PLATFORM FOR OPERATION OF DISTRIBUTION NETWORKS

Platone

PLATform for Operation of distribution NEtworks

D6.1 v1.0

Report on the most relevant standards

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Abstract

This deliverable provides a first analysis of the standards ecosystem around Platone. It describes protocols and standards utilized in the smart grid technology already defined by Institute of Electrical and Electronic Engineering (IEEE), the International and Electrotechnical Commission (IEC), and the International Organization for Standardization (ISO) which could potentially be used in the Platone project. The document analyses the standardization ecosystem of Smart Grids and identifies technological areas relevant to the solutions proposed in Platone's three demonstrations that are the main part of the project, including cybersecurity and blockchain. The objective of this document is to provide broader context in the domain of relevant standards for Platone implementation.

Keyword list

Blockchain, standards, platform, interoperability, electricity market

Executive Summary

The deliverable provides an overview and description of all relevant protocols and standards that the Platone platform will be based on. It describes protocols and standards utilized in the smart grid technology already defined by Institute of Electrical and Electronic Engineering (IEEE), the International and Electrotechnical Commission (IEC), and the International Organization for Standardization (ISO) which could potentially be used in the Platone project.

The standardization ecosystem of Smart Grids has been analysed and areas identified that are relevant to the solutions proposed in the three demonstrations that are the main part of the project. These standards will be used for different purposes such as Energy Management, Distribution Management, decentralized market based on blockchain technology and cybersecurity. As Platone consist of three demonstrations deployed in Italy, Greece and Germany, each with its own set of Use Cases that will be developed, an overview of the demonstrations and their respective relevant standards has been made. Certain common standards characteristic for the main Platone platform and associated with electricity system operation, blockchain and cybersecurity are common for all demonstration sites. However certain demos have highlighted specifics (e.g. storage technology, PMUs etc.) that need to be taken into consideration for future design and the associated standards were added in the analysis.

The objective of this document is providing broader context in the domain of relevant standards for Platone implementation. The next phase of the project will describe how specific standards or standardization efforts apply to Platone demonstrators and specific standards that would be best fit for purpose will be subsequently chosen as a final solution in the second version of this deliverable, D6.2.

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1 Introduction

The Platone project aims to develop an architecture for testing and implementing a data acquisitions system based on a two-layer approach (an access layer for customers and distribution system operator (DSO) observability layer) that will allow greater stakeholder involvement and will enable an efficient and smart network management. The tools used for this purpose will be based on platforms able to receive data from different sources, such as weather forecasting systems or distributed smart devices spread all over the urban area. These platforms, by talking to each other and exchanging data, will allow collecting and elaborating information useful for DSOs, transmission system operators (TSOs), customers and aggregators. In particular, the DSO will invest in a standard, open, non-discriminating, economic dispute settlement blockchain-based infrastructure, to give to both the customers and to the aggregator the possibility to more easily become flexibility market players. This solution will see the DSO evolve into a new form: a market enabler for end users and a smarter observer of the distribution network. By defining this innovative two-layer architecture, Platone removes technical barriers to the achievement of a carbon-free society by 2050, creating the ecosystem for new market mechanisms for a rapid roll out among DSOs and for a large involvement of customers in the active management of grids and in the flexibility markets. The Platone platform will be tested in 3 European trials (Greek, Germany and Italy) and the consortium aims to go for a commercial exploitation of the results after the project is finished.

1.1 Task 6.1

The purpose of Task 6.1 is to provide a solid overview, description and roles of all relevant standards, protocols and state-of-art on which the Platone platform is based. These standards will be used for different purposes such as Energy Management, Distribution Management, decentralized market based on blockchain technology and cybersecurity.

1.2 Objectives of the Work Reported in this Deliverable

The deliverable under Task 6.1 aims at researching mainly the standardization aspect of Platone. In the first few months of the project, the consortium partners studied the standardization ecosystem of Smart Grids and identified which areas are relevant to the solutions proposed in the three demonstrations that are the main part of the project. In the next phase, we will describe how specific standards or standardization efforts apply to Platone and produce guidelines that can include instructions on which standards to use in the project and, if necessary, how to use them. These guidelines are suggestions and not directions, as Platone consist of three demonstrations deployed in Italy, Greece and Germany, respectively and each country has different Use Cases that will be developed. This document identifies which standards are relevant to the solution proposed in the three demonstrations. The objective of this document is providing broader context in the domain of relevant standards for Platone implementation that will be subsequently be chosen as a final solution in the next deliverable on this subject, D6.2.

1.3 Outline of the Deliverable

The Introduction chapter presents an overview of the document structure and scope.

The second chapter gives a short overview of the Platone project, the Platone platform with its distinctive three blockchain layers and the implementation technologies. In particular, section 2.4 gives a short overview of the three demo sites in Italy, Greece and Germany and introduces standards according to their area of applicability. The third chapter gives a tabular overview of specific standards for each demo site, per category, including a differentiation between mandatory and optional recommendations. Following this overview, the individual standards are presented with more description and detail.

The Conclusion presents the main highlights of this document. The annex gives some additional descriptions of the IEEE standards.

1.4 How to Read this Document

This document is part of Task 6.1 of Platone. Task 6.1 aims at analysing the standards ecosystem and provide an overview that can be used by all Platone partners as the development of the demonstration's proceeds. This document should be read as an analysis of relevant standards, their most important traits and what aspects of Platone are relevant to those standards.

The reader is not expected to have a detailed knowledge of Platone or the specific standards but is expected to have a basic understanding of electrical engineering, ICT and the modern power system structure.

A subsequent deliverable D6.2 from Task 6.2 will provide guidelines on each demonstration on how to integrate the standards, including a listing of the standards that are or will be used in Platone.

2 Context of Platone

This chapter gives the necessary background information and sets the scene for the description of standards in chapter 3. This chapter gives an overview of the Platone project, the Platone platform and its use of blockchain technologies, and the three Platone demonstrators in Italy, Greece and Germany and the standards relevant for them.

2.1 Platone Project

Platone aims at creating unique synergies between market and operation, developing a multi-layer platform for customer integration in network operation. The key focus is placed on the edge for seamless, low-cost and efficient integration of the prosumers, in the process. Platone can be considered as a change of philosophy in grid operation: a change where the key is the customer. Platone's solution offers the end customers access to the flexibility market and all the financial/economic opportunities coming from supply of energy services from TSOs, DSO, EV providers, P2P local/virtual market players.

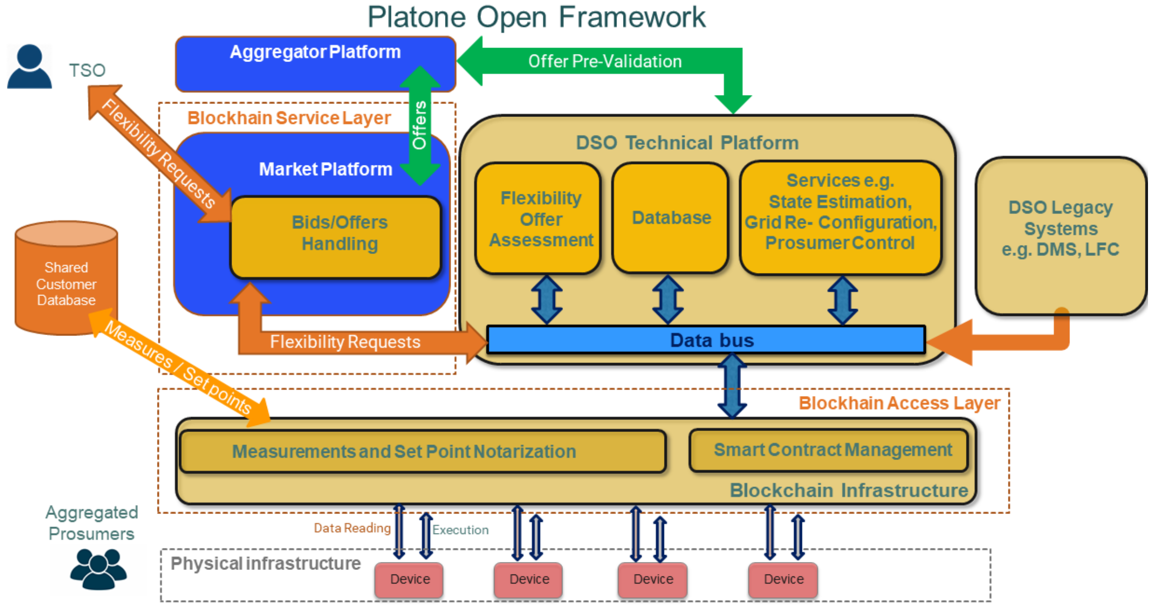

Figure 1: Platone Open Framework

The following are the areas that are of interest to the Platone demos and therefore were the main focus of our standardization ecosystem analysis.

1) Electric System Operation

a) The most central aspect of the demos is the Platone platform (DSO technical platform). Such a platform will be, naturally, in close cooperation with the Distribution Management System (DMS) of the DSOs.
b) Supervisory Control and Data Acquisition (SCADA). SCADA systems are used by all utilities. They provide information on the state of network. Although not widely used in LV, they can be an integral part of the DMS in higher voltage levels.
c) Other useful areas are Advanced Metering Infrastructure (AMI), Demand Response Management Systems (DRMS) and Energy Management System (EMS). For example, in the Greek demo, a low-cost PMU developed by RWTH Aachen will be used.

For example, of specific interest to the German demo is the use of batteries for distribution grid flexibility.

2) Home and Building Automation

Depending on the type of consumers/prosumers hypothesized or used in the demos, the relevant protocols relate to Building Management Systems, Customer Energy Management, DER control, Plug-in Electric Vehicles (PEV), Local storage and Loads. The German demo will include customer storage too.

3) Retail Energy Markets, Wholesale Energy Markets, Enterprise

Platone architecture has a Market Platform as an integral part. All Target model aspects are relevant to some extent. For example, in retail markets, AMI, DRMS, Customer Information Systems (CIS) and Billing standards are to be considered. Additionally, Aggregators and Energy Trading are relevant in wholesale markets.

4) Security

For Platone one of the most important issues is cybersecurity. Hence, relevant standards will be a separate part of the analysis. Additionally, Platone will look into the field of data handling.

5) Blockchain

a) Possibly the second most important aspect in Platone is blockchain and its application in the demos. Blockchain technology in Platone is applied in two layers. First, we have the Blockchain Access Layer which is interfacing end users with the Platone Platform, aiming at increasing security and trustworthiness.
b) Secondly, there is the Blockchain Service Layer which corresponds to the Market Platform developed in Platone. The Market Platform is built to handle flexibility requests.

The above areas of interest are categorized with the help of IEC's standards map:

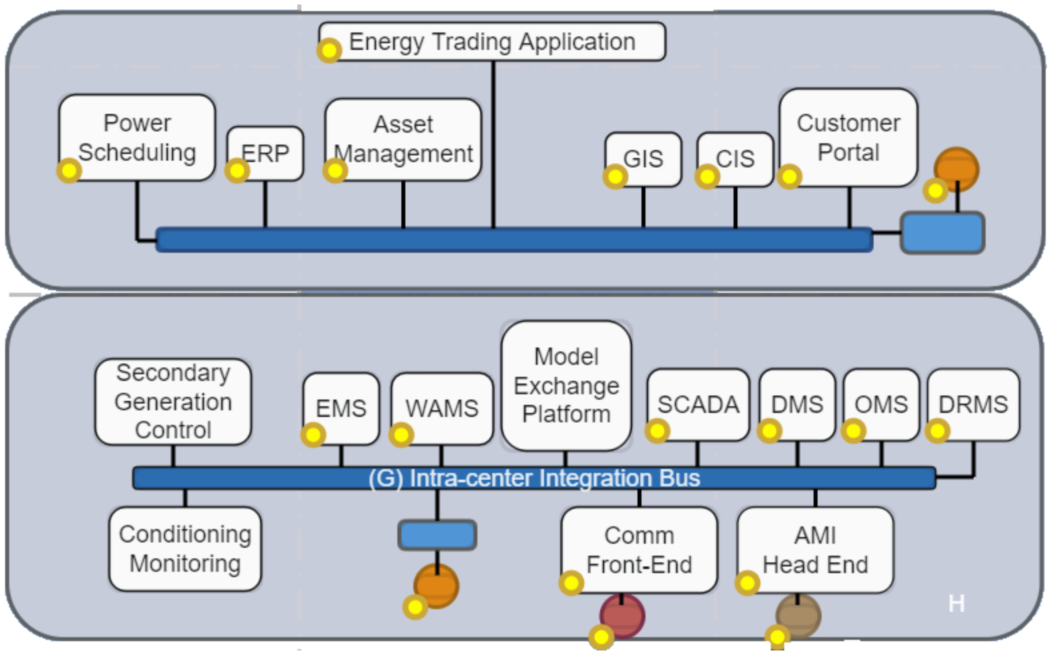

Figure 2: Categorization of sub-grouped area in smart grid standards map [1]

2.2 Blockchain Technology

2.2.1 Introduction

In the last years, there has been an increasing proliferation of energy use cases and potential applications, which might gain benefits from blockchain distributed ledger technologies (DLTs) and smart contracts technologies.

