D7.6 - Report on the contribution to standardization

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Document History

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0.2	2020-02-21	UPB	Introduction. Relevant IEC Standardization. Other relevant standards, regulations, frameworks.
0.3	2020-02-27	UNINOVA	Contributions for standardisation.
0.4	2020-02-28	UPB	S4G consortium member's contribution to standardisation and regulation. Conclusions. Acronyms. Version ready for internal review.
0.5	2020-03-08	UPB	Addressed reviewer comments.
1.0	2020-03-09	UNINOVA	Final version, ready for submission to the EC

Internal Review History

Review Date	Reviewer	Summary of Comments
2020-03-05 (v0.4)	Hamidreza Mirtaheri (LINKS)	Recommendation and question applied: • Clarification about S4G link to specific standards. • Writing conventions and issues.
2020-03-18 (v0.5)	Otilia Werner-Kytölä (FIT)	Approved: • Issues are addressed.
2020-03-18 (v0.5)	Hamidreza Mirtaheri (LINKS)	Approved: • Issues are addressed. • Minor typo corrections.

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Executive Summary

This deliverable presents the contribution to standardization in order to facilitate the acceptance and utilization by the market of the developed solutions, through the following three specific activities: the identification and analysis of S4G related existing or in development standards, the collaboration with the relevant standardization Technical Committees, and the contribution to the on-going and future standardization initiatives from the results of the project. The work in WP7 has been framed by three aspects:

- Information exchange: The high deployment of variable, highly stochastic and not controllable **renewables-based electricity generation** requires changes in the operation and development of the power system. The power system must become more flexible to respond to the variability and uncertainty of operational conditions **at various timeframes**. To this, information exchange (including with high reporting rate) is of relevance (**USM**). Also, in this framework, activity on definition and operation of DC- and hybrid microgrids is at incipient level (no standards available yet but merely Technical Specifications in work).
- Storage technologies: The focus on electricity **storage** technologies as deployed for achieving optimal operation in the proposed 3 scenarios requires specific standardization and regulation which is still ongoing.
- DC-link: The innovative **DC-link** used for balancing power flow in scenario 3 (High Level Use Case 1 – Primary Use Case 3: Resilient hybrid cooperative ecosystem use case in UPB test site) requires definition of DC energy exchange, standard levels for (voltage and current) DC installations and specific standardization of connecting equipment.

The need of high quality information from/to controlled systems requires measurement and monitoring equipment with high reporting rate, able to follow the new dynamic of phenomena to be controlled, i.e. in second-timeframe, and not in 10 minutes – or 15 minutes resolution as presently deployed for energy transfer (smart metering). The change of paradigm from energy transfer to power flow has been highlighted in the energy router operation and the deployment of USM (up to 1s reporting rate). This is a valuable input to standardization in the area of smart metering (see section 3.2.2)

Also, it has been derived from S4G work that some generic principles should guide the future investment framework for storage:

- There is a need for a European legal and regulatory framework regarding general principles for storage.
- Storage should compete in the field with other technologies, and the tariff structures should ensure neutrality of storage.
- Storage devices should not be restricted to a single service, as this would not be economically efficient.
- The TSOs should have access to data for central and distributed storage facilities for system security for all timeframes.

One highly innovative topic is the one using a DC-link for electricity transfer between one prosumer (with storage) and local loads, part of the HLUC-1 demonstrated in the Bucharest test site (at UPB premises). Emerging activity on low voltage DC networks (LVDC) started in 2019, including definition of normative / recommended voltage levels and issues of power quality. The S4G project is represented in the IEC system committee (SyC LVDC) dealing with various issues on DC networks by Mihaela Albu (UPB).

1 Introduction

The EU has defined ambitious energy policy goals with respect to competitiveness, security of supply, and sustainability (The European Green Deal[i]). These policy goals are defined for an electricity system that is in transition towards high penetration of variable renewable energy. Consequently, the system will become more complex and more decentralised. Furthermore, it is expected that the electrification of European society will further continue, and the customer will be more and more empowered and will offer its flexibility, also thanks to increasing digitalisation. This transition will result in new technological and economic needs and opportunities.

S4G is a R&D project proposing answers to the EU energy policy goals. Therefore, most of the solutions in this project are designed and tested following new technical ideas, with still incipient industrial applications, however, with a promising future not yet revealed deployment. Operation of power grids is based on existing regulations and codes of operation, which in turn are largely based on local (nationwide) standards, while these are a more restricted version of CEN-CENELEC standards; these are mostly similar or a more focused version of IEC standards. Therefore, in this deliverable we analyse primarily IEC standardisation activity.
In this project, the innovative approach has not a standardized support/back-up, while standards reflect the "recommended professional practice" which is not yet available considering the novelty of the solutions deployed in this project. This made such an endeavour very difficult (some use-cases are in DSO installations where local regulations must be applied) and equally challenging (by using new methods and scenarios).

1.1 Scope

This deliverable presents the contributions to standardization report as results of Task 7.3 – "Standardization" and its sub-tasks 7.3.1 – "Collaboration and communication with the relevant Technical Committees" and 7.3.2 – "Contribution to the on-going and future standardization developments."
D7.6. has a dual scope: to present the standardisation channels in use as a tangible result of S4G work (for example, the ongoing standardisation for DC microgrids), and to make available to the consortium relevant information from standards, technical specifications, regulatory decisions, experience disseminated by technical bodies (e.g., IEEE, CIGRE), in order to ensure that the proposed solution (and demonstrated for the selected use-cases) is feasible and in line with the general, international best practice validated work so far.

1.2 Related documents

ID	Title	Reference	Version	Date
D3.3	Final Storage Scenarios and Use Cases	[S4G-D3.3]	1.0	2019-10-17

2 Relevant IEC Standardization

The International Electrotechnical Commission (IEC) is an international standards organization that prepares and publishes international standards for all electrical, electronic and related technologies, covering a vast range from power generation, transmission and distribution to home appliances and office equipment, solar energy, batteries, storage and much more.
The IEC work considered in this deliverable is comprising from approved standards together with their new editions (in progress) together with the pre-normative activity, like technical specifications (TS) and technical reports (TR).
The IEC activity is organized in several Technical Committees (TC) (specialized on a specific branch of electrical engineering), a System Committees (SyC) (integrative, holistic approach).
For the work in S4G, the most relevant IEC activity is done by the following TCs: TC8, TC13, TC15, TC82 and TC120.

2.1 TC8 - Systems aspects for electrical energy supply

The scope of TC8 is to prepare and coordinate, in co-operation with other TC/SCs, the development of international standards and other deliverables with emphasis on overall system aspects of electricity supply systems and acceptable balance between cost and quality for the users of electrical energy. The electricity supply system encompasses transmission and distribution networks and connected user installations (generators and loads) with their network interfaces. This scope includes, but is not limited to, standardization in the field of:

- Terminology for the electricity supply sector.
- Characteristics of electricity supplied by public networks.
- Network management from a system perspective.
- Connection of network users (generators and loads) and grid integration.
- Design and management of de-centralized electricity supply systems, e.g., microgrids, systems for rural electrification.

While relying on efficient and secure data communication and exchange, TC8’s scope does not include standards for communication with appliances and equipment connected to the electric grid or for communication infrastructure serving the electric grid.
TC8 is responsible for basic publications (horizontal standards) on standard voltages, currents and frequencies ensuring the consistency of the IEC publications in these fields.
TC8 cooperates also with several organizations active in the field of electricity supply, e.g., CIGRE, CIRED, IEEE, AFSEC, IEA.
TC8 has a system function, having to deal with system aspects of electrical energy supply. However, by definition, TC8 has also a horizontal function which is limited to the items mentioned under characteristics of energy supply (voltage frequency and current and all their parameters) in order to prepare basic publications and ensure the consistency of the IEC publications in these fields.

2.1.1 IEC TS 62786-3 - Distributed energy resources connection with the grid – Part 3 Additional requirements for Stationary Battery Energy Storage System

Different aspects of Distributed Energy Resources (DERs) connection with the grid have been developed by several Technical Committees, which have increased the difficulty of developing coordinated standards and testing procedures in the field of DERs. This is the reason why TC8 decided to develop IEC TS 62786 as a series in order to be framework for the different technologies. This work is planned to be carried out under JWG10 initially established with TC82, in order to host the work on "additional requirements for PV generators" as IEC TS 62786-2.

This part of series IEC TS 62786 provides principles and technical requirements for stationary battery energy storage systems (SBESSs) connected to the distribution network complementing future IEC TS 62786-1. The considered battery energy storage systems refer to electrochemical forms such as lead-acid, lithium-ion, liquid flow and sodium-sulphur batteries. This TS applies to the design, connection, operation and testing of SBESSs. It includes general requirements, connection scheme, interface device, grounding and protection, power quality, start-up and operation, control, communication and automation, metering and grid-connected testing of SBESS. This TS specifies interface requirements for connection of distributed SBESSs with the distribution grid.

The standardization of distributed BESSs connection with the grid is in line with the needs of the users and the requirements of distributed generation integration with the grid, thus facilitating the development of smart grid. Currently, IEC TS 62786-1 specifies general requirements for distributed energy resource connection with the grid. However, additional requirements for distributed SBESSs are urgent needed. The new standard to be developed will not overlap with exiting IEC standards on safety, Electromagnetic Compatibility (EMC), environment and quality, etc. The S4G project experiences are in progress to be used as inputs in the TS evolutions.
Technical Specification in work, foreseen publication date: 2021.

2.2 SC8A - Grid Integration of Renewable Energy Generation

SC8A focuses on the impact of a high percentage of renewable connected to the grid, considering that their variability and predictability impact the functioning of the whole electricity grid. It covers grid integration standards for renewable energy, aggregating contributions of all grid users and prescribing interaction modes between the grid and power plants. This includes requirements for interconnection and related grid compliance tests, as well as standards or best practice documents for planning, modelling, forecasting, assessment, control and protection, scheduling and dispatching of renewable with a grid level perspective.

SC8A deals with the grid level requirements enabling secure, non-discriminatory and cost-effective operation of electricity supply systems with a significant share of renewable generation and cooperates with other committees to ensure technical feasibility and verification of the implementation of the grid level requirements.

2.3 SC8B - Decentralized Electrical Energy Systems

To develop IEC publications enabling the development of secure, reliable and cost-effective systems with decentralized management for electrical energy supply, which are alternative, complement or precursor to traditional large interconnected and highly centralized systems. This includes but is not limited to AC, DC, AC/DC hybrid decentralized electrical energy system, such as distributed generation, distributed energy storage, virtual power plants and electrical energy systems interacting with multiple types of distributed energy resources.

Standardization activities in SC8B will proceed with cooperation with concerned TCs, SCs and SyCs, including but not limited to IEC SyC Smart Energy, SyC LVDC, TC2, TC22, TC57, TC64, TC82, TC88, TC95, TC99, TC114 and TC120. SC8B will work on other relevant standards except to RE integration via LVDC/MVDC as previous listed for SC8A including but not limited to the planning, operation, control of LVDC/MVDC systems, such as the planning and design of non-conventional distribution grids (including DC distribution network), DC distribution network operation technology, etc.

2.3.1 IEC TS 62898-1 ED1 - Guidelines for general planning and design of microgrids

The scope of this TS is to provide technical guideline for microgrid planning and design. Microgrids considered in this TS are AC electrical systems with load and distributed resources and can satisfy customer needs for power quality and reliability requirement. Microgrids are classified into connected microgrids and isolated microgrid. Connected microgrids may act as controllable units to the power network, can operate in grid-connected mode or island mode; isolated microgrid has no electrical connection to distribution system. The

purpose of this TS is to provide basic requirements relevant to the following fields: microgrid application, resource analysis and generation forecast, load forecast, technical requirements for DER, connection to distributed network, microgrid power system planning, control and communication planning, and general evaluation of microgrid performance. The contents of evaluation for reliability, economy and environment enhancement for implementing microgrids are provided. Microgrid voltage level is either low voltage or medium voltage.
Technical Specification (publication date 2017) developed by TC8 / SC8B.

