STARGRID

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D3.2 – STANDARDISATION DOCUMENT ANALYSIS

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V1.2	2014-05-16	Marco Portula (IWES)	Review, final version, submitted

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GLOSSARY

Acronym	Explanation
CEM	Customer Energy Management
CEN	Comité Européen de Normalisation
CENELEC	Comité Européen de Normalisation Électrotechnique
CIM	Common Information Model
COSEM	Companion Specification for Energy Metering
DER	Distributed Energy Resource
DG	Distributed Generators
DLMS	Device Language Message specification
DSO	Distribution System Operator
EC	European Commission
EMC	Electromagnetic Compatibility
EMS	Energy Management System
ENTSO-E	European Network of Transmission System Operators for Electricity
EPRI	Electric Power Research Institute
ETSI	European Telecommunications Standards Institute
FRT	Fault Ride Through

HV	High Voltage
ICT	Information and Communiction Technology
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
ITU	International Telecommunication Union
JWG	Joint Working Group
kW (unit)	Kilowatts
LV	Low Voltage
ms (unit)	Milliseconds
MV	Middle Voltage
NIST	National Institute of Standards and Technology
NRA	National Regulation Authority
n.e.	Not evaluated
OpenADR	Open Automated Demand Response
OSGP	Open Smart Grid Protocol
P	Active Power (symbol) [W]
PCC	Point of Common Coupling
PAP	Priority Action Plan
PV	Photovoltaic
Q	Reactive Power (symbol) [Var]
RfG	Requirements for Generators (ENTSO-E Code)
SCADA	Supervise Control and Data Acquisition
SGCG	Smart Grid Co-ordination Group
SGIP	Smart Grid Interoperability Panel
SMCG	Smart Meter Co-ordination Group
STATCOM	Static Synchronous Generator
Std.	Standard
SVC	Static VAR Compensator
TC	Technical Committee
TSO	Transmission System Operator
U	Voltage (symbol) [V]
VPP	Virtual Power Plant
VSG	Virtual Synchronous Generator

WAN	Wide Area Network
WG	Working Group
WP	Work Package
φ	Phase (symbol) [°]

1 EXECUTIVE SUMMARY

This STARGRID project deliverable contains the results of the analysis of standards and standardisation related documents performed in WP 3. It describes the methodology used for the selection of topics and actual documents, and summarises the main results. The analysis forms that have been filled by the partners for each document are included in an appendix.

2 INTRODUCTION

2.1 PURPOSE OF WORK

The purpose of this work is to identify standards and initiatives that enable or limit certain use cases or business models, restrict or create interoperability between different Smart Grid components, and to disclose standardisation gaps, overlaps between standards, etc. The results will be used to formulate recommendations towards policy makers, standardisation bodies and regulation authorities, as well as standards users, in WP 5.

The documents considered have been broadly classified into three categories (STARGRID areas of interest):

- DER integration and grid control
- Demand Response and customer energy management
- Smart Metering

Within each of these areas, topics of particular interest have been identified through a stakeholder survey. A set of stakeholder requirements and evaluation criteria had been identified in a previous deliverable (D3.1), and a ranking of the requirements has been performed in the survey. Based on these results, a template for the analysis has been developed (see Appendix A), in order to report the analysis results in a uniform and transparent way.

Furthermore, the familiarity with particular standardisation initiatives and their expected impact have been queried in the survey, which led to the identification of a list of standards and drafts potentially relevant for further analysis. These lists can be found in Table 2, Table 3 andTable 4.

For the actual analysis we concentrated on a few of these topics – the selection criteria are explained in the respective subchapter 3.1 Selection of documents.

2.2 CONTRIBUTIONS OF PARTNERS

Most of the analysis was done by ASRO. The task leader IWES and the other partners contributed in particular to the definition of the methodology, and partly the selection of standards. IWES was also involved in the analysis of Demand Response related documents. Technalia analysed Smart Meter related documents.

2.3 POINT OF DEPARTURE

Other projects involved in the analysis of standards and initiatives include in particular the standardisation coordination groups, like the Smart Grid Coordination Group (SGCG) of CEN-CENELEC-ETSI, IEC SG3, DKE Steering committee Smart Grid standardization, etc. STARGRID members are following the ongoing discussions in these groups, and tried to take them into account in the analysis. A concrete example of core relevance for this work is the gap analysis performed by the SGCG. Stakeholder remarks, expressed either in the STARGRID survey and workshops or in dedicated publications, constitute another important source of information.

Some topics that would have been relevant for an in-depth analysis have not been addressed in detail in this task, since they are under active discussion by the standardization committees, and we realized that STARGRID would probably not be able to add significant new insights to the discussion. An example is the discussion within IEC about communication standards for Demand Response, involving in particular TC 57 WG 21 and PC 118, sparked by the question whether the OpenADR 2.0B industry standard can be published as an IEC standard, despite being non-compatible with the IEC core Smart Grid standard series. In this case we tried to summarise the state of discussions, but did not delve deeply into the topic ourselves.

2.4 RELATIONS TO OTHER ACTIVITIES

This work is based on the identification of stakeholder requirements and evaluation criteria in STARGID deliverable D3.1 and the results of the stakeholder survey (WP3 & 4) performed in late 2013. A first selection of documents had already been performed in WP2, although the list has been updated in the meantime.

The results will be particularly relevant for the development of recommendations in WP5.

3 METHODOLOGY

The analysis procedure consists of several steps. First, the documents to be analysed have to be selected, based on their relevance for certain use cases and their expected impact on different stakeholder groups. Then the analysis is performed, treating each standard separately in the beginning, and finally comparing the outcomes and drawing conclusions. These steps are explained in more detail in the following two sections.

3.1 SELECTION OF DOCUMENTS

3.1.1 DOCUMENT TYPES

Besides **standards** issued by the classical standardisation bodies (e.g. ISO, IEC, ITU, CEN, CENELEC, ETSI, national standardisation bodies), several other Smart Grid related ‘standard-like’ documents have been considered for the analysis. This includes technical regulatory provisions like **grid codes**, and **industry standards** developed by industry consortia. All these documents are collectively referred to as *standards* in this document.

3.1.2 SURVEY RANKINGS

The first aim was to identify the relevant documents. A preliminary selection was performed by the consortium for the stakeholder survey. For each of the three areas of interest, the survey contained questions on the following items:

- Stakeholder requirements
- Gaps and required actions (agreement with a predefined set of required actions and their perceived relevance - the two seem to be strongly correlated)
- Standards (awareness and perceived relevance of a set of standards/standardisation projects related to the given area of interest, selected by the consortium)

By averaging the overall answers, a ranking has been obtained in each of the three categories (focusing on the relevance of standards, not the awareness, although these are correlated as well).

We selected the *Gaps and required actions* category as the primary ranking criterion, and grouped them in a few so called *subjects,* separately for each area of interest. Standards and standardisation projects were then associated to the subjects, and ranked according to the perceived relevance. Furthermore, requirements were associated to the subjects as well. A template has been prepared to support and document this process (3.2.2 Comparison of Standards).

The analysis will proceed along the subjects: for each subject to be investigated the associated (highest-ranked) standards are analysed with respect to fulfilment of the (highest-ranked) associated requirements.

3.1.3 ADDITIONAL CONSIDERATIONS

Beyond the systematic selection procedure for documents to be analysed, as described above, a few additional aspects have to be taken into account.

1. **Use of existing results and avoidance of overlapping work**. Many other groups are investigating aspects of the Smart Grid standardisation landscape, and where results are already available, they shall be taken into account. If it appears unlikely that STARGRID will be able to add significant new

insights beyond existing arguments, the analysis of the respective topic shall be waived, and instead a short overview of the state of discussion shall be given in this report. An example is the first gap of the DR topic (5.1 Communication between grid operators or service providers and the end customer).

2. **System perspective**. The general societal and economic requirements to operate the electricity grids as effectively and securely as possible may not always be in line with the requirements of individual stakeholder groups. This is particularly relevant if the interests of different stakeholder groups are in conflict with each other.
3. **Dynamic business models**. If a certain requirement or standardisation gap is considered irrelevant by many stakeholders today, this may be due to the fact that currently feasible business model are not dependent on it, although for instance a solution to the gap could enable new opportunities. Future changes in a regulatory framework may also alter the perceived relevance of the requirements and gaps significantly.

These items have to be evaluated by the analysis team on a case by case basis, and their application will be explained wherever relevant.

3.2 DOCUMENT ANALYSIS

For each subject that has been selected, the analysis proceeds in two steps. First, the selected documents are analysed separately with regards to fulfilment of the requirements. Then a comparison between the standards is done.

3.2.1 REQUIREMENTS EVALUATION PER STANDARD

In the standards selection step (3.1.2 Survey Rankings, 3.1.3 Additional Considerations), for each subject a set of essential requirements had been identified, which are now evaluated for each standard separately. The results are reported in a so-called *Document Analysis Form* (Annex)*.* The template for these forms is shown in 3.2.2 Comparison of Standards, and the completed forms per standard are attached in an Appendix A to this report.

The analysis team is asked to provide the following information per requirement and document:

- Document-internal reference, i.e. which parts of the standard do address/are relevant to the requirement
- Gaps or contradictions related to the requirement, if any
- Fulfilment evaluation

Furthermore, there is an optional field for further notes and recommendations. Although it is not the aim to extract recommendations already at this stage of the analysis, in some cases recommendations specific to certain requirements may come up.

The *Document Analysis Form* also contains a sheet *Analysis Summary,* which has a free text field for further observations not assignable to any of the specific requirements, and asks for a brief analysis summary.

3.2.2 COMPARISON OF STANDARDS

The standard-specific analysis is followed by an overall evaluation of the applicability of the standards for the given use case/gap/etc. The written summaries, comparing the fulfilment of requirements of the selected set of standards, constitute the main part of this deliverable. They are provided in Sections 4 to 6.

Subject	Subject: questionnaire reference (row, gaps)	Questionnaire gaps ranking		Standards to be analysed	Avg. questionnaire relevance (N.e. = Not evaluated)	Maintained by	Requirements	Questionnaire reference (requirements)	Questionnaire requirements ranking
		Avg. Agreement	Avg. relevance						
Subject identifier	(row no.)			Standard 1	(Avg. score)	IEC TC X	Requirement 1	(row no)	(Average score)
							Requirement 2		
				Standard 2		n.a.	Requirement 3		
				Standard 3		n.a.	Requirement 4		

Table 1: Template for STARGRID analysis subjects

4 DER INTEGRATION AND GRID CONTROL

The gaps and required actions have been grouped into 6 Subjects:

- Std gap: Electrical connections and operation rules of DERs should be harmonized within Europe. (SGCG: Gap 12 – Gen 5 Standard for electrical connections and installation rules to ensure energy availability and security, in presence of high ratio of DER)
- Std gap: Communication protocols as well as information data models for control center <-> DER communication have to be harmonized (SGCG: Gap 8 – Gen 1 Harmonized glossary, semantic & modelling between back-office applications (CIM)) and field applications (IEC 61850))
- Std gap: Smart Grids request increased automation levels of the distribution grid, to ensure higher efficiency of operation, security, control and quality. Faults detectors will enhance operation and reduce shutdown times. (SGCG: Gap 16 – Dis 1 Feeder and Advanced Distribution automation Dis 7 Standards for Medium Voltage (MV) lines ("feeder automation")
- Std gap: New EMC requirements will arise from the development of the grid, requiring reviewing of the Standards. (SGCG: Gap 7 – EMC 3 Consider distorting current emissions from DER equipment)
- Std gap: A single communication protocol for the remote control of DERs should be imposed in interconnection rules, to ensure interoperability (SGCG Gap 26 – Other1 Smart Grid communication standards with CIM and IEC 61850

The associated standards and requirements are listed in Table 2. The analysis of the team concentrates on the first subject and the defined standards. Finally, some National codes regarding the voltage and frequency control of DER are briefly described here in order to provide the practices in national level.

4.1 EUROPEAN HARMONIZATION OF ELECTRICAL CONNECTIONS AND OPERATION RULES OF DERS

This gap reflects also a requirement for harmonised and stable technical interconnection rules at national and European level. The provision of use cases addressing the operation of the grid in high penetration of DER and the requirements and product standards for the protective devices specifically for these cases are also covered within this gap [SG-CG Report 12 Programme of standardisation work for the Smart Grid 13v 2014]

The integration of Distributed Energy Resources (DER) into the distribution grids is based on varying national rules and requirements of the grid operators, with a common basis given by the CENELEC standards EN 50438 and 50549. At international level, the IEC project PT 62786 is dealing with these questions. The ENTSO-E Generator Code will provide another set of joint European requirements, although it does leave room for individual provisions by the responsible grid operator as well. The aim of these requirements is to control the impact of DERs on grid stability, in particular on the voltage in distribution grids, and also on frequency.

Specifically the aforementioned standards which has been analysed according to the STARGRID analysis subject sheet (Appendix A), are:

1) EN 50438:2013, *Requirements for micro-generating plants to be connected in parallel with public low-voltage distribution networks;* (prepared by CLC TC 8X; M/490)

This European Standard specifies technical requirements for connection and operation of fixed installed micro-generators and their protection devices, irrespective of the micro-generators primary source of energy, in parallel with public low-voltage distribution networks, where micro-generation refers to equipment rated up to

and including 16 A per phase, single or multi phase 230/400 V or multi phase 230 V (phase-to-phase voltage). This European Standard is intended for installation mainly in the domestic market.