The state of the art DLT Blockchain-based infrastructure usage for the smart energy grids is heterogeneous. Private or permissioned blockchain backbone technology, enabling transparent yet simultaneous data sharing and coordinated market optimization, is more mature than the application of DLT and smart contracts, which are aimed at supporting grid operation and control. While blockchain seems promising for data sharing and market operation, it cannot be applied so easily for grid operation and control tasks, where the scalability is limited by the speed of the blockchain transaction protocols. DLTs and smart contracts technologies provide an immutable tamper-proof decentralized environment for data storage and multi-party simultaneous data sharing, with increased transparency, transaction traceability, and transaction verification, resulting in making available the same information on the electricity measurements, on the flexibility market transactions, as well as DSO set points for prosumers simultaneously to all the energy stakeholders.

2.2.2 Platone Platform Based on Blockchain

Platone will develop a cost effective two-layer platform where edge cloud technology supported by blockchain mechanisms provides an easy and secure access to customer-level data for operation and flexibility markets. The Platone solution will be developed integrating also advanced monitoring data-driven algorithms for increased observability up to the low voltage level and the inclusion of low cost high-precision measurement devices. The Platone platform will be a scalable solution for the distribution operator provided as a turnkey service.

Figure 3: Platone framework architecture

The Platone framework aims to create a fully replicable and scalable system that enables distribution grid flexibility/congestion management mechanisms through P2P (Peer 2 Peer) market models involving all the possible actors at any level (DSOs, TSOs, Customers, and Aggregators). The Platone framework, as shown in Figures 1 and 3, will be provided by a third-party service provider, which could be the DSO, for the benefit of the participants. The framework consists of two blockchain layers, as detailed below.

2.2.2.1 Blockchain Service Layer

- **Market Platform**

This platform allows the support of wide geographical area flexibility requests form TSOs and local flexibility requests from DSOs. These are matched with offers coming from Aggregators, resolving conflicts according to pre-defined rules of dispatching priorities. This platform will simulate all the different TSO's flexibility /congestion requests and behaviours, will collect the DSO's local requests of flexibility and will manage the aggregator's/ customers' offers of flexibility.

- **DSO Technical Platform**

The DSO Technical Platform is the core of the framework and allow DSOs to manage the distribution grid in a secure, efficient and stable manner. It includes all the tools and services that enable monitoring and control of the grid, and additionally observability mechanisms improving network security, reliability, operational quality levels and resiliency. Furthermore, this platform is able to receive flexibility request from the Market Platform and negotiate them. This platform will also have a direct connection to the classical SCADA (Supervisory Control and Data Acquisition) system adopted by the DSO using standard IEC (International Electrotechnical Commission) communication standards. A custom open API (Application Program Interface) will define how the SCADA system on the other side will access the service in the new DSO Technical Platform.

2.2.2.2 Blockchain Access Layer

The Blockchain access layer adds a further level of security and trustworthiness to the framework. It is an extension of physical infrastructure and performs multiple tasks, among which the data certification and automated flexibility execution through Smart Contracts. Furthermore, it includes a shared data archive component, where all certified data are registered together with all flexibility requests, thus resolving the entire data dispute. In particular, it registers: i) energy measurement, ii) signalling of flexibility requests from the market to the customer, iii) collection of customer response to the market request, iv) electrical behaviour of the customer respect to grid conditions. For data archive realization different technologies will be investigated including distributed file systems (such as InterPlanetary File System) and cloud-based solutions.

2.2.2.3 Physical Infrastructure

The physical infrastructure, consisting of Smart Meters and Actuators for each customer's RES plant, is integrated to the platform via the Blockchain Access Layer by exploiting a Blockchain nodes infrastructure. These components allow the Platone framework to obtain the distribution grid data and execute the flexibility requests becoming from the Market.

2.2.3 Technology concerning Blockchain Implementation in Platone

Starting from the H2020 TRL5 eDREAM DLT/Smart contract platform, we will evolve towards a more Hybrid IoT-Blockchain architecture, which will be conveniently utilized within the scope of Platone as a low-cost ICT DLT-based backbone enabling DSO-facilitated third party access to the data. This combines the benefits of traceability and simultaneous multi-party data sharing, as offered by DLT and blockchain architectures, with the scalability offered by decentralized node-level data storage, by leveraging on InterPlanetary File System (IPFS) or Story Distributed File System, with a view to ensuring the appropriate scalability of data storage and access, while minimizing the data stored in the blockchain and maintaining the data integrity.

Still for data handling, evolution solutions like BigchainDB will be investigated: this is a blockchain-based technology combining blockchain and traditional database concepts that utilizes existing blockchain consensus engines – like Tendermint (which supports Proof-of-Stake consensus algorithms) – to handle the P2P communication and immutability, and stores data in MongoDB, which makes it possible to apply powerful queries on the data, thus tackling the issue of efficient data handling via blockchain mechanism architectures. Tendermint also offers native support for representing assets such as time series and specifying multiple ownership over them.

The hybrid blockchain is best defined as the blockchain that attempts to use the best part of both private and public blockchain solutions. In an ideal world, a hybrid blockchain will mean controlled access and freedom at the same time. The distinguishing characteristic of hybrid blockchains is that they are not open to everyone, but still offer blockchain features such as integrity, transparency, and security. Hybrid blockchain is entirely customizable. The members of the hybrid blockchain can decide who can participate in the blockchain or which transactions are made public. This brings the best of both worlds and ensures that a company can work with their stakeholders in the best possible way.

2.3 Platone Demos

Platone consist of three demonstrations deployed in Italy, Greece and Germany, respectively. This chapter identifies which standards are relevant to the solution proposed in the three demonstrations that are the main part of the project.

2.3.1 Overview of Platone Demo in Italy

The Italian demo will implement a complete *"END TO END FLEXIBLE"* environment, i.e. a real integrated market where, applying highly innovative distribution network technologies like Blockchain and new grid equipment, retail and business customers interact with both Aggregators (to access new flexibility market options) and the DSO to become active players of the "network optimized management" in an effective and efficient Active Distribution Network.

The technologies implemented in this demo will be based on the grid observability in Medium and Low Voltage networks, according to the Active Distribution Network model, in conjunction with a standard, transparent and shared customer access interface, which is Blockchain-based. The general infrastructural/functional pilot architecture is represented in Figure 4.

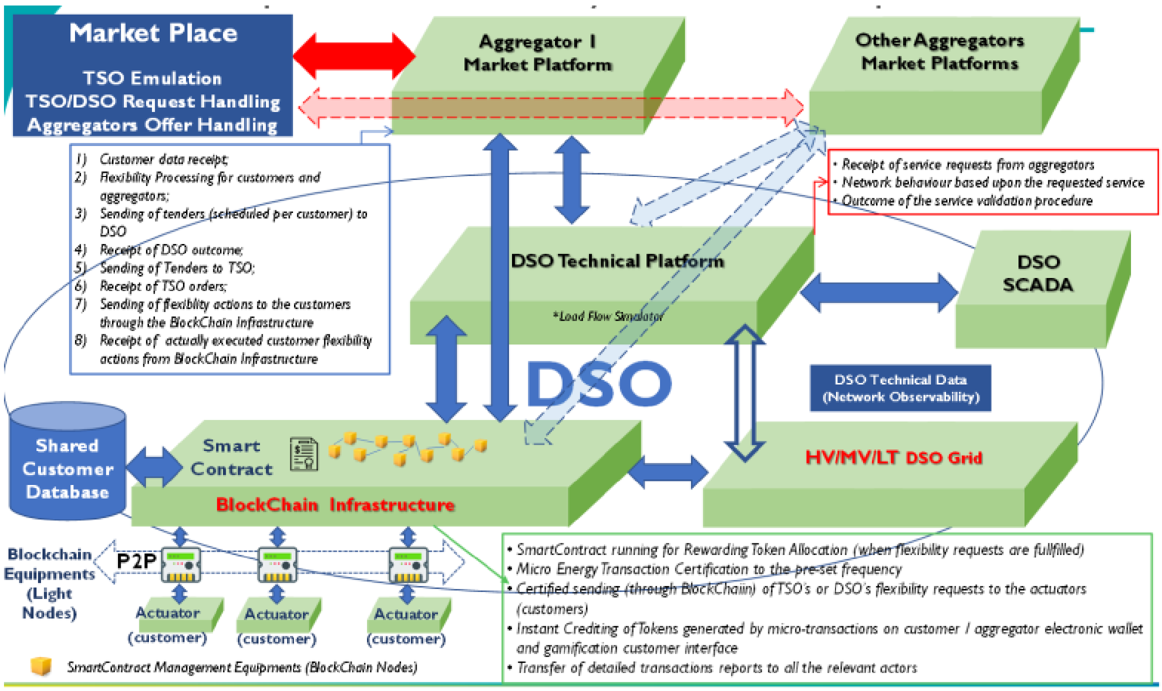

Figure 4: Architecture of the Italian demo.

To enable the Active Distribution Network, first of all, the grid observability will be increased in the Medium and in Low Voltage levels, installing new electronic devices on the: (i) DSO infrastructure to measure the electrical quantities and detect weather conditions (Device owned by DSO); (ii) – Users' "plant" to measure the electrical quantities and certify flexibility requests and actions thanks to innovative Blockchain Based apparatus; (iii) Other stakeholders' platforms and systems managing distributed IoT data.

The DSO will gather data from the field, will analyse them and will decide the actions for solving the critical grid issues (congestions, voltage violations) involving the resources (i.e. the customers) connected to the grid through a local market-based approach. In this picture, the Aggregator acts as an intermediary between the DERs at the end-customer premises and the local markets. By means of aggregation, it allows the relatively small and dispersed flexibility to be used by the DSO for solving technical problems arising due to changing electricity grid conditions.

The active role of the DSO foreshadows a new model of the dispatching market, enabling the use of the customers' flexibility in MV and LV grids and identifying solutions to overcome the barriers that limit the participation of these resources to the market. For instance, since meter data for the dispatching market must have a high sampling frequency (4 seconds), creating a cost barrier for the LV customers, to include this kind of users in the flexibility market (and opening a mass flexibility market), the Italian demo will implement a standard and cost-efficient solution for enabling this huge potential. Furthermore, another problem caused by the RES connected to distribution grid is the difficult predictability of their energy flows; the Italian demo will upgrade the DSO system architecture including the analysis of the LV grid and elaborating real-time state estimation.

The flexible power proposal offered by the Aggregator is produced thanks to information coming from the DSO's BlockChain platform. This platform has to collect and certify the meter data from the individual end-users every 4 seconds. In addition, the Blockchain infrastructure will certify the DSO validation of the Aggregator's offer and will consequently send the certified set points to the final customers to implement flexibility services. According to the DSO's responsibility in metering data collecting and sharing, a "Shared Customer Database" will be developed that transparently provides to all the authorized players (Aggregators, customers, TSOs…) involved in the flexibility market, all the Blockchain certified requests and measures logs to calculate the flexibility action results, realizing a cost-efficient general system since the same metering / certifying infrastructure serves all the market players.