2.3.2 IEC TS 62898-2 ED1 - Technical requirements for operation and control of microgrids

IEC 62898-2 is needed in order to define the general technical requirements for operation and control of microgrids. IEC TC8 / WG7 is responsible for the development of IEC 62898-2 who mainly covers the following issues:

- The scope and size of microgrids: maximum generation capacity (power), voltage level for serving loads/integrating generation units, and total capacity (including storage).
- The operation requirements and control targets of microgrids under different operation modes should be clarified (including grid-connected operation, island operation).
- According to the operation requirements and control targets of microgrids, the basic control strategies and methods under different operation modes need to be standardized.
- The requirements of microgrids relay protection, monitoring and communication under different operation modes should be standardized specifically.

Technical Specification (publication date 2018) developed by TC8 / SC8B.

2.3.3 IEC TR 63282 ED1 - Assessment of standard voltages and power quality requirements for LVDC distribution

LVDC distribution systems have recently been recognized by a number of stakeholders as an alternative approach to provide efficient power supply to the consumers. LVDC covers a wide range of power applications from USB-C up to megawatts for aluminium melting. LVDC is now seen as not only a solution for electricity access in developing economies but also a solution for greener and more sustainable energy in developed economies.

There is currently no consensus on the standard voltages to be used in LVDC systems. The standardization of DC voltages is a key and urgent work needing to be addressed. Existing LVAC systems have different standard voltages, depending on the geography. LVDC distribution voltages should be optimized to provide a good context for industries that import and export equipment but also for general travellers. Appropriate international LVDC voltage ranges will provide a basis for design and testing of electrical equipment and systems. The results and experience from the field test in the Bucharest test site are considered to be included in the TS standardization activity.

Power quality phenomena in LVDC distributed systems can be related to the topology of the entire system, and the operating condition of sources and loads. At the same time, the DC output performance of a single converter and the coordination among several converters may also result in different power quality issues. Requirements for power quality in LVDC distribution should be established. This may provide a solid basis for the planning and operation of LVDC distribution systems. In addition, the allocation and configuration of the protection system will be affected. The objective is to enhance the availability of the source, the reliability, and the lifetime of the system.

Generally, the standardization of voltage level and power quality – related phenomena of LVDC distribution may greatly stimulate the wide adoption of LVDC. Presently a lot of effort is dedicated to power quality definition in LVDC, and a new JWG9 has been formed as part of SyC LVDC, with members primarily from TC8.
Technical Report (foreseen publication date 2020) developed by TC8 / SC8B.

2.3.4 IEC TS 62898-3-1 ED1 - Microgrids - Part 3-1: Technical requirements - Protection and dynamic control

The purpose of this TS is to provide guidelines for the specification of fault protection and dynamic control in microgrids. Protection and dynamic control in a microgrid are intended to ensure safe and stable operation of the microgrid under fault and disturbance conditions.

This TS applies to AC microgrids comprising single or three-phase networks or both. It includes both isolated microgrids and non-isolated microgrids with a single point of connection (POC) to the upstream distribution network. It does not apply to microgrids with two or more points of connection to the upstream distribution network, although such systems may follow the guidelines given in this document. This TS applies to microgrids operating at LV or MV or both. DC and hybrid AC/DC microgrids are excluded from the scope, due to the particular characteristics of DC systems (extremely large fault currents and the absence of naturally occurring current zero crossings).

This TS defines the principles of protection and dynamic control for microgrids, general technical requirements, and specific technical requirements of fault protection and dynamic control. It addresses new challenges in microgrid protection requirements, transient disturbance control and dynamic disturbance control requirements for microgrids. It focuses on the differences between conventional power system protection and new possible solutions for microgrid protection functions.

Depending on specific situations, additional or stricter requirements can be defined by the microgrid operator in coordination with the distribution system operator (DSO). The S4G experience with ER and DC-DC converters is used as input for the discussions on the standard in process to be elaborated.
Technical Specification (foreseen publication date 2020) developed by TC8 / SC8B.

2.4 TC13 - Electrical energy measurement and control

TC13 works are carried out by three working groups, one JWG linked to TC57 - 2ower systems management and associated information exchange" and one project team reporting directly to the Chairman:

- WG11 – "Electricity metering equipment is responsible for type testing, acceptance testing and product safety".
- WG14 – "Data exchange for meter reading, tariff and load control" is responsible for the development of data models and communication protocols for meter data exchange.
- WG15 – "Smart metering functions and processes" is responsible to define business functions, business processes and system elements within the context of an electricity metering system. This includes payment metering systems and payment meters.
- JWG16 – "Mapping between the common information model CIM and DLMS/COSEM data models and message profiles" linked to TC57.
- PT62057, reporting directly to the Chairman, is responsible for developing standards for test equipment, techniques and procedures for electrical energy meters.

2.4.1 IEC 62053-22 ED2 - Electricity metering equipment (a.c.) - Particular Requirements - Part 22: Static meters for active energy (classes 0,1 S, 0,2 S and 0,5 S)

This part of IEC 62053 applies only to newly manufactured transformer operated static watt-hour meters of accuracy classes 0,1S, 0,2S and 0,5S for the measurement of alternating current electrical active energy in 50 Hz or 60 Hz networks and it applies to their type tests only. This international standard applies to newly manufactured electricity metering equipment designed to:

- Measure and control electrical energy on electrical networks (mains) with voltage up to 1,000 V (a.c.), or 1,500 V (d.c.).

- Have all functional elements, including add-on modules, enclosed in, or forming a single meter case with exception of indicating displays.
- Operate with integrated or detached indicating displays, or without an indicating display.
- Be installed in a specified matching sockets or racks.
- Provide additional functions other than those for measurement of electrical energy.

While there is not a direct contribution to this standardisation in S4G, the work in DC connectivity provided by the project needed to know and understand the standard specifications, with potential in future standardisation activity based on the acquired know-how.
Technical Standard (publication date 2019) developed by TC13.

2.4.2 IEC 62053-41 ED1 - Electricity metering equipment (DC) – Particular Requirements - Part 41: Static meters for direct current energy (classes 0,2, 0,5 and 1)

This international standard applies only to newly manufactured static watt-hour meters for the measurement of direct current electrical energy in direct current systems of accuracy classes 0,2, 0,5 and 1 with a measuring range 0,01 In to 1,2 In.

It applies to direct connected static watt-hour meters for indoor application consisting of a measuring element and register(s) enclosed together in a meter case. It also applies to operation indicator(s) and test output(s). If the meter has other functional elements, like maximum demand indicators, electronic tariff registers, calendar clock, data communication interfaces etc. are enclosed in the meter case, then the relevant standards for these elements apply.

Meter can have inputs according the definitions for Low Power Instrument Transformers (LPIT) instead the conventional inputs for voltage or and current.
Technical Standard (publication date 2015) developed by TC13.

2.4.3 IEC 62052-41 ED1 - Electricity metering equipment – General requirements, tests and test conditions – Part 41: Energy registration methods and requirements for multi-energy and multi-rate meters

This new standard specifies requirements for registration methods of energy measurements of multi-energy meters including the ones with bidirectional measurements, as well specifies requirements and test methods for multi-rate energy registration.

The standard specifies the requirements for the registration of additional quantities derived from electricity measurements including but not limited to load profile recording, maximum demand registration, historical data storage.
The S4G team from UPB will use the project experience to contribute in the “request for comments” phase.
Technical Standard (foreseen publication date 2020) developed by TC13.

2.4.4 IEC 62052-11 ED2 - Electricity metering equipment (a.c.) - General requirements, tests and test conditions - Part 11: Metering equipment

This part of IEC 62052 specifies requirements and associated tests, with their appropriate conditions for type testing of (a.c.) and (d.c.) electricity meters. This part details functional, mechanical, marking and electrical requirements including immunity to external influences covering electromagnetic and climatic environments.
This international standard applies to newly manufactured electricity metering equipment designed to:

- Measure and control electrical energy on electrical networks (mains) with voltage up to 1,000 V (a.c.), or 1,500 V (d.c.).
- Have all functional elements, including add-on modules, enclosed in, or forming a single meter case with exception of indicating displays.
- Operate with integrated or detached indicating displays, or without an indicating display.

- Be installed in a specified matching sockets or racks.
- Provide additional functions other than those for measurement of electrical energy.

While there is not a direct contribution to this standardisation in S4G, the work in "General requirements, tests and test conditions" has been useful for the project activity, with potential in future standardisation activity based on the acquired know-how.
Technical Standard (publication date 2019) developed by TC13.

2.4.5 IEC 62056-3-1 - Electricity metering data exchange - The DLMS/COSEM suite - Part 3-1: Use of local area networks on twisted pair with carrier signalling

This part of IEC 62056 describes two sets of profiles: the first set of profiles allows a bidirectional communication between a client and a server. This set of profiles is made of three profiles allowing local bus data exchange with stations either energized or not. For non-energized stations, the bus supplies energy for data exchange. Three different profiles are supported:

- Base profile: this three-layer profile provides remote communication services.
- Profile with DLMS.
- Profile with DLMS/COSEM.

The three profiles use the same physical layer and they are fully compatible, meaning that devices implementing any of these profiles can be operated on the same bus. The second set of profiles allows unidirectional communication between a given Energy Metering device and a Customer Energy Management System. This second set is made up of three profiles.
There is a potential to use existing standardisation to contribute with future improvements, based on the project know-how.
Technical Standard (foreseen publication date 2020) developed by TC13.

2.5 TC21 – Secondary cells and batteries

To provide standards for all secondary cells and batteries related to product (dimension and performance), safety (including marking and labelling), testing, and safe application (installation, maintenance, operation) irrespective of type or application or configuration (hybrid, stand alone, module). Main applications are:

- Automotive (car, motorcycle, truck) for starting, lighting, ignition, start/stop
- Industrial (telecom, UPS, reliable power supply and traction)
- Electrical vehicles (full electrical vehicle, hybrid car, bicycle)
- Portable (computer, tool, lamp)
- Onboard batteries
- Energy storage (renewable, on- grid and off-grid).

All electrochemical systems are considered such as lead-acid, nickel-based (NiMH, NiCd) and lithium-based. New battery technologies and chemistries such as flow batteries and high temperature batteries (e.g. sodium sulphur, sodium nickel chloride) are included.

2.5.1 IEC 61427-1 - Secondary cells and batteries for renewable energy storage – General requirements and methods of test – Part 1: Photovoltaic off-grid application

This part (1) of the IEC 61427 series gives general information relating to the requirements for the secondary batteries used in photovoltaic energy systems (PVES) and to the typical methods of test used for the verification of battery performances. This part deals with cells and batteries used in photovoltaic off-grid applications. This standard is of paramount importance when considering the circular economy and present development of EV for S4G replication/extended future applications. Moreover, related work is pursued in the frame of EURAMET – EMPIR project 17IND10 [Quality assessment of electric vehicle Li-ion batteries for second use applications[ii]].

The part 2 of this series will cover cells and batteries used in "renewable energy storage in on-grid applications". This International Standard does not include specific information relating to battery sizing, method of charge or PVES design. This standard is applicable to all types of secondary batteries.
Batteries in a typical PV system operating under average site weather conditions may be subjected to the following conditions:

- Autonomy time.
- Typical charge and discharge currents.
- Daily cycle.
- Seasonal cycle.
- Period of high state of charge.
- Period of sustainable low state of charge.
- Electrolyte stratification.
- Storage.
- Operating temperature.
- Charge control.
- Physical protection.