- Analysis summary regarding EN 50438:2013: Concerning 4.2.4 in this standard, the recommendations related to response time should be based on the frequency range derived in conformity with country regulations. Loss of mains detection should include detailed specifications on the ROCOF (rate of change of frequency) and Vector Shift measurement set-up and reporting rates. The power-frequency control (response to over and under-frequency) should include other than droop control methods (for example VSG approach). As consequence, we propose an amendment for EN 50438:2013**.**

2) TS 50549-1: Requirements for generating plants larger than 16 A per phase to be connected in parallel with a low-voltage distribution network. TS 50549-2: Requirements for generating plants to be connected in parallel with a medium-voltage distribution network.

Both TS 50549 parts relate both future European Network Codes and current technical market needs. Their purpose is to give detailed description of the functions to be implemented in products and methods to verify the compliance of the products. These Technical Specifications are also intended to serve as a technical reference for the definition of national requirements where European Network Codes requirements allow flexible implementation e.g. settings for power response to over-frequency.

CLC/ TC 8X plans future standardisation work in order to ensure compatibility of the TS 50549 parts with the evolution of the legal framework.

3) pr IEC/TS 62749 Ed.1: *Assessment of power quality – Characteristics of electricity supplied by public networks*, IEC/TC 8, DRAFT;

- Analysis summary regarding prIEC/TS 62749: Continuous phenomena analyzed in the frame of this standard should include also analysis and quality indices for rate of change of frequency (ROCOF). Appropriate changes should be included in IEC 61000-4-30 and associated standards (i.e. to be added ROCOF quantity definition and required measurement quality). All technical requirements should be clearly specified; also, the quality of document shall be improved.

4) prIEC 62786 “*Smart Grid User Interface: Demand Side Energy Sources Interconnection with the Grid*”, IEC/TC 8, DRAFT. This standard provides the principles and technical requirements for the demand side energy resources interconnected to the distribution network. It applies to the planning, construction, operation and reinforcement of demand side energy resources interconnected to the distribution network. The standard specifies the interface requirements for connection with the distribution network operating at frequency of 50 Hz or 60 Hz and applies to connection with both medium voltage (MV) and low voltage (LV) distribution network.

It includes general requirements, power quality, power control, dynamic network support, frequency and voltage responses, maximum short circuit current, grid connection and synchronization, safety and protection, metering, monitoring and communication, and testing.

The above standards are a work of the CLC/ TC 8. The main scope of this committee 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. Electricity supply system encompasses transmission and distribution networks and connected user installations (generators and loads) with their network interfaces.

TC64 AND TC 8X would focus their efforts on the specific gap and the adaptation of installation rules to allow news ways of operations. Specifically. TC64 would develop new requirements and adapt existing installation rules within the HD 60364 to cover DER needs

Moreover, an ad'hoc group is formed within IEC TC 95 to address SG specific protection functions whereas a Cenelec TC95X technical committee is formed to support this initiative in Europe

- Analysis summary regarding prIEC 62786: In the scope and objectives of prIEC62786 (clause 1), neither DR nor Demand side energy resources are adequately defined. The list of potential loads (motors, converters) is not in line with typical loads existing nowadays on customer premises and compatible with existing /future smart grids. The definitions of terms (clause 3) should be identical to or slightly modified compared to those given in the existing international electrotechnical vocabularies (IEV 60050 series) and related documents, and such reference documents shall be cited in the text. The definitions related to the harmonic/interharmonic components and flicker shall be adapted accordingly. In this document the reference quantity is the system [rated] frequency. As a consequence, the fundamental harmonic and the components are defined in relation to a fixed value of the frequency, namely 50 Hz, and this is not a typical situation for smart grid. The operation in steady state of power system is performed in reality at frequencies less or equal to nominal frequency and significant frequency variations impose an appropriate control. The voltage fluctuations and flicker should be also correlated with EN 61000-4-15 (i.e. IEC 61000-4-15) and EN 50160. The new conditions for interconnecting DER using static converters shall be taken into account in this draft. The requirements concerning Loss of Mains detection and protection systems, e.g. systems based on existing techniques such as Rate of Change of Frequency (ROCOF) to each point of common coupling (PCC) should be also correlated with EN 50438. The requirements related to low voltage ride-through capability of DER (see figure 1 in standard) should include an appropriate reference for timing which depends on grid characteristics, having in view each type of grid. Referring to clause 4.8.2.4, the suitable microgrid operation requirements have to provide widespread introduction of microgrids within smart grids. All technical requirements should be specified for each kind of energy generating plant and the PCC. This has to be clear in the whole document.

5) EN 61869-1:2007 (IEC 61869-1:2007 modified) - Current and Voltage sensors or detectors, to be used for fault passage indication purposes - Part 1: General principles and requirements. EN 61869 series is suitable to the component layer.

- Analysis summary regarding EN 61869-1: The standard EN 61869-1 contains the general requirements for instrument transformers and shall be read in conjunction with the relevant specific standards for the instrument transformer concerned.
  EMC requirements regarding the temperature conditions should be extended for RIV (radio interference) test (concerning the clause 7.2.5).
  Other recommendations concern to the annexes A and B:
  Annex A – The class, power in the secondary winding and also the life cycle should be specified; Annex B-B.4: having in view the installation and maintenance of the instrument transformers, the installation provisions provided by the manufacturer should be added, that shall include more information regarding the equipment connected in the secondary circuit, including description of the secondary winding arrangement;
  some methods of calculation referring to the measurement limit in the measurement chain should be given as example.
  As consequence, we sustain the proposal of the amendment to existing EN 61869-1.

6) EN 61869-3:2011 (identical to IEC 61869-5:2011) “Instrument transformers - Part 5: Additional requirements for capacitor voltage transformers”; prepared by IEC/TC 38; Directives: LVD (2006/95/EC), EMC related (2004/108/EC)

- Conclusion regarding EN 61869-3: To be confirmed.

7) EN 61869-5:2011 (identical to IEC 61869-5:2011) “Instrument transformers - Part 5: Additional requirements for capacitor voltage transformers”

- Analysis summary regarding EN 61869-5: Two proposals concerning the clause 5.4 should be taken into account:
  a) the use of the capacitor voltage transformers only together with frequency monitoring devices (with an aggregation time less or equal to 10 s);
  b) the equation for depreciation of the accuracy class depending on frequency variability in PCC of the capacitor voltage transformers.
  As consequence, we propose an amendment to EN 61869-5:2011.
- Recommendations and standardization gaps regarding EN 61869 series, EN 61000 series and EN 50160:
  New standardization gaps - As a result of analysis IEC 61869 series, two new gaps are outlined:
  GAP 1: a recommendation concerning the assessment of measurement quality (the total measurement uncertainty, frequency range) for measurement chain shall be included in the IEC 61869 series, EN 50160 and IEC 61000 series:
  a) Current / Voltage Instrument Transformers and the measurement devices used for the control wirings and monitoring of EMC;
  b) Instrument Transformers (current and voltage transformers) and measurement equipment (meter type).

  GAP 2: a recommendation concerning the minimum number of measurement windings, which depends on the nominal voltage level and destination: for example, for 20 kV the minimum number of windings for the current instrument transformer should be 3 - one for the main meter, and the other ones are for the witness meter and monitoring wiring respectively; for 400 kV the minimum number of windings is 5 and their arrangement for measurement wirings with allocated functions for electromagnetic compatibility - EMC, power quality, control and metering for billing. The class and the power in secondary winding as well as the life cycle should be specified.
  Recommendation concerning Power Quality **-** It may be helpful to prepare a new standard suitable to the correlation between the acceptability curves and the power quality level.
  The voltage characteristics given in EN 50160 are not intended to be used as electromagnetic compatibility (EMC) levels or user emission limits for conducted disturbances in public electricity networks. Measurement methods to be applied in this standard are described in EN 61000-4-30 (see pr IEC 61000-4-30, prepared by IEC TC 77).

4.1.1 REGIONAL STANDARDS

Distributed Energy Resourses (DER) are already required to provide ancillary services according to current standards, national grid codes and regulations. Most of the DER are equipped with suitable static converter systems which are the object of adequate control allowing grid services provision. There is a trend towards the use of more integrated power electronics technology and the development of modular universal interconnection technology – understood as a complex system connecting the energy source with the supply network. This idea would define a standard architecture for functions to be included in the interconnection system [26]. These functions, configured within the national or international standardization frameworks, could include power conversion, power conditioning and quality, protection functions, DER (both generation and storage) and load controls, ancillary services, communications, and metering. One of these functions is the voltage control.

The contribution of DG units to voltage control is already required in some countries and is being tested in others. The best generation technologies for voltage control are those that are able to absorb and deliver reactive power. These include wind turbines, small hydro and power electronics based DG. Inverters were originally designed for feeding in active power but today there is a need to support the grid voltage and

frequency. For example DERs would react to voltage changes/disturbances or faults by altering real or reactive power based on pre-defined and dynamically configurable set-points [8].

For these reasons, the regulatory framework in several countries already require the provision of new system services at distribution level, as a means of contributing to local grid stability and security of supply – a requirement of the new Energy Efficiency Directive (Art 15.1 of 2012/27/EC). Such system services are being defined in several national grid codes (voltage and reactive power contribution) and/or procured as ancillary services from DER within a transparent and non-discriminatory regulatory framework. While the role of EU-wide network codes is limited in this respect, 29 national grid codes and market arrangements backed up by European standardisation (in particular within the mandate M490 for smart grids) have already started setting up inter alia appropriate connection requirements for these network users.

National regulatory authorities (NRA) have the duty of setting or approving standards and requirements for quality of supply or contributing thereto together with other competent authorities (Article 37(1h) of Directive 2009/72/EC).

Active DSOs should be allowed to coordinate the offering of new system services, as required by the new Energy Efficiency Directive (Art 15.1 of 2012/27/EC) while ensuring the security, integrity and quality of supply in their networks.

For these purposes, a DSO should be able to sectionalise its networks, to actively interact with DGs to request supply voltage control and reactive dispatch or to exploit active demand services over the distribution network to solve operational problems. Clear interface conditions and an agreed operational framework at the interface between TSO and DSO are also necessary (including parameters for TSO-DSO interface nodes [8].

Nevertheless, voltage control is a function that has not been adopted in most of the national standards. In the USA, a new standard IEEE P1547.8 is in preparation that will provide more flexibility for interconnecting distributed resources with electric power systems through advanced functionality such as implementation of voltage regulation at the distribution level. Furthermore, utilities are testing different approaches for improved integration of PV.

NATIONAL STANDARDS FOR VOLTAGE CONTROL IN STATIC CONDITIONS

Reactive power injection or consumption is used under normal conditions to ensure the stability of voltage. Slow changes in bus voltage can be kept within acceptable limits through feed in of Q from the DER. As reactive power cannot be transported over long distances and as many regions with high DG penetration (thus voltage control challenges) have no conventional sources of reactive power, managing voltage on a local or sub-regional basis could be the most economically viable solution for the entire electricity system [8].

NATIONAL CODES FOR PV UNITS IN STEADY STATE

At the national level, the DG units are participating in the static grid support. These requirements are defined in the German, Spanish and British codes [9], [10], [11], [12], [13]. According to these regulations the PV should inject reactive power in less than one minute. Specifically, in the Spanish Decree it is proposed that this function operates when the voltage in the PCC is between $0.925 \leq V \leq 1.075$. The DG should be able to produce or consume Q to ensure that the voltage stays within the permissible range.

In Germany for MV grids, according to [9], with active power output, it must be possible to operate the generating plant in any operating point with at least a reactive power output corresponding to an active factor at the network connection point of cos φ = 0.95 underexcited to 0.95 overexcited.

With active power output, either a fixed target value for reactive power provision or a target value variably adjustable by remote control (or other control technologies) will be specified by the network operator in the transfer station. The setting value is either:

a. a fixed active factor cos φ or
b. an active factor cos φ (P) or
c. a fixed reactive power in MVar or
d. a reactive power/voltage characteristic Q(U).

The reactive power of the generating plant must be adjustable. It must be possible to pass through the agreed reactive power range within a few minutes and as often as required. If a characteristic is specified by the network operator, any reactive power value resulting from the characteristic must automatically adapt.

For LV grids according to VDE-AR-N 4105:2011-08 [10] , it must be possible to operate the generating plant in any operating point with at least a reactive power output corresponding to an active factor at the network connection point of cos φ = 0.95 (Smax<13.8 kVA) or 0.9 (Smax> =13.8 kVA) .

For PV systems with Smax>3.68 kVA, the reactive power method is set by the DSO.

The units with Smax<3.68 kVA have to behave according to EN50438 specifications (no reactive power feed-in required), but the operation aboveat cos φ >=0.95 has to be ensured.

In the USA, the IEEE has started a companion standard to IEEE 1547, called IEEE P1547.8 (Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies for Expanded Use of IEEE Standard 1547. IEEE P1547.8 will provide more flexibility in determining the design and processes used in expanding the implementation strategies used for inter-connecting distributed resources with electric power systems through advanced functionality such as implementation of LV ride through and voltage regulation at the distribution level.

Nevertheless, more national codes adopt international standardization practices, [14], [15], [16], [17], where the PF can reach 0.85 lagging.

This is also the case in Japan [18], when the voltage at inter-connection point of PV system exceeds the upper limit the PV system is required to control reactive power output or to reduce active power output. A typical control procedure is as follows: PV systems provide reactive power to reduce the voltage rise with keeping the power factor more than 0.85. If the reactive power control is not enough to regulate the voltage, PV systems reduce active power output with maintaining the power factor 0.85. Power factor of PV systems must be more than 0.85 lagging, and leading power factor is prohibited to prevent the voltage rise.

