_2_NumEntr"/>
    <DO name="SchdIntv" type="ING_1_SchdIntv"/>
    <DO name="StrTm" type="TSG_1_StrTm"/>
    <DO name="ValASG1" type="ASG_1_ValASG1"/>
    ...
    <DO name="ValASG5" type="ASG_1_ValASG1"/>
  </LNodeType>
  <DOType id="ORS_2_ActSchdRef" cdc="ORS">
    <DA name="stVal" bType="VisString255" fc="ST" dchg="true"/>
    <DA name="q" bType="Quality" fc="ST" dchg="true"/>
    <DA name="t" bType="Timestamp" fc="ST"/>
  </DOType>
  <DOType id="MV_1_Val" cdc="MV">
    <DA name="mag" type="AnalogueValue_1" bType="Struct" fc="MX" dchg="true" dupd="true"/>
    <DA name="q" bType="Quality" fc="MX" qchg="true"/>
    <DA name="t" bType="Timestamp" fc="MX"/>
  </DOType>
  <DOType id="ORG_1_InclSto" cdc="ORG">
    <DA name="setSrcRef" bType="VisString129" fc="SP" dchg="true"/>
  </DOType>
  <DOType id="ENS_1_SchdSt" cdc="ENS">
    <DA name="stVal" bType="INT32" fc="ST" dchg="true" dupd="true"/>
    <DA name="q" bType="Quality" fc="ST" qchg="true"/>
    <DA name="t" bType="Timestamp" fc="ST"/>
  </DOType>
  <DOType id="SPC_1_EnaReq" cdc="SPC">
    <DA name="Oper" type="DPCOperate_3" bType="Struct" fc="CO"/>
    <DA name="stVal" bType="BOOLEAN" fc="ST" dchg="true"/>
    <DA name="q" bType="Quality" fc="ST" qchg="true"/>
    <DA name="t" bType="Timestamp" fc="ST"/>
    <DA name="ctlModel" type="ctlModel" bType="Enum" fc="CF" dchg="true"/>
  </DOType>

```

²⁷ Because predicted flexibility is never absolutely certain, a reliability metric should be provided aligned to the offered schedules, e.g., indicating that the confidence into the amounts predicted is for example 90%, possibly communicated via 'misusing' the quality attribute.

```

<DOType id="ING_2_NumEntr" cdc="ING">
  <DA name="setVal" bType="INT32" fc="SP" dchg="true"/>
</DOType>
<DOType id="ING_1_SchdIntv" cdc="ING">
  <DA name="setVal" bType="INT32" fc="SP" dchg="true"/>
  <DA name="units" type="Unit_1" bType="Struct" fc="CF" dchg="true"/>
</DOType>
<DOType id="TSG_1_StrTm" cdc="TSG">
  <DA name="setCal" type="CalendarTime_1" bType="Struct" fc="SP" dchg="true"/>
</DOType>
<DOType id="ASG_1_ValASG1" cdc="ASG">
  <DA name="setMag" type="AnalogueValue_1" bType="Struct" fc="SP" dchg="true"/>
</DOType>
<DOType id="AnalogueValue_1">
  <BDA name="f" bType="FLOAT32" desc="The value of f shall be the FLOAT representation of the
    measured value. f shall represent the technological value in SI units."/>
</DOType>
<DAType id="DPCOperate_3">
  <BDA name="ctlVal" bType="BOOLEAN"/>
  <BDA name="origin" type="Originator_1" bType="Struct"/>
  <BDA name="ctlNum" bType="INT8U"/>
  <BDA name="t" bType="Timestamp"/>
</DAType>
  <BDA name="Test" bType="BOOLEAN"/>
  <BDA name="Check" bType="Check"/>
</DAType>
<DAType id="Originator_1">
  <BDA name="orCat" type="orCategory" bType="Enum"/>
  <BDA name="orIdent" bType="Octet64"/>
</DAType>
<DAType id="Unit_1">
  <BDA name="SIUnit" type="SIUnit" bType="Enum"/>
</DAType>
<DAType id="CalendarTime_1">
  <BDA name="occ" bType="INT16U"/>
  <BDA name="occType" type="occType" bType="Enum"/>
  <BDA name="occPer" type="occPer" bType="Enum"/>
  <BDA name="weekDay" type="weekDay" bType="Enum"/>
  <BDA name="month" type="month" bType="Enum"/>
  <BDA name="day" bType="INT8U"/>
  <BDA name="hr" bType="INT8U"/>
  <BDA name="mn" bType="INT8U"/>
</DAType>
</Data Type Templates>

```

Accumulated reporting is required if the DSTO/DPMC/DWGC/DWMX LNs managed by a STOM shall be made visible and accessible as a single unit to the EMNG actor and beyond that, e.g., to some SCADA control centre or flexibility market. Therefore, the configured Report Control Blocks (IEC 61850-6 RCB), buffered (BRCB) or unbuffered (URCB) and the assigned DataSets shall collect reported values from the managed downstream DSTOs into a single report (DataSet) provided upstream. Because DataSets contain links to DOs and DAs only, i.e., store no data, it should be easy to add a link from a 'received' DataSet into a 'provided' DataSet. See SBB section 4.1.3 for details on using the IEC 61850 reporting feature.

The two communication interfaces (up- & down-stream) shall support at least IEC 61850 via MMS for upstream communication and IEC 61850 via GOOSE or other low/deterministic latency protocols for downstream communication. To perform interoperability testing, MMS may be made available and used in either direction. If the STOM actor is integrated in the STOC, only upstream communication is tested. If the STOM is integrated in the EMNG actor, only downstream communication is tested. In the latter case, the downstream communication most probably uses some Modbus variant over a serial data connection. To monitor exchanged information during peer-to-peer tests, Modbus/TCP shall be provided as mandatory alternative if GOOSE is not provided.

The STOM actor may yet appear new, but in practice it is always somewhere present, just not mentioned explicitly. Here we do so because the transition toward smart grids will soon re-position this actor from some control centre into the then self-contained and somewhat smart storage assets.

◇ Energy Management Instance (EMNG):

Commonly, the EMNG actor manages several energy assets in parallel. The EMNG operator configures the EMNG to best fulfil all customer wishes via set-points, generic aims, and optimisation targets. Metaphorically speaking, the EMNG is the conductor of an orchestra of energy assets operated at customer premises. In a cellular approach, EMNGs can be cascaded, i.e., each EMNG appears to the outside alike a mixed DER component (DMDR) that can be managed. Here, we assume that the EMNG represents an interactive home or building energy management system, and that the resultant DMDR covers an ensemble of components that are not individually accessible from beyond the associated DECP, e.g. an *active customer* site incorporating a set of different components managed locally only.

↔ *The EMNG actor needs to support specified transactions as listed in Table 3.2.2.3.*

The EMNG shall integrate the following LNs and shall provide access to the following DOs to perform the required transactions:

- LNs: DMDR, DECP/DPC, DWGC, DWMX, DPMC, BRCB, URCB, and the LNs needed for regular operation
- DOs: InclDer, WSpt, DERRef, FctRef, OutEcpRef, power boundaries, etc., and mandatory DOs required

Note that these LNs and DOs are only required to define an EMNG server that is to be integrated into a higher control regime. For example, to realise DSM (demand side management), provide grid edge services, offer *utility node* features, or respond to grid state information, i.e., to be visualised as an asset in the DSO's SCADA environment.

Commonly, the actual architecture of the EMNG actor is tuned to needs. Thus, Figure 3.2.9 shows components commonly required for the integration of a mixed DER asset according to the use case and transactions considered

Table 3.2.2.3: Transactions related to the EMNG actor

TF-LEC-61850-Storage Transaction	stand-alone EMNG	with integrated STOM
T1: Get Storage Parameters (DSTO)	⊗	⊗
T2: Offer Storage Flexibility (FSCH)	o	
T3: Send Planned Schedule (FSCH)	x	
T4: Set ESS Power Attribute (DSTO)		x

'x' indicates the *initiator* role, 'o' the *responder* role, '⊗' where both applies.

in this IES Integration Profile so far. However, the transactions can be achieved likewise with less LNs using the according DOs of the present LNs.

LEC-61850-Storage: Energy MaNaGer (EMNG) modules
LNs required for the IED to provide the necessary functionality

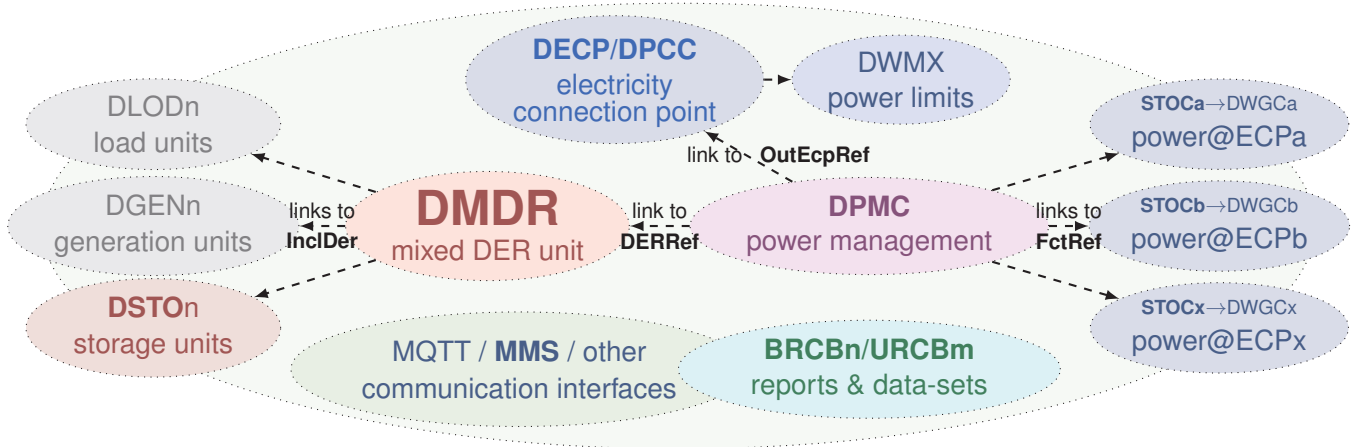


Figure 3.2.9: EMNG components required for LEC-61850-Storage transactions, based on [11, Figure 50, B.3 and B.4]

↔ The IED configuration file excerpt shown in Listing 4 specifies example LD/IED components as shown in Figure 3.2.9.

Listing 4: EMNG example configuration

```

<LDevice inst="EMNG" desc="Energy Manager" IdName="EMNG">
  <LN InClass="DMDR" InType="DMDR1" inst="1" prefix="">
    <DOI name="InclDer" desc="">
      <DAI name="setSrcRef" desc="" vallmport="false">
        <Val>STOC/DSTO1</Val>
      </DAI>
    </DOI>
    <DOI name="WSpt" desc="">
      <DAI name="ctlModel">
        <Val>direct-with-normal-security</Val>
      </DAI>
    </DOI>
  </LN>
  <LN InClass="DPMC" InType="DPMC3" inst="1" prefix="">
    <DOI name="WSpt" desc="">
      <DAI name="ctlModel" vallmport="false">
        <Val>direct-with-normal-security</Val>
      </DAI>
    </DOI>
    <DOI name="DERref" desc="">
      <DAI name="setSrcRef" desc="">
        <Val>EMNG/DMDR1</Val>
      </DAI>
    </DOI>
    <DOI name="OutEcpRef" desc="">
      <DAI name="setSrcRef" desc="">
        <Val>EMNG/DECP1</Val>
      </DAI>
    </DOI>
  </LN>
</LDevice>