There is a potential to follow-up this standardization activity based on the S4G activity.
Technical Standard (publication date 2013) developed by TC21.

2.5.2 IEC 61427-1 - Secondary cells and batteries for renewable energy storage – General requirements and methods of test – Part 2: On-grid applications

This part of IEC 61427 relates to secondary batteries used in on-grid Electrical Energy Storage (EES) applications and provides the associated methods of test for the verification of their endurance, properties and electrical performance in such applications. The test methods are essentially battery chemistry neutral, i.e. applicable to all secondary battery types.

On-grid applications are characterized by the fact that batteries are connected, via power conversion devices, to a regional or nation- or continent-wide electricity grid and act as instantaneous energy sources and sinks to stabilize the grid's performance when randomly major amounts of electrical energy from renewable energy sources are fed into it.

The aim of this part of IEC 61427 is to advise and guide future system operators to identify and select suitable rechargeable batteries for grid connected EES. This process will be aided by a set of common test methods that quantify the capability of battery systems of different chemistries and designs in a particular application scenario.
The requirements for battery endurance and electrical performance are linked to the specific EES scenarios to be implemented for the management of excess energy in the grid and the associated capital and operating expenditures for such an installation.

These requirements, expressed as energy efficiency, service life, cumulated energy throughput, installation space and similar, are highly variable since they are eminently application-scenario related and furthermore strongly tied to local costs/benefits and payback time considerations. This TS will directly benefit from the experience gathered in S4G, related to requirements for integrating batteries in on-grid applications.
Technical Standard (foreseen publication date 2021) developed by TC21.

2.6 TC57 – Power systems management and associated information exchange

To prepare international standards for power systems control equipment and systems including Energy Management Systems (EMS), Supervisory Control and Data Acquisition (SCADA), distribution automation, tele-protection, and associated information exchange for real-time and non-real-time information, used in the planning, operation and maintenance of power systems. Power systems management comprises control within control centres, substations and individual pieces of primary equipment including telecontrol and interfaces to equipment, systems and databases, which may be outside the scope of TC57. The special conditions in a high voltage environment have to be taken into consideration.

Whereas standards related to measuring and protection relays and to the control and monitoring equipment used with these systems are treated by TC95, TC57 deals with the interface to the control systems and the transmission aspects for tele-protection systems. Whereas standards related to equipment for electrical measurement and load control are treated by TC13, TC57 deals with the interface of equipment for interconnection lines and industrial consumers and producers requiring energy management type interfaces to the control system.
The standardisation activity is related especially with the resilience use-cases of the UPB tests and are milestones for future contribution based on the project outcomes.

2.6.1 IEC 62351-12 TR - Power systems management and associated information exchange – Data and communications security – Part 12: Resilience and security recommendations for power systems with Distributed Energy Resources (DER) cyber-physical systems.

The focus of this document is describing the impact of DER systems on power system resilience and covers the cyber security and engineering strategies for improving power system resilience with high penetrations of DER systems. While recognizing that many other requirements exist for improving power system resilience, this document does not address general power system configurations, operations, manual power restoration activities or the many other non-DER-specific issues. For instance, power system reliability relies on well-coordinated protective relays, stable power system designs, and well-trained field crews, while control centre cyber security relies on many best practices for communication network design and firewalls. However, this document only addresses the additional reliability and resilience issues caused by third-party managed DER systems which may not be as well-secured or operated with the same reliability as the utility-managed power system. In the energy sector, two key phrases are becoming the focus of international and national policies:

- Grid resilience.
- Cyber security of the cyber-physical grid.

Grid resilience responds to the overarching concern: "The critical infrastructure, the Smart Electric Grid, must be resilient - to be protected against both physical and cyber problems when possible, but also to cope with and recover from the inevitable disruptive event, no matter what the cause of that problem is - cyber, physical, malicious, or inadvertent."
A resilient power system is designed and operated not only to prevent and withstand malicious attacks and inadvertent failures, but also to detect, assess, cope with, recover from, and eventually analyse such attacks and failures in a timely manner while continuing to respond to any additional threats.

The “cyber-physical grid” implies that the power system consists of both cyber and physical assets that are tightly intertwined.

- **Threats – Engineering and Cyber**:
  - Physical and Electrical Threats – Mostly but Not Entirely Inadvertent. Impacts: Anti-islanding failures, Power system instability, Fluctuating energy output, Unnecessary DER disconnections, Reverse power flows.
  - Cyber Threats – Inadvertent and Deliberate. Threat agents can be defined as one of the following: Malicious person, Inadvertent mistake, Equipment failure, Natural disasters.
- **Vulnerabilities – Engineering and Cyber Vulnerabilities**:
  - Power System Vulnerabilities and Attacks.
  - Cyber Security Vulnerabilities and Attacks

  - Common human and system vulnerabilities that enable attacks are: Lack of security, Indiscretions by personnel, Simple or easy-to-guess passwords, Social engineering, Lack of trust, Resource exhaustion, etc.
- **Risk Management and Mitigation Techniques**:
  - Risk Handling
  - Risk Mitigation Categories

Technical Report (publication date 2016) developed by TC57.

2.6.2 IEC 62351-13 TR - Power systems management and associated information exchange - Data and communications security - Part 13: Guidelines on what security topics should be covered in standards and specifications

This document provides guidelines on what security topics could or should be covered in standards and specifications that are to be used in the power industry, and the audience is therefore the developers of standards and specifications.
These guidelines cannot be prescriptive for every standard, since individual standards and specifications may legitimately have very different focuses, but it should be expected that the combination of such standards and specifications used in any implementation should cover these security topics. These guidelines should therefore be used as a checklist for the combination of standards and specifications used in implementations of systems. Out-of-scope is explicit methods for cyber security in product development, implementations, or operations.

The security requirements for human users and software applications are different from the purely technical security requirements found in many communication and device standards. For user security standards, more emphasis must be on "policy and procedures" and "roles and authorization" rather than "bits and bytes" cryptographic technologies that should be included in Information and Communications Technology (ICT). In addition, engineering practices and system configurations must be considered, since no cryptography can compensate for poor design. This document is structured into three sections:

- Clause 5: Security requirements for standards and specifications which do not address specific cybersecurity technologies but where interactions between human users, software applications, and smart devices must be secured.
- Clause 6: Security requirements for standards and specifications that address information and communication technologies (ICT).
- Clause 7: Engineering design and configuration requirements that provide system reliability, 167 defence in depth, and other security threat mitigations.
- Clause 8: Security requirements related to the OSI Reference Model

While resilience has been an important focus in the HLUC-1, the communication security is one component which can affect positively or negatively the resilience. The TR has been followed by UPB and future contributions may be given to improve the existing TR.
Technical Report (publication date 2016) developed by TC57.

2.7 TC77 – Electromagnetic compatibility

The main task of TC77 and its three subcommittees is to prepare basic and generic EMC publications specifying electromagnetic environments, emissions, immunity, test procedures, measurement techniques, etc. A most important part of this is the description and classification of the EM environment so that product committees can in turn specify the characteristics of the particular products they are standardizing.

The scope covers the following aspects of EMC:

- Immunity and related items, over the whole frequency range: basic and generic standards,

- Emission in the low frequency range (f <= 9 kHz, e.g. harmonics and voltage fluctuations): basic, generic and product (family) standards,
- Emission in the high frequency range (f > 9 kHz): disturbances not covered by CISPR 10 (1992), in co-ordination with CISPR (e.g. mains signalling).

2.7.1 IEC 61000-4-30 - Electromagnetic compatibility (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods

IEC 61000-4-30:2015 is available as IEC 61000-4-30:2015 RLV, which contains the international standard and its redline version, showing all changes of the technical content compared to the previous edition.

IEC 61000-4-30:2015 defines the methods for measurement and interpretation of results for power quality parameters in a.c. power supply systems with a declared fundamental frequency of 50 Hz or 60 Hz. Measurement methods are described for each relevant parameter in terms that give reliable and repeatable results, regardless of the method's implementation. This standard address measurement methods for in-situ measurements. Measurement of parameters covered by this standard is limited to conducted phenomena in power systems. The power quality parameters considered in this standard are power frequency, magnitude of the supply voltage, flicker, supply voltage dips and swells, voltage interruptions, transient voltages, supply voltage unbalance, voltage harmonics and inter-harmonics, mains signalling on the supply voltage, rapid voltage changes, and current measurements. This edition includes some significant technical changes with respect to the previous edition:

- The measurement method for current, previously informative, is now normative with some changes.
- The measurement method for rapid voltage change (RVC) has been added.
- The measurement method for conducted emissions in the 2 kHz to 150 kHz range has been added in informative Annex C.
- Class A and Class S measurement methods are defined and clarified, while Class B is moved to informative Annex E and considered for future removal.
- Measurement methods continue in this standard, but responsibility for influence quantities, performance, and test procedures are transferred to IEC 62586-2.

Technical Standard (foreseen publication date of the new version 2021) developed by TC77. Work in S4G will enable informed feedback to the TC77.

2.8 TC82 - Solar photovoltaic energy systems

To prepare international standards for systems of photovoltaic conversion of solar energy into electrical energy and for all the elements in the entire photovoltaic energy system. In this context, the concept "photovoltaic energy system" includes the entire field from light input to a photovoltaic cell to and including the interface with the electrical system(s) to which energy is supplied.

2.8.1 IEC TR 63292 ED1 - Roadmap for robust reliability of a Photovoltaic Power System (PVPS)

This report continues the effort started with the availability TS (IEC 63019). Availability is closely related to PVPS operational capability, health and condition and to produce energy and is a real-time or historical measure.

The availability of a system or component is impacted by contractual and non-contractual reliability specifications, maintenance metrics and a corresponding maintenance and repair strategy, and also external factors such as site environmental and grid conditions. Reliability has a focus more closely aligned on the capability of the components, their health and condition, systems to sustain production, and what manner of operations, maintenance, analysis and actions are effective for economic asset management of the PVPS. This TR provides a summary of generally accepted definitions across multiple industries including PV.
Technical Report (foreseen publication date 2020) developed by TC82.

2.8.2 IEC TS 62910 ED2 - Utility-interconnected photovoltaic inverters - Test procedure for under voltage ride-through measurements

IEC TS 62910:2015(E) provides a test procedure for evaluating the performance of Low Voltage Ride-Through (LVRT) functions in inverters used in utility-interconnected PV systems. The TS is most applicable to large systems where PV inverters are connected to utility high voltage distribution systems. However, the applicable procedures may also be used for LV installations in locations where evolving LVRT requirements include such installations, e.g. single-phase or 3-phase systems.

The measurement procedures are designed to be as non-site specific as possible, so that LVRT characteristics measured at one test site, for example, can also be considered valid at other sites. This TS is for testing of PV inverters, though it contains information that may also be useful for testing of a complete PV power plant consisting of multiple inverters connected at a single point to the utility grid. It further provides a basis for utility-interconnected PV inverter numerical simulation and model validation.
The project activity followed the TS activity and has the potential for future standardization contributions in the area.
Technical Specification (foreseen publication date 2020) developed by TC82.

2.8.3 IEC TS 62257-9-4 ED3 – Recommendations for renewable energy and hybrid systems for rural electrification – Part 9-4: Integrated systems - User installation

IEC TS 62257-9-4:2016(E) specifies the general requirements for the design and the implementation of a user's installation. It applies to single phase user's electrical installations with maximum power of 500 VA, in decentralized rural electrification systems. It is applicable to installations supplied by an AC microgrid and to installations encompassing their own single-unit AC micropower plant or DC micropower plant. The main technical changes with regard to the previous edition are as follows: changing the voltage range covered by the TS to (a.c.) nominal voltage below 1 000 V and (d.c.) nominal voltage below 1 500 V. Work pursued in S4G will be valuable input to this TS.
Technical Specification (foreseen publication date 2021) developed by TC82.