More information for the regulatory framework regarding the PV can be found in the National reports provided by IEA- PVPS [19].

NATIONAL CODES FOR WIND FARMS IN STEADY STATE

Fixed-speed induction generators, like wind turbines, cannot regulate the consumption or injection of Q as the operating point of the machine changes based on the machine torque. Therefore, specific technology should be applied, like SVC, or STATCOM must be installed in wind farms. Under these conditions the requirements on the reactive power control and/or voltage regulations can be met under various operating conditions. The regulatory framework for the wind power plants as regards their voltage control capabilities differs again from country to country. Some examples of some special requirements are shown below:

- The relevant Grid Code in **Australia** defines that wind farms should be able to operate at their rated powers with a PF ranging from 0.93 capacitive to 0.93 inductive, based on the command signal received from the system operator.
- In **Canada**, the reactive power requirements are defined under continuous and dynamic operating conditions. Wind farms should be able to continuously work with a PF ranging from 0.9 capacitive to 0.95 inductive, whereas the minimum range for dynamic conditions varies from 0.95 capacitive to 0.985 inductive. Wind farms are also required to have a voltage regulation system that reacts under the voltage set point control mode.
- In **Spain** the reactive power support is defined by the Spanish Grid code.
- In **Ireland**, the current operational policy, incorporated into reinforcement planning, defines that all DG should operate at a constant power factor of 0.95 lagging unless otherwise specified

NATIONAL CODES FOR PV UNITS DYNAMIC VOLTAGE CONTROL CONDITIONS

FRT capability for PV-DG generally varies from one country to another. Nevertheless, most new grid codes [9], [10], [12], [13] and [23] adapted to PV, have similar requirements [28]. For voltage disturbances within the limits PV should continue to stay connected. Outside these borderlines PV can disconnect. After the clearance of the fault, the time necessary to recover nominal values depends on the percentage of PV penetration related to the short-circuit power. New settings also tend to cover unsymmetrical faults, i.e. single and two-fault ride-through capability.

In symmetrical faults the absorption of a large amount of the reactive power may introduce instability in the feeder, especially for high PV penetration. Therefore, according to the new codes the voltage control in the PV inverter must be capable of manage a reactive current of at least 1.8–2% of the rated current for each percentage of the voltage dip/rise within 20–40 ms [28].

Spanish Grid code appears to be more demanding. Here PV units must stay connected during voltage dips down to 0% for up to 625. However, it should be underlined that these requirements apply to the point of connection in the high voltage (HV). It should be noted that the Spanish system is characterized as a weakly interconnected one (in comparison for example with German system). Thus active power restoration to normal values is crucial to maintain the system security and stability. Additionally, the Spanish grid is more vulnerable than the grids of other countries because it has a relatively high PV penetration.

In **Germany** since April 2011 all PV systems connected to the medium voltage network have to be certified to provide these functions defined in the latest grid codes [20]. Medium Voltage Directive, 2009 [9] and its updates in 2011 [21], with several transitional arrangements is applicable to units greater than 100 kW connected to the medium voltage grid and addresses the FRT behaviour. According to the latter during voltage drops in the transmission network, generating units must be able to contribute reactive power.

According to [10] and [22], generating units must not disconnect from the network in the event of voltage drops to 0 % Uc of a duration of ≤ 150 ms.

Voltage drops with values above the borderline 1 must not lead to instability or to the disconnection of the generating plant from the network [9]. If the voltage drops at values above the borderline 2 and below the borderline 1, generating units shall pass through the fault without disconnecting from the network.

A further requirement for generators during the voltage dip is the injection of a reactive current. Depending on the magnitude of the voltage dip and the k-factor characteristic [22], an additional reactive current has to be injected by the DER unit, and this must be at least its rated current. In the calculation of the reactive current set point, reactive power injection and voltage deviations before the fault have to be taken into account.

NATIONAL CODES FOR WIND DYNAMIC VOLTAGE CONTROL PROVISION

Fault-Ride-Through-Capability (FRTC) is one of the most demanding requirements for wind turbine manufacturers due to the heavy conditions that the wind turbine must withstand in case of voltage dips in the grid. Moreover, the larger the wind turbine is the bigger its influence on the transient stability of the grid in case of faults.

In high wind penetration countries or weakly interconnected systems the grid codes define the reactive power regulation of wind farms in overcoming transient conditions. These strict regulations are set to secure the system stability following various types of disturbances, among all the reactive power regulation from wind farms is configured for voltage stability issues.

Grid codes of Germany, Denmark, Ireland, Spain, UK and Australia require that during faulty condition the wind farm should provide reactive power. These regulations of wind farms equal to 4% of their maximum continuous current for each 1% reduction in the PCC voltage, when the voltage drops to less than 90% of its rated value. This means that wind farms are supporting voltage when this is reduced more than 25% by generation reactive current.

Danish and German Grid Codes have defined similar requirement, but they demand for 2% of the reactive current injection.

In Spain, wind farms must also be fitted with a voltage control loop that generates reactive current during 3 phased faulty conditions.

British and Irish codes require that the wind farm should inject their maximum Q current within the safety limits of the farms [20].

In Portugal [24], a new Grid Code had to be developed, to ensure that wind generators to be connected to the grid will behave as much as possible as conventional power plants: they must stay connected to the grid during voltage dips (fault ride through capability), they must contribute with reactive current during short-circuits to minimize the propagation of voltage dips and contribute to the correct operation of protection systems and with different amounts of reactive power according to the day period.

DEFINITION OF FUNCTIONS FOR VOLTAGE CONTROL IN THE USA

In the USA, EPRI initiative [27] has engaged a large number of individuals representing inverter manufacturers, system integrators, utilities, universities, and research organizations. The resulting work products have provided valuable input to a number of standards organizations and activities, including the National Institute of Standards and Technology (NIST) and the International Electrotechnical Commission (IEC). EPRI worked

together with the Department of Energy, Sandia National Laboratories, and the Solar Electric Power Association to form a collaborative team to facilitate this initiative.

4.2 HARMONIZATION OF COMMUNICATION PROTOCOLS AND INFORMATION DATA MODELS FOR CONTROL CENTER <-> DER COMMUNICATION

The introduction of serial communication some years ago resulted in the use of protocols for the communication of control and protection electronic devices installed in substations. In this respect, some standards have been issued within IEC technical committees, especially the IEC TC 57 *"Power systems management and associated information exchange":* for example, the IEC 60870 specifications, which are suitable to the communication between substation and remote control centre (e.g. IEC 60870-5 family, profiles 101 and 104 to connect to the Plant) and also the communication protocols with protection equipment (e.g. IEC 60870-5, profile 103 to connect to protection relays). In particular, STARGRID team concentrates on the following standard series, due to their complimentary mission and objectives:

- IEC 60870-5 series for the transmission protocols and also the IEC 60870-6 series intended to design Inter Control Center Protocols, since the other parts not seem to play a relevant role in future smart grids;
- IEC 61850 series: Communication networks and systems in substations;
- IEC 61970 series: Energy management system application program interface (EMS-API) - Common Information Model (CIM);
- IEC 61968 series: Application integration at electric utilities - System interfaces for distribution management.

In general, the IEC communication standards are of great importance for the development of smart grids. Thus, IEC standards which are suitable to the implementation within European power system are adopted by the CENELEC mirror technical committees, on basis of the agreement between CENELEC and IEC. Therefore, IEC 60870 standard series, under general title *„Telecontrol equipment and systems"* is adopted at European level as EN 60870 series. The EN 60870-5 series "Transmission protocols" and EN 60870-6 series "*Telecontrol protocols compatible with ISO standards and ITU-T recommendations"* cover the aspects related to the network operation and substation automation (e.g. SCADA - supervisory control and data acquisition, used for local and remote operation of switchgear and high voltage equipment, alarm systems) and contain the following sections*:*

- EN 60870-5-1:1993 (identical to IEC 60870-5-1 ed1.0:1990), Part 5-1: *Transmission frame formats*;
- EN 60870-5-2: 1993 (identical to IEC 60870-5-2 ed1.0:1992), Part 5-2: *Link transmission procedures*;
- EN 60870-5-3:1992 (identical to IEC 60870-5-3 ed1.0:1992), Part 5-3: *General structure of application data*;
- EN 60870-5-4:1993 (identical to IEC 60870-5-4 ed1.0:1993), Part 5-4: *Definition and coding of application information elements*;
- EN 60870-5-5:1995 (identical to IEC 60870-5-5 ed1.0: 1995), Part 5-5: *Basic application functions*;
- EN 60870-5-6: 2009 (identical to IEC 60870-5-6ed1.0:2006), Part 5– 6: *Guidelines for conformance testing for the IEC 60870-5 companion standards*. This standard specifies methods for conformance testing of telecontrol equipment, amongst substation automation systems and telecontrol systems, including front-end functions of SCADA.

- EN 60870-5-101:2003 (identical to IEC 60870-5-101 ed. 2.0:2003), Part 5-101: *Companion standard for basic telecontrol tasks*. This standard defines a telecontrol companion standard that enables interoperability among compatible telecontrol equipment, based on the IEC 60870-5 series of documents.
- EN 60870-5-102:1996 (identical to IEC 60870-5-102 ed1.0:1996), Part 5 - 102: *Companion standard for the transmission of integrated totals in electric power systems*, which standardizes the transmission of integrated totals representing the amount of electrical energy transferred between power utilities, or between a power utility and independent producers on a high voltage or medium voltage network.
- EN 60870-5-103:1998 (identical to IEC 60870-5-103 ed1.0:1997), Part 5-103: *Transmission protocols - Companion standard for the informative interface of protection equipment, which* defines a companion standard that enables interoperability between protection equipment and devices of a control system in a substation.
- EN 60870-5-104:2006 (identical to IEC 60870-5-104 ed2.0:2006), Part 5-104: *Transmission protocols - Network access for IEC 60870-5-101 using standard transport profiles*. This standard defines a telecontrol companion standard that enables interoperability among compatible telecontrol equipment.
- EN 60870-6-2:1995, Part 6-2: *Use of basic standards (OSI layers 1-4)*;
- EN 60870-6-501:1996, Part 6-501: *TASE.1 Service definitions ;*
- EN 60870-6-502:1996, Part 6-502: *TASE.1 Protocol definitions*;
- EN 60870-6-601:1995, Part 6-601: *Functional Profile for providing the Connection-Oriented Transport Service in End System connected via permanent access to a Packet Switched Data Network;*
- EN 60870-6-701:1998, Part 6-701: *Functional profile for providing the TASE.1 application service in end systems*.

Taking into consideration the publication year, it is clearly that all communication standards have been initiated to solve the operation matters of power systems at companion level as well to the interconnected grids. Presently, the protocols used in the local automation area started to be used at level of microgrid, although those protocols are non suitable for operation of microgrids. As a result, it is more difficult to realize the concatenation of micro/mini-systems with the distribution and transmission systems. Therefore, the communication standards should be revised in such way that the system architecture concept will allow bidirectional communication on hierarchical systems, taking into account ICT industry evolution for modern power systems.

The necessity for continuous improvement of communication between SCADA/EMS control centres, on basis of the implementation TASE.2 (Tele-control Application Service Element-2) did led to the development of three projects within IEC TC 57/WG 19 “Interoperability within TC 57 on long term”. These are adopted by CLC TC 57, being under approval stage:

- FprEN 60870-6-503:2014 ”*Telecontrol equipment and systems - Part 6-503: Telecontrol protocols compatible with ISO standards and ITU-T recommendations - TASE.2 Services and protocol*, which will supersede EN 60870-6-503:2002;
- FprEN 60870-6-702:2014 “*Telecontrol equipment and systems - Part 6-702: Telecontrol protocols compatible with ISO standards and ITU-T recommendations - Functional profile for providing the TASE.2 application service in end systems”,* which will supersede EN 60870-6-702: 1998;
- FprEN 60870-6-802:2014 “*Telecontrol equipment and systems - Part 6-802: Telecontrol protocols compatible with ISO standards and ITU-T recommendations - TASE.2 Object models”,* which will supersede EN 60870-6-802:2002 and EN 60870-6-802:2002/A1:2005.

Applying the standard EN 61970, respectively IEC 61970, the planning network analysis integration with external consumers will be possible. EN 61970 standard series, under the general title „Energy management system application program interface (EMS-API)" consists of the following parts:

- Part 1 (identical to IEC 61970-1:2005) - *Guidelines and general requirements;*
- Part 2 (identical to IEC/TS 61970-2:2004) - *Glossary;*
- Part 301 (identical to IEC 61970-301:2013) - *Common Information Model (CIM) base;*
- Part 452 (identical to IEC 61970-452: 2013) - CIM Static transmission network model profile, which defines the subset of classes, class attributes, and roles from the CIM necessary to execute state estimation and power flow applications. In addition, prEN 61970-452:201X (corresponding to prIEC 61970-452:201X) is under development.
- Part 453 (identical to IEC 61970-453:2014) - Diagram layout profile;
- Part 456: (identical to IEC 61970-456:2013) - Solved power system state profiles;
- Part 501 (corresponding to IEC 61970-501:2006) - *Common Information Model Resource Description Framework (CIM RDF) schema,* which describes a CIM vocabulary to support the data access facility and associated CIM semantics.
- Part 552 (corresponding to IEC 61970-552:2013) - *CIMXML Model Exchange Format,* which supports a mechanism for software from independent suppliers to produce and consume CIM described modelling information based on a common format.