<DataTemplates>
  <LNodeType id="DMDR1" InClass="DMDR">
    <DO name="WSpt" type="APC_3_WSpt">
      <DO name="InclDer" type="ORG_1_InclSto">
        <DO name="AvlUpW" type="MV_1_AvlUpW">
          <LNodeType>
            <LNodeType id="DPMC3" InClass="DPMC">
              <DO name="DERref" type="ORG_1_InclSto">
                <DO name="OutEcpRef" type="ORG_1_InclSto">
                  <DO name="WSpt" type="APC_3_WSpt">
                    <LNodeType>
                      <LNodeType id="DECP1" InClass="DECP">
                        <LNodeType>
                          <DOType id="APC_3_WSpt" cdc="APC">
                            <DA name="Oper" type="APCOperate_5" bType="Struct" fc="CO"/>
                            <DA name="mxVal" type="AnalogueValue_1" bType="Struct" fc="MX" dchg="true"/>
                            <DA name="q" bType="Quality" fc="MX" qchg="true"/>
                            <DA name="t" bType="Timestamp" fc="MX"/>
                            <DA name="ctlModel" type="ctlModel" bType="Enum" fc="CF"/>
                          </DOType>
                          <DOType id="ORG_1_InclSto" cdc="ORG">
                            <DA name="setSrcRef" bType="VisString129" fc="SP" dchg="true"/>
                          </DOType>
                          <DOType id="MV_1_AvlUpW" cdc="MV">
                            <DAType id="APCOperate_5">
                              <BDA name="ctlVal" type="AnalogueValue_1" bType="Struct"/>
                              <BDA name="origin" type="Originator_1" bType="Struct"/>
                              <BDA name="ctlNum" bType="INT8U"/>
                              <BDA name="t" bType="Timestamp"/>
                              <BDA name="Test" bType="BOOLEAN"/>
                              <BDA name="Check" bType="Check"/>
                            </DAType>
                            <DAType id="AnalogueValue_1">
                              <BDA name="f" bType="FLOAT32" desc="The value of f shall be the FLOAT representation of the measured value. f shall represent the technological value in SI units."/>
                            </DAType>
                            <DAType id="Originator_1">
                              <BDA name="orCat" type="orCategory" bType="Enum"/>
                              <BDA name="orIdent" bType="Octet64"/>
                            </DAType>
                          </DataTemplates>

```

Here, we find two core LNs, the DMDRLN and the associated DPMCLN. Latter refers to the power management of the entire set of assets joined in the DMDR (linked-in on the far left in Figure 3.2.9). The connection to STOM and STOC actors is achieved by linking the according DWGCLNs that these are linked to as well (on the far right in Figure 3.2.9). Where the EMNG actor represents an entire site connected to the area grid, the assigned electricity connection point is a DPCCLN (Point of Common Coupling), which replaces the commonly assigned 'virtual' DECP LN and is responsible to implement the regionally applicable grid codes.

The schedules the EMNG needs to handle and communicate are to be accessed via the FSCCs linked to the DWGCs that themselves are linked into the DPMC. Where the EMNG includes the STOM, these are locally present, in all other cases they are *digital twins* bidirectionally linked to the remote instances via the communication interface.

Note: The skills required to make beneficial use of the accessible schedules and features, i.e., the 'quality' of the algorithms that convert available flexibility into utile schedules to execute, is not an interoperability issue and thus, a vendor quality not to be restricted by unnecessary specifications.

3.2.3 IEC-61850-Storage: Solution Building Blocks (SBBs)

↔ *SBBs are (generic) functional blocks that shall be (re-)usable among IES Integration Profiles and beyond in order to prevent redundant specification of the same features used in different IES Integration Profiles.*

◇ IEC 61850-7-420:2021 — DSTO and DMDR:

The logical node DSTO is used to describe, provide, and access parameters and features of storage assets. The number of specified data objects (DOs) is vast (12 pages ~ 150) [11, Table A.36], but most are optional and therefore not reliably provided by all manufacturers. From case to case different DOs will be provided and used. A huge interoperability problem arises if different DOs may be used to achieve the same goal. For example, the total power P_{tot} cannot be accessed if an asset provides current I_{tot} and voltage U_{tot} DOs only. Obviously is $P = UI$, but accessing the DO representing P_{tot} will always fail, or more precisely is not supported by that asset in the field. An automated integration relying on accessing P_{tot} is with this asset not possible.

↔ *DSTO*: Table 3.2.3.1 shows an excerpt of potentially utile DOs.

↔ *Every integration profile referencing this SBB shall unambiguously specify the DOs and DAs mandatory for the use case the profile refers to, irrespective of whether these are mandatory or optional by IEC 61850 specs. Interoperability testing must fail if any of the so specified DOs or DAs is not correctly provided.*

The Distributed "Mixed combined DER" LN (DMDR) is used to jointly describe, provide, and access parameters and features of a mixed DER that joins different asset types, including a mixture of generation, load and storage assets [11, Section A.3.1.5.3]. The list of DOs [11, Table A.32] is again vast (6 pages), mostly optional, and probably not final yet. An important feature to be noted is that DMDRs are cascadable: A DMDR can join smaller DMDRs into a jointly controllable mix of assets alike joining other DER assets. For example, a DMDR specified on the district level can include DMDRs on the building/campus level which may include DMDRs on an again lower level.

Each DMDR will commonly include a DPMC that manages the internal energy management and thereby splits and assigns requests from the outside to the merged assets, which themselves may be managed by their own DPMCs. This allows the design of cascaded management/control architectures where on each layer and for each asset grouping different aims can be realised.

◇ IEC 61850-7-420:2021 — DWGC, DPMC and DECP:

These three logical nodes enable the modelling of resource/asset management features. The DECP is a virtual Electricity Connection Point for which intended power flows can be set and limits specified. The DPMC implements power management across several linked assets, and each DWGC provides a power set-point, the WSpt DO that is linked to a DECP and into a DPMC.

The Distributed "Power Management Capability" LN (DPMC) is an *intelligent black box* that uses input from the linked DERs and provides feedback to the DER resources in form of modifying settings, requests, or commands to

Table 3.2.3.1: Excerpt showing potentially utile DOs of LN DSTO according to IEC 61850-7-420:2021 (~250 DOs in total)

DSTO 61850-7-420:2021 p.241ff				This logical node contains information related to monitoring and controlling energy storage functions and states. It can apply to single element or to aggregated one.	
Data object name	Common data class	Data Attribute	Functional Constraints	Explanation	Requirement
InclSto	ORG			References to Included storage resource, which could be virtual, aggregated, or physical. This DO points to an instance of DSTO. (DSTO)	multi-optional
OutEcpRef	ORG			Reference to ECP directly connected at the output of the DER, the "plug" part. Note: The power management function ECP associated to this same resource will refer to the "socket" part. (DER_NameplateRatingsLN)	mandatory
DERTyp	ENG (DERUnitKind)			Type of DER. (DER_NameplateRatingsLN)	mandatory
ChaWMax	ASG			Maximum active power while charging (StorageOperationalSettingsLN)	mandatory
DschWMax	ASG			Maximum active power while discharging. This DO is optional because WMax could be used. (StorageOperationalSettingsLN)	optional
UseWhMinPct UseWhMaxPct	ASG			The energy reserve level below/above which the storage system may only be dis-/charged in emergency situations, expressed as a percentage of the usable capacity, WhUseCap. (StorageOperationalSettingsLN)	optional
UseWh	ASG			Operational setpoint for usable energy storage capacity in Wh. (StorageOperationalSettingsLN)	optional
WSpt	APC			Active power setpoint. Its mxVal attribute reflects the value of the setpoint that is requested. (DER_StateAbstractLN)	optional
InWh	MV			Available energy capacity to be charged in Wh. (DER_StorageLN)	optional
OutWh	MV			Energy stored and available for discharging in Wh. (DER_StorageLN)	optional
SocWh	MV			Actual state of charge expressed in Wh. (DER_StorageLN)	optional
UseSocPct	MV			Usable state of charge (expressed as percent of total usable energy capacity UseWh) which may be directly measured or calculated. (DER_StorageLN)	optional
SocEffWhPct	MV			State of charge as percentage in relation to the effective energy capacity of the storage resource with respect to the degradation so far (EffWh). (DER_StorageLN)	optional
AvlDschW	MV			Available discharging power. (DER_StorageLN)	optional
AvlChaW	MV			Available charging power. (DER_StorageLN)	optional
AvlUpW	MV			Available capability (measured or calculated) for increasing active output, including increasing generation of active power, even if currently consuming power. (DER_ActualPowerInformationLN)	optional
AvlDnW	MV			Available capability (measured or calculated) for decreasing active power, including increasing the consumption of active power, even if currently generating power. (DER_ActualPowerInformationLN)	optional

meet specified 'goals'. Goals shall be prioritised and originate from higher level management, operational needs (e.g., grid codes), and operator requests [11, Section A.3.1.5.3].

↔ *DPMC*: Table 3.2.3.2 repeats the essential DOs (and DAs) of the DPMC to manage power flows.

Table 3.2.3.2: Selection of DPMC LN DOs according to IEC 61850-7-420:2021 [11, Table A.30]

DPMC 61850-7-4:2021 p.217ff				The DER power management capability LN (DPMC) is a "black box" that introduces "intelligence" for managing DERs. The implemented power management functions use input from associated DERs to assess the situation and provide feedback to the DERs in form of modified settings/requests/commands toward meeting differently prioritised "goals" across management levels.	
Data object name	Common data class	Data Attribute	Functional Constraints	Explanation	Requirement
WTopFct	ORS			Current top priority operational function driving the setting of the expected active power of the concerned DER	multi optional
ReqW ReqTotW ReqWMin ReqWMax	MV			Actual/Total/Min/Max active power requested from the associated DER or a hierarchically lower DPMC	multi optional
WSpt DirWSpt etc.	APC			Active (differential/other) power setpoint – the mxVal attribute reflects the value of the setpoint that is requested	multi optional
DERRef	ORG			Reference to the DER resource LN managed (DERResourceLN)	mandatory
OutEcpRef	ORG			Reference to the Electrical Reference Point LN which the power management function has an impact on (ElectricalReferencePointLN)	mandatory
FctRef	ORG			Reference(s) to Operational Function LNs (OperationalFunctionLN)	multi optional
InRef	ORG			Object reference of DO bound to the input n (DomainLN)	multi optional

The Distributed "Set Active Power" LN (DWGC) belongs to the Active Power LNs ([11, Section A.3.2.9]) in the DER Operational Functions block. Its DOs are mostly optional, except for *InEcpRef*, the link to a DECP (see next),

the currently requested active power *ReqW* (of MV type – measured value), the *RmpRteUse* specifying whether ramping is limited or not, and either *WSpt* or *WSptPct*, the active power set-point in absolute or in percent of the *WMax* at the linked DECP, respectively [11, Table A.102].

↔ *DWGC*: Table 3.2.3.3 lists the essential DOs (and DAs) of the DWGC LN that implements operational function to set target active power values (generation or consumption) at a Reference ECP that a DER entity (LD) should achieve.

Table 3.2.3.3: Selection of DWGC LN DOs according to IEC 61850-7-420:2021 [11, Table A.102]

DWGC 61850-7-4:2021 p.409ff			The Set Active Power operational function (DWGC) is used to set target active power values (generating or consuming) that the DER should achieve at the referenced ECP.		
Data object name	Common data class	Data Attribute	Functional Constraints	Explanation	Requirement
ReqW	MV			Requested active power resulting from the function – quality attribute shall be invalid when function is not active (ActivePowerLN)	mandatory
SocExpc SocWhExpc SocExpcTms	MV MV INS			Expected State of Charge (% or Wh) at SocExpcTms Time in seconds from now – assuming persistence of the current command (ActivePowerLN)	optional
WSpt WSptPct	APC			Active power setpoint (Wh or % of Maximum Power capability WMax (?) of the assignend ECP) – mxVal attribute reflects the value of the setpoint that is requested (ActivePowerLN)	only one optional
RmpRteUse	SPG			True = use limited ramp rates – False = not limited to ramp rates (RampRatesLN)	mandatory
RmpTms	ING			Ramp time for moving from current operational mode settings to new mode settings upon enabling of the new mode (OperationalFunctionLN)	optional
ModPsAcc ModNsAcc	ASG			Average plus/minus accuracy with which the function will follow that stated values of the dependent curve values (OperationalFunctionLN)	optional
InEcpRef	ORG			Referenced ECP which is the source of the measurements used by the DER mode – consists of index/address of the appropriate DECP LN – within the DER or the proxy of the ECP or a device at the ECP (ElectricalContextReferenceLN)	mandatory
InRef	ORG			Object reference of DO bound to the input n (DomainLN)	multi optional

The Distributed "Electrical Connection Point" LN (DECP) contains the operational characteristics of an operational connection point. Every LN representing some DER asset is mandatorily connected by it's own DECP, even if DECPs reside on the same physical wire. Therefore, it is virtual, in contrast to the Physical Electrical Connection Point LN (PECP?), which represents an energy conducting medium.

↔ *DECP*: Table 3.2.3.4 repeats the essential DOs (and DAs) of the DECP to manage individual power flows.

Table 3.2.3.4: Selection of DECP LN DOs according to IEC 61850-7-420:2021 [11, Table A.26]

DECP 61850-7-4:2021 p.207ff			This LN contains the operational characteristics of a virtual Electric Connection Point (ECP).		
Data object name	Common data class	Data Attribute	Functional Constraints	Explanation	Requirement
VRef	ASG			Default reference voltage for functions using voltage at this ECP as input. May be overridden by VRef setpoints in specific operational functions (PhysicalElectricalConnectionPointLN)	mandatory
VRefPct	ASG			Percent of VRef to use in operational function calculations (PhysicalElectricalConnectionPointLN)	optional
VMax	ASG			Rated maximum Voltage (PhysicalElectricalConnectionPointLN)	optional
VMin	ASG			Rated minimum Voltage (PhysicalElectricalConnectionPointLN)	optional
InRef	ORG			Object reference of DO bound to the input n (DomainLN)	multi optional

A special version of the DECP is the Distributed "Point of Common Coupling" LN (DPCC), which refers to the point where the local system is coupled to the area management, i.e. to the responsibility of the local distribution system operator (DSO) [11, Section A.3.1.4.4]. This is the point where the grid codes need to be implemented mandatorily, and therefore is the *AreaEpsWMax* DO mandatory for the DPCC only.

◇ **IEC 61850-7-420:2021 — FSCC and FSCH:**

These functional logical nodes are used to specify and run planned schedules on some controllable or setting DO of a DER. Having scheduled expected behaviours of DERs is very common, and thanks to 61850-90-10, now merged into IEC 61850-7-4:2010+AMD1:2020, some scheduling capabilities are supported by the IEC 61850 series.²⁹

²⁹We find the specification of the functional LNs FSCC and FSCH in IEC 61850-7-4:2010+AMD1:2020 (Edition 2.1 – consolidated version,

How to integrate them with DERs is presented in IEC 61850-7-420:2021 on page 95ff, section 4.3.3.6 "**Modelling of scheduled or differed energy behaviours of DERs**". The scheduling concepts of IEC 61850, as defined in IEC 61850-7-4:2010/AMD1:2020 relies on three main element types:

- The **scheduled entity**: a DO of CDC of "controllable" type (APC, ENC, SPC, etc.) or setting type (ASG, ENG, SPG, ORG, etc.) or the Mod DO to en-/dis-able operational functions or change their priorities (ModPrio).
- The **schedule description**: each schedule is hosted into one LN instance of class FSCH that specifies a sequence of scheduled entity settings, sequence properties, and control parameters
- The **schedule controller**: each scheduler, hosted into one LN instance of class FSCC, is associated to a set of schedules and to a single controllable entity, and computes the current value of the scheduled entity

↪ *FSCH*: Table 3.2.3.5 repeats the essential DOs and DAs of the functional logical node FSCH.

Concurring schedules are handled by an FSCC LN. An individual FSCC instance is required for each DA that shall be controlled/set using schedule(s) (FSCHs). It assures that at every time instance the schedule with the highest priority is executed and keeps track of all FSCH LNs available, i.e., implements the state machine shown in figure 3.2.10.

↪ *FSCC*: Table 3.2.3.6 repeats the essential DOs and DAs of the functional logical node FSCC.

Every configured schedule needs to be validated, i.e., pass the *Integrity-Check*, before an execution can be triggered. The validation is triggered by the *Enable* request. Schedules can be reusable (e.g., event triggered), repetitive (i.e., periodic or time-instance triggered), or one-time executable only. Accordingly, different *Trigger* criteria need to be configured and considered. For example, an array of UTC start times (*StrTm*) configures specific time instances if a schedule is non-periodic, whereas for a periodic schedule the same array specifies one or more periodicities via interval times (durations).

The reuse properties determine what happens whenever the execution of a schedule ends, i.e., which state follows when leaving the *Running* state. Periodic schedules automatically return to the *Ready* state, as do schedules with remaining execution instances (*StrTm*) in the future. Reusable schedules proceed to the *Standby* state, except in the case they are event triggered, which enables a direct return to the *Ready* state. If a schedule is neither *reusable* nor *periodic*, it proceeds to the *Not ready* state once all *StrTm* reside in the past. A reusable non-periodic time triggered schedule needs to be assigned new start times (*StrTm*) before it can be enabled again. The resultant state machine is depicted in figure 3.2.10.

At any time, if a schedule becomes *Disabled* it instantly changes into the *Not ready* state, where it needs to pass the *Integrity-Check* again to proceed to the *Ready* state again. States residing in the *Ready* or *Running* state shall not be altered, i.e., configured and stored schedules shall be available for altering in the *Standby* and *Not ready* state only, where they have to pass the *Integrity-Check* triggered by a dedicated *Enable* request before the schedule may again become *Ready* and its execution triggered after having been altered.

We shall note that (cite): "Schedules and operational functions are both tagged with given priorities (respectively FSCH/SchdPrio DO and OperationalFunctionLN/ModPrio DO), however these priorities are set within disconnected priority scales (no superseding rules between schedule priorities and operational functions priorities), except specified differently for a given project."

FSCH and FSCC are also mentioned in Addendum D.2 (Table D.1 "*DER functions and operational functions*", row #21, page 530) in IEC 61850-7-420:2021, page 525ff, introduced as (cite): "*A list of the most common DER operational functions is shown in Table D.1. The table also indicates where the operational functions are described in the EPRI Common Functions report, IEC TR 61850-90-7 (will be included in the IEC 61850-7-520 guidelines), and the current edition of IEC 61850-7-420. In addition, it indicates which operational functions are mandatory in different jurisdictions.*"

page 165ff). Again, it is promised that (cite): "*The coming IEC TR 61850-7-5 Edition 2 should provide some additional examples of case of use of these specific LNs.*" It is also mentioned that these guidelines are (cite): "*Under preparation. Stage at the time of IEC 61850-7-4:2010+AMD1:2020 publication: IEC/ADTR 61850-7-5:2021.*"

Table 3.2.3.5: The DOs of the functional LN FSCH according to IEC 61850-7-4:2010+AMD1:2020

FSCH 61850-7-4:2010+AMD1:2020 p.165ff				This logical node contains information related to specifying timely scheduled changes of a controllable/settable DO.	
Data object name	Common data class	Data Attribute	Functional Constraints	Explanation	Requirement
NamPit	LPL			Name plate of the logical node (DomainLN)	optional
Beh	ENS (Behaviour ModeKind)			Read-only value, describing the behaviour of a domain logical node. It depends on the current operating mode of the logical node ('DomainLN.Mod'), and the current operating mode of the logical device that contains it ('LLN0.Mod'). Processing of the quality status ('q') of the received data is the prerequisite for correct interpretation of 'DomainLN.Beh'.	mandatory
Health	ENS (HealthKind)			Reflects the state of the LN related to hard- and software. More detailed information related to the source of a problem may be provided by specific DA of the LN (DomainLN)	optional
Mir	SPS			If <i>true</i> , the LN is a mirror of an LN from another LD that does not reflect this physical device. If <i>false</i> , it is recommended to omit the DO Mir. (DomainLN)	conditional mandatory
Mod	ENC (Behaviour ModeKind)			Operating mode of the domain logical node that may be changed by operator. Processing of the quality status ('q') of the received data is the prerequisite for correct interpretation of the operating mode.	optional
InRef	ORG			Object reference of DO bound to the input n (DomainLN)	multi optional
SchdSt	ENS (ScheduleStateKind)			State of this schedule (ControlEquipmentInterfaceLN)	mandatory
ActStrTm	TCS			The time at which the schedule started running. Quality of the value shall be <i>invalid</i> if the schedule is not running.	optional
NxtStrTm	TCS			The next time the schedule is planned/intended to start or re-start running. The quality of the value shall be <i>invalid</i> if no (re-)start time is planned.	mandatory
SchdEntr	INS			Data-Instance-ID of the current schedule entry (Val[ASG ING SPG ENG]) of a running schedule. As long as the schedule is not running, the value shall be 0.	optional
ValMV ValINS ValSPS ValENS	MV INS SPS ENS (EnumDA)			Current value determined by the schedule. As long as the schedule is not running the quality DA of the value is invalid. The unit of this data shall be the same as the unit of the data object(s) Val[ASG ING SPG ENG].	at most one
EnaReq DsaReq	SPC			(controllable) Operating with value true initiates enable/disable transition requests according to the state diagram; operating with value false is ignored. The change of its status value is a local issue.	both mandatory
SchdEnaErr	ENS (ScheduleEnabling ErrorKind)			Enumeration reflecting the assumed error that occurred at the last Schedule Enabling request	mandatory
SchdPrio	ING			The priority relation of this schedule (0..n) with higher numbers superseding lower numbers. Shall be a positive value. If missing the default is zero.	optional
NumEntr	ING			The number of schedule entries that are valid out of the instantiated ValASG, ValING, ValSPG or ValENG. NumEntr shall be > 0 AND <= number of instantiated Val[ASG ING SPG ENG]'s]	mandatory
SchdIntv	ING			The schedule interval duration in time entities as specified in the unit DA. The SIUnit is mandatory in this data object. The total duration of a schedule results from NumEntr times SchedIntv	mandatory
ValASG ValING ValSPG ValENG	ASG ING SPG ENG (EnumDA)			The instantiated ASG ING SPG ENG schedule values	mandatory one only
StrTm	TSG			Start time of the schedule in UTC time	optional
EvtTrg	SPG			If true the change of the schedule to the running and ctivated state is triggered by an external event and not by the start time, The external event si referenced through 'InSyn'.	optional
InSyn	ORG			Object reference of the external trigger if the schedule is triggered by a event	mandatory if EvtTrg exists
SchedReuse	SPG			If true, once terminated or disabled, the schedule will change to the validated state, otherwise it will change to the not ready state.	mandatory

3.2.4 LEC-61850-Storage: Notes

↔ *Optional information utile for an interoperable implementation* of the above specified actors and transactions, i.e., utile but not essential to realise the specified procedures and features.³⁰

³⁰If the information is essential for the realisation it shall be included above and not in the notes subsection.

Table 3.2.3.6: The DOs of the functional LN FSCH according to IEC 61850-7-4:2010+AMD1:2020

FSCC 61850-7-4:2010+AMD1:2020 p.165ff			This logical node contains information related to executing timely scheduled changes of a controllable/settable DO.		
Data object name	Common data class	Data Attribute	Functional Constraints	Explanation	Requirement
NamPlt	LPL			Name plate of the logical node (DomainLN)	optional
Beh	ENS (BehaviourModeKind)			Read-only value, describing the behaviour of a domain logical node. It depends on the current operating mode of the logical node ('DomainLN.Mod'), and the current operating mode of the logical device that contains it ('LLNO.Mod'). Processing of the quality status ('q') of the received data is the prerequisite for correct interpretation of 'DomainLN.Beh'.	mandatory
Health	ENS (HealthKind)			Reflects the state of the LN related to hard- and software. More detailed information related to the source of a problem may be provided by specific DA of the LN (DomainLN)	optional
Mir	SPS			If <i>true</i> , the LN is a mirror of an LN from another LD that does not reflect this physical device. If <i>false</i> , it is recommended to omit the DO Mir. (DomainLN)	conditional mandatory
Mod	ENC (BehaviourModeKind)			Operating mode of the domain logical node that may be changed by operator. Processing the quality status ('q') of the received data is the prerequisite for correct interpretation of the operating mode.	optional
InRef	ORG			Object reference of DO bound to the input n (DomainLN)	multi optional
ActSchdRef	ORS			Indication of which schedule is currently active as an object reference. Quality is invalid if no schedule is active. Active schedule is selected by the priority of the running schedules.	mandatory
ValMV ValINS ValSPS ValENS	MV INS SPS ENS			Current value determined by the schedule. As long as the schedule is not running the quality of the value shall be set to invalid. The unit of this data shall be the same as the unit of the data object(s) FSCH.ValASG.	at most one
CtlEnt	ORG			Object reference to the entity controlled by the schedule.	mandatory
Schd{n}	ORG			Object reference to schedule n, i.e., reference to the n th FSCH LN present.	multi mandatory

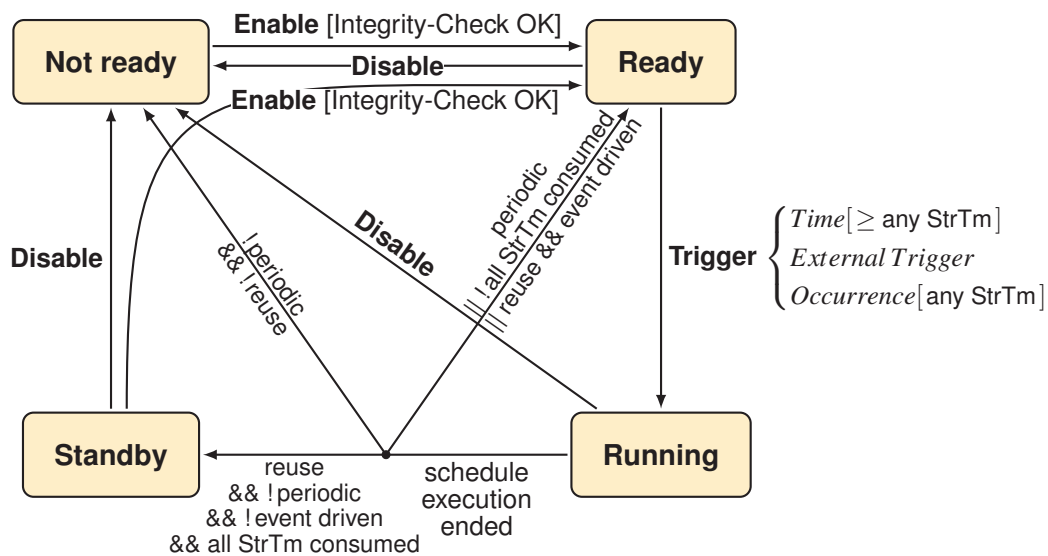


Figure 3.2.10: FSCH State Machine according to IEC 61850-7-4:2010+AMD1:2020

3.2.5 LEC-61850-Storage Attachment: Complete SCD file example

Listing 5: Example Substation Configuration Description including all actors – EMNG, STOM and STOC