2.8.4 IEC TS 62786 (and future series) - Distributed energy resources connection with the grid

IEC TS 62786:2017(E) provides principles and technical requirements for DERs connected to the distribution network. It applies to the planning, design, operation and connection of DERs to distribution networks. It includes general requirements, connection scheme, choice of switchgear, normal operating range, immunity to disturbances, active power response to frequency deviation, reactive power response to voltage variations and voltage changes, EMC and power quality, interface protection, connection and start to generate electrical power, active power management, monitoring, control and communication, and conformance tests.
This document specifies interface requirements for connection of generating plants with the distribution network operating at a nominal frequency of 50 Hz or 60 Hz.

Even if there was no direct implication in this standard activity, there is a potential for future contribution, through the project experience gained with the ER prototypes operation.
Technical Specification (foreseen publication date 2020) developed by TC82.

2.8.5 IEC/TS 62786-41 – Distributed energy resources connection with the grid – Part 41 Requirements for frequency measurement used to control DER and loads

This TS defines minimum requirements for frequency and rate of change of frequency (ROCOF) measurements for DER as well as loads to be connected to electrical power networks. These measurements are intended for self-regulating control of DER or loads in case of power frequency deviations. Characteristics to be developed are:

- Framework conditions for measurement and analysis.
- Immunity requirements.

For different kinds of use-cases, at least the P-by-f droop (see e.g. TS 62786 and control strategies using the ROCOF (used for enhanced protection systems and the emulation of system inertia), the TS provides recommended combinations of:

- Maximum permissible duration of a measurement & analysis interval.
- Minimum accuracy of the measurement & analysis.
- Ranges for the response characteristic (step response) of the measuring & analysis element.

These use-cases comprise cases with high accuracy (and certain measurement duration) as well as cases with a focus on fast reaction (and lower accuracy).

Content in this TS is a valuable input for further development of the S4G solution.
Technical Specification (foreseen publication date 2021) developed by TC82.

2.9 TC85 - Measuring equipment for electrical and electromagnetic quantities

The scope of TC85 is to prepare international standards for equipment, systems, and methods used in the fields of measurement, test, recurrent test, monitoring, evaluation, generation and analysis of steady state and dynamic (including temporary and transients) electrical and electromagnetic quantities, as well as their calibrators.

Such equipment includes devices for testing the safety of power distribution systems and connected equipment, devices for monitoring the power distribution systems, electrical measuring transducers, signal generators, recorders together with their accessories.

2.9.1 IEC 61557-12 - Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. – Equipment for testing, measuring or monitoring of protective measures – Part 12: Performance measuring and monitoring devices (PMD)

Increasingly, digital equipment is replacing analogue equipment in electrical installations. It supports more accurate measurement of new values and is able to make these available to users at both local and remote locations.
Devices intended to perform monitoring have various characteristics which require a shared reference system. This system must allow users to make easier choices in terms of performance levels, dependability and to interpret different measured parameters.

All these various measuring devices (referred to as Power Metering and Monitoring Device (PMD)) have to meet the requirements of international standard IEC 61557-12 "Electrical safety in low voltage distribution systems up to 1000V (a.c.) and 1500 V (d.c.) – Equipment for testing, measuring or monitoring of protective measures – Part 12: Power Metering and monitoring devices (PMD)".

The standard gives a list of the main requirements applicable to PMD with guidance about sensors to use (in case sensors are requested).
All the possible electrical parameters to be measured are listed. For each parameter, a list of requirements is specified, such as the rated range of operation, the range of influence quantities, the measurement techniques, etc. The considered electrical parameters are:

- Active energy (classes are equivalent to the classes defined in IEC 62053-21 and IEC 62053-22).
- Reactive energy (classes are equivalent to the classes defined in IEC 62053-23).
- Apparent energy.
- Active, reactive and apparent power.
- Frequency.
- r.m.s. phase and neutral current.

- r.m.s. voltage.
- Power factor.
- Voltage dip and swell.
- Voltage interruption.
- Voltage unbalance.
- Harmonic voltage and distortion.
- Harmonic current and distortion.
- Maximum, minimum, peak, average, demand and values.

Technical Standard (foreseen publication date 2020) developed by TC85.

2.10 TC120 – Electrical Energy Storage (EES) Systems

TC120 focuses on system aspects on EES Systems rather than energy storage devices, on the interaction between EES Systems and Electric Power Systems (EPS) investigates system aspects and the need for new standards for EES Systems. For the purpose of TC120, "grid" includes and is not limited to applications in: transmission grids, distribution grids, commercial grids, industrial grids, residential grids, islanded grids, Municipal/Military, Utilities/Universities, Schools, Hospitals (MUSH) grids, Institutional, Commercial and Industrial (ICI) grids. It is also confirmed that TC120 can include "smart grid." Storage in railway systems is considered if it contributes as an EES System to the grid.

EES Systems include any type of grid connected EES Systems which can both store electrical energy from a grid or any other source and provide electrical energy to a grid. By that feature, it maintains the balance between electrical energy demand and supply over a period of time. TC120 considers all storage technologies as long as they are capable to store and to discharge electrical energy. Energy storage itself is not in the scope of the work.
The scope of TC120 is to prepare normative documents dealing with the system aspects of EES Systems (defining unit parameters, testing methods, planning and installation, guide for environmental issues and system safety aspects).

2.10.1 IEC TS 62933 - Electric Energy Storage Systems; Part 3-2: Planning and performance assessment of electrical energy storage systems - Additional requirements for power intensive and for renewable energy sources integration related applications

This part of IEC 62933 provides the requirements for power intensive and renewable energy sources integration related applications of EES systems, including grid integration, performance indicators, sizing and planning, operation and control, monitoring and maintenance. The power intensive applications of EES systems are usually used to improve the dynamic performance of the grid by discharging or charging based on corresponding control strategies. The renewable energy sources integration related applications of EES systems are usually used to mitigate short term fluctuation and/or to keep long term stability. This document includes the following applications of EES systems:

- Frequency regulation/support
- Grid voltage support (Q(U), Volt/Var support)
- Power quality support (P(U), Voltage sag mitigation)

To date, we did not have identified a direct communication channel to TC120. however, work in S4G will be a valuable input to this TS.
Technical Specification (foreseen publication date 2023) developed by TC120.

2.10.2 IEC 62933-1 Electrical energy storage (EES) systems - Part 1: Vocabulary

This part of IEC 62933 defines terms applicable to EES systems including terms necessary for the definition of unit parameters, test methods, planning, installation, safety and environmental issues.

This terminology document is applicable to grid-connected systems able to extract electrical energy from an electric power system, store it internally, and inject electrical power to an electric power system. The step for charging and discharging an EES system may comprise an energy conversion.
Technical Standard (publication date 2018) developed by TC120.

2.10.3 IEC 62933-2-1 ED1 - Electrical Energy Storage (EES) systems - Part 2-1: Unit parameters and testing methods – General specification

This part of IEC 62933 focuses on unit parameters and testing methods of EES systems. The energy storage devices and technologies are outside the scope of this document. This document deals with EES system performance defining:

- Unit parameters.
- Testing methods.

The following parameters shall be specified as the common basic parameters to ensure EES system capability and performance:

- Nominal energy capacity (Wh).
- Input and output power rating (W, var, VA).
- Roundtrip efficiency (%).
- Expected service life (years, duty-cycles).
- System response (step response time (s) and ramp rate (W/s)).
- Auxiliary power consumption (W).
- Self-discharge of ESSs (Wh/h).
- Voltage range (V).
- Frequency range (Hz).

The EES system shall be tested under the conditions followed listed. However, if it cannot be tested under standard test conditions, conversion to standard test conditions is allowed. Standard testing conditions are:

- Ambient air temperature at 25 ºC.
- Altitude at <= 1 000 m.
- Humidity at <= 95 % with no condensation.

Technical Standard (foreseen publication date 2020) developed by TC120.

2.10.4 IEC 62933-3-1 ED1 - Electrical Energy Storage (EES) systems - Part 3-1: Planning and installation- General specifications

This part of IEC 62933 is applicable to EES systems designed for grid connected indoor or outdoor installation and operation at a.c. or d.c. irrespective of voltage. This document considers:

- Necessary functions and capabilities of EES systems.
- Test items and validation methods for EES systems.
- The requirements for monitoring and acquisition of EES system operating parameters.
- Exchange of system information and control capabilities required.

IEC 62933-2 series should be used as a reference when selecting testing items and their corresponding evaluation methods as well as principal parameters. Principal terms used in this document are defined in IEC 62933-1. Stakeholders of this document comprise of personnel involved with EES systems, which includes

- Planners.
- Owners.
- Operators.
- Constructors.
- Equipment suppliers.

- System suppliers.
- Grid operators.
- Grid aggregators.

Use-case specific technical documentation, including planning and installation specific tasks such as system design, monitoring and measurement, operation and maintenance, are necessary and can be found throughout this document.
Technical Standard (publication date 2017) developed by TC120.

2.10.5 IEC TS 62933-4 Ed. 1: Electrical Energy Storage (EES) Systems – Guidance on Environmental Issues

This document describes environmental issues associated with ESS systems and presents guidelines to address the environmental impacts to and from EES systems including the impacts to human due to chronic exposure. This document considers the issues in both normal and abnormal operating conditions.

This document applies to all EES system regardless of the type of electrical energy storage technologies. The aim of this document is to describe environmental issues that are applicable to EES systems.
Technical Standard (publication date 2016) developed by TC120.

2.10.6 IEC TS 62933-5 Ed.1: Safety considerations related to the integrated electrical energy storage (EES) systems

This TS specifies safety considerations related to the grid integrated EES systems, includes a variety of storage technologies, a wide range of storing capacity, and a variety of installation environments. In this TS, common consideration and requirements for safety are described, with all these varieties in mind. This document is believed to be a decisive step towards the gradual alignment with specific technologies and applications concerning the safety of grid integrated EES system.
Technical Standard (publication date 2016) developed by TC120.

2.10.7 IEC 62933-5-2 ED1 - Electrical energy storage (EES) systems Part 5-2: Safety requirements for grid integrated EES systems - electrochemical based systems

This part of IEC 62933 primarily describes safety aspects of people and, where appropriate, safety matters related to the surroundings and living beings for grid connected energy storage systems where an electrochemical storage subsystem is used. This safety standard is applicable to the whole life cycle of BESS (from design to end of service life management).

This standard provides further safety provisions that arise due to the use of an electrochemical storage subsystem (e.g. battery system) in energy storage systems that are beyond the general safety considerations described in IEC TS 62933 Part 5-1.
This standard prescribes the safety requirements of an “electrochemical” energy storage system as a "system" to reduce the risk of harm or damage caused by the hazards of an electrochemical energy storage system due to interactions between the subsystems as presently understood.
Technical Standard (publication date 2020) developed by TC120.

2.10.8 IEC 61427-2 - Secondary cells and batteries for renewable energy storage – General requirements and methods of test – Part 2: On-grid applications

This part of IEC 61427 relates to secondary batteries used in on-grid ESS applications and provides the associated methods of test for the verification of their endurance, properties and electrical performance in such applications. The test methods are essentially battery chemistry neutral, i.e. applicable to all secondary battery types.

On-grid applications are characterized by the fact that batteries are connected, via power conversion devices, to a regional or nation- or continent-wide electricity grid and act as instantaneous energy sources and sinks to stabilize the grid's performance when randomly major amounts of electrical energy from renewable energy sources are fed into it. Related power conversion and interface equipment is not covered.
Technical Standard (publication date 2015) developed by TC120.