The IEC 61968 series is intended to facilitate inter-application integration, as opposed to intra-application integration, of the various distributed software application systems supporting the management of utility electrical distribution networks. Some standards from IEC 61968 series are adopted by CLC TC 57X asEN 61968 series, which consists of the following parts under the general title "Application integration at electric utilities":

- Part 1 - *Interface architecture and general recommendations;*
- Part 3- *Interface for network operation;*
- Part 4 - *Interface for records and asset management*;
- Part 6 (FprEN 61968-6:2013 corresponding to IEC 61968-6:201X) - *Interfaces for maintenance and construction;*
- *Part 8* (FprEN 61968-8:2013 corresponding to IEC 61968-8:201X) - *Interface standard for customer support;*
- Part 9: *Interface for meter reading and control*;
- Part 11: *Common information model (CIM) extensions for distribution;*
- Part 13: *CIM RDF model exchange format for distribution;*
- Part 100: *Implementation profiles*.

The IEC 61850 series covers all aspects related to the communication inside substation. Besides the mentioned maintenance of the standard for communication within substations, certain activities have been started to extend the use of IEC 61850 outside the substation. Numerous parts from IEC 61850 series are adopted at European level as EN 61850 series, under the general title „Communication networks and systems in substations":

- EN 61850-10:2013 (IEC 61850-10:2013) - Part 10: *Conformance testing*;
- IEC/TS 61850-2:2003 - Part 2: *Glossary* ;
- EN 61850-3:2002 (IEC 61850-3:2002) - Part 3: *General requirements, which is already under revision*;
- EN 61850-4:2011 (IEC 61850-4:2011) - Part 4: *System and DRAFT management*;
- EN 61850-5:2013 (IEC 61850-5:2013) - Part 5: *Communication requirements for functions and device models*;

- EN 61850-6:2010 (IEC 61850-6:2009) - Part 6: *Configuration description language for communication in electrical substations related to IEDs* ;
- EN 61850-7-1:2011 (IEC 61850-7-1:2011) - Part 7-1: *Basic communication structure - Principles and models*;
- EN 61850-7-2:2010 (IEC 61850-7-2:2010) - Part 7-2: *Basic information and communication structure - Abstract communication service interface (ACSI)*;
- EN 61850-7-3:2011 (IEC 61850-7-3:2010) - Part 7-3: *Basic communication structure for substation and feeder equipment - Common data classes*;
- EN 61850-7-4:2010 (IEC 61850-7-4:2010) - Part 7-4: *Basic communication structure - Compatible logical node classes and data object classes*;
- EN 61850-7-410:2013 (IEC 61850-7-410:2012) - Part 7-410: *Basic communication structure - Hydroelectric power plants - Communication for monitoring and control*;
- EN 61850-7-420:2009 (IEC 61850-7-420:2009) - Part 7-420: *Basic communication structure - Distributed energy resources logical nodes (under revision)* ;
- EN 61850-8-1:2011 (IEC 61850-8-1:2011) - Part 8-1: *Specific Communication Service Mapping (SCSM) - Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3*;
- IEC 61850-8-2 Ed. 1.0 - Part 8-2: *Specific communication service mapping (SCSM) - Mappings to web-services*;
- EN 61850-9-2:2011 (IEC 61850-9-2:2011) - Part 9-2: *Specific Communication Service Mapping (SCSM) - Sampled values over ISO/IEC 8802-3*;
- CLC/TS 61850-80-1:2010 (IEC/TS 61850-80-1:2008) - Part 80-1*: Guideline to exchanging information from a CDC-based data model using IEC 60870-5-101 or IEC 60870-5-104*;
- IEC/TS 61850-80-4 Ed. 1.0 - *Part 80-4: Mapping between the DLMS/COSEM (IEC 62056) data models and the IEC 61850 data models*;
- IEC/TR 61850-90-1:2010 - Part 90-1: *Use of IEC 61850 for the communication between substations;*
- IEC/TR 61850-90-4:2013 - Part 90-4: *Network engineering guidelines*;
- IEC/TR 61850-90-5:2012 - Part 90-5: *Use of IEC 61850 to transmit synchrophasor information according to IEEE C37.118*;
- IEC/TR 61850-90-7:2013 - Part 90-7: *Object models for power converters in distributed energy resources (DER) systems*;

The communication standards are of core relevance for Smart Grids (cross-cutting issues). The implementation of these standards shall be accordingly to the operation of distributed energy resources (wind turbines/farms, photovoltaic systems, micro-hydro power plants etc.) in order to assure the interoperability of smart grid systems/applications (e.g. smart auto-healing and protection systems, smart metering, etc). In any case, all communication specifications are currently under intensive discussions within working groups of IEC TC 57 (mainly WG 14, WG 16, WG 17, WG 19, WG 21) and the relevant IEC technical committees (e.g. IEC TC 8, TC 13, TC 38, TC 69, TC 82, TC 95, PC 118 etc.), as well as within CENELEC and ETSI committees, in order to develop new standardisation projects. In addition, the alignment of glossaries represents another gap identified by SGCG, because the terms and their definitions should be the same in all smart grid publications.

4.3 INCREASED AUTOMATION LEVELS OF THE DISTRIBUTION GRID, TO ENSURE HIGHER EFFICIENCY OF OPERATION, SECURITY, CONTROL AND QUALITY

IEC 62351 series deals with the aspects related to the information security for power system control operations. The main objective of IEC 62351 series is the security assurance of the communication protocols defined by the IEC TC 57, specifically the IEC 60870-5 series, the IEC 60870-6 series, the IEC 61850 series, the IEC 61970 series, and the IEC 61968 series.

IEC 62351 series contains the following parts, under the general title "Power systems management and associated information exchange - Data and communications security":

IEC 62351 series - Publications	IEC 62351 series – currently four coming standards are under development:
IEC/TS 62351-1 ed1.0 - Part 1: Communication network and system security - Introduction to security issues; IEC/TS 62351-2 ed1.0 -Part 2: - Glossary of terms IEC/TS 62351-3 ed1.0 - Part 3: Communication network and system security - Profiles including TCP/IP: IEC 62351-4 ed1.0 Part 4: Profiles including MMS IEC 62351-5 ed2.0 Part 5: Security for IEC 60870-5 and derivatives IEC 62351-6 ed1.0 -Part 6: Security for IEC 61850 IEC 62351-7 ed1.0- Part 7: Network and system management (NSM) data object models IEC 62351-8 ed1.0- Part 8: Role-based access control IEC/TR 62351-10 ed1.0 – Part 10: Security architecture guidelines	▶ prIEC 62351-3 Ed. 1.0 - Part 3: Communication network and system security - Profiles including TCP/IP; ▶ prIEC 62351-7 Ed. 1.0 - Part 7: Network and system management (NSM) data object models; ▶ prIEC 62351-9 Ed. 1.0 - Part 9: Cyber security key management for power system equipment ▶ IEC 62351-11 Ed. 1.0 - Part 11: Security for XML Files

Currently, the work programme of IEC TC 57/WG 17 contains two new work items:

- prIEC 61850-8-2 „Specific communication service mapping (SCSM) – Mappings to web-services";

- a new proposal concerning distribution automation systems , namely PWI 61850-90-6 Ed. 1.0 "Use of IEC 61850 for distribution automation systems"

4.4 CUSTOMER LEVEL ENERGY MANAGEMENT (NEW EMC REQUIREMENTS)

EN 61000 series consists of harmonised standards published under EMC Directive (2004/108/EC), prepared by IEC TC 77 and only few of them are on basis of M/490 mandate. EN 61000 series is identical to IEC 61000 series, known under the general title "Electromagnetic compatibility (EMC)". It consists of six parts. For example, IEC 61000-2 series gives the compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems, IEC 61000-3 series specifies the limits of voltage changes which may be produced by an equipment tested under specified conditions, IEC 61000-4 series gives guidance on testing and measurement techniques, IEC 61000-5 series gives performance requirements for protective devices, while IEC 61000-6 series gives the immunity requirements for apparatus at residential, commercial and light-industrial locations. The use of EMC standards is recommended for all domains/zones of Smart Grid architecture (cross-cutting topics).

Having in view the purpose of STARGRID project, only the analysis of the following EMC immunity standards has been performed:

1) EN 61000-4-11:2004 (identical to IEC 61000-4-11:2004), Electromagnetic compatibility (EMC) - Part 4-11: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests; prepared by IEC/SC 77A; Basic EMC publication; M/490.

2) EN 61000-4-27:2000 (identical to IEC 61000-4-27:2000) including A1:2009 ”Electromagnetic compatibility (EMC) - Part 4-27: Testing and measurement techniques - Unbalance, immunity test for equipment with input current not exceeding 16 A per phase”;
3) EN 61000-4-34:2007 (identical to IEC 61000-4-34:2005) and A1:2009, “Electromagnetic compatibility (EMC) - Part 4-34: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests for equipment with mains current more than 16 A per phase”.

In grid sections with high penetration of DER, the electromagnetic environment classes should include a distinct class (e.g. class 4) for those cases where power electronics based converter is used for the energy transfer in PCC; (for example, within a microgrid all PCCs of the distributed generators that use power converters for grid-connection). As consequence, an amendment to IEC 61000-4-11:2004 (respectively to EN 61000-4-11:2004) should be taken as recommendation.

Moreover, the revision of the other parts in IEC 61000 -4 series may be useful for the correlation of power acceptability curves and the power quality level. Most normative references are withdrawn or replaced by new publications and as a general recommendation, the revision of IEC 61000 standard series is needed in order to align their requirements to the new power quality issues. Other aspects regarding EMC standards should be taken into account: voltage variation in weak networks with distributed energy resources, immunity tests to voltage variations (voltage dips/sags), power acceptability curves (new curves have to be derived); smart meters should include reference to voltage events easy to correlate with immunity classes according to this standard; the aggregation of prosumers should follow [and check] the individual equipment immunity class (to voltage variations).

4.5 COMMUNICATION PROTOCOL FOR THE REMOTE CONTROL OF DERS

CIM is defined in the following standards: IEC 61968 series prepared by TC 57/WG14”System interfaces for distribution management”, IEC 62325 series from TC 57/WG16 “Deregulated energy market communications” and IEC 61970 series from TC 57/WG13 “Energy management system application program interface (EMS-API)”.

IEC TC57/WG 17 deals with the communications systems for distributed energy resources (DER). Currently, the work programme of this working group contains the revision of standard IEC 61850-7-420:2009, Part 7-420: Basic communication structure - Distributed energy resources logical nodes. The new edition of this standard can be available on September 2015. IEC 61850-7-420 is adopted as EN 61850-7-420 by CENELEC/TC 57, and defines IEC 61850 information models to be used in the exchange of information with distributed energy resources (DER). It utilizes existing IEC 61850-7-4 logical nodes where possible, but also defines DER-specific logical nodes where needed.

Subject	Subject: questionnaire reference (gaps)	Questionnaire gaps ranking		Standards to be analysed	Avg. questionnaire relevance	Maintained by	Requirements	Questionnaire reference (requirements)	Questionnaire requirements ranking (2014-03-17)
		Avg. Agreement	Avg. relevance						
Std gap: Electrical connections and operation rules of DERs should be harmonized within Europe. **(SGCG: Gap 12 – Gen 5 Standard for electrical connections and installation rules to ensure energy availability and security, in presence of high ratio of DER)**	Row 46	4,12	3,90	ENTSO-E RfG	3,45	-	Electrical Connection of DER to the grid and disconnection	Row 15	4,08
				Regional Standards	n.e.	-			
				EN 50438:2013	3,13	YES (CLC TC8X WG3)			
				TS 50549-1 TS 50549-2	3,02	YES (TC8X WG3)	Remote control of DER	Row 16	4,06
				IEC 62786	3,40	TC 8 – PT 62786	Harmonized and stable technical interconnection rules at national and EU level	Row 34	4,16
				IEC/TS 62749 (coming technical specification)	n.e.	TC 8 – PT 62749			
				EN 61869 series (identical to IEC 61869 series)	n.e.	TC 38			
Std gap: Communication protocols as well as information data models for control center <-> DER communication have to be harmonized	Row 54	4,05	3,93	IEC 61968	3,59	YES (TC57 WG14)	Seamless communication between control centers, substations and DER installations	Row 11	4,00
				IEC 61970	3,13	YES (TC57 WG13)			
				IEC 61850	3,54	YES (TC57 WG10)	Information and data exchange	Row 28	4,05

(SGCG: Gap 8 – Gen 1 Harmonized glossary, semantic & modelling between back-office applications (CIM) and field applications (IEC 61850))				IEC 60870 -5 series	2,87	YES (IEC TC 57)	(definition of the information and data models)		
				IEC 60870 -6 series	2,58	YES (IEC TC 57)			
Std gap: Smart Grids request increased automation levels of the distribution grid, to ensure higher efficiency of operation, security, control and quality. Faults detectors will enhance operation and reduce shutdown times **(SGCG: Gap 16 – Dis 1 Feeder and Advanced Distribution automation Dis 7 Standards for Medium Voltage (MV) lines (“feeder automation”)**	Row 45	4,40	4,21	IEC 61850- 90-6	3,61 (90-X set)	YES (TC57 WG17)	Grid management (Configuration and re-configuration; fault diagnosis, self-healing, island operation) Forecasting of power and loads DER Monitoring and Sensors Security of data and protection of the information	Row 8 Row 14 Row 18 Row 32	4,05 3,90 3,85 4,31
				IEC 62689-1	2,96	YES (TC38 WG46)			
				IEC 61850-8-2	n.e.	YES (TC57 WG17)			
				IEC 62351 series	3,11	YES (TC57 WG15)			
Std gap: New EMC requirements will arise from the development of the grid, requiring	Row 48	3.44	3,49	EN 61000-X-series EN 61000-4 -11 EN 61000-4 -27 EN 61000-4 -34	3,31	YES (TC77 SC77)	Safety (of the Grid and of the DER); protection schemes	Row 11	4,00

reviewing of the Standards **(SGCG: Gap 7 – EMC 3 Consider distorting current emissions from DER equipment)**							EMC immunity	Row 12	3,52
Std gap: A single communication protocol for the remote control of DERs should be imposed in interconnection rules, to ensure interoperability **(SGCG Gap 26 – Other1 Smart Grid communication standards with CIM and IEC 61850)**	Row 53	4,07	4,00	IEC 61850	3,54/ 3,17	YES (TC57 WG17)	Seamless communication between control centers, substations and DER installations; CIM Market extension	Row 11	4,00
				IEC 61968	3,16/ 3,22				
				IEC 61970	3,13	IEC TC57 WG13			
				IEC 62325	2,70				

Table 2: Subjects of DER integration and grid control

5 DEMAND RESPONSE AND CUSTOMER ENERGY MANAGEMENT

The gaps and required actions have been grouped into four Subjects:

1. Communication between grid operators or service providers and the end customer
2. Data model abstraction layer for home automation and customer energy management
3. Customer energy management
4. Ancillary services through demand response (market perspective), and DR participation in energy markets

The associated standards and requirements are shown in Table 3. The analysis of the STARGRID team concentrates on the subjects 3 and 4, since the first subject is currently under intensive discussions within IEC TC 57 (mainly WG 21) and IEC PC 118, which have already performed an analysis of the relevant standardisation projects. The second subject is covered by an ongoing study Semantics of Smart Appliances, aiming at the provision of a data model abstraction layer for the ETSI M2M specification, to which we refer for an in-depth investigation of existing and ongoing standardisation projects.