```

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  ="http://www.iec.ch/61850/2003/SCLcoordinates" xsi:schemaLocation
  ="http://www.iec.ch/61850/2003/SCL SCL.xsd http://www.iec.ch
  /61850/2003/SCL&#xD;&#xA; misc/scl-specs/SCL.xsd" version="
  2007" revision="B" release="4" xmlns="http://www.iec.ch/61850/2003/
  SCL">
<Header id="" version="1" revision="1" toolID="ASE61850 SCL Manager
  V5.4.0" nameStructure="IEDName">
  <History>
    <Hitem version="1" revision="1" when="2/6/2023 10:50:46 AM" who="
      SCL Manager" what="Modifications" why="Improvements"/>
  </History>
</Header>
<Communication>
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        <P type="IP-GATEWAY">10.0.0.101</P>
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        <P type="OSI-PSEL">00000001</P>
        <P type="OSI-SSEL">0001</P>
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    </ConnectedAP>
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        <P type="IP-SUBNET">255.255.255.0</P>
        <P type="IP-GATEWAY">10.0.0.101</P>
        <P type="OSI-TSEL">0001</P>
        <P type="OSI-PSEL">00000001</P>
        <P type="OSI-SSEL">0001</P>
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        <P type="IP-GATEWAY">10.0.0.101</P>
        <P type="OSI-TSEL">0001</P>
        <P type="OSI-PSEL">00000001</P>
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  </SubNetwork>
</Communication>
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    <GetDataSetValue/>
    <DataSetDirectory/>
    <ConfDataSet max="20" maxAttributes="50" modify="true"/>
    <ReadWrite/>
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    <SettingGroups>
      <SGEdit resvTms="true"/>
      <ConfSG resvTms="true"/>
    </SettingGroups>
    <GetCBValues/>
    <ConfLNs fixPrefix="false" fixLnInst="false"/>
    <GOOSE max="20" fixedOffs="false" goose="true" rGOOSE="false"/>
    <GSSE max="20"/>
    <FileHandling/>
    <GSEDir/>
    <TimerActivatedControl/>
    <ConfLdName/>
    <SupSubscription maxGo="0" maxSv="0"/>
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      owner="true"/>
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      unbufReport="true" supportsLdName="false" maxAttributes="1000"
      maxReports="20" maxGOOSE="20" maxSMV="20"/>
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    <DynDataSet max="20" maxAttributes="50"/>
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        <LN0 InClass="LLN0" InType="LLN02" inst="">
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            </DAI>
          </DOI>
          <DOI name="InclDER" desc="">
            <DAI name="setSrcRef" desc="" vallImport="false">
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            </DAI>
          </DOI>
          <DOI name="WSpt" desc="">
            <DAI name="ctlModel">
              <Val>direct-with-normal-security</Val>
            </DAI>
          </DOI>
        </LN>
        <LN InClass="DPMC" InType="DPMC3" inst="1" prefix="">
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            </DAI>
          </DOI>
          <DOI name="WSpt" desc="">
            <DAI name="ctlModel" vallImport="false">
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          <DOI name="DERref" desc="">
            <DAI name="setSrcRef" desc="">
              <Val>EMNG/DMDR1</Val>
            </DAI>
          </DOI>
          <DOI name="OutEcpRef" desc="">
            <DAI name="setSrcRef" desc="">
              <Val>EMNG/DECP1</Val>
            </DAI>
          </DOI>
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        <LN InClass="DECP" InType="DECP1" inst="1" prefix="">
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            </DAI>
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  </IED>