This Blockchain-based infrastructure will cost-efficiently and easily enable:

- Aggregators to elaborate financial statements to remunerate customers and get paid by the Market Place;
- Customers to verify their flexibility behaviour and the financial remuneration coming from the Aggregator;
- TSO to obtain all the requested aggregated data of customer energy production/consumption;
- thanks to the "Smart Contract" technology embedded in the Blockchain Platform, the system automatically solves commercial disputes between parties and enables easy billing services;
- Switching capability of customers between different Aggregators;
- Lowering of access barriers to the flexibility market for Aggregators and customers, since the investments on the grid-customer interface are implemented by the DSO;
- Standardization, toward customer automation, fostering the growth of the automation equipment market.

2.3.1.1 Standards concerning the Italian Demo

This demo site requires extensive use of standards associated with DSO data exchange, namely standards associated with SCADA systems like IEC 60870 part 5, which define systems used for telecontrol in electrical engineering and power system automation applications, aimed for communication of data between the control centre and field units such as RTUs and relay protection. This extends also to consideration of the more novel IEC 61850 standard. In addition, the standards for communication between control centres, such as IEC 60870 part 6 are relevant. Active distribution network standards also described in the following chapters apply as well, as do standards described in AMI and building management systems. In particular, blockchain standards associated with electricity market apply here too.

2.3.2 Overview of Platone Demo in Greece

The Mesogia demo aims to demonstrate the ability of DERs to provide ancillary services to the system, participate in the DA and Balancing market and contribute to the secure operation of the distribution network. Such demonstrations allow for the increase in penetration of renewable energy, in use of ICT to provide better services to the customers and in the social welfare through better exploitation of resources. The demo site "Mesogia" is located in the area of Mesogia at the south-eastern part of Attica, near Athens. HEDNO has used Mesogia for the implementation of innovative pilot projects (e.g. Geographic Information System), which are expected to be expanded in the future to the rest of Greece after their successful completion there. Besides, the Mesogia area is considered as ideal for demonstration purposes since: a) it combines parts of the mainland and interconnected islands, which is an interesting mixture of locations, systems and infrastructure to be studied, b) provides a mix of rural, urban and suburban areas, c) consists of a customer mix including households, small, medium and large industries, d) has good RES penetration of various types and e) is close to the capital.

In the Mesogia demo, the following High-Level Use cases will be implemented:

- Use of Distributed Energy Sources (DERs) to provide ancillary services and balancing market participation to the TSO. The use of DERs will be economically optimal within the limits of the transmission and distribution system.
- Advanced, observability, automation and controllability in the distribution network fault-detection, self-reconfiguration and self-healing for increased security and resilience of the distribution system. State-estimation and forecasting methods will be employed.
- Optimal control of DERs both in the DA and real-time time frames for market participation, mitigation of congestions and voltage limit violations, and minimization of losses

2.3.2.1 Standards concerning the Greek Demo

This demo site also requires the use of standards associated with DSO’s data exchange, namely, standards associated with SCADA systems that facilitate communication between the control centre and a smart distribution station. This extends also to consideration of the more novel IEC 61850 standard. Also, low-cost PMU developed by RWTH Aachen will be used. Active distribution network standards associated with DRMS also described in the following chapters apply as well, as do standards described in AMI. In particular, blockchain standards associated with electricity market apply here too. These standards are elaborated further in section 3.

2.3.3 Overview of the Platone Demo in Germany

The German Demo Site consists of a low voltage network in a rural area with a high penetration of DER. It is in these regions where a high potential for DER meets a low residential and commercial load that the challenges of the energy transition surface first. Due to a low load situation, dimensioned network limits are likely to be exceeded. For example, over the past years, Avacon has been uprating numerous distribution transformers to account for a power export-potential that exceeds the local consumption. The German demonstrators aim at utilizing energy storage to minimize the exchange between the local network and the supplying mid-voltage feeder. In this way, the cumulative strain on the MV feeder caused by a number of power-exporting substations shall be reduced. While the control-logic to dispatch the battery will be key, the demonstrator also targets questions concerning the combination of different control strategies for small scale flexibilities. There will be an element of local control, but it must be operated in the larger context of the distribution network. At some point, the requirements of higher voltage levels might clash with the local balancing mechanism. DSOs need to prepare for these situations and develop control mechanisms and decision-making tools to properly allocate flexibility between networks at different voltage levels.

Beyond the coordination between local balancing and distribution operation, another path of investigation is the uncoupling of low- and medium voltage networks in terms of momentary power. Instead of supplying the local network in real-time, Avacon will develop the control logic and forecasting algorithms to deliver energy in bulk to the network in advance at times suitable for the network. The energy then gets stored in the local storage assets and can be withdrawn as needed. Similarly, power exports can be stored in local storage assets and then get “collected” by the DSO at suitable times. This concept of energy up- and downloads requires efficient forecasting mechanisms for local consumption and production and an effective algorithm to plan the energy up- and downloads from and into the local network. Scaled across an entire feeder and equipped with sufficient storage capacity, this concept could significantly reduce feeder loading and increase hosting capacity for DER.

The field test site consists of

- A smart distribution station which includes metering devices, on-line communication with SCADA, remote controllability and a control module to coordinate the local flexibility.
- A battery that stores energy and enables the use cases.
- Battery installations on customer premises.

- Customers equipped with smart metering and control devices to leverage existing flexibility in households.
- A central control engine in the grid control environment to monitor the network and flexibility and coordinate between local balancing mechanism and SCADA.

2.3.3.1 Standards concerning the German Demo

This demo site also requires use of standards associated with DSO data exchange, namely standards associated with SCADA systems aimed for communication of data between control centre and smart distribution station. Particular consideration of storage standards is relevant for this demo site. Active distribution network standards also described in the following chapters apply as well, as do standards described in AMI and building management systems. In particular, blockchain standards associated with electricity market apply here too. These standards are elaborated further in section 3.

3 Standards Relevant to Platone

The demo sites have different characteristics and therefore in order to interpret and link the standards and their relevance to individual sites, the following tables provide more information. Chapter 3.1 gives an overview of standards relevant for the three demonstration sites grouped under relevant domains of application. Details of the standards are given per domain in the sub-chapters 3.2 to 3.10.

3.1 Summary Tables per Demo

3.1.1 Italian Demo

Table 1: Proposed standards for the Italian demo site

Standards	Mandatory	Optional
DRMS		
IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems	•	
IEEE P2030 Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the (EPS) and End-Use Applications and Loads		•
IEEE P2030.4 Guide for Control and Automation Installations Applied to the Electric Power Infrastructure		•
IEC 61850 Power Utility Automation		
SCADA		
IEC 60870-5 Telecontrol (supervisory control and data acquisition)	•	
IEC 60870-6 Telecontrol (supervisory control and data acquisition)	•	
C37.118 Standard for Synchrophasor Measurements for Power System	•	
IEEE 1815 Standard for Electric power system communication Distributed Network protocol(DNP)	•	
IEEE 1711 Standard for a Cryptographic Protocol for Cyber Security of Substation Serial Links		•
IEEE 1711.1 Standard for a Cryptographic Protocol for Cyber Security of Substation Serial Links: Substation Serial Protection Protocol		•
IEEE 1711.2 Standard for Secure SCADA Communications Protocol (SSCP)	•	
AMI		
IEC 62056 Standard for Energy Metering	•	

IEC 62051-54/58/59 - Electricity Metering	•	
IEC 62055 Payment System	•	
ANSI C12.19 Standard for Utility Industry End Device Data Tables	•	
IEEE 1377 Standard for Utility Industry metering Communication Protocol Application Layer (End Device Data Tables		•
IEEE 1701 Standard for Optical Port Communication Protocol to Complement the Utility Industry End Device Data Tables	•	
IEEE 1703 Standard for (LAN/WAN) Node Communication Protocol to Complement the Utility Industry End Device Data Tables	•	
Building Energy Management System		
ISO 1780 Facility Smart Grid Information Model	•	
Blockchain and Energy Market		
IEC 62325 Framework for Energy Market Communications	•	
IEEE P2418.5 Standard for Blockchain in Energy	•	
ISO/TR 23455:2019 Blockchain and distributed ledger technologies	•	
IEEE P2418.1 Standard for the Framework of Blockchain Use in Internet of Things	•	
IEEE P2140.1 Standard for General Requirements for Cryptocurrency Exchanges	•	
IEEE P2140.2 Standard for Security Management for Customer Cryptographic Assets on Cryptocurrency Exchanges		•
IEEE P2140.4 Standard for Distributed/Decentralized Exchange Framework using DLT	•	
IEEE P2141.3 Standard for Transforming Enterprise Information Systems from Distributed Architecture into Blockchain-based Decentralized Architecture		•
IEEE P2144.1 Standard for Framework of Blockchain-based Internet of Things Data Management	•	
IEEE P2144.2 Standard for Functional Requirements in Blockchain-based Internet of Things Data Management	•	
IEEE P2144.3 Standard for Assessment of Blockchain-based Internet of Things Data Management	•	

3.1.2 Greek Demo

Table 2: Proposed standards for the Greek demo site

Standards	Mandatory	Optional
DRMS		
IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems	•	
IEEE P2030 Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the (EPS) and End-Use Applications and Loads		•
IEEE P2030.4 Guide for Control and Automation Installations Applied to the Electric Power Infrastructure		•
IEC 61850 Power Utility Automation		
Distribution Automation		
IEC 61850-7-4 Part 7-4: Basic communication structure – Compatible logical node classes and data object classes	•	
IEC 61850-7-420 Part 7-420: Basic communication structure – Distributed energy resources logical nodes	•	
SCADA		
IEC 60870 – 5 Telecontrol (supervisory control and data acquisition)	•	
IEC 60870 -6 Telecontrol (supervisory control and data acquisition)	•	
C37.118 Standard for Synchrophasor Measurements for Power System	•	
IEEE 1815 Standard for Electric power system communication Distributed Network Protocol (DNP)	•	
IEEE 1711 Standard for a Cryptographic Protocol for Cyber Security of Substation Serial Links		•
IEEE 1711.1 Standard for a Cryptographic Protocol for Cyber Security of Substation Serial Links: Substation Serial Protection Protocol		•
IEEE 1711.2 Standard for Secure SCADA Communications Protocol (SSCP)	•	
AMI		
IEC 62056 Standard for Energy Metering	•	
IEC 62051-54/58/59 - Electricity Metering	•	

IEC 62055 Payment System	•	
ANSI C12.19 Standard for Utility Industry End Device Data Tables	•	
IEEE 1377 Standard for Utility Industry metering Communication Protocol Application Layer (End Device Data Tables		•
IEEE 1701 Standard for Optical Port Communication Protocol to Complement the Utility Industry End Device Data Tables		•
IEEE 1703 Standard for (LAN/WAN) Node Communication Protocol to Complement the Utility Industry End Device Data Tables	•	
Building Energy Management System		
ISO 1780 Facility Smart Grid Information Model	•	
Blockchain and Energy Market		
IEC 62325 Framework for Energy Market Communications	•	
IEEE P2418.5 Standard for Blockchain in Energy	•	
ISO/TR 23455:2019 Blockchain and distributed ledger technologies	•	
IEEE P2418.1 Standard for the Framework of Blockchain Use in Internet of Things	•	
IEEE P2140.1 Standard for General Requirements for Cryptocurrency Exchanges	•	
IEEE P2140.2 Standard for Security Management for Customer Cryptographic Assets on Cryptocurrency Exchanges		•
IEEE P2140.4 Standard for General Requirements for Cryptocurrency Exchanges	•	
IEEE P2141.3 Standard for Transforming Enterprise Information Systems from Distributed Architecture into Blockchain-based Decentralized Architecture		•
IEEE P2144.1 Standard for Framework of Blockchain-based Internet of Things Data Management	•	
IEEE P2144.2 Standard for Functional Requirements in Blockchain-based Internet of Things Data Management	•	
IEEE P2144.3 Standard for Assessment of Blockchain-based Internet of Things Data Management	•	

3.1.3 German Demo

Table 3: Proposed standards for the German demo site.