5.1 COMMUNICATION BETWEEN GRID OPERATORS OR SERVICE PROVIDERS AND THE END CUSTOMER

This issue is under active discussions in IEC committees TC 57 and PC 118, and also the Smart Grid Coordination Group. Therefore we restrict ourselves to a summary of the current state of the gap. Figure 1 shows the basic communication architecture according to the SGCG.

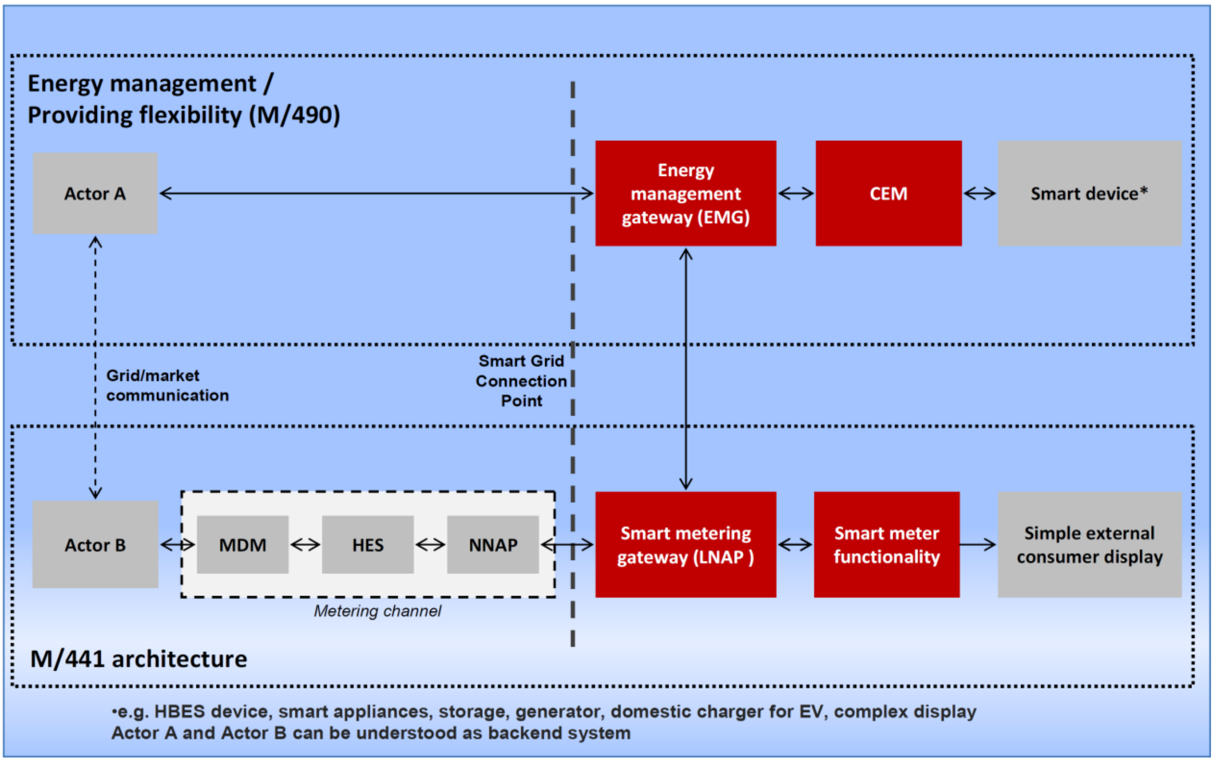

Figure 1: Communication Architecture Demand Response, Energy Management and Smart Metering according to the SMCG and SGCG. Source: [4]. The gap is concerned with the communication between Actor A and the EMG, and as an alternative, between Actor B and the EMG using the metering infrastructure.

Three standardisation gaps (Gen-3, Ind-2, HB-2) have been recognized in the report of the Joint Working Group related to the protocol and data models for communicating demand response signals between any market actor and the end customer. The three gaps have been combined into one by the Smart Grid Coordination Group, under the Gen-3 title Extended field data modelling standard (part of IEC 61850) to support demand response, DER, VPP and home/building/industry automation. Their work plan assigns the task of filling this gap to the working group IEC TC 57 WG 21, which started work on the new item IEC 62746 (System interfaces and communication protocol profiles relevant for systems connected to the Smart Grid) in 2011. Besides that, a similar gap had been identified by SGIP in the US, and a priority action plan was set up1. The PAP group investigated three industrial initiatives deemed relevant: OpenADR 2.0, ZigBee Smart Energy Profile (SEP) 2.0, and OASIS Energy Interoperation (Energy Interop). OpenADR and Energy Interop are closely related, the former defining a profile of the latter standard, whereas the focus of the SEP is more on the communication between in-home devices. After their respective publications in 2013, the PAP group issued recommendations for the usage of OpenADR 2.0 and SEP 2.0.

In addition to WG 21, another initiative with focus on DR was launched in IEC in September 2011, the PC118 Smart grid user interface. Its first task was the investigation of existing DR solutions in different countries, including in particular industry standards, which lead to the drafting of a technical report Smart Grid user interface (still in draft stage as of the writing of this report). On the other hand, the group identified an urgent market need for a DR standard, and pushed for the publication of OpenADR 2.0B as an IEC Publicly Available Specification (PAS). The following discussion centred mainly about the lack of interoperability of OpenADR with the Common Information Model (CIM – IEC 61970, 61968 and 62325) and the IEC 61850, considered as the IEC

[1] PAP09: Standard DR and DER Signals. See http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP09DRDER

core Smart Grid standards. Since OpenADR defines its own data model (or rather uses the Energy Interop model) instead of the CIM, it cannot be directly integrated into CIM-based IT-systems. Nevertheless, following a positive vote, OpenADR 2.0B has been published as IEC/PAS 62746-10-1 ed1.0 in February 2014.

In order to solve the interoperability issue, TC 57 and PC 118 have agreed to continue the development of IEC 62746 towards a CIM-compatible DR standard, by first defining an OpenADR <-> CIM adaptor, followed by a purely CIM-based version of OpenADR. TC 57 has established a task force on CIM extension for this purpose.

Regarding the communication protocol, there have recently been intensive discussions within TC 57 to identify the most suitable solution for an internet-based protocol to be supported by IEC 61850. The need for this comes from the fact that the currently favoured IEC 61850 over MMS solution is often too expensive for smaller distributed energy resources. The decision was finally made to define a mapping of 61850 to XMPP. Other mappings remain possible, of course, but will not be standardised by TC 57. The same solution is supported by OpenADR, which defines mappings to HTTP and XMPP, and will also be used by WG 21 for the IEC 62746.

Another TC 57 activity worth mentioning in this context is the ongoing extension of IEC 61850 for distributed energy resources, the future IEC 61850-7-420 ed2 (WG 17). Currently, the work on this item is divided into several technical reports, which will later be integrated into the 7-420. Examples are 61850-90-15 (Object models for power converters in distributed energy resources (DER) systems), TR 61850-90-7 (Object Models for Photovoltaic, Storage and other DER inverters) and TR 61850-90-9 (Object Models for Batteries).

Most DR communication scenarios assume an internet-based connection to the service provider. If a household is equipped with a smart meter with communication capabilities, the latter may be used for the communication as well. This may require an interface between the advanced metering infrastructure (AMI) and the energy management gateway (gap Ind-3 of the JWG report; see Figure 1). A separate work item of the SGCG is addressing this issue, with CENELEC TC 205 WG 18 as the responsible party, who is developing prEN 50491-12 Smartgrid - Application specification –Interface and framework for customer energy management. On the data model layer, this use case will require a harmonization of CIM, respectively IEC 62746, with DLMS/COSEM (IEC 62056), the language of the AMI.

5.1.1 REGIONAL SOLUTIONS

We briefly sketch the situation regarding DR standards in different regions of the world.

North America. The OpenADR standard is widely in use. It has been developed originally by the Lawrence Berkeley National Laboratory, and is now owned by the OpenADR alliance. The standard versions 2.0A and 2.0B have been published and received recommendations by the Smart Grid Interoperability Panel (SGIP). Smart thermostats play a quite important role.

Europe. No widespread commercial use of DR. In most countries only large industrial facilities have the possibility to participate in DR programs, and they typically rely on proprietary solutions (for an overview on the regulatory frameworks in selected countries, see Ref. [6]). Several field tests have investigated the potential of DR, however, and regulatory improvements for DR participation are likely to occur in the coming years. The roll-out of Smart meters has started in many countries and is planned in most others, but so far most installed meters do not support advanced DR enabling functionalities. It can be expected that the coming IEC 62746 standard will play a major role.

Japan. The situation in Japan is somewhat different from the rest of the world in that a single standard for home automation has found large support there, the Echonet standard, which is also the basis for several international standards by IEC TC 100 and ISO/IEC JTC 1/SC 25/WG 1. It includes remote direct load control capabilities, but no advanced DR features.

Australia/New Zealand. A standard for direct control of mainly air conditioning systems has been developed, AS/NZS 4755 Framework for demand response capabilities and supporting technologies for electrical products. Extensions are under way to cover additional device types.

5.2 DATA MODEL ABSTRACTION LAYER FOR HOME AUTOMATION AND CUSTOMER ENERGY MANAGEMENT

This gap is related to the upper right part of Figure 1, the Customer Energy Management System and the Home Automation Network. A wide variety of home automation protocols in use leads to market fragmentation and interoperability problems. A possible approach to this problem is the definition of an abstract data model with defined mappings to the different protocols. This data model can be the basis for energy management applications which are independent of the underlying protocol, at least to a certain extend.

The gap is currently being addressed by a study for the ETSI M2M protocol[2], which is why we do not delve into a deeper investigation here. A preliminary list of relevant initiatives can be found in Table 3. The number of initiatives suggests that there is a certain risk of ending up with several abstraction layers, which would lead the approach ad absurdum. A highly coordinated approach will be required to achieve the goal.

5.3 CUSTOMER ENERGY MANAGEMENT

The customer energy management deals with control and monitoring of energy consuming and to a lesser extend energy generating devices in the end customer premises. It covers a diverse set of use cases, like tariff based management, management based on other KPIs like CO2 minimization, increase of self-consumption of locally generated power, energy efficiency improvements, etc. There are significant contact points with other home automation applications, like Ambient Assistant Living (AAL), e-Health, etc.

Standardisation of the CEM is not well advanced, which may be due to a limited economic potential in the current regulatory frameworks. In particular the increasing significance of demand response in the US may be changing this picture. In any case, there are several industrial initiatives which issue specifications on different aspects of energy management.

In its basic core, the CEM infrastructure requires a gateway for communication with smart devices and potentially with external parties which provide incentives or control commands. General machine-to-machine standards can be applicable to the gateway, like the ETSI M2M specification or the HGI (Home Gateway Inititative) TR-069.

A standardised energy management framework has to take into account different application scenarios. Extensibility to use cases beyond energy management would be useful as well. One approach is the specification of an application runtime environment, allowing for the installation of applications from different vendors/providers, like an operating system for PCs or smartphones. Other specifications define profiles for energy management purposes of more general home automation standards.

[2] http://www.etsi.org/news-events/news/772-2014-04-etsi-launches-work-on-smart-applia9nces-standard

ZigBee SEP. The ZigBee Smart Energy profile defines data models and inter-device messages for energy management. Version 2.0 is based on an IP stack (independent of ZigBee) and includes demand response, DER control and smart metering use cases. The data model is derived from IEC 61968 (CIM for distribution) and others, like IEC 61850. It has a rather broad scope, covering both the communication in-house and with external parties, and includes even Smart Metering. This reduces the need for a high number of interfaces in the system. The interworking with other home automation protocols is unclear, however. A gateway will still be required in case devices based on other protocols must be integrated.