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    <DataSetDirectory/>
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    <SettingGroups>
      <SGEdit resvTms="true"/>
      <ConfSG resvTms="true"/>
    </SettingGroups>
    <GetCBValues/>
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    <GOOSE max="20" fixedOfs="false" goose="true" rGOOSE="false"/>
    <GSSE max="20"/>
    <FileHandling/>
    <GSEDir/>
    <TimerActivatedControl/>
    <ConfLdName/>
    <SupSubscription maxGo="0" maxSv="0"/>
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      owner="true"/>
    <ClientServices bufReport="true" goose="true" gsse="false" readLog="
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      unbufReport="true" supportsLdName="false" maxAttributes="1000"
      maxReports="20" maxGOOSE="20" maxSMV="20"/>
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    <DynDataSet max="20" maxAttributes="50"/>
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        <DataSet name="config" desc="configuration data">
          <FCDA IdInst="STOC" InClass="DSTO" fc="SP" InInst="1" doName
            ="UseWhMinPct"/>
          <FCDA IdInst="STOC" InClass="DSTO" fc="SP" InInst="1" doName
            ="UseWhMaxPct"/>
          <FCDA IdInst="STOC" InClass="LLNO" fc="ST" doName="Health"/>
        </DataSet>
        <DataSet name="DynDat" desc="dynamic data">
          <FCDA IdInst="STOC" InClass="DSTO" fc="MX" InInst="1" doName
            ="WSpt" daName="mxVal.f"/>
          <FCDA IdInst="STOC" InClass="DSTO" fc="MX" InInst="1" doName
            ="SocWh" daName="mag.f"/>
          <FCDA IdInst="STOC" InClass="DSTO" fc="MX" InInst="1" doName
            ="OutWh" daName="mag.f"/>
          <FCDA IdInst="STOC" InClass="DSTO" fc="MX" InInst="1" doName
            ="InWh" daName="mag.f"/>
          <FCDA IdInst="STOC" InClass="DPMC" fc="MX" InInst="1"
            doName="WSpt" daName="mxVal.f"/>
          <FCDA IdInst="STOC" InClass="DWGC" fc="MX" InInst="1"
            doName="WSpt" daName="mxVal.f"/>
        </DataSet>
        <ReportControl name="config" confRev="0" dataSet="config" rptID="
          STOCSTOC/LLN0.rcb1" buffered="true" intgPd="60000" bufTime="2"
          desc="configuration data">
          <TrgOps dchg="true" qchg="true" dupd="true" period="false" gi="
            true"/>
          <OptFields seqNum="true" timeStamp="true" dataSet="true"
            reasonCode="true" dataRef="true" bufOvfl="true" entryID="true"
            configRef="true"/>
          <RptEnabled max="2" desc=""/>
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  </AccessPoint>
</IED>
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  reasonCode="true" dataRef="true" bufOvfl="true" entryID="true"
  configRef="true"/>
  <RptEnabled max="2" desc=""/>
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  <DAI name="subEna" desc="">
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</DOI>
<DOI name="NamPlt" desc="">
  <DAI name="vndor" desc="">
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  </DAI>
</DOI>
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  </DOI>
  <DOI name="OutEcpRef" desc="">
    <DAI name="setSrcRef" desc="">
      <Val>STOC/DECP1</Val>
    </DAI>
  </DOI>
  <DOI name="WSpt" desc="">
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    </DAI>
  </DOI>
  <DOI name="DERUnit" desc="">
    <DAI name="setSrcRef" desc="">
      <Val>STOC/DBAT1</Val>
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  </DOI>
  <DOI name="OutEcpRef" desc="">
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      <Val>STOC/DECP1</Val>
    </DAI>
  </DOI>
  <DOI name="FctRef" desc="">
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      <Val>STOC/DWGC1</Val>
    </DAI>
  </DOI>
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<LN InClass="DWGC" InType="DWGC1" inst="1" prefix="">
  <DOI name="Beh" desc="">
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  <DAI name="ctlModel">
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    </DAI>
  </DOI>
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<LN InClass="DBAT" InType="DBAT1" inst="1" prefix="">
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  </DOI>
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    <GetDirectory/>
    <GetDataObjectDefinition/>
    <GetDataSetValue/>
    <DataSetDirectory/>
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    <ReadWrite/>
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    <SettingGroups>
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      <ConfSG resvTms="true"/>
    </SettingGroups>
    <GetCBValues/>
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    <GSSE max="20"/>
    <FileHandling/>
    <GSEDir/>
    <TimerActivatedControl/>
    <ConfLdName/>
    <SupSubscription maxGo="0" maxSv="0"/>
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      owner="true"/>
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      unbufReport="true" supportsLdName="false" maxAttributes="1000"
      maxReports="20" maxGOOSE="20" maxSMV="20"/>
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    <DynDataSet max="20" maxAttributes="50"/>
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            <DAI name="vendor" desc="" vallimport="false">
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            </DAI>
          </DOI>
        </LN0>
      </LDevice>
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  </AccessPoint>
</IED>
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  <DOI name="Beh" desc="">
    <DAI name="stVal">
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    </DAI>
  </DOI>
<DOI name="CtlEnt" desc="">
  <DAI name="setSrcRef" desc="" vallimport="false">
    <Val>STOC/DWGC1</Val>
  </DAI>
</DOI>
<DOI name="Schd1" desc="">
  <DAI name="setSrcRef" desc="">
    <Val>STOM/FSCH1</Val>
  </DAI>
</DOI>
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  <DAI name="setSrcRef" desc="">
    <Val>STOM/FSCH2</Val>
  </DAI>
</DOI>
<DOI name="Schd3" desc="">
  <DAI name="setSrcRef" desc="">
    <Val>STOM/FSCH3</Val>
  </DAI>
</DOI>
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    <DAI name="stVal">
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    </DAI>
  </DOI>
<DOI name="DsaReq" desc="">
  <DAI name="ctlModel" vallimport="false">
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  </DAI>
</DOI>
<DOI name="EnaReq" desc="">
  <DAI name="ctlModel">
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  </DAI>
</DOI>
<DOI name="ValASG1" desc="">
  <SDI name="setMag" desc="">
    <DAI name="f" desc="" vallimport="false">
      <Val/>
    </DAI>
  </SDI>
</DOI>
<DOI name="ValASG2" desc="">
  <SDI name="setMag" desc="">
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    </DAI>
  </SDI>
</DOI>
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  </DOI>
  <DOI name="Beh" desc="">
    <DAI name="stVal">
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</LN>

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    </DAI>
  </DOI>
  <DOI name="Beh" desc="">
    <DAI name="stVal">
      <Val>on</Val>
    </DAI>
  </DOI>
  <DOI name="EnaReq" desc="">
    <DAI name="ctlModel">
      <Val>direct-with-normal-security</Val>
    </DAI>
  </DOI>
</LN>
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</AccessPoint>
</IED>
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    <DO name="Mod" type="ENC_1_Mod"/>
    <DO name="Beh" type="ENS_2_Beh"/>
    <DO name="Health" type="ENS_1_Health"/>
    <DO name="NamPit" type="LPL_1_NamPit"/>
  </LNodeType>
  <LNodeType id="DMDR1" InClass="DMDR">
    <DO name="WSpt" type="APC_3_WSpt"/>
    <DO name="InclDER" type="ORG_1_InclSto"/>
    <DO name="AvlUpW" type="MV_1_AvlUpW"/>
    <DO name="AvlDnW" type="MV_1_AvlUpW"/>
    <DO name="Beh" type="ENS_7_Beh"/>
  </LNodeType>
  <LNodeType id="DPMC3" InClass="DPMC">
    <DO name="DERref" type="ORG_1_InclSto"/>
    <DO name="OutEcpRef" type="ORG_1_InclSto"/>
    <DO name="WSpt" type="APC_3_WSpt"/>
    <DO name="Beh" type="ENS_7_Beh"/>
  </LNodeType>
  <LNodeType id="DECP1" InClass="DECP">
    <DO name="Beh" type="ENS_2_Beh"/>
  </LNodeType>
  <LNodeType id="FSCH2" InClass="FSCH">
    <DO name="NumEntr" type="ING_2_NumEntr"/>
    <DO name="ValASG1" type="ASG_1_ValASG"/>
  </LNodeType>
  <LNodeType id="FSCC1" InClass="FSCC">
    <DO name="ActSchdRef" type="ORS_2_ActSchdRef"/>
    <DO name="ValMV" type="MV_1_Vol"/>
    <DO name="CtlEnt" type="ORG_1_InclSto"/>
    <DO name="Beh" type="ENS_2_Beh"/>
    <DO name="Schd1" type="ORG_1_InclSto"/>
    <DO name="Schd2" type="ORG_1_InclSto"/>
    <DO name="Schd3" type="ORG_1_InclSto"/>
  </LNodeType>
  <LNodeType id="FSCH1" InClass="FSCH">
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    <DO name="EnaReq" type="SPC_1_EnaReq"/>
    <DO name="DsaReq" type="SPC_1_EnaReq"/>
    <DO name="SchdEnaErr" type="ENS_1_SchdSt"/>
    <DO name="NumEntr" type="ING_2_NumEntr"/>
    <DO name="SchdIntv" type="ING_1_SchdIntv"/>
    <DO name="StrTm" type="TSG_1_StrTm"/>
    <DO name="ValASG1" type="ASG_1_ValASG1"/>
    <DO name="ValASG2" type="ASG_1_ValASG1"/>
    <DO name="ValASG3" type="ASG_1_ValASG1"/>
    <DO name="ValASG4" type="ASG_1_ValASG1"/>
    <DO name="ValASG5" type="ASG_1_ValASG1"/>
    <DO name="Beh" type="ENS_7_Beh"/>
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  <LNodeType id="LLN03" InClass="LLN0">
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    <DO name="Beh" type="ENS_5_Beh"/>
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  <DO name="Health" type="ENS_1_Health"/>
  <DO name="NamPit" type="LPL_1_NamPit"/>
</LNodeType>
<LNodeType id="DBAT1" InClass="DBAT">
  <DO name="Beh" type="ENS_7_Beh"/>
</LNodeType>
<LNodeType id="DWGC1" InClass="DWGC">
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  <DO name="InEcpRef" type="ORG_1_InclSto"/>
  <DO name="Beh" type="ENS_7_Beh"/>
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  <DO name="OutEcpRef" type="ORG_1_InclSto"/>
  <DO name="FctRef" type="ORG_1_InclSto"/>
  <DO name="WSpt" type="APC_1_WSpt"/>
  <DO name="Beh" type="ENS_7_Beh"/>
</LNodeType>
<LNodeType id="DSTO1" InClass="DSTO">
  <DO name="InWh" type="MV_1_Vol"/>
  <DO name="OutWh" type="MV_1_Vol"/>
  <DO name="SocWh" type="MV_1_Vol"/>
  <DO name="AvlDschW" type="MV_1_Vol"/>
  <DO name="AvlChaW" type="MV_1_Vol"/>
  <DO name="AvlUpW" type="MV_1_Vol"/>
  <DO name="AvlDnW" type="MV_1_Vol"/>
  <DO name="UseWhMinPct" type="ASG_1_ValASG1"/>
  <DO name="UseWhMaxPct" type="ASG_1_ValASG1"/>
  <DO name="OutEcpRef" type="ORG_1_InclSto"/>
  <DO name="DERUnit" type="ORG_1_InclSto"/>
  <DO name="WSpt" type="APC_1_WSpt"/>
  <DO name="Beh" type="ENS_7_Beh"/>
</LNodeType>
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  <DA name="q" bType="Quality" fc="ST" qchg="true"/>
  <DA name="t" bType="Timestamp" fc="ST"/>
  <DA name="ctlModel" type="ctlModel" bType="Enum" fc="CF"/>
</DOType>
<DOType id="ENS_2_Beh" cdc="ENS">
  <DA name="stVal" type="Mod" bType="Enum" fc="ST" dchg="true" dupd="true"/>
  <DA name="q" bType="Quality" fc="ST" qchg="true"/>
  <DA name="t" bType="Timestamp" fc="ST"/>
</DOType>
<DOType id="ENS_1_Health" cdc="ENS">
  <DA name="stVal" type="Health" bType="Enum" fc="ST" dchg="true" dupd="true"/>
  <DA name="q" bType="Quality" fc="ST" qchg="true"/>
  <DA name="t" bType="Timestamp" fc="ST"/>
</DOType>
<DOType id="LPL_1_NamPit" cdc="LPL">
  <DA name="vndor" bType="VisString255" fc="DC"/>
  <DA name="swRev" bType="VisString255" fc="DC"/>
  <DA name="configRev" bType="VisString255" fc="DC"/>
  <DA name="ldNs" bType="VisString255" fc="EX"/>
</DOType>
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  <DA name="Oper" type="APCOperate_8" bType="Struct" fc="CO"/>
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  <DA name="q" bType="Quality" fc="MX" qchg="true"/>
  <DA name="t" bType="Timestamp" fc="MX"/>
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</DOType>
<DOType id="MV_1_AvlUpW" cdc="MV"/>
<DOType id="APC_3_WSpt" cdc="APC">
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  <DA name="q" bType="Quality" fc="MX" qchg="true"/>
  <DA name="t" bType="Timestamp" fc="MX"/>