Standards	**Mandatory**	**Optional**
Energy Storage		
IEC 62933 Electrical Energy Storage	•	
IEEE 2030.2.1 Guide for Design, Operation and Maintenance of Battery Energy Storage Systems, both Stationary and Mobile and Applications Integrated with Electric Power System	•	
IEEE 937 Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for (PV) Systems		•
IEEE 1679 Recommended Practice for Characterization and Evaluation of Emerging Energy Storage Technologies in Stationary Applications		•
IEEE 1013 Recommended Practice for Sizing Lead-Acid Batteries for Stand-Alone Photovoltaic (PV) Systems		•
IEEE 1361 Guide for Selecting, Charging, Testing and Evaluating Lead-Acid Batteries Used in Stand-Alone Photovoltaic (PV) Systems		•
IEEE 1561 Guide for Optimizing the Performance and Life of Lead-Acid Batteries in Remote Hybrid Power System		•
IEEE 1661 Guide for Test and Evaluation of Lead-Acid Batteries used in Photovoltaic (PV) Hybrid Power System		•
SCADA		
IEC 60870 – 5 Telecontrol (supervisory control and data acquisition)	•	
IEC 60870 -6 Telecontrol (supervisory control and data acquisition)	•	
C37.118 Standard for Synchrophasor Measurements for Power System	•	
IEEE 1815 Standard for Electric power system communication Distributed Network protocol(DNP)	•	
IEEE 1711 Standard for a Cryptographic Protocol for Cyber Security of Substation Serial Links		•
IEEE 1711.1 Standard for a Cryptographic Protocol for Cyber Security of Substation Serial Links: Substation Serial Protection Protocol		•

IEEE 1711.2 Standard for Secure SCADA Communications Protocol (SSCP)	•	
AMI		
IEC 62056 Standard for Energy Metering	•	
IEC 62051-54/58/59 - Electricity Metering	•	
IEC 62055 Payment System	•	
ANSI C12.19 Standard for Utility Industry End Device Data Tables	•	
IEEE 1377 Standard for Utility Industry metering Communication Protocol Application Layer (End Device Data Tables		•
IEEE 1701 Standard for Optical Port Communication Protocol to Complement the Utility Industry End Device Data Tables		•
IEEE 1703 Standard for (LAN/WAN) Node Communication Protocol to Complement the Utility Industry End Device Data Tables	•	
Building Energy Management System		
ISO 1780 Facility Smart Grid Information Model	•	
Blockchain and Energy Market		
IEC 62325 Framework for Energy Market Communications	•	
ISO/TR 23455:2019 Blockchain and distributed ledger technologies	•	
IEEE P2418.5 Standard for Blockchain in Energy	•	
IEEE P2418.1 Standard for the Framework of Blockchain Use in Internet of Things	•	
IEEE P2140.1 Standard for General Requirements for Cryptocurrency Exchanges	•	
IEEE P2140.2 Standard for Security Management for Customer Cryptographic Assets on Cryptocurrency Exchanges		•
IEEE P2140.4 Standard for Distributed/Decentralized Exchange Framework using DLT	•	
IEEE P2141.3 Standard for Transforming Enterprise Information Systems from Distributed Architecture into Blockchain-based Decentralized Architecture		•
IEEE P2144.1 Standard for Framework of Blockchain-based Internet of Things Data Management	•	

IEEE P2144.2 Standard for Functional Requirements in Blockchain-based Internet of Things Data Management	•	
IEEE P2144.3 Standard for Assessment of Blockchain-based Internet of Things Data Management	•	

3.2 Standards regarding SCADA communications

- **IEC 60870-5**

The IEC 60870-5 standard was developed by IEC Technical Committee 57 to provide a protocol for sending basic telecontrol messages from the telecontrol master station to outside stations which are connected through some form of permanent communication link. The telecontrol messages are transferred between the telecontrol equipment in the form of coded serial data which is used for monitoring and controlling of wide are processes. The part 5 of IEC 60870 defines the interoperability among the telecontrol equipment. This standard is a combination of application layer of IEC 60870-5-101 and transport layer of TCP/IP standard. Within the TCP/ IP, there is an independent choice of telecommunication networks such as X.25, ATM, and Frame Relay. The IEC 60870-5 supports unbalanced and balanced modes of data transfer, provides unique addresses for master telecontrol stations, a time synchronization facility, a data classification facility and a cyclic data updating facility. [2]

Table 4: IEC 60870-5 standards regarding SCADA controlling and monitoring

IEC 60870-5-101	Telecontrol equipment and systems - Part 5-101: Transmission protocols - Companion standard for basic telecontrol tasks. [3]
IEC 60870-5-103	Telecontrol equipment and systems - Part 5-103: Transmission protocols - Companion standard for the informative interface of protection equipment. [4]
IEC 60870-5-104	Telecontrol equipment and systems - Part 5-104: Transmission protocols - Network access for IEC 60870-5-101 using standard transport profiles. [5]

- **IEC 60870-6**

This is one of the IEC 60870 set of standards which define systems used for telecontrol (supervisory control and data acquisition) in electrical engineering and power system automation applications. The IEC Technical Committee 57 (Working Group 03) has developed part 6 to provide a communication profile for sending basic telecontrol messages between two systems which is compatible with ISO standards and ITU-T recommendations. [6]

- **IEEE C37.118.1-2011 - IEEE Standard for Synchrophasor Measurements**

Synchronized phasor (synchrophasor) measurements for power systems are presented. This standard defines synchrophasors, frequency, and rate of change of frequency (ROCOF) measurement under all operating conditions. It specifies methods for evaluating these measurements and requirements for compliance with the standard under both steady-state and dynamic conditions. Time tag and synchronization requirements are included. Performance requirements are confirmed with a reference model, provided in detail. This document defines a phasor measurement unit (PMU), which can be a stand-alone physical unit or a functional unit within another physical unit. This standard does not specify hardware, software, or a method for computing phasors, frequency, or ROCOF. [7]

- **IEEE C37.118.2-2001 - IEEE Standard for Synchrophasor Communication**

The IEEE C37.118.2 standard defines a method of exchange of synchrophasor data between the power system devices. It provides the guidelines for data message formats which are to be exchanged between a PMU and PDC. It defines various messages which are exchanged for realizing a handshake operation between the PMU and PDC. The following type of messages are employed in synchrophasor measurement viz. data, configuration, header and command. [8]

- **IEEE 1815-2012 Standard for Electric power system communication Distributed Network protocol(DNP)**

Distributed network protocol (DNP3) was drafted for providing open, interoperable communication among substation computers, IEDs, remote terminal unit (RTUs) and master stations in the electric utility industry. DNP3 was developed by IEC TC 57 working group (WG-3) who have been working on OSI three layer “enhanced performance architecture (EPA)” for telecontrol applications. DNP3 is also the recommended practice for RTU to IED communication protocol. DNP3 was first developed by Harris Distributed Automation Products (originally Westronic, Inc.) and later it was managed by the DNP3 users group which is composed of vendors and electric utilities which are using the DNP3 protocol. Amendments and modifications in the current draft of DNP3 are carried out by the DNP3 users’ technical group. To ensure interoperability, longevity and upgradeability of DNP3 protocol, the modifications and recommendations are made open to DNP3 technical group. DNP3 is not limited to serial communication inside the substations but the widespread functionality of DNP3 make it usable with TCP/IP networks having Ethernet, frame relay, fibre-optic-based communication media.[9]

3.3 Standards regarding DMS and EMS

CIM (Common information model IEC 61970/61968)

- **IEC 61970 – Energy management**

Provides a set of guidelines and general infrastructure capabilities required for the application of the EMS-API interface standards. Describes typical integration scenarios where these standards are to be applied and the types of applications to be integrated. Defines a reference model and provides a framework for the application of the other parts of this EMS-API standards. [10]

- **IEC 61968 – Distribution management**

This is the first part in a series of standards that define interfaces for the major elements of an interface architecture for Distribution Management Systems. It identifies and establishes requirements for standard interfaces based on an Interface Reference Model. This set of standards is limited to the definition of interfaces and is implementation independent; it provides for interoperability among different computer systems, platforms, and languages. [11]

- **IEC 62357 - Service Oriented Architecture**

IEC/TR 62357-1:2016(E) specifies a reference architecture and framework for the development and application of IEC standards for the exchange of power system information. This technical report provides an overview of these standards as well as guidelines and general principles for their application in distribution, transmission, and generation systems involved in electric utility operations and planning. The future multi-layer reference architecture described in this technical report takes into account new concepts and evolving technologies, such as semantic modelling and canonical data models, in order to build on technology trends of other industries and standards activities to achieve the interoperability goals of the Smart Grid. [12]

3.4 Standards regarding AMI

- **IEC 62056 Standards for Electricity Metering - Data exchange for meter reading, tariff and load control specifies meter data exchange, including data models, messaging methods and communication media specific protocols.**

DLSM/COSEM Protocol

DLMS/COSEM is global standard for smart energy metering, control and management. It utilizes an object-oriented data model to abstractly define an energy application and a protocol tailored for communication with smart meters that lies in the application layer. It includes data model, messaging and communication protocol standards for data exchange over local ports, PSTN, GSM, GPRS, Internet and, more recently, narrow band PLC.

The COSEM interface is capable of producing the necessary classes (and their instances) to adequately model every energy application that is needed. The main advantages of this methodology is that it boosts the process of application creation, facilitates their maintenance and monitoring and makes them portable since it is a modular approach. Furthermore, this modularity offers the capability of forming all types of use cases, from simple ones to highly sophisticated ones.

This standard adopts a client/server approach to transform information deriving from objects/application into messages. In this context, meters are considered to be the servers and aggregator units, where data is collected, corresponding to clients. At a lower level DLMS/COSEM supports several lower layer protocols like communication over TCP, UDP, RS-232, RS-485 and as well as power line protocols such as G3. Moreover, there is optical interface installed in front of numerous meters. [13]

- **The IEC 62055 Series Electricity metering – Payment System**

Payment System specifies a framework for standardization, including functions, processes, data elements, system entities and interfaces, type testing of payment interfaces and a physical and application layer protocol for one way and two way token carrier systems. Recently, work has been started on multi-part installations, which may be highly relevant for smart metering. Its approach may be useful for the specification of smart metering systems.

Table 5: IEC 62055 standards regarding payment systems

IEC 62055-21: 2005	**Electricity metering - Payment systems - Part 21: Framework for standardization. [14]**
IEC 62055-31: 2005	Electricity metering - Payment systems - Part 31: Particular requirements - Static payment meters for active energy (classes 1 and 2). [15]
IEC 62055-41: 2018	Electricity metering - Payment systems - Part 41: Standard transfer specification (STS) - Application layer protocol for one-way token carrier systems. [16]
IEC 62055-51: 2007	Electricity metering - Payment systems - Part 51: Standard transfer specification (STS) - Physical layer protocol for one-way numeric and magnetic card token carriers. [17]
IEC 62055-52: 2008	Electricity metering - Payment systems - Part 52: Standard transfer specification (STS) - Physical layer protocol for a two-way virtual token carrier for direct local connection. [18]

- **ANSI C12.19**

The ANSI C12.19 standard provides a common data structure used in transferring data and from the utility End Devices, typically meters. It is initiated by ANSI and has been approved after considerable cooperative effort among utilities, meter manufacturers, ANSI, NEMA, IEEE, and others. Today, it is widely adopted by AMI vendors in the North American Market. The heart of this standard is a set of defined standardized tables and procedures, which are described by extensible markup language (XML) notation. Tables are used to store the collected meter data and control parameters; while procedures provide a method of invoking actions in the meter. In its latest version, C12.19 has been extended to cover Smart Grid related functionalities, such as Time-Of-Use function and the Load Profile function. [19]

- **IEEE 1377-2012 - IEEE Standard for Utility Industry metering Communication Protocol Application Layer (End Device Data Tables)**

This standard defines a table structure for utility application data to be passed between an End Device and any other device. It neither defines device design criteria nor specifies the language or protocol used to transport that data. The tables defined in this standard represent data structure that shall be used to transport the data, not necessarily the data storage format used inside the End Device. [20]

- **IEEE 1701-2011 – IEEE Standard for Optical Port Communication Protocol to Complement the Utility Industry End Device Data Tables**

This is identified by three numbers, MC1218-2009, ANSI C12.18-2006 and IEEE 1701-200X. The standard details the criteria required for communications with a Utility End Device by another device via an optical port. The other device could be a hand held reader, a laptop or portable computer, a master station system, or some other electronic communications device. [21]

- **IEEE 1703-2012 – IEEE Standard for Local Area Network/Wide Area Network(LAN/WAN) Node Communication Protocol to Complement the Utility Industry End Device Data Tables**