EEBus. The EEBus initiative defines an energy management data model and protocol converter. It propagates the use of existing communication protocols.

Energy@Home. The Energy@Home specification is a mainly Italian initiative, and is based on the ZigBee Smart Home profile.

FAN. The Flexible Power Alliance Network defines an application runtime environment and a data model for energy management. Its purpose is to set the stage for advanced energy markets with increased end customer participation, and it includes the PowerMatcher as one application, an agent-based market place system. It allows for the connection via different protocols through corresponding hardware drivers.

OGEMA. The OGEMA specification defines a runtime environment for applications and a data model for energy management. It allows the connection via different protocols through corresponding hardware drivers.

Besides the initiatives listed here, several home and building automation protocols are relevant to this use case. Furthermore, there are further initiatives to define an abstract data model to be mapped to the communication protocols, see 5.2.

5.4 ANCILLARY SERVICES THROUGH DEMAND RESPONSE (MARKET PERSPECTIVE), AND DR PARTICIPATION IN ENERGY MARKETS

a) ENTSO-E Network Codes

The ENTSO-E Network Codes Demand Connection Code (DCC), Electricity Balancing (EB) and Operational Planning and Scheduling (OPS) are considered together in the following. The codes facilitate different ancillary services by defining details partly mandatorily, partly voluntarily. In some cases the codes apply with regard to "significant devices", which have to be defined during a process according to Directive 2009/125/EC (Eco Design Directive).

The **aggregation of small providers** is generally included as a possibility, but no explicit measures are taken to foster the participation of small providers.

Regarding **standardised market processes** TSO shall design, set up and manage procedures for the procurement of ancillary services (EB Art. 50). All TSOs shall develop a proposal for standard products for balancing capacity and balancing energy (EB Art. 28 par. 2). Therefore, the responsibility for establishing standardised market processes is deputed to the TSOs. German national legislation states an obligation for TSOs to provide a web based procurement platform (see below).

Cost-effectiveness is referenced throughout the codes e. g. in DCC Recital 7, DCC Art. 9 par. 1 and Art. 10. The same applies to fair and non-discriminatory data access for service providers, which are also referenced throughout the codes e.g. in DCC Recital 7 and Art. 9 par. 1.

An **opt-out right at any time** is not addressed by the Network Codes. This is comprehensible as the Network Codes focus on grid stability, interoperability and enabling markets (non-discriminating aspects), but not on consumer rights. The definition of a **standard communication interface** would be nearer to that focus but is also not addressed.

Grid stability could be considered as one of the major reason for all efforts risen by Network Codes.

b) National regulatory provisions drawing on the example of German legislation and regulation

The energy industry act (Energiewirtschaftsgesetz –EnWG), the draft of a metering system regulation (Entwurf Messsystemverordnung – MsysV-E) and a technical directive regarding smart metering developed by the Federal Office for Information Security (BSI TR-03109) were examined.

No general provision regarding **ancillary services** are given. For the particular case of direct remote load control § 14a EnWG entitles consumers connected to lower voltage grids to provide these service for the benefit of reduced grid feed under certain conditions. Details (amount of benefit, required communication interface, etc.) are subject of a pending regulation.

Indirectly § 40 V EnWG encourage the offer of ancillary services by obligatory tariffs to foster energy conservation or enable control of consumption. However, this obligation is widely met by offering day/night tariffs instead of tariffs with regard to actual power production or grid load. The TR-03109 describes in section 4.2.2 different tarif use cases like privacy friendly, time/load/enegy/incident/ max-load/dependend. This variety promotes tariffs for ancillary services.

A **standardised market processes** could be expected for the particular case of direct remote load control, addressed by § 14a EnWG, and the pending regulation based on that legislation. For the procurement and use of bids for balancing energy the control grid operators are committed to a defined process. This led to the public accessible procurement platform regelleistung.net.

Cost-effectiveness is considered in the process for procurement and using the bids.

A **fair and non-discriminatory data access for service providers** could cause a conflict of interests with privacy rights of consumers. Non-discriminating must not lead to data access for every service provider, but only to these service providers chosen by the consumer. § 21g II EnWG states that the consumer decides who is entitled to access data. Nevertheless, the purpose of data usage is restricted.

The **opt-out right at any time** could be subject of a pending tariff regulation which is entitled by EnWG to implement appropriate legislation.

The EnWG also entitles a regulation to demand a **Standard communication interface** described in TR-03109 for the particular case of direct remote load control in low voltage grids according to § 14a EnWG. The referred interface described in TR-03109 applies to the communication between the controllable device and the external market partner.

As stated for network codes, **Grid stability** could be considered as one of the major reason for all efforts risen by national regulatory provisions.

Subject	Subject: Questionnaire reference (row, gaps DR)	Questionnaire gaps ranking (V 2014-01-23)		Standards to be analysed	Avg. questionnaire relevance (N.e. = Not evaluated)	Requirements	Questionnaire reference (row)	Questionnaire requirements ranking (2014-01-28)
		Avg. Agreement	Avg. relevance					
Std. gap: Communication between grid operators or service providers and the end customer.	60	4.0	3.60	OpenADR 2.0B	2.93	Modular architecture	8	3.86
				IEC 62746	3.18	Scalability	9	3.96
				ZigBee SEP 2.0	2.64	Information Security	10	4.00
						Support for operating modes: direct control, incentives based, autonomous mode (qu.: Ancillary Services group)	15-21, 41	3.57
						Data Privacy	23	3.70
(SGCG: Gap 10 - Gen-3 Ind-2 HB-2 - Extended field data modelling standard (part of IEC 61850) to support demand response, DER, VPP and home/building/industry automation)				Possible extension to IEC 61850-7-420, IEC 61850-90-X, Echonet, AS/NZS 4755	 3.39 N.e. N.e. N.e.	Bidirectional communications (support for status information of connected devices)	32	3.74
						Support for multiple and upcoming communication technologies	36	3.90
						Seamless communication	-	-
Std gap: data model abstraction layer for home automation and customer energy management	55	3.84	3.58	prEN 50491-12	2.74	Support for operating modes: direct control, incentives based, autonomous mode (qu.: Ancillary Services group)	15-21, 41	3.57
				Facility Smart Grid	2.39	Standard communication interface: CEMS <-> grid operator	30	3.77

				Information Model (FSGIM)		unique representation of data	-	-
						Bidirectional communications, feedback from the customer installation to grid or market operator, Providing status information on capabilities/connected devices to authorized third parties	32, 42	3.49
				OGEMA	2.43	Integration of Home Gateways in legacy grid control systems	33	3.33
						Interface between customer energy management infrastructure and the advanced metering infrastructure (AMI)	34	3.74
						Support for multiple and upcoming communication technologies	36	3.91
						Coverage of existing data models (across domains)	-	-
Std gap: Customer energy management	56 57	3.42 3.36	3.21 3.24	EEBUS	2.25	Modular and scalable architecture	8-9	3.91
						Information Security	10	4.00
						Grid stability	-	-
						Data privacy	23	3.71
						Affordability	24	3.64
						Simple handling of devices and software	25	3.77
				ZigBee SEP 2.0	2.64	Standard communication interface: customer energy management system (CEMS)/market/grid-operator (all bidirectional)	29-31	3.71
				FAN (Flexible Power Alliance Network)	N.e.	Integration of Home Gateways in legacy grid control systems	33	3.33
				Energy@Home	2.56	Interface between customer energy management infrastructure and the advanced metering infrastructure (AMI)	34	3.74
				OGEMA	2.43	Security: authentication and encryption	35	4.05
				prEN 50491-12	2.74	Support for multiple and upcoming communication technologies	36	3.91

				IEC 61850-7-420	3.39	Standardised basic services, such as registration, access rights & authentication, data-transfer, time synchronisation, etc.	38	3.58
				IEC 61850-90-X	N.e.	Standardised protocol translation (gateway functionality)	39	3.67
				Possible extension to ANSI/CEA-2045, Echonet, AS/NZS 4755	N.e.	Standardised runtime environment for applications; accessible to multiple service providers	40	3.35
						Transparent forwarding of external control commands to connected devices	41	3.51
						Decent self-consumption	43	3.24
						Providing status information on capabilities/connected devices to authorised third parties	42	3.28
						Specification of basic hardware requirements	44	3.24
						Applicability for a broad range of use cases and extensibility		
Use Case: Ancillary services through demand response (market) Use Case: DR participation in energy markets (general; including ancillary markets)	65, 62	3.44 3,67	3.16 3,10	ENTSO-E Network Code: Demand Connection Code	2.82	Modular market model for different ancillary services and energy products	15-21, 41	3,57
				ENTSO-E Network Code: Electricity Balancing	**N.e.**	Aggregation of small providers	-	-
						Standardised market processes (such as customer or device de-/registration with a service provider)	12	3.39
				ENTSO-E Network Code: Operational Planning and Scheduling	**N.e.**	Cost-effectiveness	-	-
						Fair and non-discriminatory data access for service providers	13	3.51
						Opt-out right at any time in Demand Response programs	26	3.38
				German national regulatory provisions	N.e.	Standard communication interface: customer energy management system (CEMS)/market/grid-operator (all bidirectional)	29-31	3.71
						Grid stability	-	-

Table 3: Subjects of Demand response and customer energy management

6 SMART METERING

The critical issues, gaps and required actions have been grouped into six *Subjects:*

1. Interoperability at data model level
2. Security of WAN communication
3. Low voltage grid operation based on smart meter data
4. Smart meter gateway for load control
5. Communication profile for connection of controllable loads
6. Smart meter certification process

The associated relevant standards and requirements are shown in Table 4. In this table it is shown also the gaps detected by the SGCG linked to above subjects. Many of the standards included in this table have been analysed in more detail against the specific requirements affecting the subjects (see Annexes). In the following paragraphs an exercise of synthesis is done in order to provide general conclusions on the mentioned subjects derived from the analysed standards.

Some of these standards are specifying the lower communication layers, which hardly have impact on most of the mentioned subjects or critical issues (mainly prescribed at a higher level).

6.1 INTEROPERABILITY AT DATA MODEL LEVEL

Clearly, the dispersion of communication standards for smart metering, especially for the lower layers (physical and data link mainly) of the protocol stack implies a lack of interoperability between them. Many of these specifications are using DLMS/COSEM standard for the upper layers (application layer and data model), or are analysing how to convert its own data model to it, which could lead to a potential interoperability at this level.

For example, PRIME specification (ITU G9904) uses normally DLMS/COSEM as the application layer and data model. On the other hand, some solutions have been developed for ETSI GS OSG 001 (OSGP) to reach this interoperability allowing the access of OSGP-based smart meters to use the widely used DLMS/COSEM application data model using IEC 62056 parts 47, 53, 61, and 62. Also EN 13757-1[3] provides a specification for the COSEM based application layer for EN 13757 lower communication layers (M-Bus and wireless M-Bus), instead of the direct option of EN 13757-3 (original application layer specification).

Finally it is worth to mention the initiative of harmonization between IEC 61968-9 and DLMS/COSEM. IEC 61968-9 extends the CIM to support the exchange of meter data and the integration of the meter system into the utility enterprise and operation applications. IEC 61968-9 covers the utility enterprise systems up to the AMI head-end, and DLMS/COSEM covers from the AMI head-end up to the end meters. The message translation should be done at the AMI head-end.

6.2 SECURITY OF WAN COMMUNICATION

In general, the analysed standards contain considerations for data protection and privacy (authentication and encryption mechanisms), which can mean that security is implemented at several layers of the communication stack reinforcing the final solution.

[3] Electricity meters are not covered by this standard, as the standardization of remote readout of electricity meters is a task for CENELEC.

For example, data protection and privacy is included in the PRIME specification and also DLMS/COSEM (IEC 62056-6-2) in upper level specifies three levels of authentication (no, low and high security). Similar situation can be found with ETSI GS OSG 001 (OSGP), which uses EN 14908 as the networking layer, and already includes authentication services, but OSGP extends them at the application layer and complementing them with confidentiality services (encryption).

ZigBee related standards (SEP2 and Energy@Home profiles) also define security mechanisms at the application level, complemented with other security features at lower layers.

6.3 ACCESS TO SMART METER DATA FOR GRID OPERATION

In general, this subject is not addressed by the analysed standards, which are fully focused on customer-related applications: revenue metering, tariffing, billing, energy management at customer premises, etc. Pure low voltage grid supervision and control seem to be out of the scope at the moment.

A possible exception to this can be IEC 61968-9 (CIM) that has the objective of integrating the meter system (and meter information) into the operation application of the utility company. Doing this, the meter data can be used by the Distribution Management System to supervise and manage the low voltage distribution grid.

6.4 SMART METER GATEWAY FOR LOAD CONTROL

The use of the smart meter like a gateway by which the electricity supply can be controlled remotely (including individual appliances or the complete supply) by the utility has been always controversial and has regulatory implications.

At a lower level that functionality must be supported by standards. Several of the analysed standards formulate specifications for load control like ETSI GS OSG 001 (OSGP), Energy@Home and ZigBee SEP2.

The reference architecture of TR 50572 (SMCG) has been developed to allow also this functionality (remote disablement and enablement of supply and flow/power limitation).

6.5 COMMUNICATION PROFILE FOR CONNECTION OF CONTROLLABLE LOADS

The possibility of connection between the smart metering system and an Energy Management System (EMS) at the customer premises is identified in the technical report TR 50572 (SMCG) and included in the reference architecture for smart metering communications specified there. The optimization process that takes part in the EMS needs the meter data to operate, so an interface must be enabled between the smart meter gateway and the energy management gateway for the provision of energy efficiency and demand-side management services.