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    <DA name="ctlModel" type="ctlModel" bType="Enum" fc="CF"/>
  </DOType>
  <DOType id="ING_2_NumEntr" cdc="ING">
    <DA name="setVal" bType="INT32" fc="SP" dchg="true"/>
  </DOType>
  <DOType id="MV_1_Vol" cdc="MV">
    <DA name="mag" type="AnalogueValue_1" bType="Struct" fc="MX"
      dchg="true" dupd="true"/>
    <DA name="q" bType="Quality" fc="MX" qchg="true"/>
    <DA name="t" bType="Timestamp" fc="MX"/>
  </DOType>
  <DOType id="SPC_1_EnaReq" cdc="SPC">
    <DA name="Oper" type="DPCOperate_3" bType="Struct" fc="CO"/>
    <DA name="stVal" bType="BOOLEAN" fc="ST" dchg="true"/>
    <DA name="q" bType="Quality" fc="ST" qchg="true"/>
    <DA name="t" bType="Timestamp" fc="ST"/>
    <DA name="ctlModel" type="ctlModel" bType="Enum" fc="CF" dchg="
      true"/>
  </DOType>
  <DOType id="ASG_1_ValASG1" cdc="ASG">
    <DA name="setMag" type="AnalogueValue_1" bType="Struct" fc="SP"
      dchg="true"/>
  </DOType>
  <DOType id="ENS_5_Beh" cdc="ENS">
    <DA name="stVal" type="Mod" bType="Enum" fc="ST" dchg="true" dupd
      ="true"/>
    <DA name="q" bType="Quality" fc="ST" qchg="true"/>
    <DA name="t" bType="Timestamp" fc="ST"/>
    <DA name="subEna" bType="BOOLEAN" fc="SV"/>
    <DA name="subVal" type="Mod" bType="Enum" fc="SV"/>
    <DA name="subQ" bType="Quality" fc="SV"/>
    <DA name="subID" bType="VisString64" fc="SV"/>
  </DOType>
  <DOType id="ENS_7_Beh" cdc="ENS">
    <DA name="stVal" type="Beh" bType="Enum" fc="ST" dchg="true" dupd
      ="true"/>
    <DA name="q" bType="Quality" fc="ST" qchg="true"/>
    <DA name="t" bType="Timestamp" fc="ST"/>
  </DOType>
  <DOType id="ASG_1_ValASG" cdc="ASG">
    <DA name="setMag" type="AnalogueValue_1" bType="Struct" count="5"
      fc="SP" dchg="true"/>
  </DOType>
  <DOType id="ORS_2_ActSchdRef" cdc="ORS">
    <DA name="stVal" bType="VisString255" fc="ST" dchg="true"/>
    <DA name="q" bType="Quality" fc="ST" dchg="true"/>
    <DA name="t" bType="Timestamp" fc="ST"/>
  </DOType>
  <DOType id="ENS_1_SchdSt" cdc="ENS">
    <DA name="stVal" bType="INT32" fc="ST" dchg="true" dupd="true"/>
    <DA name="q" bType="Quality" fc="ST" qchg="true"/>
    <DA name="t" bType="Timestamp" fc="ST"/>
  </DOType>
  <DOType id="TSG_1_StrTm" cdc="TSG">
    <DA name="setCal" type="CalendarTime_1" bType="Struct" fc="SP"
      dchg="true"/>
  </DOType>
  <DOType id="ING_1_SchdIntv" cdc="ING">
    <DA name="setVal" bType="INT32" fc="SP" dchg="true"/>
    <DA name="units" type="Unit_1" bType="Struct" fc="CF" dchg="true"/>
  </DOType>
  <DAType id="AnalogueValue_1">
    <BDA name="f" bType="FLOAT32" desc="The value of f shall be the
      FLOAT representation of the measured value. f shall represent the
      technological value in SI units."/>
  </DAType>
  <DAType id="Originator_1">
    <BDA name="orCat" type="orCategory" bType="Enum"/>
    <BDA name="orIdent" bType="Octet64"/>
  </DAType>
  <DAType id="DPCOperate_3">
    <BDA name="ctlVal" bType="BOOLEAN"/>
    <BDA name="origin" type="Originator_1" bType="Struct"/>
    <BDA name="ctlNum" bType="INT8U"/>
    <BDA name="T" bType="Timestamp"/>
  </DAType>
  <BDA name="Test" bType="BOOLEAN"/>
  <BDA name="Check" bType="Check"/>
  </DAType>
  <DAType id="ScaledValueConfig_1">
    <BDA name="scaleFactor" bType="FLOAT32"/>
    <BDA name="offset" bType="FLOAT32"/>
  </DAType>
  <DAType id="CalendarTime_1">
    <BDA name="occ" bType="INT16U"/>
    <BDA name="occType" type="occType" bType="Enum"/>
    <BDA name="occPer" type="occPer" bType="Enum"/>
    <BDA name="weekDay" type="weekDay" bType="Enum"/>
    <BDA name="month" type="month" bType="Enum"/>
    <BDA name="day" bType="INT8U"/>
    <BDA name="hr" bType="INT8U"/>
    <BDA name="mn" bType="INT8U"/>
  </DAType>
  <DAType id="DPCOperate_1">
    <BDA name="ctlVal" bType="BOOLEAN"/>
    <BDA name="origin" type="Originator_1" bType="Struct"/>
    <BDA name="ctlNum" bType="INT8U"/>
    <BDA name="T" bType="Timestamp"/>
    <BDA name="Test" bType="BOOLEAN"/>
    <BDA name="Check" bType="Check"/>
  </DAType>
  <DAType id="DPCOperate_2">
    <BDA name="ctlVal" bType="BOOLEAN"/>
    <BDA name="origin" type="Originator_1" bType="Struct"/>
    <BDA name="ctlNum" bType="INT8U"/>
    <BDA name="T" bType="Timestamp"/>
    <BDA name="Test" bType="BOOLEAN"/>
    <BDA name="Check" bType="Check"/>
  </DAType>
  <DAType id="APCOperate_1">
    <BDA name="ctlVal" type="AnalogueValue_2" bType="Struct"/>
    <BDA name="origin" type="Originator_1" bType="Struct"/>
    <BDA name="ctlNum" bType="INT8U"/>
    <BDA name="T" bType="Timestamp"/>
    <BDA name="Test" bType="BOOLEAN"/>
    <BDA name="Check" bType="Check"/>
  </DAType>
  <DAType id="APCOperate_2">
    <BDA name="ctlVal" type="AnalogueValue_2" bType="Struct"/>
    <BDA name="origin" type="Originator_1" bType="Struct"/>
    <BDA name="ctlNum" bType="INT8U"/>
    <BDA name="T" bType="Timestamp"/>
    <BDA name="Test" bType="BOOLEAN"/>
    <BDA name="Check" bType="Check"/>
  </DAType>
  <DAType id="APCOperate_3">
    <BDA name="ctlVal" type="AnalogueValue_2" bType="Struct"/>
    <BDA name="origin" type="Originator_1" bType="Struct"/>
    <BDA name="ctlNum" bType="INT8U"/>
    <BDA name="T" bType="Timestamp"/>
    <BDA name="Test" bType="BOOLEAN"/>
    <BDA name="Check" bType="Check"/>
  </DAType>
  <DAType id="Unit_1">
    <BDA name="SIUnit" type="SIUnit" bType="Enum"/>
  </DAType>
  <DAType id="APCOperate_4">
    <BDA name="ctlVal" type="AnalogueValue_2" bType="Struct"/>
    <BDA name="origin" type="Originator_1" bType="Struct"/>
    <BDA name="ctlNum" bType="INT8U"/>
    <BDA name="T" bType="Timestamp"/>
    <BDA name="Test" bType="BOOLEAN"/>
    <BDA name="Check" bType="Check"/>
  </DAType>

```

```

<DAType id="APCOperate_5">
  <BDA name="ctlVal" type="AnalogueValue_1" bType="Struct"/>
  <BDA name="origin" type="Originator_1" bType="Struct"/>
  <BDA name="ctlNum" bType="INT8U"/>
  <BDA name="T" bType="Timestamp"/>
  <BDA name="Test" bType="BOOLEAN"/>
  <BDA name="Check" bType="Check"/>
</DAType>
<DAType id="APCOperate_6">
  <BDA name="ctlVal" type="AnalogueValue_2" bType="Struct"/>
  <BDA name="origin" type="Originator_1" bType="Struct"/>
  <BDA name="ctlNum" bType="INT8U"/>
  <BDA name="T" bType="Timestamp"/>
  <BDA name="Test" bType="BOOLEAN"/>
  <BDA name="Check" bType="Check"/>
</DAType>
<DAType id="APCOperate_7">
  <BDA name="ctlVal" type="AnalogueValue_2" bType="Struct"/>
  <BDA name="origin" type="Originator_1" bType="Struct"/>
  <BDA name="ctlNum" bType="INT8U"/>
  <BDA name="T" bType="Timestamp"/>
  <BDA name="Test" bType="BOOLEAN"/>
  <BDA name="Check" bType="Check"/>
</DAType>
<DAType id="Point_1">
  <BDA name="xVal" bType="FLOAT32"/>
  <BDA name="yVal" bType="FLOAT32"/>
</DAType>
<DAType id="Vector_1">
  <BDA name="mag" type="AnalogueValue_1" bType="Struct"/>
</DAType>
<DAType id="Point_2">
  <BDA name="xVal" bType="FLOAT32"/>
  <BDA name="yVal" bType="FLOAT32"/>
</DAType>
<DAType id="Vector_2">
  <BDA name="mag" type="AnalogueValue_1" bType="Struct"/>
</DAType>
<DAType id="Point_3">
  <BDA name="xVal" bType="FLOAT32"/>
</DAType>
<DAType id="APCOperate_8">
  <BDA name="ctlVal" type="AnalogueValue_1" bType="Struct"/>
  <BDA name="origin" type="Originator_1" bType="Struct"/>
  <BDA name="ctlNum" bType="INT8U"/>
  <BDA name="T" bType="Timestamp"/>
  <BDA name="Test" bType="BOOLEAN"/>
  <BDA name="Check" bType="Check"/>
</DAType>
<EnumType id="Mod">
  <EnumVal ord="1">on</EnumVal>
  <EnumVal ord="2">blocked</EnumVal>
  <EnumVal ord="3">test</EnumVal>
  <EnumVal ord="4">test/blocked</EnumVal>
  <EnumVal ord="5">off</EnumVal>
</EnumType>
<EnumType id="ctlModel">
  <EnumVal ord="0">status-only</EnumVal>
  <EnumVal ord="1">direct-with-normal-security</EnumVal>
  <EnumVal ord="2">sbo-with-normal-security</EnumVal>
  <EnumVal ord="3">direct-with-enhanced-security</EnumVal>
  <EnumVal ord="4">sbo-with-enhanced-security</EnumVal>
</EnumType>
<EnumType id="Health">
  <EnumVal ord="1">Ok</EnumVal>
  <EnumVal ord="2">Warning</EnumVal>
  <EnumVal ord="3">Alarm</EnumVal>
</EnumType>
<EnumType id="orCategory">
  <EnumVal ord="0">not-supported</EnumVal>
  <EnumVal ord="1">bay-control</EnumVal>
  <EnumVal ord="2">station-control</EnumVal>
  <EnumVal ord="3">remote-control</EnumVal>
  <EnumVal ord="4">automatic-bay</EnumVal>
  <EnumVal ord="5">automatic-station</EnumVal>
  <EnumVal ord="6">automatic-remote</EnumVal>
  <EnumVal ord="7">maintenance</EnumVal>
  <EnumVal ord="8">process</EnumVal>
</EnumType>
<EnumType id="occType">
  <EnumVal ord="1">Time</EnumVal>
  <EnumVal ord="2">WeekDay</EnumVal>
  <EnumVal ord="3">WeekOfYear</EnumVal>
  <EnumVal ord="4">DayOfMonth</EnumVal>
  <EnumVal ord="5">DayOfYear</EnumVal>
</EnumType>
<EnumType id="occPer">
  <EnumVal ord="1">Hour</EnumVal>
  <EnumVal ord="2">Day</EnumVal>
  <EnumVal ord="3">Week</EnumVal>
  <EnumVal ord="4">Month</EnumVal>
  <EnumVal ord="5">Year</EnumVal>
</EnumType>
<EnumType id="weekDay">
  <EnumVal ord="1">reserved,</EnumVal>
  <EnumVal ord="2">Monday</EnumVal>
  <EnumVal ord="3">Tuesday</EnumVal>
  <EnumVal ord="4">Wednesday</EnumVal>
  <EnumVal ord="5">Thursday</EnumVal>
  <EnumVal ord="6">Friday</EnumVal>
  <EnumVal ord="7">Saturday</EnumVal>
  <EnumVal ord="8">Sunday</EnumVal>
</EnumType>
<EnumType id="month">
  <EnumVal ord="1">reserved,</EnumVal>
  <EnumVal ord="2">January</EnumVal>
  <EnumVal ord="3">February</EnumVal>
  <EnumVal ord="4">March</EnumVal>
  <EnumVal ord="5">April</EnumVal>
  <EnumVal ord="6">May</EnumVal>
  <EnumVal ord="7">June</EnumVal>
  <EnumVal ord="8">July</EnumVal>
  <EnumVal ord="9">August</EnumVal>
  <EnumVal ord="10">September</EnumVal>
  <EnumVal ord="11">October</EnumVal>
  <EnumVal ord="12">November</EnumVal>
  <EnumVal ord="13">December</EnumVal>
</EnumType>
<EnumType id="Beh">
  <EnumVal ord="1">on</EnumVal>
  <EnumVal ord="2">blocked</EnumVal>
  <EnumVal ord="3">test</EnumVal>
  <EnumVal ord="4">test/blocked</EnumVal>
  <EnumVal ord="5">off</EnumVal>
</EnumType>
<EnumType id="SIUnit">
  <EnumVal ord="1"/>
  <EnumVal ord="10">rad</EnumVal>
  <EnumVal ord="11">sr</EnumVal>
  <EnumVal ord="2">m</EnumVal>
  <EnumVal ord="21">Gy</EnumVal>
  <EnumVal ord="22">q</EnumVal>
  <EnumVal ord="23">°C</EnumVal>
  <EnumVal ord="24">Sv</EnumVal>
  <EnumVal ord="25">F</EnumVal>
  <EnumVal ord="26">C</EnumVal>
  <EnumVal ord="27">S</EnumVal>
  <EnumVal ord="28">H</EnumVal>
  <EnumVal ord="29">V</EnumVal>
  <EnumVal ord="3">kg</EnumVal>
  <EnumVal ord="30">ohm</EnumVal>
  <EnumVal ord="31">J</EnumVal>
  <EnumVal ord="32">N</EnumVal>
  <EnumVal ord="33">Hz</EnumVal>
  <EnumVal ord="34">Ix</EnumVal>
  <EnumVal ord="35">Lm</EnumVal>
  <EnumVal ord="36">Wb</EnumVal>
  <EnumVal ord="37">T</EnumVal>
  <EnumVal ord="38">W</EnumVal>
  <EnumVal ord="39">Pa</EnumVal>

```