2.10.9 IEC TS 62933-4 Ed. 1: Electrical Energy Storage (EES) Systems – Guidance on Environmental Issues

This document describes environmental issues associated with EES systems and presents guidelines to address the environmental impacts to and from EES systems including the impacts to human due to chronic exposure. This document considers the issues in both normal and abnormal operating conditions and applies to all EES system regardless of the type of electrical energy storage technologies.

It is not the aim of this document to describe environmental issues associated with components and products used in EES systems that are already described in other IEC/ISO standards and to describe environmental issues that are applicable to EES systems.
Technical Standard (foreseen publication date 2022) developed by TC120.

2.10.10 IEC 62933-5-2 ED1 Electrical energy storage (EES) systems Part 5-2: Safety requirements for grid integrated EES systems - electrochemical based systems

This part of IEC 62933 primarily describes safety aspects of people and, where appropriate, safety matters related to the surroundings and living beings for grid connected energy storage systems where an electrochemical storage subsystem is used.
This safety standard is applicable to the whole life cycle of BESS (from design to end of service life management).

This standard provides further safety provisions that arise due to the use of an electrochemical storage subsystem (e.g. battery system) in energy storage systems that are beyond the general safety considerations described in IEC TS 62933 Part 5-1.
This standard prescribes the safety requirements of an "electrochemical" energy storage system as a "system" to reduce the risk of harm or damage caused by the hazards of an electrochemical energy storage system due to interactions between the subsystems as presently understood.

Risks may depend on many factors including location, chemistry and the size/scale (e.g. power) of the BESS and will need to be assessed accordingly. The location of BESS' can range from single domestic situations, commercial and industrial applications to utility scale systems – risks need to be assessed accordingly. Selection of chemistry for the electrochemical accumulation subsystem of the BESS may be dependent on environment, performance characteristics and any associated costs and benefits.
Technical Standard (foreseen publication date 2023) developed by TC120.

2.10.11 IEC TS 62933-5 Ed.1: Safety considerations related to the integrated electrical energy storage (EES) systems

This TS specifies safety considerations related to the grid integrated EES systems Grid integrated EES systems includes a variety of storage technologies, a wide range of storing capacity, and a variety of installation environments. In this TS, common consideration and requirements for safety are described, with all these varieties in mind.

Secondary batteries are rechargeable batteries that convert reversibly chemical energy into electricity. They consist of a cell or of a connected group of cells. The most common rechargeable batteries are lead-acid, NiCd, NiMH and Li-ion and Li-ion polymer. However, other types of batteries are also rechargeable like Li-metal, Sodium-Sulphur (NaS), Sodium-Nickel chloride (ZEBRA) and flow batteries and used in large storage applications. The main risks scenarios for secondary batteries (except the flow batteries) are:

- Internal failure of a cell (over-charging, over-discharging, external short circuit, internal short circuit, temperature rise, loss of containment).
- Propagation of electrical effects between cells in the same assembly following the failure of a first cell.
- Insufficient dissipation of the heat in the housing assembly.
- Thermal runaway of a cell with opening of the outer shell.
- Spread of thermal and mechanical effects to neighbouring cells.

Technical Specification (foreseen publication date 2022) developed by TC120.

2.11 IEC - SyC LVDC - Low Voltage Direct Current And Low Voltage Direct Current For Electricity Access

LVDC lacks legacy, field experience, good practices and for some matters, detailed standards and design rules. Physics are not always similar to AC. DC facts are simply different. Installation general characteristics like rating, voltage bands for safe interoperability and earthing systems are basic issues for the LVDC and require careful study. Up to date the earthing system in some DC electrical installations was a question of technical – economic optimum for the DC source and not a safety question.
Power electronic converters are part of the installation, along with Solar modules, wind generation, fuel cells batteries.

This system group of IEC drafts roadmap proposals for low-voltage DC electrical distribution. IEC's technical committees asked for contribution: TC8, TC22, TC23, TC34, SC37A, TC64, TC69, TC77, TC81, TC82, TC85, TC109, TC121 etc. should support, advice, and help integration of the results in their own standards.

3 Other relevant standards, regulations, frameworks related to measurement information for controlling RES-based power systems, working with USM and microgrids

3.1 CEN-CENELEC

CEN and CENELEC are international non-profit associations. They are officially recognized as European Standardization Organizations (alongside the European Telecommunications Standards Institute (ETSI)).

CEN, CENELEC and their national members and committees work jointly to develop and define standards that are considered necessary by market actors and/or to support the implementation of European legislation.
A majority of European Standards are initiated by business and developed in partnership with other stakeholders. Around 30% are mandated by the EC in the framework of EU legislation.

The European Standardization System is unique in the world. After the publication of a European Standard, each national standards body or committee is obliged to withdraw any national standard which conflicts with the new European Standard. Hence, one European Standard becomes the national standard in all the 34 member countries of CEN and/or CENELEC.

CEN and CENELEC are business catalysts in Europe, removing trade barriers for European industry and consumers. Their mission is to foster the European economy in global trading, the welfare of European citizens and the environment. Through their services, they provide platforms for the development of European Standards and other technical specs.

3.1.1 CLC/EN 50549-1 - Requirement for generating plants to be connected in parallel with distribution networks – Part 1: Connection to a LV distribution network

This document specifies the technical requirements for the protection functions and the operational capabilities for generating plants, intended to operate in parallel with LV distribution networks. For practical reasons this document refers to the responsible party where requirements have to be defined by an actor other than the DSO e.g. TSO, member state, regulatory authorities according to the legal framework. Typically, the DSO will inform the producer about these requirements.
It includes European network codes and their national implementation, as well as additional national regulations. Additional national requirements especially for the connection to the distribution network and the operation of the generating plant may apply.

The requirements of this European Standard apply, irrespective of the kind of energy source and irrespective of the presence of loads in the producer's network, to generating plants, generating modules, electrical machinery and electronic equipment that meet all the following conditions:

- Converting any energy source into AC electricity.
- Generating modules capacity of type B or smaller according to COMMISSION REGULATION (EU) 2016/631 while considering national implementation for the decision regarding power limits between A and B types and B and C types.
- Connected to and operated in parallel with an AC LV distribution network.

Generating plants connected to a MV distribution network fall into the scope of EN 50549–2. Electrical energy storage systems (EESS) in meeting the previous conditions are included. If generating modules of different type (A or B) are combined in one plant, different requirements apply for the different modules based on the type of each module.

This document recognizes the existence of specific technical requirements (e.g. grid codes) of the DSO or another responsible party within a member state and these must be complied with.
Excluded from the scope are:

- The selection and evaluation of the point of connection.

- Power system impact assessment e.g. assessment of effects on power quality, local voltage increase, impact online protections operation.
- Connection assessment, the set of technical verifications made as part of the planning of the connection.
- Island operation of generating plants, both intentional and unintentional, where no part of the distribution network is involved.
- Four-quadrant rectifier of drives feeding breaking energy back into the distribution network for limited duration with no internal source of primary energy.
- Uninterruptible power supply with duration of parallel operation limited to 100 ms.

European Norm. Publication date 2019.

3.1.2 CLC/EN 50549-1 - Requirement for generating plants to be connected in parallel with distribution networks – Part 2: Connection to a MV distribution network

This document specifies the technical requirements for the protection functions and the operational capabilities for generating plants, intended to operate in parallel with MV distribution networks. For practical reasons this document refers to the responsible party where requirements have to be defined by an actor other than the DSO e.g. TSO, member state, regulatory authorities according to the legal framework. Typically, the DSO will inform the producer about these requirements.
It includes European network codes and their national implementation, as well as additional national regulations. Additional national requirements especially for the connection to the distribution network and the operation of the generating plant may apply.

The requirements of this European Standard apply, irrespective of the kind of energy source and irrespective of the presence of loads in the producer's network, to generating plants, generating modules, electrical machinery and electronic equipment that meet all the following conditions:

- Converting any energy source into AC electricity.
- Generating modules capacity of type B or smaller according to COMMISSION REGULATION (EU)
- 2016/631 while considering national implementation for the decision regarding power limits between A and B types and B and C types.
- Connected to and operated in parallel with an AC MV distribution network.

Generating plants connected to a MV distribution network fall into the scope of EN 50549–2. EESS in meeting the previous conditions are included. If generating modules of different type (A or B) are combined in one plant, different requirements apply for the different modules based on the type of each module.

This document recognizes the existence of specific technical requirements (e.g. grid codes) of the DSO or another responsible party within a member state and these must be complied with. Excluded from the scope are:

- The selection and evaluation of the point of connection.
- Power system impact assessment e.g. assessment of effects on power quality, local voltage increase, impact online protections operation.
- Connection assessment, the set of technical verifications made as part of the planning of the connection.
- Island operation of generating plants, both intentional and unintentional, where no part of the distribution network is involved.
- Four-quadrant rectifier of drives feeding breaking energy back into the distribution network for limited duration with no internal source of primary energy.
- Uninterruptible power supply with duration of parallel operation limited to 100 ms.

European Norm. Publication date 2019.

3.2 National standards for Romania

The Romanian **electricity market** consists of the following specific markets:

- Centralized bilateral contracts market operated by Romanian gas and electricity operator (OPCOM)
- Day-Ahead Market operated by OPCOM. The price cap for the day-ahead market is 3000 EUR/MWh, while the minimum value is 0.2 EUR/MWh.
- Balancing Market operated by Transelectrica (Romanian TSO). The price cap for balancing reserves is currently 100 EUR/MWh. The price cap of the balancing market is so low; consequently, the suppliers sometimes do not buy energy from the day ahead market, but they buy it from the balancing market. This imposes penalties on them.
- Intra-day Market operated by OPCOM
- Ancillary Service Market (ASM)/Reserves market

The first three producers in Romania in 2016 were: Hidroelectrica (29.8%) – hydro based generation, "Oltenia" Energetic Complex (21.21%) – coal-based generation, and Nuclearelectrica (17.9%) – nuclear based generation. In 2016, the Romanian generation mix was: 42.4% from RES (29% from hydro, 10% from wind, 2.6% from PV, 0.8% other sources), 24.5% from coal, 17.5% from Nuclear, 15% from gas and 0.6% from other sources. RES are participating in the market once for selling the energy and on a different market for selling the Green Certificates (the Green Certificates Market).
Generation units above 5 MW are considered dispatchable, and thus they must be connected to the national dispatching centre by SCADA. Generation units of less than 5 MW rating power must enter the portfolio of a third-party. Green certificates are sold on the green certificates market for a price between 29.4 and 35 EUR/certificate.

There are only one TSO (Transelectrica), eight DSOs (Electrica Distributie Transilvania Nord, Electrica Distributie Transilvania Sud, Electrica Distributie Muntenia Nord, Enel Distribuţie Muntenia, Enel Distribuţie Banat, Enel Distribuţie Dobrogea, CEZ Distribuţie Energie Oltenia, EON Delgaz Grid), one market operator (OPCOM) and one balancing market operator.
In Romania, standardization activity is overseen and organized by the Romanian Standards Association (ASRO), a member with full rights in European Committee for Standardization (CEN) and European Committee for Electrotechnical Standardization (CENELEC), an International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) member. ASRO is also a member with observer right in ETSI.