Energy@Home ZigBee profile, which extends the capabilities of the "Home Automation" profile and "Smart Energy Profile", contains specifications for the use of the smart meter in connection to an EMS for load control, allowing several “customer awareness” scenarios like the optimization of energy cost in case of multitariff contract, visualization of energy and price, etc.

Similar possibilities can be offered by the functions defined by ZigBee SEP2 profile: demand response, load control, price communications, energy flow (storage charging/discharging), DER management (including generation and electrical vehicles), etc., always within the home area network (HAN) in the “Customer” SGAM

domain. The server device can be a premises energy management system that can act as a proxy for upstream applications.

Finally, ETSI GS OSG 001 (OSGP) also specifies some data structures for demand side management, load control, variable tariffs, etc.

6.6 SMART METER CERTIFICATION PROCESS

No testing or certification process is described in the analysed standards, which can imply that this gap is not still addressed and has less priority than others.

However, some efforts are in progress but are not yet published. For example, the Yellow Book developed by the DLMS Association specifies the methods and processes for conformance testing and certification of metering equipment implementing the DLMS/COSEM specification, but it not published as an IEC standard.

Similarly, the PRIME Alliance has developed Test Books to describe the certification procedures of the PRIME devices (smart meter and concentrators), and testing is being carried out by designated laboratories. Apparently, the documents are only available to alliance members and it is not clear at what extent this will become also an ITU Recommendation or a European Standard/Technical Specification/Technical Report.

The ZigBee protocol can be another example. Clearly, at the moment it seems to be a lack of visibility of this conformance process and certification is done inside each industrial association.

EN 62056 series is identical to IEC 62056 series, under general title “Electricity metering data exchange”. These standards are prepared under M/441 and M/490 mandates.

The EN 62056 standard series should include information related to the data aggregation (pre-processing), time reference source, minimal accuracy and format; and the reporting rate[s] of data obtained/transmitted from the meter. Communication constraints resulting from meters' timing accuracy and data reporting rate should be made available per use-case.

In addition, the EN 62053 series (identical to IEC 62053 series) specifies the type test requirements and test methods for a.c. meters for active / reactive / apparent energy, including power supply and pulse interface requirements. These publications are of high relevance for Smart Grid. EN 62053 series consists of the following parts, under general title "Electricity metering equipment (a.c.) - Particular requirements": 11, 21, 22, 23, 31, 52, 68. Part 11 for the electromechanical meters is not relevant to smart metering but deployment of smart grids will have a phase of coexistence and operation with equipment of older generation. It is needed therefore to correlate the requirements with those in force for the entire measurement chain. There are only two drafts, prepared by IEC TC13/WG11-*Electricity metering equipment:* prIEC 62053-24 (draft approved for publication) "Electricity metering equipment (a.c) - Particular requirements - Part 24: Static meters for reactive energy at fundamental frequency (classes 0,5 S, 0,5, 1S and 1)" and prIEC 62053-41 (approved new work) titled "Electricity metering equipment (DC direct current) - Particular requirements - Part 41 - Static meter for active energy (class 0.5 and 1)". Considering the publication year (1998, 2003; 2005) of the remaining parts of IEC 62053, there is a strong need for reviewing of these issues.

Concerning EN 62053-11, the accuracy classes, although they are valid for the current facilities, should be compatible with the new requirements corresponding to measurement chain of modern networks. The standard includes limits on measurement quality impairment in case of the connection with current transformers. In this context, there is a need of standard revision because in the existing grids the current transformers of 02S class are changed accordingly to new measurement codes and grid codes, which means

that errors' limit of the meters shall be correlated. Also the influence quantities (voltage variation, frequency, wave distortion, should be reviewed (table 11); the meter shall be able to measure more variations. When the maximum tolerances for meters are verified, the reference conditions for networks shall be higher than those listed in Table 11, because the meters will work in more severe conditions in real networks and especially the new ones. So, there is a need for the revision of EN 62053 -11 (IEC 62053-11 respectively). Moreover, having in view the publication year (1998, 2003; 2005) of the other parts of IEC 62053 series it is clearly a need for reviewing of concerned standards.

- Recommendation concerning smart metering and power quality (MARKET-End user): there is a need for preparing new standard or technical specification concerning meter functionalities which shall contain a set (classes) of acceptability curves (quality levels for different voltages in conformity with each kind of the consumer).

Subject	Subject: questionnaire reference (row, gaps SM)	Questionnaire gaps ranking (v 2014-02-07) Avg agreement	Questionnaire gaps ranking (v 2014-02-07) Avg relevance	Standards to be analysed	Avg. questionnaire relevance (N.e. = Not evaluated)	Maintained by	Requirements	Questionnaire reference (requirements)	Questionnaire requirements ranking (v 2014-02-07)
Interoperability for the different smart meter standards to be achieved at the data model level (for example, using DLMS/COSEM) **Related JWG Gaps1: Gen-2, SM-1, Ind-1 Other-2**	Row 50	3.20	3.39	IEC 61850	3.54	SMCG IEC TC13 WG14 IEC TC57 WG10 IEC TC13/57 JWG16 CLC TC13	Interoperability Standardized interfaces and data exchange formats Support for multiple and upcoming communications technologies Standardized data profiles	Row 7 Row 31 Row 35 Row 36	4.60 4.26 4.14 4.07
				IEC 61968-9 (CIM)	3.25				
				IEC 62056 (DLMS/COSEM)	3.55				
				EN 13757 (M-Bus)	2.70				
				prTS 50568 (Meters & More)	2.87				
				ETSI GS OSG 001 (OSGP) ETSI TS 103 908	3.08				
				prTS 50567-1 (PRIME) prTS 52056-8-4	3.13				
				prTS 50567-2 (G3-PLC) prTS 52056-8-5	3.03				
				ZigBee Smart Energy Profile (SEP) 1.x ZigBee Smart Energy Profile (SEP) 2.0	2.60 2.73				
				SyM^2 specification	2.38				

				IEEE 1377	N.e.				
Strong security mechanisms (encryption & authentication) mandatory for the WAN communication of the smart meter gateway **Related SGCG gaps:** **Dis-42** **New Gap 423** **New Gap 444** **New Gap 455**	Row 51 (Row 52)	4.13	3.87	IEC 62056-5-3 (DLMS/COSEM Security)	N.e.	SGIS IEC TC13 WG14 IEC TC13 WG02 IEC TC57 WG15 IEC TC22 SC3	Security Data privacy Secure communications (ensuring data integrity & confidentiality) Mandatory security provisions (authentication and encryption, data management)	Row 9 Row 25 Row 33 Row 38	4.49 4.16 4.21 4.19
				IEC 61968-9 (CIM)	3.25				
				IEC 62351 Series (Security)	3.11				
				ETSI GS OSG 001 (OSGP) ETSI TS 103 908	3.08				
				prTS 50568 (Meters & More)	2.87				
				prTS 50567-1 (PRIME) prTS 52056-8-4	3.13				
				prTS 50567-2 (G3-PLC) prTS 52056-8-5	3.03				
				ZigBee Smart Energy Profile (SEP) 1.x ZigBee Smart Energy Profile (SEP) 2.0	2.60 2.73				
				EN 13757 (M-Bus)	2.70				
				SyM^2 specification	2.38				
				TR 50572 (SMCG)	3.10				
				IEEE 1377	N.e.				
Full access to grid related smart meter data at the customer connection	Row 53	4.07	3.74	IEC 62056 (DLMS/COSEM)	3.55		Remote reading and management	Row 13	4.44
				EN 62053 series		IEC TC13			

point by the grid operators (for example: voltage, current, cos φ)				IEC 61968-9 (CIM)	3.25	IEC TC 57	Quality of Supply control	Row 15	4.07
				TR 50572 (SMCG)	3.10		High availability	Row 16	4.30
				EN 13757 (M-Bus)	2.70		Load profile data	Row 17	4.21
				ETSI GS OSG 001 (OSGP) ETSI TS 103 908	3.08		Provision of data from AMI for grid control purposes (e.g. voltage and phase measurements)	Row 19	4.05
				prTS 50568 (Meters & More)	2.87				
				prTS 50567-1 (PRIME) prTS 52056-8-4	3.13				
				prTS 50567-2 (G3-PLC) prTS 52056-8-5	3.03				
				ZigBee Smart Energy Profile (SEP) 1.x ZigBee Smart Energy Profile (SEP) 2.0	2.60 2.73				
				SyM^2 specification	2.38				
Home devices control: smart meters to be the gateway by which electricity supply can be controlled remotely (entire supply or individual appliances)	Row 54	3.93	3.59	TR 50572 (SMCG)	3.10		Modularity	Row 11	3.95
				EN 13757 (M-Bus)	2.70		Remote reading and management	Row 13	4.44
				ETSI GS OSG 001 (OSGP) ETSI TS 103 908	3.08		Remote connection and disconnection	Row 14	4.16
				prTS 50568 (Meters & More)	2.87		High availability	Row 16	4.30
				prTS 50567-1 (PRIME) prTS 52056-8-4	3.13		Load profile data	Row 17	4.21
				prTS 50567-2 (G3-PLC) prTS 52056-8-5	3.03		Allow advanced information, management and	Row 20	3.95
				ZigBee Smart Energy Profile (SEP) 1.x ZigBee Smart Energy Profile (SEP) 2.0	2.60 2.73				

				SyM^2 specification	2.38		control systems for services suppliers and customers		
				energy@home	2.65		Standardized interfaces and data exchange formats	Row 31	4.26
							Bidirectional communications	Row 34	4.16
							Support for multiple and upcoming communication technologies	Row 35	4.14
Standardized communication profile for the connection of controllable loads or an energy management system to the smart meter gateway is missing **Related JWG Gaps6: Ind-3**	Row 55	3.77	3.23	IEC 62056 (DLMS/COSEM)	3.55		Modularity	Row 11	3.95
				IEC 61968-9 (CIM)	3.25		Remote reading and management	Row 13	4.44
				EN 13757 (M-Bus)	2.70		Remote connection and disconnection	Row 14	4.16
				ETSI GS OSG 001 (OSGP) ETSI TS 103 908	3.08		Load profile data	Row 17	4.21
				prTS 50568 (Meters & More)	2.87		Usability of AMI for additional services	Row 18	3.86
				prTS 50567-1 (PRIME) prTS 52056-8-4	3.13		Allow advanced information, management and control systems for services suppliers and customers	Row 20	3.95
				prTS 50567-2 (G3-PLC) prTS 52056-8-5	3.03				
				ZigBee Smart Energy Profile (SEP) 1.x	2.60				
				ZigBee Smart Energy Profile (SEP) 2.0	2.73				
				SyM^2 specification	2.38				
				energy@Home	2.65				

				prEN 50491-11 prEN 50491-12 TR 50572 (SMCG)	N.e. N.e. 3.10	CLC TC205 SMCG IEC TC13 CEN TC247 CEN TC294 ETSI M2M CLC TC57	Provision of a variable price signal to customers Fair and non-discriminatory data access for service providers On-demand meter data access Standardized interfaces and data exchange formats Bidirectional communications Support for multiple and upcoming communication technologies Standardized data profiles	Row 21 Row 22 Row 27 Row 31 Row 34 Row 35 Row 36	4.00 3.74 4.12 4.26 4.16 4.14 4.07
Smart meter certification process (non-metrology aspects) still too unclear: lack of harmonised standards-procedures, list of tests, etc. for	Row 56 (Row 57) (Row 58)	3.78	3.23	IEC 62056 (DLMS/COSEM) IEC 61968-9 (CIM) TR 50572 (SMCG)	3.55 3.25 3.10	 CEN/CLC/ETSI/SMCG	Interoperability Secure communications (ensuring data integrity &	Row 7 Row 33	4.60 4.21

	conformance certification (one meter in lab conditions) and/or performance certification (meter in the entire system, with many meters operating)				ETSI GS OSG 001 (OSGP) ETSI TS 103 908	3.08		confidentiality) Remote meter reading and management High availability Load profile data Data visualisation (consumption and billing information) Noise limitations ensuring PLC viability Bidirectional communications Standardized interfaces and data exchange formats	 Row 13 Row 16 Row 17 Row 28 Row 32 Row 34 Row 31	 4.44 4.30 4.21 4.05 3.62 4.17 4.26
					prTS 50568 (Meters & More)	2.87				
					prTS 50567-1 (PRIME) prTS 52056-8-4	3.13				
					prTS 50567-2 (G3-PLC) prTS 52056-8-5	3.03				
					ZigBee Smart Energy Profile (SEP) 1.x ZigBee Smart Energy Profile (SEP) 2.0	2.60 2.73				
					EN 13757 (M-Bus)	2.70				
					SyM^2 specification	2.38				
					Energy@Home	2.65				
Other JWG/SGCG gaps	**Smart metering functionalities for EV (SM-2)**	N.e.	N.e.	N.e.	EN 62056 (DLMS/COSEM) EN 13757 (M-Bus)	3.55 2.70	CLC TC 69 CLC TC 13 CLC TC 57	N.e.	N.e.	N.e.
	From Smart metering to Smart Grid, and e-mobility (SM-3)	N.e.	N.e.	N.e.	Cosem - CIM harmonisation project draft TS102921 draft TR102935 ISO/IEC 15118 Series	N.e. N.e. N.e. N.e.	Ad-Hoc Group IEC TC13 IEC TC57 WG17 ETSI M2M	N.e.	N.e.	N.e.