```

<EnumVal ord="4">s</EnumVal>
<EnumVal ord="41">m2</EnumVal>
<EnumVal ord="42">m3</EnumVal>
<EnumVal ord="43">m/s</EnumVal>
<EnumVal ord="44">m/s2</EnumVal>
<EnumVal ord="45">m3/s</EnumVal>
<EnumVal ord="46">m/m3</EnumVal>
<EnumVal ord="47">M</EnumVal>
<EnumVal ord="48">kg/m3</EnumVal>
<EnumVal ord="49">m2/s</EnumVal>
<EnumVal ord="5">A</EnumVal>
<EnumVal ord="50">W/m K</EnumVal>
<EnumVal ord="51">J/K</EnumVal>
<EnumVal ord="52">ppm</EnumVal>
<EnumVal ord="53">1/s</EnumVal>
<EnumVal ord="54">rad/s</EnumVal>
<EnumVal ord="6">K</EnumVal>
<EnumVal ord="61">VA</EnumVal>
<EnumVal ord="62">Watts</EnumVal>
<EnumVal ord="63">VAr</EnumVal>
<EnumVal ord="64">theta</EnumVal>
<EnumVal ord="65">cos(theta)</EnumVal>
<EnumVal ord="66">Vs</EnumVal>
<EnumVal ord="67">V2</EnumVal>
<EnumVal ord="68">As</EnumVal>
<EnumVal ord="69">A2</EnumVal>
<EnumVal ord="7">mol</EnumVal>
<EnumVal ord="70">A2t</EnumVal>
<EnumVal ord="71">VAh</EnumVal>
<EnumVal ord="72">Wh</EnumVal>
<EnumVal ord="73">VArh</EnumVal>
<EnumVal ord="74">V/Hz</EnumVal>
<EnumVal ord="8">cd</EnumVal>
<EnumVal ord="9">deg</EnumVal>
</EnumType>
<EnumType id="dirGeneral_1">
  <EnumVal ord="0">unknown</EnumVal>
  <EnumVal ord="1">forward</EnumVal>
  <EnumVal ord="2">backward</EnumVal>
  <EnumVal ord="3">both</EnumVal>
</EnumType>
</DataTypeTemplates>
</SCL>

```

4 Common Features — Solution Building Blocks (SBBs)

This section shall provide Solution Building Blocks (SBBs) that can be used to realise the implementation requirements stated by different IES Integration Profiles in Section 3.³¹ The *Common Features* mentioned in the introduction (section 1.2, figure 1.2.1) will commonly be described here or referenced if already described somewhere else. Their actual usage for different Use Cases shall be confined by specifications stated in the according IES Integration Profile, not here.

- Table of only referenced *Common Features* → where to find them.

↪ *Yet no external SBBs have been referenced.*

In the following sections find the description of *Common Features* introduced by this Technical Framework on Local Energy Communities.

³¹Solution Building Blocks (SBBs) are per se implementation examples [12], i.e., applicable pieces toward profile compliant business function implementation/realisation. However, where a referenced standard provides a single option only, requesting standard conform implementation of such a unitary feature causes that the according SBB is the only possible implementation, and thus, SBB integration can happen to be mandatory. But be aware that this is not always the case; not all SBBs provided need to be implemented. In general, how features are implemented shall not be specified in IIPs, only what these features need to offer and perform needs to be perfectly compatible to achieve interoperability. Only that shall be specified in IES Integration Profiles. Exemplary implementation options (SBBs) may be provided here in section 4. Basically is providing SBBs optional, but highly recommended for better understanding and ease of application.

4.1 General IEC61850 Solution Building Blocks (SBBs)

↪ *These SBBs would be better placed in a generic IEC 61850 SBBs document.*

{An SBB describes a generic procedure, e.g., a file format, an encryption method, a transport protocol, or something as simple as a physical connector. But as always, if there are no interoperability issues (risk of divergent realisation), such features shall not be specified in detail. If the format, standard, or whatever a required feature stems from specifies it definite and obvious (unambiguously), referencing suffices and no SBB shall be specified.}

4.1.1 IEC 61850-6:2010 — Substation Configuration Language Model:

The Substation Configuration Language(SCL) describes the entire substation network including the required Intelligent Electronic Devices(IEDs) their configuration and network topology. All these specifications are outlined in a Substation Configuration Description(SCD) file, structured as followed:

- Header: identify versions and other basic information about the SCL configuration.
- System structure: which entities are included (transformers, Voltage Level bays, ...).
- Communication system: how IEDS are connected to sub-/networks and their access points.
- Application level communication: how data of IEDs are grouped into datasets and reports and supported services.
- IEDs: configuration of the IED including pre-configured parameters.
- DataTypeTemplates: defines the complete data structure and data types used logical devices and logical nodes.

The communication system model uses access points to model logically possible connections between IEDs in and across subnetworks. At this level of description, a subnetwork is considered only as a logical connection node, not necessarily a physical structure.

Logical devices or clients of the IED are connected to the subnetwork through an access point, which can be a physical port or a logical address (server) of the IED. Client LNs use the Access Point Address attribute to establish connections with servers on other IEDs and with LNs contained in logical devices of these IEDs.

A Subnetwork can be connected through routers, but GOOSE and Sampled Value messages cannot cross routers and can only reach IEDs on the same Subnetwork.

The maintenance and description of the physical structure are not part of the SCL scope. But this access point description is matching with a physical communication implementation.

◇ **Data flow model** describes conceptually the data flow between a server/publisher as a source and client/subscriber as a client. The real connection between these entities is built at a communication profile level like MMS/TCP (see SBB MMS based communication). If this channel is built up by an IED all LNs within that IED, have access to the provided server model. This channel is also the level where access rights are checked.

Data object references (Common Data Class ORG) can be used to link input data to specific Logical Nodes or to the LLN0 Node to enable access for the whole IED.

◇ **SCD Example** : Listing 6 shows the fundamental structure of an SCL description introduced above. Some parts are shortened since **Services** are highly use case related and **DataSet** and *ReportControl* will be discussed in SBB Reporting and Logging.

↪ *The following listings is syntactically correct but not fully completed/valid at the application level.*

Listing 6: SCD example configuration

```

<?xml version="1.0" encoding="UTF-8"?>
<SCL xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns:sxy="http://www.iec.ch/61850/2003/SCLcoordinates" xsi:schemaLocation="http://www.iec.ch/61850/2003/SCL SCL.xsd http://www.iec.ch/61850/2003/SCL&#xD;&#xA; misc/scl-specs/SCL.xsd" version="2007" revision="B" release="4" xmlns="http://www.iec.ch/61850/2003/SCL">
  <Header id="" version="1" revision="1" toolID="" nameStructure="">
    <History>
      <Item version="1" revision="1" when="" who="" what="" why="">
    </History>
  </Header>
  <Substation name="SUBSTATION">
    <VoltageLevel name="VOLTAGELEVEL">
      <Bay name="BAY"/>
    </VoltageLevel>
  </Substation>
  <Communication>
    <SubNetwork name="SN1" type="8-MMS">
      <Text>Communication Bus</Text>
      <BitRate unit="b/s">10</BitRate>
      <ConnectedAP iedName="STOC" apName="accessPoint1">
        <Address>
          <P type="IP">10.0.2.15</P>
          <P type="IP-SUBNET">255.255.255.0</P>
        </Address>
      </ConnectedAP>
      <ConnectedAP iedName="STOM" apName="accessPoint1">
        <Address>
          <P type="IP">10.0.2.16</P>
          <P type="IP-SUBNET">255.255.255.0</P>
        </Address>
      </ConnectedAP>
    </SubNetwork>
  </Communication>
  <IED name="STOC">
    <Services nameLength="64">
      <ReportSettings cbName="Conf" datSet="Conf" rptID="Dyn" ... optFields="Dyn"/>
      <DynDataSet max="20" maxAttributes="50"/>
    </Services>
    <AccessPoint name="accessPoint1" desc="">
      <Server>
        <Authentication/>
        <LDevice inst="STOC" desc="Storage Controller" IdName="STOC">
          <LN0 InClass="LLN0" InType="LLN01" inst="">
            <DataSet>
              ...
            </DataSet>
            <ReportControl>
              <ReportControl>
                <DOI name="Beh" desc="">
                  <DAI name="stVal">
                    <Val>on</Val>
                  </DAI>
                </DOI>
              </ReportControl>
            </LN0>
          </LDevice>
        </Server>
      </AccessPoint>
    </IED>
  </DataObjectTemplates>
  <LNNodeType id="LLN01" InClass="LLN0">
    <DO name="Beh" type="ENS_1_Beh"/>
  </LNNodeType>
  <LNNodeType id="LLN02" InClass="LLN0">
    <DO name="Beh" type="ENS_1_Beh"/>
  </LNNodeType>
  <DOType id="ENS_1_Beh" cdc="ENS">
    <DA name="stVal" type="Mod" bType="Enum" fc="ST" dchg="true" dupd="true"/>
  </DOType>
</DataObjectTemplates>
</SCL>

```

4.1.2 IEC 61850 — Parameter Monitoring:

A Data Object (DO) or a single Data Attribute (DA) of a Logical Node (LN) can be monitored in two different ways:

By reporting: periodic and event triggered reports including a DO/DA. In addition, a report can be manually polled by setting the *GI* flag within the report control block (see SBB Reporting and Logging).

By polling: client can manually request specific DO/DA from the server (explained below).

◇ **Example** Client can use the *GetDataValues* service (see [13, Section 11.4] with the related reference and Functional Constraint) to poll a DO/DA.

↪ *Example reference: myLDevice/LNode.DObject.DAttribute Data Attribute Value:* Describes the actual hierarchy of the received data.

↪ *tAnyLN* → *tDOI* → *tSDI* → *tDAI* → *tVal*

An object of type Any Logical Node (*tAnyLN*) can hold instance-related Data Objects (*tDOI*) with a single Data Attribute instance (*tDAI*) or a Sub-Data element (*tSDI*) which is a structure of Data Attributes (see example Listing 7). A detailed XML scheme of each Data Type is available in [14, Section 9.3].

Listing 7: Data structure example.

```

<LN inst="1" InClass="ZBAT" InType="ZBAT1">
  <DOI name="Vol">
    <SDI name="mag">
      <DAI name="f">
        <Val>20</Val>
      </DAI>
    </SDI>
  </DOI>
</LN>
  <DAI name="q">
    <Val>good</Val>
  </DAI>
</SDI>
</DOI>
</LN>

```

◇ **GetDataValue service sequence:**

Request: Contains the parameter reference which defines the functional constrained data (FCD) - attributes (FCDA) of the requested Data Object (see FCDA XML scheme in Listing 8 and description in Table 4.1.2.1).

Listing 8: Functional Constrained Data/Attribute (FCDA) definition according to IEC61850

```
<xs:complexType name="tFCDA">
  <xs:attribute name="ldInst" type="tLDInst" use="optional"/>
  <xs:attribute name="prefix" type="tPrefix" use="optional" default=""/>
  <xs:attribute name="lnClass" type="tLNClassEnum" use="optional"/>
  <xs:attribute name="lnInst" type="tLNInst" use="optional"/>
  <xs:attribute name="doName" type="tName" use="optional"/>
  <xs:attribute name="daName" type="tName" use="optional"/>
  <xs:attribute name="fc" type="tFCEnum" use="required"/>
  <xs:attribute name="ix" type="xs:unsignedInt" use="optional"/>
</xs:complexType>
```

Table 4.1.2.1: Attributes of the FCDA element [14, Table 22]

Attribute Name	Description
ldInst	The LD where the DO resides; shall always be specified except for GSSE
prefix	Prefix identifying together with lnInst and lnClass the LN where the DO resides; optional, default value is the empty string
lnClass	LN class of the LN where the DO resides; shall always be specified except for GSSE DataLabel empty string
lnInst	Instance number of the LN where the DO resides; shall be specified except for LLN0
doName	A name identifying the DO (within the LN). A name standardized in IEC 61850-7-4. If doName is empty, then FC can contain a value, selecting the attribute category of all DOs of the defined LN. For elements or parts of structured data object types, all name parts are contained, separated by dots (.), down to (but without) the level where the FC is defined. If an SDO array element is selected, the appropriate name part shall contain at its end before a possible dot the array element number in the form (ArrayElementNumber).
daName	The attribute name – if missing, all attributes with functional characteristics given by FC are selected. For elements or parts of structured data types, all name parts are contained, separated by dots (.), starting at the level where the FC is defined. If an attribute’s array element is selected, the appropriate attribute name part shall contain at its end before any separating dot the array element number in the form (ArrayElementNumber).
FC	All attributes of this functional constraint are selected. Possible constraint values see IEC 61850-7-2 or the FC definition in 9.5
ix	An index to select an array element in case that one of the data elements is an array. The ix value shall be identical to the ArrayElementNumber value in the doName or daName part.

Response-: Indicates a failed service request, *ServiceError* shall be returned.

Response+: Indicates successful service request and return the *DataAttributeValue* [1...n] parameter containing:

↔ *All Data Attributes of a Data Object referenced by FCD.*

↔ *A single Data Attribute referenced by FCDA (see Listing 8)*

Mapping: Table 4.1.2.2 defines the mapping from AC SI GetDataValues service to MMS read service. MMS is further explained in section 4.1.4 MMS based communication.

Table 4.1.2.2: Mapping of GetDataValues service parameters[15, Table 42]

GetDataValues parameters	MMS service or parameter	Constraint
Request Reference	Read request service variableAccessSpecification	Maps to a 8-1VARSPEC
Response+ DataAttributeValue[1...n]	Read response service listOfAccessResult	
Response-		MMPM NamedVariable Services/Read see 8.1.3.4.4.1

4.1.3 IEC 61850 — Reporting and Logging:

Instead of consecutive polling data, buffered or unbuffered reports can be generated through periodic or event triggered events and send from server to client.

◇ **Report Control Block configuration:** All control blocks that reference a data set should be located in the same Logical Node. Therefore, data set references within a control block only contain the LN relative data set name. One instance of a control block can only report to one single client, if multiple clients need access to the same data set, a new instance of the RCB is necessary.

A RCB need to be declared in the Substation Configuration Language (SCL) file. Individual parameters can be pre specified in the SCL file or by setting the specific parameters (see Table 4.1.3.1) during the runtime using the **SetxRCBValues** service.

The following list should give a general sequence of configuring and enabling a report:

- Reserving the RCB exclusively for the client *Resv* (URCB) and *ResvTms* (BRCB).
- Setting the *ObejectReference* of the required data set (*DatSet*).
- Configuring the trigger options according to the use case (*TrgOps*).
- Adjusting additional report settings (*OptFlds*, *BufTm*, *IntgPd*).
- Enabling reporting by setting *RptEna* TRUE.

A report can contain the following additional information: sequence number, report time stamp, reason for inclusion, dataset name, data reference, buffer overflow, entry ID and configuration revision by configuring the *OptFlds* attribute. *SqNum*, *Datset*

The attribute *xRCBRef* shall be a unique path name in form of **LDName/LNName.BRCBName**. If *RptID* is NULL then *xRCBRef* shall be reported instead. If *entryID* is set to TRUE within *OptFlds* the report also includes the related *EntryID*, this helps to determine which reports are missing in case of a connection loss.

◇ **Reporting Example:** A Reporting Control Block can be pre-configured in the ICD file, or individually configured during runtime with related service from *GenDataObjectClass* class (see Table 4.1.3.2). For the complete reporting XML template and further insights see [14, Chapter 9].

In the following example, a maximum of three clients can reserve a RCB with the name *ExampleReport01-03*. Where the instance one smf two, *ExampleReport01/02* are already reserved for the clients *EX1/IHMI1* and *EX1/IHMI1*. Reports are triggered according to *dchg* (data change) and *qchg* (quality change). Reports include the optional information *SequenceNumber*, *TimeStamp* and *Dataset* reference according to *OptFields*.

Listing 9: Reporting Control Block example according to IEC 61850.