This standard provides a set of application layer messaging services that are applicable for the enterprise and End Device ends of an Advanced Metering Infrastructure (AMI). The application services include those useful for managing the AMI network assets defined by this standard. These messages may be transported over a wide range of underlying network transports such as TCP/IP, UDP, IEEE 802.11, IEEE 802.15.4 IEEE 802.16, PLC and SMS over GSM, over a wide range of physical media. [22]

3.5 Standards regarding DRMS

- **IEC 61850 - Power Utility Automation**

This standard defines the communication between intelligent electronic devices in the substation and the related system requirements. IEC 61850 is found to be most suitable and acceptable worldwide for communication standardization of active distribution networks. [23]

- **Open Automated Demand Response**

OpenADR is an open, highly secure, and two-way information exchange model and global Smart Grid standard. OpenADR standardizes the message format used for Auto-DR and DER management so that dynamic price and reliability signals can be exchanged in a uniform and interoperable fashion among utilities, ISOs, and energy management and control systems. While previously deployed Auto-DR systems are automated, they are not standardized or interoperable. OpenADR was created to automate and simplify DR and DER for the power industry with dynamic price and reliability signals that allow end users to modify their usage patterns to save money and optimize energy efficiency, while enhancing the effectiveness of power delivery across the Smart Grid. [19]

- **1547- IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems**

This standard is the first in the 1547 series of interconnection standards and is a benchmark milestone demonstrating the open consensus process for standards development. Traditionally, utility electric power systems (EPS--grid or utility grid) were not designed to accommodate active generation and storage at the distribution level. As a result, there are major issues and obstacles to an orderly transition to using and integrating distributed power resources with the grid. The lack of uniform national interconnection standards and tests for interconnection operation and certification, as well as the lack of uniform national building, electrical, and safety codes, are understood. IEEE Std. 1547 and its development demonstrate a model for ongoing success in establishing additional interconnection agreements, rules, and standards, on a national, regional, and state level. IEEE Std. 1547 has the potential to be used in federal legislation and rulemaking and state public utility commission (PUC) deliberations, and by over 3000 utilities in formulating technical requirements for interconnection agreements for distributed generators powering the electric grid. This standard focuses on the technical specifications for, and testing of, the interconnection itself. It provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. It includes general requirements, response to abnormal conditions, power quality, islanding, and test specifications and requirements for the design, production, installation evaluation, commissioning, and periodic tests. The stated requirements are universally needed for interconnection of distributed resources (DR), including synchronous machines, induction machines, or power inverters/converters and will be sufficient for most installations. The criteria and requirements are applicable to all DR technologies, with an aggregate capacity of 10 MVA or less at the point of common coupling, interconnected to electric power systems at typical primary and/or secondary distribution voltages. Installation of DR on radial primary and secondary distribution systems is the main emphasis of this document, although the installation of DR on primary and secondary network distribution systems is considered. This standard is written considering that the DR is a 60 Hz source. [24]

Table 6: Standards for interconnecting DRs to EPS IEC 1547

IEEE 1547.1	**IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems. [25]**
IEEE 1547.2	IEEE Application Guide for IEEE 1547, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems. [26]
IEEE 1547.3	IEEE Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected with Electric Power Systems. [27]
IEEE 1547.4	Draft Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems. [28]
IEEE 1547.6	Draft Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks. [29]

- **IEEE P2030 - IEEE Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS) and End-Use Applications and Loads**

This standard provides alternative approaches and best practices for achieving smart grid interoperability. It is the first all-encompassing IEEE standard on smart grid interoperability providing a roadmap directed at establishing the framework in developing an IEEE national and international body of standards based on cross-cutting technical disciplines in power applications and information exchange and control through communications. [30]

- **IEEE P2030.4 – Guide for Control and Automation Installations Applied to the Electric Power Infrastructure**

This document is a guide to users of IEEE Std. 2030-2011, Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), and End-Use Applications and Loads. It provides guidance in applying the smart grid interoperability reference model (SGIRM) of IEEE Std. 2030 in the development of control and automation components. This guide outlines approaches to defining the requirements for control and automation applications within the electric power infrastructure and describing their design while adhering to a common open architecture. [30]

- **IEEE P1815.1 - Standard for exchanging information between Networks implementing IEC 61850 and IEEE Std. 1815 (Distribution Network Protocol)**

This document specifies the standard approach for mapping between IEEE Std. 1815 (Distributed Network Protocol (DNP3)) and IEC 61850 (Communications Networks and Systems for Power Utility Automation). Two primary use cases are addressed; A) Mapping between an IEEE Std. 1815 based master and an IEC 61850 based remote site and B) Mapping between an IEC 61850 based master and an IEEE Std. 1815 based remote site. Mapping aspects included in the standard are: conceptual architecture; general mapping requirements; the mapping of Common Data Classes, Constructed Attribute Classes and Abstract Communication Service Interface (ASCI); cybersecurity requirements, the architecture of a gateway used for translation and requirements for embedding mapping configuration information into IEC 61850 System Configuration Language (SCL) and DNP3 Device Profile. This specification addresses a selection of features, data classes and services of the two standards. [31]

3.6 Standards concerning Energy Storage and Battery Storage systems

- **IEC 62933 - Electrical energy storage systems (EESS)**

This guide defines terms applicable to electrical energy storage (EES) systems including terms necessary for the definition of unit parameters, test methods, planning, installation, safety and environmental issues.

This terminology document is applicable to grid-connected systems able to extract electrical energy from an electric power system, store it internally, and inject electrical power to an electric power system. The step for charging and discharging an EES system may comprise an energy conversion.

- **IEC 62933-1 - Electrical energy storage (EES) systems**

Covers the detailed terminology within the standard. Notably a distinction is made between low voltage, medium voltage and high voltage Electrical energy storage systems (EESS) and residential EESS, commercial and industrial EESS and utility EESS. (See IEC 60050 for voltage level definitions). [32]

- **IEC 62933-2-1 - Electrical energy storage (EES) systems – Part 2–1: Unit parameters and testing methods – General specification**

This formally defines EESS parameters such as active and reactive power, round trip efficiency, expected service life etc., and formally sets out how to verify these parameters in testing. [33]

- **IEC 62933-4-1 - Electrical energy storage (EES) systems – Part 4–1: Guidance on environmental issues – General specification**

Assesses the interaction of the EESS with the environment across its entire life-cycle and how adverse mutual effects on the EESS/environment may be considered and mitigated. [34]

- **IEEE 2030.2.1-2019 – IEEE Guide for Design, Operation and Maintenance of Battery Energy Storage Systems, both Stationary and Mobile and Applications Integrated with Electric Power System**

Application of this standard includes: (1) Stationary battery energy storage system (BESS) and mobile BESS; (2) Carrier of BESS, including but not limited to lead acid battery, lithium-ion battery, flow battery, and sodium-sulphur battery; (3) BESS used in electric power systems (EPS). Also provided in this standard are alternatives for connection (including DR interconnection), design, operation, and maintenance of stationary or mobile BESS used in EPS. Introduction, overview, and engineering issues related to the BESS are given. [35]

- **IEEE 937-2019 - IEEE Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic (PV) Systems**

Design considerations and procedures for storage, location, mounting, ventilation, assembly, and maintenance of lead-acid storage batteries for photovoltaic power systems are provided in this standard.

Safety precautions and instrumentation considerations are also included. Even though general recommended practices are covered, battery manufacturers may provide specific instructions for battery installation and maintenance. [36]

- **IEEE 1679-2010 – IEEE Recommended Practice for Characterization and Evaluation of Emerging Energy Storage Technologies in Stationary Applications**

Recommended information for an objective evaluation of an emerging energy storage device or system by a potential user for any stationary application is covered in this document. Energy storage technologies are those that provide a means for the reversible storage of electrical energy, i.e., the device receives electrical energy and is able to discharge electrical energy at a later time. The storage medium may be electrochemical (e.g., batteries), kinetic (e.g., flywheels), electrostatic (e.g., electric double-layer capacitors), thermal, or some other medium. Devices recharged by non-electrical means, such as fuel cells, are beyond the scope of this document. The document provides a common basis for the expression of performance characteristics and the treatment of life-testing data. A standard approach for analysis of failure modes is also provided, including assessment of safety attributes. The intent of this document is to ensure that characterization information, including test conditions and limits of applicability, is sufficiently complete to allow valid comparisons to be made. [37]

- **IEEE 1013-2019 – IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stand-Alone Photovoltaic (PV) Systems**

A method for determining the energy-capacity requirements (sizing) of both vented and valve-regulated lead-acid batteries used in terrestrial stand-alone photovoltaic (PV) systems is described. Sizing batteries for hybrid or grid-connected PV systems is beyond the scope of this document. Installation, maintenance, safety, testing procedures, and consideration of battery types other than lead-acid are beyond the scope of this document. Recommended practices for the remainder of the electrical systems associated with PV installations are also beyond the scope of this document. [38]

- **IEEE 1361-2014 – IEEE Guide for Selecting, Charging, Testing and Evaluating Lead-Acid Batteries Used in Stand-Alone Photovoltaic (PV) Systems**

This guide is applicable to all stand-alone photovoltaic (PV) systems where PV is the only charging source. Stand-alone PV system parameters and operating conditions are discussed in relation to battery characteristics and expected system performance. Charging parameters for PV systems are suggested to help in the selection of a battery for a specific application. Finally, a performance test to verify the battery selection and system parameters is provided, including discussions on how to interpret test results. Test results only provide information on initial battery performance. No cycle-life predictions are made. [39]

- **IEEE 1561-2019 – IEEE Guide for Optimizing the Performance and Life of Lead-Acid Batteries in Remote Hybrid Power System**

This guide is applicable to lead-acid batteries that are used as the energy storage component in remote hybrid power supplies. The remote hybrid application, with its dual generator option, i.e., both renewable and dispatchable generation, is advantageous in that the battery can usually be charged at will and under circumstances that may also be advantageous for the dispatchable generator. [40]

- **IEEE 1661-2019 – IEEE Guide for Test and Evaluation of Lead-Acid Batteries used in Photovoltaic (PV) Hybrid Power System**

This guide is specifically prepared for a PV/engine generator hybrid power system, but may also be applicable to all hybrid power systems where there is at least one renewable power source, such as PV, and a dispatchable power source, such as an engine generator. Taper-charge parameters for PV hybrid systems are suggested to help in preparing the battery for a capacity test. A test procedure is provided to ensure appropriate data acquisition, battery characterization, and capacity measurements. Finally, a process to review test results and make appropriate decisions regarding the battery is provided. No cycle-life predictions are made. [41]

3.7 Standards and Protocols Concerning Building Energy Management System (BEMS)

- **ISO 17800: 2017 - Facility Smart Grid Information Model**

ISO 17800:2017 provides the basis for common information exchange between control systems and end use devices found in single - and multi-family homes, commercial and institutional buildings, and industrial facilities that is independent of the communication protocol in use. It provides a common basis for electrical energy consumers to describe, manage, and communicate about electrical energy consumption and forecasts. [42]

ISO 17800:2017 defines a comprehensive set of data objects and actions that support a wide range of energy management applications and electrical service provider interactions including: [42]

- on-site generation,
- demand response,
- electrical storage,
- peak demand management,
- forward power usage estimation,
- load shedding capability estimation,
- end load monitoring (sub metering),
- power quality of service monitoring,
- utilization of historical energy consumption data, and
- direct load control

- **Open Building Information Exchange (oBIX)**

The oBIX is a focused effort by industry leaders and associations working toward creating a standard XML and Web Services guideline to facilitate the exchange of information between intelligent buildings, enable enterprise application integration and bring forth true systems integration. Based on Standards widely used by the IT Industry, the oBIX guideline will improve operational effectiveness giving facility managers and building owners increased knowledge and control of their properties. Comprised of representatives from the entire spectrum of the buildings systems industry, oBIX includes professionals from the security, HVAC, building automation, open protocol and IT disciplines. [43]

- **IEEE 802.15.4 – IEEE Draft Standard for Low-Rate Wireless Network**

The protocol and compatible interconnection for data communication devices using low data-rate, low-power, and low-complexity short-range radio frequency (RF) transmissions in a wireless personal area network (WPAN) are defined in this standard. A variety of physical layers (PHYs) have been defined that cover a wide variety of frequency bands. [44]

3.8 Cybersecurity Standards – applicable to all Demo Sites

- **IEC 62351:2020 - Power systems management and associated information exchange - Data and communications security**

Provides an introduction to the remaining parts of the IEC 62351 series, primarily to introduce the reader to various aspects of information security as applied to power system operations. The scope of the IEC 62351 series is information security for power system control operations. Its primary objective is to undertake the development of standards for the security of the communication protocols defined by 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. [46]

- **ISO/IEC 27001:2013 - Information security management systems**

This is one of the best-known ISMS standards for describing a systematic approach to the management of sensitive information in organizations, risk management and security aspects of people, processes and IT systems. Standards help organizations to keep their assets secure and meet legislative and organizational security requirements for certification of ISMS. [47]

- **ISO/IEC 27002:2013 - Code of practice for information security control**

Allows organizations to assess and prepare information security management practices including selection, implementation and management of information security controls to assess risk environments. [48]

- **ISO/IEC 27019:2017 - Information security controls for the energy utility**

The industry provides guidance based on the ISO/IEC 27002 security controls tailored for use in the energy utility industry for purposes of controlling and monitoring of generation, production, transmission, storage and distribution of electricity, gas, oil and heat as well as control of necessary supporting processes. [49]

- **ISO/IEC 30111:2019 - Vulnerability handling processes**

Guides requirements, recommendation and mitigation process of potential vulnerabilities of critical or supporting products and services. [50]

- **ISO/IEC 15408**

Encompass a three-part collection of Evaluation criteria for IT security. The standards contain a set of requirements for assessment of security functions of IT products, systems and assurance measures during a security evaluation.