							SMCG IEC TC8 AHG4 JWG V2G CI IECTC 69 & ISO/TC22 /SC 3			
	Further develop power/distribution line communication (Com-1)	N.e.	N.e.	N.e.	IEC 62056 (DLMS/COSEM) IEEE P1901 ITU-T PLC G.9955 EMC standards	3.55 N.e. N.e. N.e.	CEN TC13 CLC TC13 CLC TC210 IEC SC 77A	N.e.	N.e.	N.e.

Table 4: Subjects of Smart metering

[1] Gen-2, SM-1, Ind-1: (Revenue metering) Harmonisation between IEC 62056-XX (DLMS/COSEM) data model and IEC 61850/CIM.
Other-2: Integration of other standardized (or on-going to be) revenue metering protocols such as Meters&More, OSGP into TC13 architecture using DLMS/COSEM as the single data model.
[2] Dis-4: Develop cyber-security around IEC 62351.
[3] New Gap 42: Enabling to use harmonized infrastructure security and administration standards across smart grid sectors and layers.
[4] New Gap 44: Applicability of requirement standards for operation and implementation of security and privacy measures.
[5] New Gap 45: Applicability of solution standards implementation of IT security measures.
[6] Ind-3: Smart metering data to building system interface.

5 SUMMARY

The selection of subjects was prepared as described in the methodology section, taking as its main guideline the perceived relevance from the point of view of various stakeholder groups. For this deliverable all in all 65 different standards or standard series were examined regarding the chosen gaps. 23 of the analysed standards concern DER subjects, 19 were chosen with respect to DR and 27 standards regarding Smart Metering. The standards were investigated with respect to a set of requirements that had been identified as crucial for the development of the Smart Grid in previous work. Furthermore, the most important contents of the standards were described and, if obvious or already known from other work, recommendations for further development were given.

This is only an intermediate step on the way to form recommendations in WP5. The scale of the selected standards and the complexity of the individual documents occupied a lot of time for identifying and scrutinise the relevant sections. Therefore focusing on the limited list of chosen subjects was a necessary restriction, even though important developments in other areas of the Smart Grid could not be covered. Even with respect to this limited but focused scope the examination can be taken as the first attempt from outside the standardisation bodies to draw an extensive picture of current Smart Grid related standardisation activities.

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APPENDIX A: DOCUMENT ANALYSIS FORM

TAB README

Sheets: The sheets *General Information* and *Classification* should preferably be filled for all standards considered.
Results of an in-depth analysis are entered in *Generic Analysis* (mainly pertaining to the relation to other standards, overall role in the standardisation landscape), and the respective *Requirements Evaluation ...* sheet (results pertaining to a specific STARGRID Area of Interest). Note that not all Requirements should be evaluated for a given document, but only those relevant to the main criticality investigated. A short publishable summary of the findings should be provided in the *Analysis Summary* sheet, where you can also find a column 'Further Observations', for any remarks relevant to the analysis, but not intended for publication.

Allowed Values: Some fields in the sheet *General Information* and all fields (except 'Comments') in the sheet *Classfication* have a fixed set of permitted entries. They can be found in the sheet *Allowed Values* .

TAB GENERAL INFORMATION

Acronym	Title	Series	Type*	Status*	Committee	Publication Date	Version	Weblink / Shop	Availability*	Scope	Normative References	Further References
e.g. IEC 61850-7-420					e.g. IEC TC 57 WG 21	YYYY (not required for standard series or industry standard series)				optional field: 1-2 sentences describing	optional field	optional field

<u>*For the allowed values in the marked columns, see sheet 'Classification Allowed Values'</u>

TAB CLASSIFICATION

STARGRID priority topic	Component Cluster*	Component / Network	SGAM Interoperability Layer	OSI communication layers	SGAM Systems (mapped to domains in WG Interop Excel sheet)	SGAM Zones	Use Cases	Affected Std. Gaps	Keywords	Roadmaps / Inventories	Medium	Comments
Note: all columns are **independent** of each other! Exception: Component Cluster and Component/ Network	The two columns are connected: the component must belong to the cluster given. If all clusters of a component are affected, choose Cluster = All			optional field May contain a range of layers (like 5-7). Note: the OSI layer(s) determine the SGAM Interoperability Layer(s), which is Communication: lower layer for OSI 1-4 and Communication: higher-layer for OSI 5-7.			optional field For Use Cases please provide a reference to a Use Case repository, where possible.	optional field reference to the SGCG gaps doc. CENCLCETSI_SGCG_Sec0059_DC or STARGRID gaps		list here roadmaps, standards inventories and the like in which the standard is mentioned and recommended for use (e.g. First Set of Standards, SGIP catalogue of standards, IEC roadmap)	optional field, for communication standards. e.g. Wireless, Cable, Power Line, optical fibre	E.g., if you are insecure about the classification, please explain the reason here. Not for publication.

For the allowed values in the different columns, see sheet 'Classification Allowed Values'

* In the IEC mapping tool standards are associated to Components only, not a specific cluster (i.e. the same standards apply to all Routers, independently of the cluster). If a standard is supposed to apply to a certain Component in all Clusters in which the Component appears, choose Cluster = All.

TAB GENERIC ANALYSIS

		Mapping to lower level communication standards	Standards with overlapping scope	Overlap description, comparison of the two standards	Documents: background information
comments		Indicate here standards at a lower interoperability layer (or OSI layer) onto which a mapping is defined. For instance, for IEC 61850 a mapping is defined to MMS and GOOSE. For TCP a mapping is defined to IP, etc.	Note: the standards listed here must be located at the same interoperability level (or OSI layer) as the original one. Only considerable overlaps should be reported (competing standards). Examples: For IEC 61850 one could list IEC 60870-5-104, both being used for substation automation. For PLC standards used in Smart Metering, other such standards could be cited (PRIME, M&M, G3-PLC, ...)		Documents containing useful background information on the standard.

TAB ANALYSIS SUMMARY

Further observations	Publishable Summary of Analysis

TAB REQUIREMENTS EVALUATION DER

	Main criticality investigated (e.g. a standardisation gap, suitability for a particular Use Case or Business Case, compatibility with regulatory aims).		**Evaluation of the standard with respect to the main criticality.**				
	Requirement/ Evaluation Criterion	**Priority Stakeholder***	**Specification of requirement/criterion [to be adapted on a case by case base]**	**Document-internal reference(s)**	**Gaps or contradictions related to the requirement**	**Fulfilment evaluation**	**Notes, Recommendations**
High Level Requirements for Standards	Manegeability		Practical application of the provisions				
	Scalability		Applicability in different contexts and dimensions				
	Affordability		Cost benefit analysis. Socio Economic benefits				
	Legal compliance		Legal aspects subtentend in compliance with current laws				
	Longevity		Time lasting perspective				

		Quality of the document		Overall quality of the document and reliability of the generation and approval process					
Specific Requirements for "DER integration and Grid Control"	System	Management of security and stability of the Supply		Provisions for Connection and Interconnection; Configuration and re-configuration; monitoring and fault diagnosis, self-healing, island operation, etc.					
		Interoperability		Reference architecture					
				Seamless communication between control centers, substations and DER installations					
				Integration into legacy grid control systems					
				Common semantic understanding					
		Safety of the system		Provisions regarding safety of Grid and DER (protection schemes)					
		Safety of the personnel		Provisions regarding Staff and Users					

		Security of the System		Provision for security to intrusions				
		EMC compatibility		EMC compatibility provisions				
	Operation	Forecasting		Forecasting of power and loads				
		Performances		Provisions of performance of systems and components				
		Remote control		Remote control of DER				
		Monitoring and instrumentation		Provisions on monitoring of Grid and DER and for sensors				
	Service	Support Quality of Supply		Continuity, Voltage and Frequency stability, FRT capability as Ancillary Services				
		Flexibility by DERs		Provisions for the Control aspecst				
	Market	Connection procedures		Provisions for connection procedures				
		Aggregation of power and loads		Aggregation of power and loads				
		Power Market access		Non- discriminatory Power Market access (including procurement)				

		Consumer empowerment		Stimulate/regulate an active attitude by users				
		Services Market		Operation/flexibility conditions; revenue of the service				
	Data Handling	Information and data exchange (definition of the information and data models)		Data to be exchanged, protocols, data models				
		Compliance certification		Compliance Testing and certification specifications (incl. e.g. simulation models requirements)				
		Data access rules		Objective and non-discriminatory data access rules for service providers (like aggregators).				
		Security of data and protection of the information.		Privacy protection provisions				

	Regulation	Harmonization and Stability		Harmonized and stable technical connection and interconnection rules at national and EU level				

Note: only selected Requirements relevant to the main criticality investigated should be evaluated.

*Priority Stakeholders are listed in the Allowed Values sheet

TAB REQUIREMENTS EVALUATION DR

	Main criticality investigated (e.g. a standardisation gap, suitability for a particular Use Case or Business Case, compatibility with regulatory aims).		**Evaluation of the standard with respect to the main criticality.**				
	Requirement/ Evaluation Criterion	**Priority Stakeholder***	**Specification of requirement/criterion [to be adapted on a case by case base]**	**Document-internal reference(s)**	**Gaps or contradictions related to the requirement**	**Fulfilment evaluation**	**Notes, Recommendations**
High Level Requirements for Standards	Manegeability		Practical application of the provisions				
	Scalability		Applicability in different contexts and dimensions				
	Affordability		Cost benefit analysis. Socio Economic benefits				
	Legal compliance		Legal aspects subtentend in compliance with current laws				
	Longevity		Time lasting perspective				

		Quality of the document		Overall quality of the document and reliability of the generation and approval process				
Specific Requirements for "DER integration and Grid Control"	System architecture	Modular architecture						
		Interoperability						
		Information Security						
	Services	Standardised market processes		E.g. customer or device de-/registration with a service provider				
		Fair and non-discriminatory data access for service providers						
	Ancillary Services	Direct remote load control						
		Incentives based load control						
		Baseline definition and service verification						

		Support for Low Frequency Demand Disconnection and Low Voltage Demand Disconnection		autonomous load disconnection in case of severe underfrequency or undervoltage				
		Support for System Frequency Control		autonomous adaption of suitable load/generation devices, e.g. temperature controlled devices, to the system frequency				
		Support for Active/Reactive Power Control		load or generation remotely adaptable by the relevant network operator for re-/active power control				
		Support for Transmission Constraint Management		load or generation remotely adaptable by the relevant network operator for the purpose of constraint management				
	Consumer empowerment	Data privacy						
		Affordability						
		Simple handling of devices and software						

		Opt-out right at any time in Demand Response programs						
		Data visualisation		e.g. operating schedules, tariff, weather forecasts				
	Communication	Standard communication interface: customer energy mangement system (CEMS) <-> market						
		Standard communication interface: CEMS <-> grid operator						
		Standard communication interface: grid operator <-> market						

		Bidirectional communications, feedback from the customer installation to grid or market operator							
		Integration of Home Gateways in legacy grid control systems							
		Interface between customer energy management infrastructure and the advanced metering infrastructure (AMI)							
		Security: authentication and encryption							

		Support for multiple and upcoming communication technologies						
	Home Gateway	Standardised basic services, such as registration, access rights & authentication, data-transfer, time synchronisation, etc.						
		Standardised protocol translation (gateway functionality)						
		Standardised runtime environment for applications; accessible to multiple service providers						

		Transparent forwarding of external control commands to connected devices						
		Providing status information on capabilities/connected devices to authorised third parties						
		Decent self-consumption						
		Specification of basic hardware requirements						

Note: only selected Requirements relevant to the main criticality investigated should be evaluated.

*Priority Stakeholders are listed in the Allowed Values sheet

TAB REQUIREMENTS EVALUATION SMART METERING

Main criticality investigated (e.g. a standardisation gap, suitability for a particular Use Case or Business Case, compatibility with regulatory aims).	Evaluation of the standard with respect to the main criticality.

	Requirement/ Evaluation Criterion	Priority Stakeholder*	Specification of requirement/criterion [to be adapted on a case by case base]	Document-internal reference(s)	Gaps or contradictions related to the requirement	Fulfilment evaluation	Notes, Recommendations
High Level Requirements for Standards	Manegeability		Practical application of the provisions				
	Scalability		Applicability in different contexts and dimensions				
	Affordability		Cost benefit analysis. Socio Economic benefits				
	Legal compliance		Legal aspects subtentend in compliance with current laws				
	Longevity		Time lasting perspective				
	Quality of the document		Overall quality of the document and reliability of the generation and approval process				

Specific Requirements for "DER integration and Grid Control"	e &	Interoperability						
		Security						
		Modularity						
	Services	Remote meter reading and management						
		Remote connection/disconnection						
		Quality of Supply control						
		High availability						
		Load profile data						
		Usability of AMI for additional services						
		Provision of data from the AMI for grid control purposes		e.g. voltage and phase measurements				
		Allow advanced information, management and control systems for services suppliers and customers						

		Provision of a variable price signal to customers							
		Fair and non-discriminatory data access for service providers							
	Consumer Empowerment	Billing based on actual consumption							
		Data privacy							
		Affordability							
		On-demand meter data access							
		Data visualisation (consumption and billing information)							
		Seamless change of provider (facilitate switching and moving)							

	Communications	Standardised interfaces and data exchange formats						
		Noise limitations ensuring PLC viability						
		Secure communications (ensuring data integrity & confidentiality)						
		Bidirectional communications						
		Support for multiple and upcoming communication technologies						
		Standardised data profiles						
	Regulation	Mandatory security provisions		authentication and encryption, data management				

		European harmonisation of metering regulations						

Note: only selected Requirements relevant to the main criticality investigated should be evaluated.

*Priority Stakeholders are listed in the Allowed Values sheet