```
<ReportControl name="ExampleReport" rptID="ExampleDevice" datSet="ExampleDataset" confRev="0">
  <TrgOps dchg="true" qchg="true"/>
  <OptFields seqNum="true" timeStamp="true" dataSet="true"/>
  <RptEnabled max="3">
    <ClientLN iedName="EX1" IdInst="LD0" InInst="1" InClass="IHMI"/>
    <ClientLN iedName="EX2" IdInst="LD0" InInst="2" InClass="IHMI"/>
  </RptEnabled>
</ReportControl>
```

An example data set *ExampleDataset* is defined in Listing 10 including whole DOs, single DAs or a specific index of an enumeration. The FCDA type definition is introduced in the SBB Parameter Monitoring Listing 8.

Listing 10: Data set example according to IEC 61850.

```
<DataSet name="ExampleDataset"/>
  <FCDA IdInst="IDevice1" InClass="LLN0" doName="NamPlt" fc="DC"/>
  <FCDA IdInst="IDevice1" InClass="MMXU" InInst="1" doName="TotW" fc="MX"/>
  <FCDA IdInst="IDevice1" InClass="MMXU" InInst="1" doName="TotW" fc="MX" daName="mag.f"/>
```

```

<FCDA IdInst="IDevice1" InClass="LPHD" InInst="1" doName="PhyNam" fc="DC"/>
<FCDA IdInst="IDevice1" InClass="FCSD" InInst="1" doName="Crv" fc="DC" daName="crvPts" ix="1"/>
<FCDA IdInst="IDevice1" InClass="FCSD" InInst="1" doName="Crv" fc="DC" daName="crvPts.xVal" ix="2"/>
</DataSet>
    
```

◇ **Reporting building blocks:**

Figure 4.1.1 illustrates the building blocks and dependencies of reporting and logging.

Data set: Contains references to individually selected DAs and DOs (example see Listing10).

Report/Log control blocks (RCB/LCB): Is responsible for parameter configuration like trigger options, data sets, or the related client information (example see Listing 9).

Event monitor block: Forwards data set to the Report/Log handler depending on the state of the real data and the control configuration.

Report/Log handler: Assigns the *EntryIDs* and *TimeOfEntry* to the forwarded values and also sends the report to the subscribed client. In the case of the buffered RCB, a general queue is holding the *EntryIDs* of the current, the past, and the newest entries that are not transmitted so far.

Log handler: Is storing the log entries to the **Log**, where clients can pull the list of log entries from.

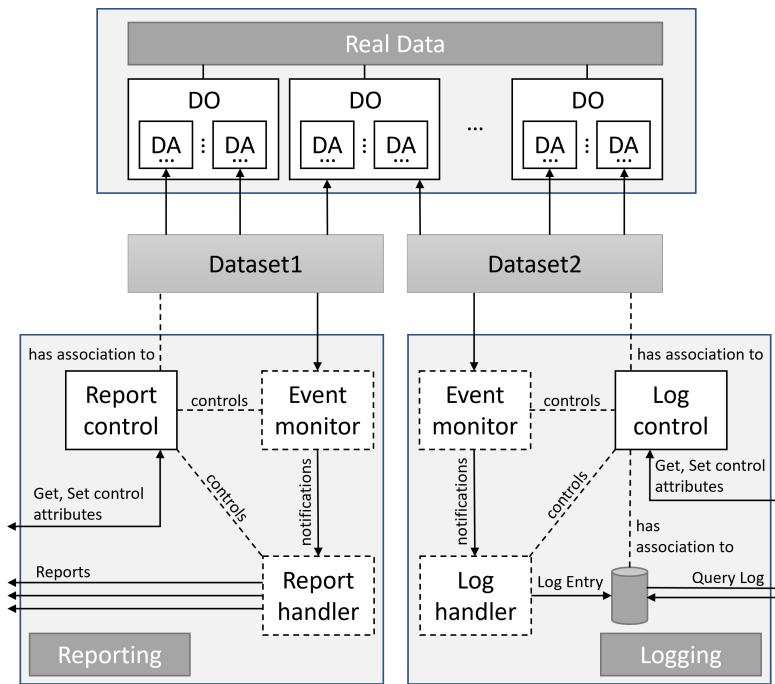


Figure 4.1.1: Basic building blocks for logging and reporting[13].

◇ **Buffered/Unbuffered RCB State Machine:**

Figure 4.1.2 describes the state machine of a buffered/unbuffered RCB.

Initial power up: *RptEna* is FALSE, and no reports should be issued. Transition from **disable state** is only possible with a valid *DatSet* reference.

Client can use the *SetBRCBValues* service to set the *EntryID*, for example to the last received report *EntryID* before a previously connection loss. If that *EntryID* exists within the queue of entries, state shall transition to **resynchronize state** and server response with a *SetBRCBValues response+* (indicates successful set request).

If the *EntryID* is set to zero (0), client resynchronize to the first entry in the queue, and state should transition to **disable**. By setting the *RptEna* TRUE, state should transition to **enabled state** and reports from the current *EntryID* will be sent.

Table 4.1.3.1: Attributes of the buffered/unbuffered report control block[13, Chapter 17.2].

Attribute Name	Description
xRCBName ¹	Name of the xRCB that unambiguously identifies the xRCB within a logical-node.
xRCBRef ¹	Unique path-name of a xRCB.
RptID	Client-specified report identifier of the xRCB which causes the report.
RptEna	Used by a client to enable and disable reporting.
DatSet	Specifies the ObjectReference of the data set being monitored.
ConfRev	Counter for data set changes.
OptFlds	Client-specified optional fields to be included in the report.
BufTm	Specifies the time interval in milliseconds for the buffering of internal notifications caused by Trigger-Events
SqNum	Counter for every report generated and sent.
TrgOps	Trigger conditions: data/quality change, data update, integrity, GI
IntgPd	Indicate the period in milliseconds used for generating a periodical report.
GI	If General Interrogation TRUE, a report is sent independent from trigger options, after wards automatically set back to FALSE.
Owner	Identifies the client which owns the control block instance (IP address or IED name).
PurgeBuf ²	If TRUE, discard all buffered events, after wards automatically set back to FALSE.
EntryID ²	Unique number of the position within the report handler queue.
TimeOfEntry ²	The time at which the internal event notification was received by the report handler, and also assigned to a specific EntryID.
ResvTms ²	-1: BRCB is reserved, 0: BRCB is not reserved, >0 dynamically reserved (time in s the reservation will be maintained after connection loss)
Resv ³	If set to TRUE, shall indicate that the URCB is currently exclusively reserved for the client that has set the value to TRUE.

Notes:

¹ x should be replaced with U or B depending on Unbuffered or Buffered RCB.

² BRCB exclusive attributes

³ URCB exclusive attributes

Table 4.1.3.2: ACSI models and services [16, Table 5]

Data	Data set	Buffered RCB	Unbuffered RCB	Log CB
GetDataValues	GetDataSetValues	Report	Report	GetLCBValues
SetDataValues	SetDataSetValues	GetBRCBValues	GetURCBValues	SetLCBValues
GetDataDefinition	CreateDataSet	SetBRCBValues	SetURCBValues	QueryLogByTime
GetDataDirectory	CreateDataSet			QueryLogAfter
	GetDataSetDirectory			GetLogStatusValues

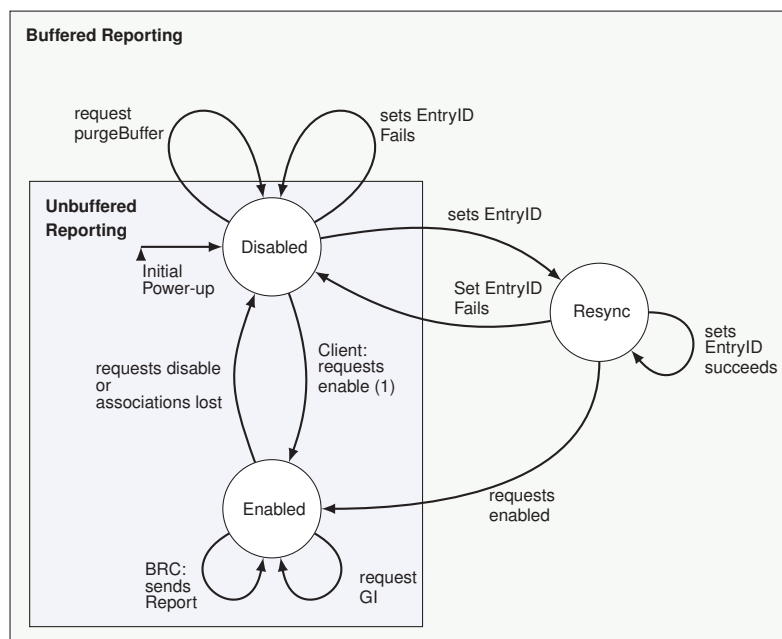


Figure 4.1.2: State machine of (un)buffered report control blocks[13].

4.1.4 IEC 61850 — MMS based communication:

MMS (Manufacturing Message Specification) is an OSI application layer messaging protocol for the remote control and monitoring of devices, specified in ISO 9506-1 and ISO 9506-2. According to the IEC 61850-5 specification of message types and performance classes, MMS is used for

- medium speed messages (type 2: typically messages for automation processes as well as status information with a required transfer time ≤ 100 ms),
- low speed messages (type 3: typically used for event records, reading or changing set-point values and general presentation of system data with required transfer times ≤ 500 ms (respectively ≤ 1000 ms)) and
- file transfer functions (type 5: required transfer time $\leq 10\,000$ ms).

MMS establishes a communication channel via a virtual connection over TCP/IP. The following stack of Standards is required above TCP/IP (in ascending order):

- * RFC 1006 (ISO transport over TCP)
- * ISO 8326/8327 (Connection Oriented Session)
- * ISO 8824/8825 (ASN.1 – Abstract Syntax Notation One)
- * ISO 8822/8823 (Connection Oriented Presentation)
- * ISO 8649/8650 (ACSE – Application Common Service Element)
- * ISO 9506-1 /-2 (MMS – Manufacturing Message Specification)
- * IEC 61850-8-1 (SCSM – Specific Communication Service Mapping)

MMS objects and services that shall be used in context of IEC 61850 are defined in IEC 61850-8-1 (see Table 4.1.4.1).

◇ Security considerations:

IEC 62351-4 provides several methods for securing the MMS communication:

On the application level, peer authentication information, that comprises a X.509 (ITU-T-standard for defining the format of public key certificates) encoded certificate, a timestamp, and a digitally signed time value is performed in the ACSE AARQ and AARE PDUs.

On the transport level, IEC 62351 refers to TLS and port 3782 for secure communications instead of the standard port 102. The standard includes a set of recommended and mandatory cipher suites to be supported (at a minimum: TLS DH DSS WITH AES 256 SHA and TLS DH RSA WITH AES 128 SHA).

◇ Environment And General Management Services:

Figure 4.1.3 shows the service primitives that enable the MMS-user

- to initiate communication and to establish the needed requirements and capabilities;
- to conclude communication in a graceful manner;
- to abort communications in an abrupt manner;
- to cancel pending service requests;
- to receive notification of protocol errors that occur.

◇ **Initiate Service:** The communicating MMS-users exchange information regarding their capabilities and requirements to establish the MMS environment (the state of connection, in which other services can be executed). The Service must be completed successfully before any other service may be carried out. The Initiate-RequestPDU (see Listing 11) is sent by the calling MMS-user and contains the proposed connection parameters (described below) according to the capabilities of the calling MMS-user. The request is answered by the called MMS-user with an Initiate-ResponsePDU (see Listing 12) in case of a successful connection. The called system may reduce the proposed parameter values according to the rules in the parameter descriptions. If the connection cannot be established, the called MMS-user responds with an Initiate-ErrorPDU (see Listing 13).

Table 4.1.4.1: MMS objects according to 61850-8-1

IEC 61850 Object	MMS Object	MMS service in use
Server	Application Process VMD	Initiate Conclude Abort Reject Cancel Identify
Logical Notes and Data	Named Variable Objects	Read Write InformationReport GetVariableAccessAttribute GetNameList
Data Sets	Named Variable List Objects	GetNamesVariableListAttributes GetNameList DefineNamedVariableList Read Write InformationReport
Logs	Journal Objects	ReadJournal InitializeJournal GetNameList
Logical Devices	Domain Objects	GetNameList SetDomainContents
Files	Files	FileOpen FileRead ObtainFile FileClose FileDirectory FileDelete

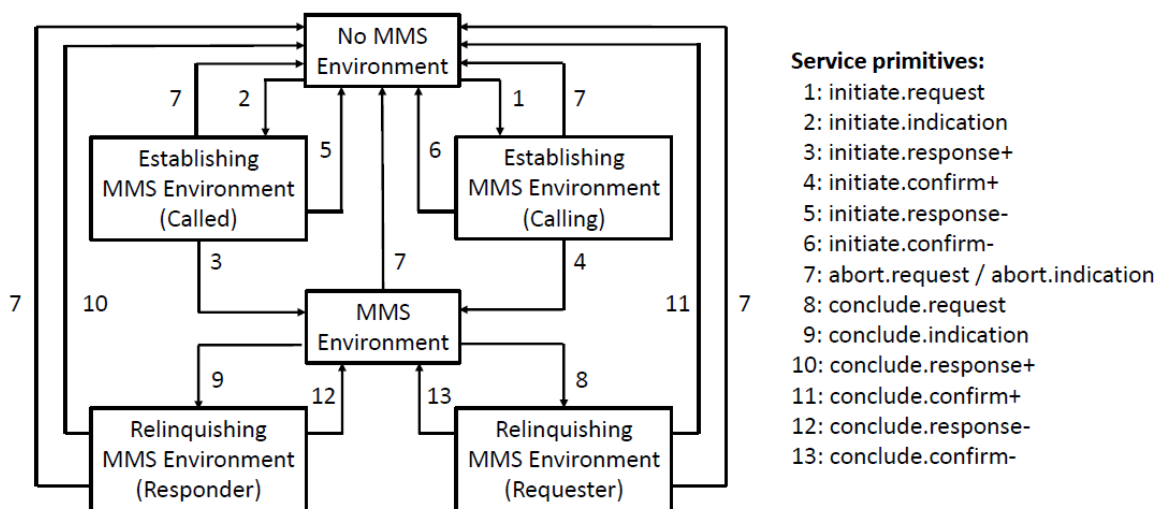


Figure 4.1.3: MMS Environment State Diagram according to ISO 9506-1

Listing 11: Initiate service request PDU according to ISO 9506-2 (Notation: ASN.1)