3.2.1 Prosumer Guide[iii]

Romanian Regulatory Authority for Energy (ANRE) is an autonomous public institution from Romania who has the mission to create and to apply necessary regulations to the energy sector functioning and to electrical, thermal, and natural gases energy market under efficiency, competition, transparency and user protection conditions.
In Romania the prosumers defined by law are the consumers of electrical energy, both physical and juridical bodies, must meet a few conditions, namely:

- Owning electrical energy systems or cogeneration electrical and thermal energy systems.
- Their specific activity is not the production of electricity (in the case of juridical entities it does not have to exist a CAEN code for electricity production defined in the main activity, and authorized physical persons do not have to perform electricity production activities). In the case of physical bodies that are not developing economic activities is indicated to keep the installed power of the existing production capacity lower than the power approved for consumption already written on the connection approval. In this way, it is avoided the risk to be considered an economic activity actor and you can receive grants.
- Consume, store and sell electricity produced from RES produced in their buildings (including an apartment block, a residential area, a shared service location, commercial or industrial or in the same

closed distribution system) with the mention that in the case of autonomous non-household energy consumers with RES, these activities do not represent their primary commercial or professional activity.

The prosumer who owns an electricity production unit from RES and has no more than 27kW installed power per consumption place can address the DSO to which the unit is connected in order to get a prosumer certification. It is a mandatory document, because the DSO needs to know the number and the figures of the electricity production units for ensuring an efficient management of the grid, but also the amount of the electrical energy from RES made by prosumers – as a percent of the total Romanian electrical renewable energy amount which needs to be monitored.
After this step, the DSO will release the certification and establish a selling-buying contract of the electrical energy, allowing to the prosumer to commercialize electrical energy.

A prosumer can sell their own produced energy to the grid operators based on the contract and the energy suppliers are obliged to accept this energy into the grid and to send to the prosumer in a 10-day due interval a selling-buying contract. In addition, the prosumers have covered the financial regularization between the delivered and the energy consumed from the grid. The physical owners do not have to meet the annual or trimestral acquisition demand of green certificates for the energy produced and used for his own final consumption (different from his own technological consume of the power station). Moreover, these last entities do not have to pay the taxes for the electrical energy amount produced and self-consumed or sold to suppliers. The price in this context can be either a negotiated price, either an accepted weighted average price of the Day Ahead Market.

The certified prosumer can sell the produced electricity only to the electricity supplier with which he already had made a supply contract for the grid consumed energy. For a new place of consumption and/or production, the prosumer sale-purchase energy contract, certified for this purpose, can be signed on the same date as the electricity supply contract. In order to be able to sell the electricity produced and delivered to the electricity grid, it is necessary that the prosumer, based on of the prosumer connection, to conclude a contract of sale-purchase of electric energy products with the electricity supplier with which, as final consumer, he/she has an electricity contract (for energy consumed from the grid).

The sale-purchase contract can have a validity period of at most equal to the validity period of the contract of electricity supply. Electricity suppliers have the obligation to purchase the electricity produced in electrical units belonging to prosumers and delivered to the grid from the starting date of the sale-purchase energy contract.

Monthly quantities of electricity produced in the power plant belonging to the prosumer expected to be delivered to the grid are established in the sale-purchase contract. The electricity bill includes the quantity delivered in that contract month. Invoicing the electricity consumed from the grid, as a final customer, and the electricity delivered to the grid, is done monthly (calendar month).

In the electricity bill, prosumers owning RES electrical energy production units with the installed electric power below 27 kW per place of consumption, will benefit (from electricity suppliers with whom they have concluded contracts) by the regularization service (the sum algebraic) between the value of the electricity delivered by the prosumer in the network (with the minus sign) and the value of the electricity consumed from the network (with the plus sign). The value of the delivered electricity is shown separately in the electricity bills with the minus sign and is calculated as the product between the amount of electricity produced and delivered by the prosumer in the grid and the accepted weighted average price of the Day Ahead Market.

Prosumers owning RES electricity production units with an installed electric power below 27 kW per consumption place, accredited to benefit from the system of promotion through green certificates, can opt for the sale of the electricity produced in the respective plants at the legal established price. For the entire sell-purchase contract period the access to green certificates is suspended. If the prosumer wants to close the sale-purchase contract before ending the contract period, the green certificates interdiction closes.

In order to be able to commercialize the surplus of electricity produced, the power plant connection of the prosumer must allow, both the supply of his own consumption from the grid and the injection of electricity produced in the grid through the same grid connection.

Electricity measurement is performed either with smart meters or with meters that allow at least remote reading, integrated into intelligent metering systems, in compliance with the terms of the current Measurement Code in force. Therefore, the amount of the energy injected to the grid from the overall energy produced from the RES can be calculated.
If the prosumer owns a RES electricity production unit with an electrical storage technology, he will need to mount at least one extra meter on the storage technology, in order to measure the actual amount of RES electricity delivered to the grid.

If the prosumer connected to the distribution grid wants to mount his own RES plants, he can do it at his expense or, in the case of the photovoltaic plants, he can submit the required documents for the AFM ("Program on the installation of panel systems photovoltaics for the production of electricity, in order to cover the consumption needs and the delivery of the surplus in the national grid" - issued by the Environmental Fund Administration) program funding.

The costs of purchasing, installing, sealing the electricity meters, including the meter related communication system are supported as follows for the legal entities:

- For the meter mounted at the delimitation point - by the distribution operator to the grid to which the installation is electric connected.
- For the meter that measures the electricity produced by the power plant - by the prosumer

And in the case of physic entities:

- For the other meters that measure the electricity required to determine the electricity that benefits from the price set by law, if the electrical scheme of the power plant contains a storage system of the electricity produced from RES, which can be powered by electricity from the electricity grid - by the prosumer.
- For the meter that measures the electricity produced by the power plant - by the Environmental Fund Administration - in the case of physical entities accessing the AFM Program, except for the costs of sealing it, which are borne by prosumer.
- For the meter that measures the electricity produced by the plant, in the case of physical entities who do not access the AFM Program - by the DSO the grid to which the power plant is connected.

In the case of physical entities who do not access the AFM Program, it is not necessary to install the meter for measuring the electricity produced from RES in the following situations:

- The electrical diagram of the power plant does not contain a system of electricity storage.
- The electrical diagram of the power plant which contains electricity storage system produced from RES that cannot be supplied with energy power from the electrical grid.

The following sections present the simplified steps of the user for becoming a prosumer, considering both the new users' case and existing users' case.

3.2.1.1 For new users:

- The first step of documentation and information. The user can request through an application to the grid operator information on the conditions and possibilities of connecting to the grid a consummation

and/or production unit by presenting its characteristic data. After that, the grid operator must transmit general information.
- Submission of the connection request and the related documentation for obtaining the technical connection notice.
- The grid operator establishes the connection solution to the electrical grid and issues the technical connection notice, as a connection offer.
- Conclusion of the connection contract between the grid operator and the user.
- The grid operator performs, under the conditions and within the deadlines provided in the connection contract, the connection activities to the electrical grid and the commissioning of the connection installation:
    - The design of the connection installation.
    - Obtaining the building legal authorization for the connection installation.
    - Construction and commissioning of the connection installation.
    - Performing the necessary reinforcement works in the installations upstream of the connection point, if needed.
    - Installation tests, if needed.
    - Verification of the fulfilment of the requirements stipulated in the secondary legislation regarding the status of prosumer.
- Issuing by the grid operator the certificate of connection of the consumption and production place, with the mention that the consumer character is certified.
- Putting the final installation under voltage use.
- The electricity supplier requests the prosumer (certified) electrical energy trading.
- The electricity supplier sends the sale-purchase contract, issued according to the legal form of the contract, signed within 10 days from the request.
- The final signature on the sale-purchase contract between the prosumer and the electricity supplier (the prosumer has the obligation to return to the supplier the sale-purchase contract signed, within 10 days from receiving it or to communicate, in writing, within the same term, the causes for which he does not sign/return the contract.

3.2.1.2 For existing users

In the case of existing users, owners of installations for the electricity production, including in cogeneration, with electricity installed power under 27 kW per consumption place connected to the grid:
- Submission of the request and the related documentation for updating the technical connection notice/connection certificate, if needed, including for certifying the prosumer character, to the DSO of the grid to which the place of consumption and/or production is connected.
- The distribution operator verifies the fulfilment of the requirements stipulated in the secondary legislation regarding the prosumer status.
- Issuing by the distribution operator the certificate of connection of the place of consumption and/or production, with the mention that the prosumer character is certified.
- Request to the electricity supplier with which the prosumer has concluded the contract for the electricity supply, for the sale of electricity produced as a certified prosumer.
- The transmission by the electricity supplier of the sale-purchase contract.
- The final signature on the sale-purchase contract between the prosumer and the electricity supplier.

In the case of existing users, who are to connect electricity production facilities to the installation of use of the place of consumption, with evacuation in the network of the network operator of surplus electricity (in certain user operating modes):
- The preliminary stage of documentation and information. The user can request through a request to the network operator information on the conditions and possibilities of making a network connection

of a place of consumption and/or production, presenting the characteristic data of the network is obliged to transmit the general information.

- Submission of the request and the related documentation for updating the connection technical notice or updating the connection certificate, as the case may be, including for certifying the quality of a prosumer, to The distribution operator of the network to which the consumer and the electricity production facilities are connected.
- The grid operator performs the connection activities to the electrical grid, according to connection contract conditions and terms:
    - Design of the connection installation, if applicable.
    - Obtaining the mounting authorization for the connection installation, if applicable.
    - Construction and commissioning of the connection installation, if applicable.
    - performing the necessary reinforcement works in the installations upstream of the connection point, if applicable.
    - Installation tests, if needed.
    - Verification of the fulfilment of the requirements stipulated in the secondary legislation regarding the status of prosumer.
- Issuing by the distribution operator the certificate of connection of the consumption and/or production place, as the case may be, with the mention that the quality of prosumer is certified.
- Request to the electricity supplier with which the prosumer has concluded the contract for the supply of electricity and commercialization of the electricity produced by certified prosumer.
- The transmission by the electricity supplier of the sale-purchase contract.
- Final signature on the sale-purchase contract between the prosumer and the electricity supplier.

3.2.2 Smart metering[iv]

The result of the cost-benefit analysis for smart meter roll-out in Romania, which was conducted in 2012 by AT Kearney, was positive. The net benefit of smart meter roll-out is around 260 million EUR. The national regulatory agency (ANRE) is currently working on updating the analysis. The price of the smart meter considered in AT Kearney's study is 96 EUR per meter (without installation). Although the cost-benefit analysis is positive, the smart meter roll-out in Romania did not start yet. The ANRE decision regarding the start of the roll-out is not publish yet. Meanwhile, the DSOs started their own pilot projects on installing smart meters. PLC and GPRS are the main communication technologies used in smart meters in Romania.

According to the Romanian Regulatory Agency (ANRE order No. 91/2013) on the implementation of smart metering systems, the following functionalities are required in the smart metering system:

- The client information relevant to the energy consumption should be available to the client and to any other third-party designated by the client.
- The information should be updated with a rate enabling the reduction of the energy consumption (however, this refresh rate is not specified).
- Support advanced tariff systems.
- Allow remote control of the supply.
- Remote meter reading.
- Two-way communication between the smart meter and meter data management system.
- Meter readings with high refresh rate to enable distribution network management and planning.
- Enable communication with other metering systems and Home Area Network (HAN) [Optional].
- Data storage of meter data to be large enough to solve potential supplier-client issues related to invoice/interruptions [Optional].
- The metering infrastructure should allow scaling-up without any charges in the existing set-up [Optional].
- Local access to metering data [Optional].