- **ISO/IEC 15408-1**

This standard covers the introduction and general model for assessment of IT security with general concepts and principles for evaluation. It contains a general model for evaluation and strategic objectives for selection and definition of organizational IT security requirements for products and systems. [51]

- **ISO/IEC 15408-2**

This standard covers evaluation of security functional components with guidelines to create functional components of the target of evaluation including components, families and classes. [52]

- **ISO/IEC 15408-3**

This standard covers evaluation of security assurance with guidelines for assessing, defining and establishing a set of assurance components to evaluate assurance requirements of organizations and products, services and systems. [53]

- **IEEE 1686 – 2013 – IEEE Standard for Intelligent Electronic Devices (IEDs) Cybersecurity Capabilities**

The functions and features to be provided in intelligent electronic devices (IEDs) to accommodate critical infrastructure protection programs are defined in this standard. Security regarding the access, operation, configuration, firmware revision and data retrieval from an IED are addressed. Communications for the purpose of power system protection (teleprotection) are not addressed in this standard. [54]

- **P1402 – IEEE Draft Guide for Physical Security of Electric Power Substation**

This guide describes recommended practices for the physical security of electric power substations. It is designed to address a number of threats, including unauthorized access to substation facilities, theft of material, and vandalism. It describes options for positive access control, monitoring of facilities, and delay/deter features which could be employed to mitigate these threats. This guide also establishes options for different levels of physical security for electric power substations. The guide does not establish recommendations based on voltage levels, size or any depiction of criticality of the substation. The user will make these decisions based on threat assessment and criticality assignment by the substation owner. Overt attacks against the substation for the purpose of destroying its capability to operate, such as explosives, projectiles, vehicles, etc. are beyond the scope of this guide. [55]

- **IEEE 1711-2010 – IEEE Trial Use Standard for a Cryptographic Protocol for Cyber Security of Substation Serial Links**

A cryptographic protocol to provide integrity, and optional confidentiality, for cybersecurity of serial links is defined in this trial use standard. Specific applications or hardware implementations are not addressed, and the standard is independent of the underlying communications protocol. [56]

- **IEEE 1711.2-2019 – IEEE Standard for Secure SCADA Communications Protocol (SSCP)**

A cryptographic protocol to provide integrity with optional confidentiality for cybersecurity of substation serial links is defined in this standard. It does not address specific applications or hardware implementations and is independent of the underlying communications protocol. The elevated concern of cybersecurity throughout the power industry has created a need to protect communications to and from substations. This standard defines a cryptographic protocol known as Secure SCADA Communications Protocol (SSCP) that protects the integrity and, optionally, the confidentiality of asynchronous serial communications typically used by control system equipment. SSCP is primarily intended to protect serial SCADA communications, but can be applied to other serial communications, such as the maintenance ports of intelligent electronic devices. SSCP is independent of the underlying communications link and protocol (e.g., Modbus, DNP3, IEC 60870- 5), and is appropriate for serial communications over leased lines, dial-up lines, multi-drop links, radio, power line carrier, fibre optic, etc. SSCP is suitable for implementation in new equipment or for deployment in bump-in-the-wire devices retrofitting protection to existing systems. [57]

- **IEEE PC37.240 Standard for Cyber Security Requirements for Substation Automation, Protection and Control System**

This document provides technical requirements for substation cybersecurity. It presents sound engineering practices that can be applied to achieve high levels of cybersecurity of automation, protection and control systems independent of a voltage level or criticality of cyber assets. Cybersecurity includes trust and assurance of data in motion, data at rest and incident response. [58]

- **ANSI/ISA- 99 - Security for Industrial Automation and Control System**

Covers the process for establishing an industrial automation and control systems security programme based on risk analysis, establishing awareness and countermeasures, and monitoring and cybersecurity management systems. [59]

- **NERC CIP-002 and CIP-003 to CIP-009**

The North American Electric Reliability Corporation (NERC) has issued the Critical Infrastructure Protection (CIP) cybersecurity Standards to protect electrical systems. The CIP cybersecurity standards are mandatory and enforceable across all users, owners and operators of the bulk-power system. CIP-002 specifies the means by which critical cyber assets are identified. CIP-003 through CIP-009 cover security management controls, personnel and training, electronic security perimeters, physical security of cyber assets, systems security management, incident handling and recovery planning. In spite of it not being part of IEC family, and driven by US, this standard is widely used worldwide. [60]

3.9 Standards concerning Energy Market

To harmonise and implement standardised electronic data interchange, since 2009 ENTSO-E has supported the integration, at an international level, of Member TSOs' business requirements and use cases into the Common Information Model (CIM), and contributions to its further development. For market-related exchanges, this has been achieved through ENTSO-E's liaison with the International Electrotechnical Commission Technical Committee 57 and Working Group 16 (IEC TC 57 / WG 16).

The CIM standards are continuously evolving to meet the changing requirements for data exchange, which are increasing in both frequency and type, with higher RES integration and the introduction of smart grids. Specific ENTSO-E CIM standards have been defined to ensure the suitability of the CIM for ENTSO-E and to reflect the complexity of TSO data exchanges.

The IEC TC 57 (Power System Management and Associated Information Exchange) is currently developing the IEC CIM 62325 series of standards for the exchange of data required by deregulated energy markets. WG 16 (Deregulated Energy Markets) is developing these standards as a framework for energy market communications encompassing two market styles: European style and North American style markets.

- **IEC 62325 – Framework for Energy Market Communication**

Table 7: Standards for Energy Market Communication 62325

IEC 62325-301	**Common information model (CIM) extensions for markets.** [61]
IEC 62325-351	CIM European market model exchange profile. [62]
IEC 62325-450	Profile and context modelling rules. [63]
IEC 62325-451-1	Acknowledgement business process and contextual model for CIM European market. [64]
IEC 62325-451-2	Scheduling business process and contextual model for CIM European market. [65]
IEC 62325-451-3	Transmission capacity allocation business process and contextual models for European market [66]
IEC 62325-451-4	Settlement and reconciliation business process, contextual and assembly models for European market. [67]
IEC 62325-451-5	Problem statement and status request business processes, contextual and assembly models for European market. [68]
IEC 62325-451-6	Publication of information on market, contextual and assembly models for European style market. [69]
IEC 62325-502	Profile of ebXML. [70]
IEC 62325-503	Market data exchanges guidelines for the IEC 62325-351 profile. [71]
IEC 62325-504	Utilization of web services for electronic data interchanges on the European energy market for electricity. [72]

3.10 Blockchain Technology Standardisation

So far, due to blockchain technology still being in its early adoption phase, there has been minimal work on standardization in this area. Nevertheless, given the rapid increase in the use of this technology in various areas, the EU and the ISO committee is paying attention to blockchain from a standardization point of view.

An EU Blockchain roundtable was held on the 20th November 2018, and aimed to gather industry leaders and policy makers to explore the potential of blockchain technology for EU in sectors such as supply chain management, manufacturing, financial services, transport, energy etc. It highlighted the need for a comprehensive EU blockchain strategy and a common approach to blockchain for EU in international arena. The intention was to develop close cooperation between the government and economic sectors, as is required to leverage innovative technologies such as blockchain to transform digital services and increase trust in a wide range of industries and sectors. [73]

In December 2018, ETSI announced the creation of a new Industry Specification Group on Permissioned Distributed Ledger (ISG PDL) [74]. The main goal of this group is to analyze operational needs and to contribute to providing indications on the indispensable standards to ensure interoperability in the field of permissioned blockchains designed to serve more industries and more organizations. Attention to permissioned blockchains is naturally justified by the fact that these are platforms that specifically target the world of businesses and governmental organizations and that pose system themes such as the attributes of digital identity, such as tracking methods, such as the issues of privacy of shared information, such as the verification and implementation of Service Level Agreements (SLA).

In March 2020, the group published the first two specification documents: ETSI GS PDL 005-Proof of Concepts Framework [75] and ETSI GR PDL 001-Landscape of Standards and Technologies. [75]

A new Australian-lead ISO technical committee, ISO/TC 307 has been established to lay the groundwork for future standardization of blockchain technology at the international level. [76]

Up to now, one ISO standard was published and nine ISO standards are under development. The table below shows the standards currently being developed by this committee, along with their developmental stage, as defined in the International harmonized stage codes (Figure 5).

Figure 5: ISO standard stage codes

Table 8: ISO/TC 307 standard stages

Standard under development	Name	Stage
ISO/TR 23455:2019	Overview of and interactions between smart contracts in blockchain and distributed ledger technology systems. [77]	60.60 (Published Sept 2019)
ISO/TR 23244	Privacy and personally identifiable information protection considerations	60.00
ISO/FDIS 22739	Vocabulary	50.20
ISO/CD 23257.3	Reference Architecture	30.60
ISO/CD TR 23576	Security management of digital asset custodians	30.60

ISO/CD TR 23245.2	Security risks, threats and vulnerabilities	30.20
ISO/CD TR 3242	Use cases	30.00
ISO/WD TS 23258	Taxonomy and Ontology	20.20
ISO/AWI TS 23259	Legally binding smart contracts	20.00
ISO/AWI TS 23635	Guidelines for governance	10.99

In addition, IEEE recognizes the vital role standards will play in the development and adoption of blockchain technologies. IEEE Standards Association (IEEE SA), a globally recognized standards-setting body within IEEE, has been actively pursuing blockchain standardization efforts through various activities in multiple sectors. Below is a list of IEEE active standards project concerning blockchain technology:

- **IEEE P2418.5 – Standard for Blockchain in Energy**

This standard provides an open, common, and interoperable reference framework model for blockchain in the energy sector. It also covers three aspects: 1) Serve as a guideline for Blockchain use cases in Electrical Power industry; Oil & Gas industry and Renewable energy industry and their related services. 2) Create standards on reference architecture, interoperability, terminology, and system interfaces for blockchain applications in Energy sector by building an open protocol and technology agnostic layered framework. 3) Evaluate and provide guidelines on scalability, performance, security, and interoperability through evaluation of consensus algorithm, smart contracts, and type of blockchain implementation, etc. for the Energy sector. [78]

- **IEEE P2418.1 – Standard for the Framework of Blockchain Use in Internet of Things**

This standard provides a common framework for blockchain usage, implementation, and interaction in Internet of Things (IoT) applications. The framework addresses scalability, security and privacy challenges with regard to blockchain in IoT. Blockchain tokens, smart contracts, transaction, asset, credentialed network, permissioned IoT blockchain, and permission-less IoT blockchain are included in the framework. [79]