```

Initiate-RequestPDU ::= SEQUENCE {
    localDetailCalling          [0] IMPLICIT Integer32 OPTIONAL,
    proposedMaxServOutstandingCalling [1] IMPLICIT Integer16,
    proposedMaxServOutstandingCalled [2] IMPLICIT Integer16,
    proposedDataStructureNestingLevel [3] IMPLICIT Integer8 OPTIONAL,
    initRequestDetail          [4] IMPLICIT InitRequestDetail
}

```

◇ **ASN.1 (Abstract Syntax Notation One)** is a formal notation used to describe data transmitted by telecommunication protocols, specified in ISO 8824 and ISO 8825. The ASN.1 notation above can be read as follows: *Initiate-RequestPDU* is defined as ($::=$) a sequence (key-word *SEQUENCE*) of five parameters of different data types (*Integer32*, *Integer16*, ...), that are numbered from [0] to [4]. The numbering is necessary to distinguish them, because the use of the parameters [0] and [3] is *OPTIONAL*. When tagged as *IMPLICIT*, like in the example, only the data is sent. So the en-/decoder must know the corresponding data types.

localDetailCalling: optional; shall represent information about the Calling MMS-User's implementation. Content is a local matter and not a subject for further standardisation.

proposedMaxServOutstandingCalling: identifies the proposed maximum number of Transaction Object instances whose Application Association Identifier attribute references this association that may be created at the Calling MMS-user. The value may be reduced by the MMS-provider.

- value in the indication primitive \leq value in the request primitive
- value in the request or indication primitive ≥ 0

proposedMaxServOutstandingCalled: identifies the proposed maximum number of Transaction Object instances that may be created at the called MMS-user whose Application Association Identifier attribute references this association.

- The value may be reduced by the MMS-provider
- value in the indication primitive \leq value in the request primitive
- value in the request or indication primitives ≥ 0

proposedDataStructureNestingLevel: indicates the proposed maximum number of levels of nesting supported by both of the MMS-users that may occur within any data element used in the association.

- Absence of this parameter indicates an unlimited number of nesting levels.
- The request and indication primitives shall specify the maximum nesting level that the calling MMS-user desires to use in the negotiated MMS environment.
- A value of zero shall indicate that only simple types are allowed.
- The value of this parameter may be reduced by the MMS-provider.
- value in the indication primitive \leq value in the request primitive

initRequestDetail: specifies additional information (Proposed Version Number, Proposed Parameter CBB, Services Supported Calling) necessary for the establishment of an MMS communication

Initiate service response The called MMS-user shall issue an *initiate.response+* primitive to indicate if that MMS-user is willing to accept communications in the MMS environment under the constraints identified in the indication primitive. Otherwise, an *initiate.response-* primitive shall be issued.

When the *initiate.response+* primitive is issued, an *Initiate-ResponsePDU* is sent which is structured accordingly to the *Initiate-RequestPDU* and contains the adjusted values.

Listing 12: Initiate service response PDU according to ISO 9506-2

```
Initiate-ResponsePDU ::= SEQUENCE {
    localDetailCalled          [0] IMPLICIT Integer32 OPTIONAL,
    negotiatedMaxServOutstandingCalling [1] IMPLICIT Integer16,
    negotiatedMaxServOutsadingCalled [2] IMPLICIT Integer16,
    negotiatedDataStructureNestingLevel [3] IMPLICIT Integer8 OPTIONAL,
    initResponseDetail        [4] IMPLICIT InitResponseDetail
}
```

When the initiate.response- primitive is issued, the Initiate-ErrorPDU is sent.

Listing 13: Initiate service error PDU according to ISO 9506-2

```
Initiate-ErrorPDU ::= ServiceError
```

◇ Variable Access Services

Read Service: is used by a client MMS-user to request a Virtual Manufacturing Device (VMD) to return the value of one or more variables defined at the VMD.

Listing 14: Initiate service according to ISO 9506-2

```
Read-Request ::= SEQUENCE {
    specificationWithResult [0] IMPLICIT BOOLEAN DEFAULT FALSE,
    variableAccessSpecification [1] VariableAccessSpecification
}

Read-Response ::= SEQUENCE {
    variableAccessSpecification [0] VariableAccessSpecification OPTIONAL,
    listOfAccessResult [1] IMPLICIT SEQUENCE OF AccessResult
}
```

specificationWithResult: this boolean parameter indicates whether (true) or not (false) the Variable Access Specification parameter is requested in the response primitive.

variableAccessSpecification: specifies which variables are to be accessed.

Listing 15: Variable Access Specification according to ISO 9506-2

```
VariableAccessSpecification ::= CHOICE {
    listOfVariable [0] IMPLICIT SEQUENCE OF SEQUENCE {
        variableSpecification VariableSpecification,
        alternateAccess [5] IMPLICIT AlternateAccess OPTIONAL
    },
    variableListName [1] ObjectName
}
```

listOfAccessResult: contains the values of the specified variables in the order specified by the Variable Access Specification parameter.

4.1.5 IEC 61850 — GOOSE based communication:

This IEC 61850 connection option is used to establish a fast communication channel over Ethernet, omitting the stochastic IP delays to achieve short and trustworthy transport latency. GOOSE (Generic Object Oriented Substation Events) is a controlled model mechanism in which any format of data (status, value) is grouped into a data set and transmitted within a time period of few milliseconds according to the required performance class specified in IEC 61850-5:2013 (11.2.1 Type 1 – Fast messages):

P1	\leq 3 ms	Total transmission time below a quarter of a cycle (5 ms at 50 Hz and 4 ms at 60 Hz)
P2	\leq 10 ms	Total transmission time in the order of half a cycle (10 ms at 50 Hz and 8 ms at 60 Hz)
P3	\leq 20 ms	Total transmission time in the order of one cycle (20 ms at 50 Hz and 17 ms at 60 Hz)

Fast messages refer to time critical, protection like functions. P1 and P2 are required for "Trip" messages, which are the most important fast messages in a substation. P3 applies for other fast messages, e.g., "Close", "Start", "Stop", "Block", "Trigger", "Release". The receiving IED shall act immediately on receipt of these types of messages since otherwise no fast message is needed.

The following mechanisms are used to ensure the specified transmission speed and reliability demand:³²

- * Data is directly embedded into Ethernet data packets transported using a publisher-subscriber regime on multicast or broadcast MAC addresses to ensure the same event message is received by multiple physical devices in parallel.
- * VLAN and priority tagging as per IEEE 802.1Q are used to get a separate virtual network within the same physical network with appropriate message priority level.
- * Enhanced re-transmission mechanisms: The same GOOSE message is re-transmitted with varying and increasing re-transmission intervals. A new event occurring within any GOOSE dataset element will result in the existing GOOSE re-transmission message being stopped. A state number within the GOOSE protocol identifies whether a GOOSE message is a new message or a re-transmitted message.
- * Messages are designed to be brand independent. Some vendors offer intelligent electronic devices (IEDs) that fully support IEC 61850 for a "truly interoperable" approach within the substation network without requiring vendor specific cables or algorithms.

↔ *This SBB is yet not covered in detail comparable to MMS.* If you expect interoperability issues resulting from different GOOSE implementation options, feel free to suggest specs.

³²https://en.wikipedia.org/wiki/Generic_Substation_Events#Generic_Object_Oriented_Substation_Events

Abbreviations

Every abbreviation used anywhere in the Technical Framework and accompanying documents shall be included. Product and company names that only look like being abbreviations need not be included.

AAA	Authentication Authorisation Access-control	FPGA	Field-Programmable Gate Array
ABB	Architecture Building Block	FSK	Frequency-Shift Keying
ABB_spec	Architecture Building Block Specifications		
ADU	Application Data Unit	GNU	GNU's Not Unix!
AMD	AMenDment	GPIO	General-Purpose Input/Output
AMI	Advanced Metering Infrastructure	GPL	GNU General Public License
APDS	Application Protocol Data Units	GPRS	General Packet Radio Service
API	Application Programming Interface	GSM	Global System for Mobile Communications
ASCII	American Standard Code for Information Interchange	HAL	Hardware Abstraction Layer
		HEMS	Home Energy Management System
BESS	Battery Electric Storage System	HDLC	High-Level Data Link Control
BF	Business Function	HTTP	Hypertext Transfer Protocol
		HV	High Voltage level
CAPEX	CAPital EXpenditures		
CC	Creative Commons	I2C	Inter-Integrated Circuit
CCTS	Core Components Technical Specification	IBF	IES Business Function
CEC	Citizens Energy Community	ICT	Information and Communication Technology
CEP	Clean Energy Package	ID	IDentifier
CF	Common Feature	IEC	International Electrotechnical Commission
CHP	Combined Heat and Power	IED	Intelligent Energy Device
CIM	Common Information Model	IEEE	Institute of Electrical and Electronics Engineers
COAP	COstrained Application Protocol	IEM	Internal Electricity Market
COSEM	Companion Specification for Energy Metering	IES	Integrating the Energy System
CPA	Collaboration Protocol Agreement	IETF	Internet Engineering Task Force
CPP	Collaboration Protocol Profile	IHE	Integrating the Healthcare Enterprise
CPU	Central Processing Unit	IIP	IES Integration Profile
CRC	Cyclic Redundancy Check	IIT	IES Interoperability Testing
CSV	Comma-Separated Values	IMA	IES Meta-Actor
C/EMS	Community Energy Management System	lopL	Interoperability Level
		IP	Internet Protocol
DA	Data Attribute	ISBN	International Standard Book Number
DACH	Germany, Austria, Switzerland	ISO	International Organization for Standardization
DER	Distributed Energy Resource		
DLC	Direct Load Control	IT	Information Technology
DLMS	Device Language Message Specification	ITU	International Telecommunication Union
DO	Data Object	IUC	IES Use Case
DR	Demand Response		
DSM	Demand Side Management	JSON	JavaScript Object Notation
DSO	Distribution System Operator		
		LD	Logical Device
EC	European Commission	LEC	Local Energy Community
EDA	Energiewirtschaftlicher Datenaustausch	LN	Logical Node
EDI	Electronic Data Interchange	LN	Local Network
EHV	Extra High Voltage level	LV	Low Voltage level
EIWOG	Elektrizitätswirtschafts- und organisationsgesetz	L/GCI	Local Grid Control Instance
EMS	Energy Management System	M/EMS	Member Energy Management System
EnCo	Energy Community	MQTT	Message Queuing Telemetry Transport
ESMP	European Style Market Profile	MUC	Meta Use Case
EU	European Union	MV	Medium Voltage level
EV	Electric Vehicle		

OBIS	OBject Identification System
OFDM	Orthogonal Frequency-Division Multiplexing
OPEX	OPerational EXpenditures
OSGi	Open Services Gateway initiative
OSI	Open Systems Interconnection
OT	Operations Technology
PAN	Personal Area Network
PCC	Point of Common Coupling
PDU	Protocol Data Unit
PLC	Power Line Communication
PLC	Programmable Logic Controller
PPP	Public-Private Partnership
PSTN	Public Switched Telephone Network
PV	PhotoVoltaic
RDF	Resource Description Framework
REC	Renewable Energy Community
RES	Renewable Energy Source
REST	REpresentational State Transfer
RFC	Request For Comments
RPC	Remote Procedure Call
RTU	Remote Terminal Unit
R&D	Research and Development
SBB	Solution Building Block
SCADA	Supervisory Control And Data Acquisition
SES	Smart Energy System
SGAM	Smart Grid Architecture Model
SME	Small and Medium Business
SML	Service Modelling Language
SMTP	Simple Mail Transfer Protocol
SNMP	Simple Network Management Protocol
SOAP	Simple Object Access Protocol
TCP	Transmission Control Protocol
TE	Technische Einheit / Technical Entity
TF	Technical Framework
TSO	Transmission System Operator
UA	User Association
UBL	Universal Business Language
UCMR	Use Case Management Repository
UDP	User Datagram Protocol
UI	User Interface
UML	Unified Modelling Language
URL	Uniform Resource Locator
W3C	World Wide Web Consortium
WG	WorkGroup
Wi-Fi	trademark of the Wi-Fi Alliance
WPAN	Wireless Personal Area Network
XML	eXtensible Markup Language

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All references used to prepare, extend, or amend the Technical Framework shall be listed; possibly with embedded link.