3.2.3 Adoption of European legislative framework – Renewable energy sources

In April 2009, the European Parliament approved Directive 2009/28 / EC on the promotion of use energy from renewable sources. According to Annex I of Directive 2009/28 / EC of the European Parliament and of the Council of April 23, 2009 on promoting the use of energy from renewable sources, by amending and subsequently repealing Directives 2001/77 / EC and 2003/30 / EC, the country objective for Romania is 24% and represents the share of energy from renewable energy sources in final consumption gross energy, to be achieved by 2020.
As of December 11, 2018, the European Parliament has adopted Directive 2018/2001 / EC on promoting the use of energy from renewable sources. Directive 2018/2001 / EC establishes for the year 2030 a mandatory objective regarding the share of energy from renewable energy sources in gross final energy consumption of the EU of 32%, collectively provided by the Member States with the possibility of being increased by the EC in 2023.

National legislative framework:
The transposition of the Directive 2009/28 / EC into the national legislation was made by the adoption of Law no. 220/2008 for establishing the system for promoting the production of E-SRE, which has set itself to make it more attractive the CV promotion system for investors introducing new facilities, including the granting of a higher number of green certificates, differentiated according to the type of E-SRE production technology.
The system for promoting the production of E-SRE established by Law no. 220/2008, republished with the amendments and the subsequent additions were authorized by the EC in July 2011 by Decision C (2011) 4938 regarding the state aid SA 33134 (20011 / N) for Romania - green certificates for promotion the production of electricity from renewable energy sources, modified in 2015 by the Decision C (2015) 2886 and in 2016 by Decision C (2016) 8865/2016.

By law no. 184/2018[v]:

- Starting with the analysis year 2018, ANRE establishes by order, by March 1 of each year, the mandatory annual percent for the purchase of green certificates for the previous year, based on final electricity consumption from the previous year, so the average impact to the final consumer will be maximum 11.7 EUR / MWh in 2018, 12.5 EUR / MWh in the year 2019, 13 EUR / MWh in 2020 and 2021 and 14.5 EUR / MWh starting in 2022.
- The economic operators provided in Law no 220/2008 at art. 8 paragraph (1) will buy from the market centralized anonymous spot green certificates, both annually and quarterly, a minimum percentage 50% of the number of green certificates related to the fulfilment of the compulsory annual percent of purchase of green certificates, except for the bilateral contracts concluded prior to the coming into force of the Ordinance Government Emergency no. 24/2017 and / or the number of green certificates transferred from the account producer in the one of the supplier for the situation when the economic operator has the obligation to purchase certified green and has the quality of both producer and supplier."
- Ensures the take-over of all the green certificates estimated to be issued on April 1, 2017-31 December 2031, including deferred green certificates from trading, provided that the final annual consumption of electricity does not fall below the average value recorded in the period 2017- 2022.
- By derogation from art. 23 of the Law on electricity and natural gas no. 123/2012, with subsequent amendments and additions, and from art. X of the Government Emergency Ordinance no. 24/2017 regarding the modification and completion of Law no. 220/2008 for establishing the system of promoting the production of energy from renewable energy sources and amending certain acts regulations, electricity producers and public authorities that own power plants from renewable energy sources benefiting from the green certificates promotion system or who have benefited from the promotion system and hold green certificates, with powers installed at most 3 MW per manufacturer, can only conclude contracts negotiated directly with the consumer suppliers final for the sale of electricity and / or green certificates.

- Prosumers holding units for the production of electricity from renewable sources with power installed at most 27 kW per place of consumption can sell the electricity produced and delivered to the grid electricity to the electricity suppliers with whom they have concluded supply contracts of electricity, according to ANRE regulations.
- The quantity of electricity for which the obligation to purchase green certificates is established includes electricity produced in Romania and sold by suppliers to some consumers / suppliers outside the territory of Romania, through bilateral electricity transactions, in the states with which the Government of Romania has signed bilateral agreements in this regard.

Conclusions of *Monitoring report on the functioning of the system of 2018 RES produced electricity promotion:*

- The RES energy promotion system was applied in 2018, in accordance with the Law no. 220/2008 for establishing the system for promoting the production of RES energy, republished, with subsequent modifications and completions, for all RES accredited electricity.
- The total production of electricity from RES was 26,939 in 2018 GWh (normalized value), of which 9 082 GWh were supported by the applied RES energy promotion scheme.
- Total electric capacity installed at the end of 2018 in the E-SRE production units accredited was 4 785 MW.
- The share of electricity from RES in the final consumption of electricity in 2018 it was 43.6%, with an achievement rate of 118% compared to the target level regarding the share of electricity produced from RES in the final consumption gross of electricity established by Law 220/2008 of 38% for the year 2020.
- The revenues received, reported by the RES energy producers from the Green Certificates sale for the year 2018, were of approx. 1834 million RON.
- The average impact of the green certificates in the final consumer electricity bill, for the year 2018 was 11 EUR / MWh (51.1 lei / MWh), under the one provided by Law no 220/2008 of maximum 11.7 EUR / MWh, respectively 5,.446 RON / MWh.
- The obligation to purchase the Green Certificates returned in 2018 to a number of 217 economic operators with obligation to purchase green certificates, among them a number of 19 economic operators did not fulfil the annual obligation, penalizing them for unpaid Green Certificates, was 325,775 RON / Green Certificate, respectively 70 EUR / Green Certificates, which represented a total of 4,915 million RON.

3.3 ENTSOE code - Relevant regulatory framework and codes for DER-connection in distribution networks

ENTSO-E is the official interface between the EU and transmission system operators. It was established and given legal mandates by the EU's Third Legislative Package for the Internal Energy Market in 2009, which aims at further liberalizing the gas and electricity markets in the EU. ENTSO-E gathers 41 members and one observer member across 35 countries. ENTSO-E members serve half a billion customers linking power generation to distribution systems and large industrial customers, and countries to countries. They facilitate one of the largest power markets in the world. They plan the development of transmission infrastructure that in most cases they own. By EU law, ENTSO-E is responsible for several building blocks of the energy union. To name a few, ENTSO-E is in charge of drafting new EU technical rules for the power system and market – the EU network codes. ENTSO-E is also issuing every two years a pan-European 10-year network development plan to support Europe's climate objectives. It also manages a European transparency platform making near to real-time grid data accessible to all market participants. ENTSO-E is also advising and making proposals on EU policies impacting the power system taking a European, system and customer view. ENTSO-E supports the energy transition and innovation in power networks.

The emergence of storage technologies is now challenging all actors in the electricity value chain to see how, when, and where storage could be used and how it could be managed. This is especially relevant as storage technology has features that fit within the remit of both regulated and market parties. As such, ENTSO-E agrees with the EC view[vi] that storage is neither generation nor demand. As an overarching principle, one of the main roles for TSOs and ENTSO-E is being neutral market facilitators. In the context of Energy Storage and Storage Services ENTSO-E Position (October 2016 paper), ENTSO-E assess the potential of storage – as one tool in the toolbox – in providing the necessary flexibility to the system.

Report from the Expert Group (EG) Identification of storage devices (EG STORAGE, 2018)[vii]. Evaluation of Requirements for Generators (RfG) for storage modules:

- The EG acknowledged the relevance with the tasks of GB Grid Code Electricity Storage Working Group (GC0096).
    - The GB experience can be used a good reference and guidance for the EG STORAGE.
- A template with RfG requirements has been created to assess better the different storage technologies.
    - The template was updated with the results of the GB group and is being further updated by the rest of the EG members.
- The EG discussed about classifying the different storage technologies into:
    - Synchronous Electricity Storage module – similar requirements to SPGMs.
    - Non-Synchronous Electricity Storage module – similar requirements to PPMs.
- If necessary, a separate category can be introduced for certain storage technologies e.g. flywheels or superconducting storage (SMES).
- Additional requirements coming from DCC or/and HVDC or storage specific requirements (e.g. switching) will be considered.
- Analysis of existing IEC and CENELEC standards is within the actions.

3.4 IEEE1547 - IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

The TS for, and testing of, the interconnection and interoperability between utility EPSs and DERs are the focus of this standard. It provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. It also includes general requirements, response to abnormal conditions, power quality, islanding, and test specifications and requirements for design, production, installation evaluation, commissioning, and periodic tests.

The stated requirements are universally needed for interconnection of DER, including synchronous machines, induction machines, or power inverters/converters and will be sufficient for most installations. The criteria and requirements are applicable to all DER technologies interconnected to EPSs at typical primary and/or secondary distribution voltages. Installation of DER on radial primary and secondary distribution systems is the main emphasis of this document, although installation of DERs on primary and secondary network distribution systems is considered. This standard is written considering that the DER is a 60 Hz source.
IEEE Standard, Publication date 2018.

3.5 Establishing Electrical Compatibility - Part 1 – General Considerations and Implementation of a Single DC Supply, Single Load Solution based on Printed Labels (ECAS Draft TS1)

European Citizen Action Service (ECAS)[viii] is an international, Brussels-based non-profit organisation with a pan-European membership and nearly 30 years of experience, who intends to empower citizens in order to create a more inclusive and stronger EU by:

- Promoting and defending citizens' rights.
- Developing and supporting mechanisms to increase citizens and citizen organisations' democratic participation in, and engagement with, the EU.

In "General Considerations and Implementation of a Single DC Supply, Single Load Solution based on Printed Labels" a system is proposed, whereby the electrical and physical parameters of an interface between an electricity supply and a load can be encoded into concise data packets describing the supply and the load, in such a way that a computer program can compare the data packets, and predict with confidence whether the supply and load can work effectively, safely and reliably together, and provide an easily-understood compatibility statement to a non-technical user.
Some theoretical work is required to determine the required contents of the data packet, initially for a single supply driving a single load. Later developments must include multiple loads, and eventually also multiple supplies.

A first application of this is proposed, in which the data packets are encapsulated in printed barcode labels, readable by the camera on a smartphone, and interpreted by a smartphone app to give the compatibility statement. This application does not require any modification to the hardware of the electricity supply system or the load. Subsequent developments are hypothecated, supporting real-time updating of available power and energy, embedding of the logic in hardware, and integration with other power-related digital signalling functions such as demand management, usage authorisation, etc.

The intention behind this document is to facilitate the development of off-grid electricity systems and appliances, and ultimately to ensure that when used by non-technical people, off-grid electricity has the same reliability, versatility and operational safety as on-grid electricity.
An electrical system consists of a combination of electricity supplies and electrical loads. In industrial applications, an electrical engineer takes the necessary steps at the system design stage to ensure that the specifications of the components of the system are compatible and that the result is a system that is safe and reliable, and that functions as intended.

In the domestic or small business environment, there is no skilled engineer to confirm suitability before a load is connected to a supply. In the past, this has been solved by portable electrical appliances being tested before sale against a standardised electricity supply, in order to gain type approval. The assumption is made that the user has access to an electricity supply that does not deviate significantly from the standardised supply, and that when connected, the load therefore operates correctly and safely.
In the off-grid world, no such standardised supply exists. However, it is clearly impossible to test every possible appliance with every possible variation of off-grid electricity supply, and a new solution is required.

Non-technical consumers purchase technical products on the basis of a sales promise. No-one wants the consumer to purchase a product that they cannot use – or that is unsafe in their particular installation. For a supplier also, handling returns is expensive, both in cost and reputation. As a standard-creating body for the electrical industry, we have a responsibility to create compatibility standards that avoid these outcomes.

3.6 CIGRE recommendations of good practices - Hybrid Systems for Off-Grid Power Supply (WG C6.28)

In order to meet targets of the Paris Agreement of decarbonisation while providing universal access to electricity calls for renewable energy solutions. It is a key strategic goal of CIGRE to provide electricity for all in a sustainable way. In its sustainability paper CIGRE states how the organizations contribute with power system expertise to reach the Paris Agreement.