- **IEEE P4218.2:2020 – IEEE Approved Draft Standard Data Format for Blockchain System**

The standard establishes data format requirements for blockchain systems(s). The standard addresses the following attributes of the system, including but not limited to, data structure, data classification (and its correlation), data element format, data type, identifier and data length. [80]

- **IEEE P2140.1 – Standard for General Requirements for Cryptocurrency Exchanges**

The factors of concern for this standard involve multiple aspects, including self-discipline and professional ethics of cryptocurrency exchange platforms, as well as the relevance between them and to the cryptocurrency wallets. This standard also describes the exchanges' business logic, operational procedures, transaction specifications, user authentication programs, and fair voting system to ensure the safety of users' assets and keep the overall exchanges fair and transparent to all participants. In addition, the standard provides a small but necessary technical category of requirements, including terminologies, data modeling, basic architectural framework, key indicators, end-user interface specifications, in order to achieve the previously mentioned goals. [81]

- **IEEE P2140.2 – Standard for Security Management for Customer Cryptographic Assets on Cryptocurrency Exchanges**

This standard defines requirements for multiple aspects of security management for customer cryptographic assets on cryptocurrency exchanges, such as user identification using multi-factor authentication, prioritized protection of customer assets under unforeseen circumstances, and professional ethics of operation for cryptocurrency exchange platforms. [82]

- **IEEE P2140.4 – Standard for Distributed/Decentralized Exchange Framework using DLT (Distributed Ledger Technology)**

This standard defines an extension framework based on P2140.1. The extension framework uses a Smart Contract mechanism to process transactions on an exchange, to replace the role of exchange operators. Cryptographic solutions to provide "data privacy" and "data protection" are defined. This standard also defines a series of extensible interfaces for the exchange scenario, enabling support of third-party financial derivatives using tokens. [83]

- **IEEE P2141.3 – Standard for Transforming Enterprise Information Systems from Distributed Architecture into Blockchain-based Decentralized Architecture**

This standard specifies the requirements, systems, methods, testing and verification for transforming enterprise information systems from a legacy distributed architecture into a blockchain-based decentralized architecture in order to improve the trust among multiple parties and participants while minimizing the transformation cost. [84]

- **IEEE P2144.1 – Standard for Framework of Blockchain-based Internet of Things Data Management**

This standard defines a framework of Blockchain-based Internet of Things (IoT) data management. It identifies the common building blocks of the framework that Blockchain enabled during IoT data lifecycle including data acquisition, processing, storage, analysing, usage/exchange and obsolescence, and the interactions among these building blocks. [85]

- **IEEE P2144.2 – Standard for Functional Requirements in Blockchain-based Internet of Things Data Management**

This standard defines the functional requirements in data compliance, governance and risk management in the operational process for Blockchain-based IoT data management systems. [86]

- **IEEE P2144.3 – Standard for Assessment of Blockchain-based Internet of Things Data Management**

This standard defines the assessment framework for data compliance, governance and risk management in Blockchain-based IoT data management, provides performance metrics such as availability, security, privacy, integrity, continuance, scalability, etc.[87]

4 Conclusion

Smart Grids and new platforms enabling flexibility of the marketplace depend on a variety of technologies used with a high degree of heterogeneity and complexity. At the same pace as technologies evolve, the security and standards used in Smart Grid develop, as do associated disruptive technologies such as blockchain.

The application of IEC and IEEE standards in deployments offers appropriate means to protect against any issues that might be raised due to these heterogeneities of technologies. This document is striving into this direction by proposing standards to be considered during development of Platone platform and its deployment in the three demo sites, with their local specific needs.

The demo site stakeholders and platform developers can apply the standards guidance given in this document in the development of their use cases, in particular for decentralized energy resources, substation automation or disruptive emerging technology such as blockchain and DLT. However, in addition to electric system operation it must be noted, that cybersecurity is a continuous process as cybersecurity measures and threats in energy systems are constantly evolving.

5 List of Tables

6 List of Figures

7 List of References

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8 List of Abbreviations

Abbreviation	Term
ADN	Active Distribution Network
AES	Advanced Encryption Standard
AMI	Advanced Metering Infrastructure
ANSI	American National Standards Institute
API	Application Program Interface
ASCI	Abstract Communication Service Interface
ATM	Asynchronous Transfer Mode
BEMS	Building Energy Management System
BESS	Battery Energy Storage System
BPL	Broadband Over Power Lines
BWA	Broadband Wireless Access
CIP	Critical Infrastructure Protection
CIM	Common Information Model
CIS	Customer Information Systems
COSEM	Companion Specification for Energy Metering
CSMA/CD	Carrier-sense Multiple Access with Collision Detection
DA	Distribution Automation
DER	Distributed Energy Resources
DLSM	Distribution Line Message Specification
DLT	Distributed Ledger Technology
DMS	Distribution Management System
DNP	Distributed Network Protocol
DR	Distributed Resources
DRMS	Demand Response Management Systems
DSO	Distribution System Operator
EESS	Electrical Energy Storage System
EES	Electrical Energy Storage
EMC	Electromagnetic Compatibility
EMS	Energy Management System
EPA	Enhanced Performance Architecture
EPS	Electric Power System
EV	Electric Vehicle
GPRS	General Packet Radio Service
GPS	Global Positioning System

GSM	Global System for Mobile Communication
HEDNO	Hellenic Electricity Distribution Network Operator
HVAC	Heating Ventilation and Air Condition
HW	Hardware
ICT	Information and Communication Technology
IEC	International and Electrotechnical Commission
IED	Intelligent Electronic Device
IEEE	Institute of Electrical and Electronic Engineering
INEA	Innovations and Networks Executive Agency
IoT	Internet of Things
IP	Internet Protocol
IPFS	InterPlanetary File System
IPv4	Internet Protocol Version 4
ISA	Industrial Automation
ISMS	Information Security Management System
ISO	International organization for Standardization
IT	Information Technology
ITU-T	Telecommunication Standardization Sector
LAN	Local Area Network
LLC	Logical Link Control
LV	Low Voltage
MAC	Medium Access Control
MAN	Metropolitan Area Network
MIC	Maximum Input Capacity
MV	Medium Voltage
NEMA	National Electrical Manufacturers Association
NERC	North American Electric Reliability Corporation
NTUA	National Technical University of Athens
oBIX	Open Building Information Exchange
P2P	Peer to Peer
PDC	Power Distribution Centre
PDL	Permission Distributed Ledger
PDU	Protocol Data Unit
PEV	Plug-in Electric Vehicles
PHY	Physical Layers
PLC	Power Line Communication
PMU	Phasor Measurement Unit

PPP	Point-to-Point Protocol
PSTN	Public Switched Telephone Networks
PUC	Public Utility Commission
PV	Photovoltaic
RES	Renewable Energy Source
RF	Radio Frequency
ROCOF	Rate of Change of Frequency
RTU	Remote Terminal Unit
RS	Recommended Standard
SCADA	Supervisory control and Data Acquisition
SCL	System Configuration Language
SGIRM	Smart Grid Interoperability Reference Model
SMS	Short Message Service
SMTP	Simple Mail Transfer Protocol
SSCP	Secure SCADA Communication Protocol
STS	Standard Transfer Specification
SW	Software
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TR	Technical Report
TSO	Transmission System Operator
TVE	Total Vector Error
UDP	User Datagram Protocol
WAN	Wide Area Network
WG	Working Group
WPAN	Wireless Personal Area Network
XML	Extensible Markup Language

Annex A Additional Description of IEEE Standards

A.1 IEEE Blockchain Standards

IEEE P2418.5 – Standard for Blockchain in Energy

This standard provides an open, common, and interoperable reference framework model for Blockchain in the energy sector. It also covers three aspects: 1) Serve as a guideline for Blockchain use cases in the Electrical Power industry; the Oil & Gas industry and the Renewable energy industry and their related services. 2) Create standards on reference architecture, interoperability, terminology, and system interfaces for blockchain applications in the Energy sector by building an open protocol and technology layered agnostic framework. 3) Evaluate and provide guidelines on scalability, performance, security, and interoperability through evaluation of consensus algorithm, smart contracts, and type of blockchain implementation, etc. for the Energy sector. [78]

IEEE P2418.1 – Standard for the Framework of Blockchain Use in the Internet of Things

This standard provides a common framework for blockchain usage, implementation, and interaction in the Internet of Things (IoT) applications. The framework addresses scalability, security and privacy challenges with regard to Blockchain in IoT. Blockchain tokens, smart contracts, transaction, asset, credentialed network, permissioned IoT blockchain, and permission-less IoT blockchain are included in the framework. [79]

IEEE P2140.1 – Standard for General Requirements for Cryptocurrency Exchanges

This standard covers self-discipline and professional ethics of cryptocurrency exchange platforms, as well as relevance between them and to the cryptocurrency wallets. This standard also describes the exchanges' business logic, operational procedures, transaction specifications, user authentication programs, and fair voting system to ensure the safety of users' assets and keep the overall exchanges fair and transparent to all participants. In addition, the standard provides a small but necessary technical category of requirements, including terminologies, data modelling, basic architectural framework, key indicators, end-user interface specifications, in order to achieve the previously mentioned goals. [81]

IEEE P2140.2 – Standard for Security Management for Customer Cryptographic Assets on Cryptocurrency Exchanges

This standard defines requirements for multiple aspects of security management for customer cryptographic assets on cryptocurrency exchanges, such as user identification using multi-factor authentication, prioritized protection of customer assets under unforeseen circumstances, and professional ethics of operation for cryptocurrency exchange platforms. [82]

IEEE P2140.4 – Standard for Distributed/Decentralized Exchange Framework using DLT (Distributed Ledger Technology)

This standard defines an extension framework based on P2140.1. The extension framework uses a Smart Contract mechanism to process transactions on an exchange, to replace the role of exchange operators. Cryptographic solutions to provide "data privacy" and "data protection" are defined. This standard also defines a series of extensible interfaces for the exchange scenario, enabling support of third-party financial derivatives using tokens. [83]

IEEE P2141.3 – Standard for Transforming Enterprise Information Systems from Distributed Architecture into Blockchain-based Decentralized Architecture

This standard specifies the requirements, systems, methods, testing and verification for transforming enterprise information systems from a legacy distributed architecture into a blockchain-based decentralized architecture in order to improve the trust among multiple parties and participants while minimizing the transformation cost. [84]

IEEE P2144.1 – Standard for Framework of Blockchain-based Internet of Things Data Management

This standard defines a framework of Blockchain-based Internet of Things (IoT) data management. It identifies the common building blocks of the framework that Blockchain enabled during IoT data lifecycle including data acquisition, processing, storage, analysing, usage/exchange and obsolescence, and the interactions among these building blocks. [85]

IEEE P2144.2 – Standard for Functional Requirements in Blockchain-based Internet of Things Data Management

This standard defines the functional requirements in data compliance, governance and risk management in the operational process for Blockchain-based IoT data management systems. [86]

IEEE P2144.3 – Standard for Assessment of Blockchain-based Internet of Things Data Management

This standard defines the assessment framework for data compliance, governance and risk management in Blockchain-based IoT data management, provides performance metrics such as availability, security, privacy, integrity, continuance, scalability, etc. [87]

A.2 Other IEEE Standards

IEEE 2030 – Standard for Interoperability

This standard provides alternative approaches and best practices for achieving smart grid interoperability. It is the first all-encompassing IEEE standard on smart grid interoperability providing a roadmap directed at establishing the framework in developing an IEEE national and international body of standards based on cross-cutting technical disciplines in power applications and information exchange and control through communications. [30]

IEEE 2030.2 – Interoperability of Energy Storage Systems Integrated with the Electric power infrastructure

This document provides guidelines for discrete and hybrid energy storage systems that are integrated with the electric power infrastructure, including end-use applications and loads. This guide builds upon IEEE Standard 2030 Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), and End-Use Applications and Loads. [85]

P2030.4 – Guide for Control and Automation Installations Applied to the Electric Power Infrastructure

This document is a guide to users of IEEE Std 2030-2011, Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), and End-Use Applications and Loads. It provides guidance in applying the smart grid interoperability reference model (SGIRM) of IEEE Std 2030 in the development of control and automation components. This guide outlines approaches to defining the requirements for control and automation applications within the electric power infrastructure and describing their design while adhering to a common open architecture. [30]