This brochure shares experiences on techno-economic pre-feasibility studies, as well as on advanced stability studies for hybrid systems for off-grid power supply. It will further present operation experience from systems that have been successfully in operation for several years. This study shall encourage decision makers in distribution utilities and industry to consider a hybrid system with renewable energy and energy storage as reliable and affordable solution for their energy needs. It will show the main aspects to be considered and will guidance and best practices to financial institutions, management as well as for engineers who will design the off-grid hybrid systems.

3.7 Low Voltage Directive 2014/35/EU - Guidelines - Electrical equipment designed for use within certain voltage limits

These Low Voltage Directive Guidelines are intended to be a manual for all parties directly or indirectly affected by Directive 2014/35/EU, commonly referred to as the LVD, applicable from 20 April 2016, replacing the previous Directive 2006/95/EC.
These guidelines supersede the "Guidelines on the application of Directive 2006/95/EC" of August 2007 (last modification January 2012). The LVD Guidelines refer only to the application of Directive 2014/35/EU unless otherwise indicated.

Readers' attention is drawn to the fact that these Guidelines are intended only to facilitate the application of Directive 2014/35/EU and it is the text of the Directive and the national laws transposing the directive that are legally binding. However, this document does represent a reference for ensuring consistent and harmonised application of the Directive by all stakeholders.

They are intended not only for the use of Member States' competent authorities, but also by the main economic operators concerned, such as manufacturers, importers and distributors and their trade associations; bodies in charge of the preparation of standards as well as those involved in the conformity assessment procedures.
These guidelines are not exhaustive; they focus on certain issues only, which, in the light of the experience, are of direct and specific interest for the application of the "Low Voltage" Directive. These Guidelines should be used in conjunction with the Directive itself and with the EC's document "The Blue Guide on the implementation of EU product rules", which further explains concepts such as "placing on the market", "manufacturer", "authorised representative", "importer".

4 S4G consortium members' contribution to standardisation and regulation

In addition to follow-up of relevant standardisation activities previous described, with direct contribution or with potential of future recommendations based on the experience and lessons learned during the project activity, **UPB** has actively participated in several standardization bodies:

IEEE -SA[ix] . M. Albu has been a ballotter for P1547a: Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces Amendment to IEEE Std 1547-2018 to provide more flexibility for adoption of abnormal operating performance Category III (2019-2020).

For IEC, UPB has been designated representant of Romania (with voting rights) for work pursued in the following committees (with relevance for S4G):

IEC, **TC77/SC77A/WG9** EMC - Low Frequency Phenomena Subcommittee - Power Quality Measurement Methods. M. Albu has participated with voting rights to the WG meetings in San Francisco (April 2018), Wohlen (June 2019), Berlin (January 2020) with contribution to the new edition of the standard IEC 61000-4-30.

TC8/SC8B/JWG 1 - General Planning, Design, Operation and Control of Microgrids, UPB has kept the contact with the members of Task Force for TS 62898-3-1, in various web- or informal meetings (including during the international microgrids symposium series[x]).

TC38/WG 55 - Uncertainty evaluation in the calibration of Instrument Transformers. M. Albu has participated with voting rights (Romania) in the meetings in Houston, May 2018 (joint work of IEC TC38/WG55 & IEEE/TC39) and Frankfurt (November 2018), hosted by DKE German Commission for Electrical Electronic & Information Technologies of DIN and VDE. Moreover, it has been decided UPB will host the TC38 meeting in October 2020.

SyC LVDC/OF Open Forum 1 - Platform for open exchange of technologies, innovations, challenges in LVDC and **SyC LVDC/WG 1** - LVDC Standards for Electricity Access. UPB contributes starting with the meeting in January 2019 (Horgen, CH) to the TS on installations of LVDC, including Electricity Access with LVDC for Tier II and Tier III of ESMAP Multi-Tier Framework for household Electricity Supply. In January 2020 M. Albu (UPB) has been also designated as a member of the newly created IEC TC8/JWG 9 - LVDC distribution, to contribute to definitions of power quality indices in DC distribution systems (meeting organized by TU Delft in conjunction with, 2020 DC Summit).

IEC TC8/JWG12 Power frequency measurement for DER management: System aspects of electrical energy supply-Requirements for frequency measurement used to control DER and loads). UPB contributes to this work, and M. Albu has participated to the first meeting held in Paris (AFNOR offices) on 19th and 20th June 2019. The second meeting has been organised by UPB (2nd meeting, November 27th and 28th, 2019, Bucharest - Romania), to which several S4G members of the UPB team have been invited. M. Albu has voting rights (Romania). UPB team contributes to two working teams of this JWG.

UPB has been involved (remote work, 2019-2020) to the development of a TS: Microgrids Part 3-3: Technical requirements – Self-regulation of dispatchable loads (work within TC8: Systems Aspects for Electrical Energy Supply, Subcommittee SC8B: Decentralized Electrical Energy Systems).

In addition, UPB has contributed to the IEC/CEN-CENELEC mirroring standardization committees in Romania, ASRO (Romanian Standards Association), as follows:

CT140 (corresponding to CLC/TC57 & CEI/TC57, Power systems management and associated information exchange EMS-SCADA); CT167 (corresponding to IEC/PC118; IEC/SC8A; IEC/TC115; IEC/TC8; CLC/SR115; CLC/SR118; CLC/TC8X, System aspects of electrical energy supply); CT24 (corresponding to CLC/SR66 & CEI/TC66, Safety of measuring, control, and laboratory equipment).

Moreover, as activity in the national boundaries, UPB has been active in providing inputs for the legislation related to prosumer's connection to the main grid.

In the last year of S4G project timeline, Mr. Sanduleac from UPB has been accepted to be new member of ETIP-SNET WG1 (Reliable, economic and efficient smart grid system) and WG2 (Storage technologies and sector interfaces) and in this position he had various contributions which used the experience gained in S4G project. Especially, he promoted resilience for energy communities and new microgrid solutions based on energy routers and solid-state transformers, in line with the S4G project use-cases and with the studies published in Energies related to the project theoretical and practical outcomes.

UNINOVA participates on the Portuguese national technical commission for electrotechnical standardization activities through Mr. Vasco Delgado-Gomes specifically in the activities related with the IEC TC57 – "Power systems management and associated information exchange". This TC is working on the harmonization between the IEC 61850 and CIM standards:

- IEC 61850 – "Communication networks and systems for power utility automation".
- IEC 61970 – "Energy management system application program interface".
- IEC 61968 – "Application integration at electric utilities - System interfaces for distribution management".
- IEC 62325 – "Framework for energy market communications".

IEC 61850 is used on the S4G project to interact with the Energy Router (ER). The CIM and IEC 61850 are two important standards for the development and integration of high-level applications (such as SCADA and energy management systems) and substation automation. However, the considerable difference between their data models has become an obstacle for device and system interoperability between these standards. Consequently, IEC is working on CIM and IEC 61850 harmonisation in several Working Groups (WGs), namely:

- WG 10 - "Power system IED communication and associated data models".
- WG 13 - "Software interfaces for operation and planning of the electric grid".
- WG 14 - "Enterprise business function interfaces for utility operations".
- WG 15 - "Data and communication security".
- WG 16 - "Deregulated energy market communications".
- WG 17 - "Power system intelligent electronic device communication and associated data models for microgrids, distributed energy resources and distribution automation".
- WG 19 - "Interoperability within TC57 in the long term".
- WG 21 - "Interfaces and protocol profiles relevant to systems connected to the electrical grid".

Additionally, IEC 60870 – "Telecontrol equipment and systems" and TC57 WG 3 – "Telecontrol protocols" developments are also being monitored since the S4G project uses this standard for DSO SCADA data transfer.

5 Conclusions

Contribution to the standardization /regulatory activity is crucial in order to keep the S4G solutions in line with the best industrial efforts accepted worldwide, while also ensuring a good start for future applications of proposed innovative technologies. The project work is impacting existing standardisation activities and it is influenced by a large set of standards (especially IEC), with high volume of ongoing activity which shows the timely contribution of the S4G project to the efficient transfer of electricity using storage as an optimization asset.

As S4G solutions are considered to be part of the holistic energy solutions towards decarbonised economy, the S4G activity for standardisation focused on various aspects of these targets, with high potential impact for on-going and future standardisation activities. Relevant standardisation activities during the project period and having potential for future standardisation activities based on project experience have been presented mainly in chapter 3, while effective contribution of S4G consortium members highly related to the project use-cases have been presented in chapter 4.

Acronyms

Acronym	Explanation
AC	Alternating current (also referred as a.c.)
AFSEC	African Electrotechnical Standardization Commission
ANRE	Romanian Regulatory Authority for Energy (in Romanian: “Autoritatea Naţională de Reglementare în domeniul Energiei”)
ASM	Ancillary Service Market
ASRO	Romanian Standards Association (in Romanian: “Asociația de Standadizare din România”)
CEN	The European Committee for Standardization (from French “Comité Européen de Normalisation”)
CEN/TR	CEN Technical Report
CEN/TS	CEN Technical Specification
CENELEC	European Committee for Electrotechnical Standardization (from French “Comité Européen de Normalisation Électrotechnique”)
CIGRE	International Council on Large Electric Systems (from French “Conseil International des Grands Réseaux Électrique”)
CIM	Common Information Model
CIRED	International Conference on Electricity Distribution
CISPR	International Special Committee on Radio Interference
CLC	CENELEC (in document references)
COSEM	Companion Specification for Energy Metering
DC	Direct Current (also referred as d.c.)
DCC	Demand Connection Code
DER	Distributed Energy Resources
DLMS	Device Language Message Specification
DSO	Distribution System Operator
EC	European Commission
ECAS	European Citizen Action Service
ED	Edition
EES	Electrical Energy Storage
EESS	Electrical Energy Storage Systems
EG	Expert Group
EM	Electromagnetic

Acronym	Explanation
EMC	Electromagnetic Compatibility
EMS	Energy Management System
EN	In conjunction with standardisation: European Standard (or Norm)
ENTSOE	The European Network of Transmission System Operators
EPS	Electrical Power System
ER	Energy Router
ETIP-SNET	European Technology & Innovation Platform - Smart Networks for Energy Transition
ETSI	The European Telecommunications Standards Institute
EU	European Union
EV	Electric Vehicle
GPRS	General Packet Radio Service
HAN	Home Area Network
HLUC	High Level Use Case
ICE	Institutional, Commercial and Industrial
ICT	Information and Communications Technology
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
JWG	Joint Working Group
LPIT	Low Power Instrument Transformers
LV	Low Voltage
LVD	Low Voltage Directive
LVDC	Low Voltage Direct Current
LVRT	Low Voltage Ride-Through
MUSH	Municipal/Military, Utilities/Universities, Schools, Hospitals
MVDC	Medium Voltage Direct Current
NaS	Sodium-Sulphur
NiCd	Nickel–Cadmium
NiMH	Nickel–Metal Hydride
OPCOM	Romanian gas and electricity operator

Acronym	Explanation
PLC	Programmable Logic Controller
PMD	Power Metering and Monitoring Device
PPM	Power Park Module
PUC	Primary Use Case
PV	Photovoltaic
PVES	Photovoltaic Energy Systems
PVPS	Photovoltaic Power Systems
R&D	Research and Development
RE	Renewable Energy
RfG	Requirements for Generators
ROCOF	Rate of Change of Frequency
RVC	Rapid Voltage Change
S4G	Storage4Grid
SBESS	Stationary Battery Energy Storage Systems
SC	Subcommittee
SCADA	Supervisory Control and Data Acquisition
SME	Superconducting Magnetic Energy
SPGM	Synchronous Power Generating Module
SyC	Systems Committees
TC	Technical Committee
TR	Technical Report
TS	Technical Specification
TSO	Transmission System Operator
USM	Unbundled Smart Meter
WG	Working Group
WP	Work Package
ZEBRA	Sodium-Nickel Chloride

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