IEEE 2030-2011 – Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS) and End-Use Applications and Loads

This document provides guidelines for smart grid interoperability. This guide provides a knowledge base addressing terminology, characteristics, functional performance and evaluation criteria, and the application of engineering principles for smart grid interoperability of the electric power system with end-use applications and loads. The guide discusses alternate approaches to good practices for the smart grid. [30]

IEEE P1815.1 – Standard for exchanging information between Networks implementing IEC 61850 and IEEE Std 1815 (Distribution Network Protocol)

This document specifies the standard approach for mapping between IEEE Std 1815 (Distributed Network Protocol (DNP3)) and IEC 61850 (Communications Networks and Systems for Power Utility Automation). Two primary use cases are addressed; A) Mapping between an IEEE Std 1815 based master and an IEC 61850 based remote site and B) Mapping between an IEC 61850 based master and an IEEE Std 1815 based remote site. Mapping aspects included in the standard are: conceptual architecture; general mapping requirements; the mapping of Common Data Classes, Constructed

Attribute Classes and Abstract Communication Service Interface (ASCI); cybersecurity requirements, the architecture of a gateway used for translation and requirements for embedding mapping configuration information into IEC 61850 System Configuration Language (SCL) and DNP3 Device Profile. This specification addresses a selection of features, data classes and services of the two standards. [9]

IEEE 1815-2012 – Standard for Electric power system communication Distributed Network Protocol (DNP)

The DNP3 protocol structure, functions, and interoperable application options (subset levels) are specified. The simplest application level is intended for low-cost distribution feeder devices, and the most complex for full-featured systems. The appropriate level is selected to suit the functionality required in each device. The protocol is suitable for operation on a variety of communication media consistent with the makeup of most electric power communication systems. [9]

IEEE 1808 -2011 – Guide for Collecting and Managing Transmission Line Inspection and Maintenance Data

Reference information to assist electric utilities and their contractors with the development of computer-based means for collecting and managing transmission line inspection and maintenance data and associated asset information is provided. The guide provides a high-level overview of key principles and considerations learned through experience that will help ensure common pitfalls are avoided and enhance the usability of systems. It is not intended to provide an exhaustive discussion of the many details and specifics that must be accounted for when designing and developing a system for an individual utility's application and needs. [88]

IEEE P1909.1 – Recommended Practice for Smart Grid Communication Equipment

This document includes Recommended Practice for testing and installing different types of smart grid communication equipment according to national and international standards available for equipment to be used in the smart grid. The Recommended Practice includes Safety, EMC, Environmental and Mechanical battery of tests but excludes the interoperability testing. This document captures Recommended Practice for communication equipment to be installed in various domains of the smart grid such as generation, transmission and distribution. [89]

IEEE P1901.2 – Standard for Low Frequency(less than 500 kHz) Narrow Band Power Line Communication for Smart grid Application

This standard specifies communications for low frequency (less than 500 kHz) narrowband power line devices via alternating current and direct current electric power lines. This standard supports indoor and outdoor communications over low voltage line (the line between transformer and meter, less than 1000 V), through transformer low-voltage to medium-voltage (1000 V up to 72 kV) and through transformer medium-voltage to low-voltage power lines in both urban and in long-distance (multi-kilometre) rural communications. The standard uses transmission frequencies less than 500 kHz. Data rates will be scalable to 500 kbps depending on the application requirements. This standard addresses grid to the utility meter, electric vehicle to charging station, and within home area networking communications scenarios. [90]

IEEE 1901 – Standard for Broadband over Power Line Networks

A standard for high-speed communication devices via electric power lines, so-called broadband over power line (BPL) devices, is defined. Transmission frequencies below 100 MHz are used. All classes of BPL devices can use this standard, including BPL devices used for the first-mile/last-mile connection to broadband services as well as BPL devices used in buildings for local area networks (LANs), Smart Energy applications, transportation platforms (vehicle) applications, and other data distribution. The balanced and efficient use of the power line communications channel by all classes of BPL devices is the main focus of this standard, defining detailed mechanisms for coexistence and interoperability between different BPL devices, and ensuring that desired bandwidth and quality of service may be delivered. The necessary security questions are addressed to ensure the privacy of communications between users and to allow the use of BPL for security-sensitive services. [91]

IEEE P1854 – Guide for Smart Distribution Applications Guide

This guide categorizes important smart distribution applications, develops descriptions of the critical functions involved, defines important components of these systems, and provides examples of the systems that can be considered as part of distribution management systems or other smart distribution systems. [92]

IEEE 1711-2010 – Standard for Secure SCADA Communications Protocol

This standard defines the Secure SCADA Communication Protocol (SSCP), a cryptographic protocol to provide integrity and optional confidentiality, for cybersecurity of substation serial links communications without broadcast message support and without any time requirements. [56]

IEEE C37.118.1-2001 – Standard for Synchrophasor Measurements for Power System

This standard is for synchronized phasor measurement systems in power systems. It defines a synchronized phasor (synchrophasor), frequency and rate of change of frequency measurements. It describes time tag and synchronization requirements for measurement of all three of these quantities. It specifies methods for evaluating these measurements, and requirements for compliance with the standard under both static and dynamic conditions. It defines a Phasor Measurement Unit (PMU) which can be a stand-alone physical unit or a functional unit within another physical unit. This standard does not specify hardware, software or a method for computing phasors, frequency, or rate of change of frequency. [7]

IEEE P1704 – Standard for Utility Industry End Device Communications Model

This document defines the physical hardware interface and interface signals between IEEE 1703 Devices (such as IEEE 1377 meters or distribution automation devices) and IEEE 1703 communication modules. The communication modules are described as being attachable and removable to/from the IEEE 1703 Devices and are not intended to be internal to the metering devices. Included in this standard are the physical dimensions, electrical connections, communication hardware interface signals, and module positioning, which involves the secure physical mounting, weather elements, and communications propagation considerations. This standard serves as the extension of (but not limited to) IEEE 1703, MC1222, and ANSI C12.22 standards in regard to the communications module hardware interfaces, reference signals, their description and specification. [93]

IEEE 1703-2012 – Standard for Local Area Network/Wide Area Network (LAN/WAN) Node Communication Protocol to Complement the Utility Industry End Device Data Tables

This standard provides a set of application layer messaging services that are applicable for the enterprise and End Device ends of an Advanced Metering Infrastructure (AMI). The application services include those useful for managing the AMI network assets defined by this standard. These messages may be transported over a wide range of underlying network transports such as TCP/IP, UDP, IEEE 802.11, IEEE 802.15.4 IEEE 802.16, PLC and SMS over GSM, over a wide range of physical media. Additionally, interfaces are defined for a Communication Module and a Local Port (e.g. an IEEE 1701 optical port). The described protocol is tailored for, but not limited to, the transport of IEEE 1377 Table data. The standard also provides a means by which information can be sent in a secure manner using AES-128 and the EAX mode. This standard was developed jointly with ANSI (published as ANSI C12.22) and Measurement Canada (published as MC12.22). [94]

IEEE 1702-2011 – Standard for Telephone Modem Communication Protocol to Complement the Utility Industry End Device Data Tables

This standard details the criteria required for communication between a device and a client conforming to ANSI C12.21 via a modem connected to the switched telephone network. The C12.21 Client could be a laptop or portable computer, a master station system or some other electronic communications device. This Standard does not specify the implementation requirements of the telephone switched network to the modem, nor does it include definitions for the establishment of the communication channel. This document provides details for an implementation of the OSI 7-layer model in accordance with ISO/IEC 7498-1. The protocol specified in this Standard was designed to transport data in Table format. The Table definitions are in ANSI C12.19, and Annex D of the document. This Standard specifies the differences between ANSI C12.18-2006, Protocol Specification for ANSI Type 2 Optical Port and ANSI C12.19-1997, Utility Industry End Device Data Tables, and those features and services required to describe a protocol specification for Tele9phone Modem Communications. [95]

IEEE 1615-2007 – Recommended Practice for Network Communication in Electric Power Substation

Recommended practices for communication and interoperation of devices connected on an electric power substation Internet protocol (IP) network are provided. For the power engineer new to IP networking, this document provides an introduction to the concepts that need to be mastered as well as specific recommendations to follow when deploying the technologies. For equipment manufacturers and system integrators, it provides direction and requirements to facilitate interoperable electric utility information networks. [96]

IEEE 1547-2003 – Standard for Interconnecting Distributed Resources with Electric Power Systems

This standard is the first in the IEEE 1547 series of interconnection standards and is a benchmark milestone demonstrating the open consensus process for standards development. Traditionally, utility electric power systems (EPS--grid or utility grid) were not designed to accommodate active generation and storage at the distribution level. As a result, there are major issues and obstacles to an orderly transition to using and integrating distributed power resources with the grid. The lack of uniform national interconnection standards and tests for interconnection operation and certification, as well as the lack of uniform national building, electrical, and safety codes, are understood. IEEE Std 1547 and its development demonstrate a model for ongoing success in establishing additional interconnection agreements, rules, and standards, on a national, regional, and state level. IEEE Std 1547 has the potential to be used in federal legislation and rulemaking and state public utility commission (PUC) deliberations, and by over 3000 utilities in formulating technical requirements for interconnection agreements for distributed generators powering the electric grid. This standard focuses on the technical specifications for, and testing of, the interconnection itself. It provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. It includes general requirements, response to abnormal conditions, power quality, islanding, and test specifications and requirements for the design, production, installation evaluation, commissioning, and periodic tests. The stated requirements are universally needed for interconnection of distributed resources (DR), including synchronous machines, induction machines, or power inverters/converters and will be sufficient for most installations. The criteria and requirements are applicable to all DR technologies, with an aggregate capacity of 10 MVA or less at the point of common coupling, interconnected to electric power systems at typical primary and/or secondary distribution voltages. Installation of DR on radial primary and secondary distribution systems is the main emphasis of this document, although the installation of DR on primary and secondary network distribution systems is considered. This standard is written considering that the DR is a 60 Hz source. [24]

IEEE 1547.6-2011 – Recommended Practice for Interconnecting Distributed Resources With Electric Power Systems Distribution Secondary Networks

This standard builds upon IEEE Standard 1547 for the interconnection of distributed resources (DR) to distribution secondary network systems. This standard establishes recommended criteria, requirements and tests, and provides guidance for interconnection of distribution secondary network system types of area electric power systems (Area EPS) with distributed resources (DR) providing electric power generation in local electric power systems (Local EPS). [29]

IEEE 1547.4-2011 – Guide for Design, Operation and Integration of Distributed Resource Island Systems with Electric Power Systems

This document provides alternative approaches and good practices for the design, operation, and integration of distributed resource (DR) island systems with electric power systems (EPS). This includes the ability to separate from and reconnect to the part of the area EPS while providing power to the islanded local EPSs. This guide includes distributed resources, interconnection systems, and participating in electric power systems. [28]

IEEE 1547.3-2007 – Guide for Monitoring, Information Exchange and Control of Distributed Resources Interconnected With Electric Power Systems

This guide is intended to facilitate the interoperability of distributed resources (DR) and help DR project stakeholders implement monitoring, information exchange, and control (MIC) to support the technical and business operations of DR and transactions among the stakeholders. The focus is on MIC between DR controllers and stakeholder entities with direct communication interactions. This guide incorporates information modelling, use case approaches, and an information exchange template and introduces the concept of an information exchange interface. The concepts and approaches are compatible with historical approaches to establishing and satisfying MIC needs. This guide is primarily concerned with MIC between the DR unit controller and the outside world. However, the concepts and methods should also prove helpful to manufacturers and implementers of communications systems for loads, energy management systems, SCADA, electric power system and equipment protection, and revenue metering. The guide does not address the economic or technical viability of specific types of DR. It provides use case methodology and examples (e.g., examples of DR unit dispatch, scheduling, maintenance, ancillary services, and reactive supply). Market drivers will determine which DR applications become viable. This document provides guidelines rather than mandatory requirements or prioritized preferences. [27]

IEEE 1547.2-2008 – Guide for Std. 1547, Standard for Interconnecting Distributed Resources with Electric Power Systems

This guide gives technical background and application details to support understanding of IEEE Std 1547-2003. The guide facilitates the use of IEEE Std 1547-2003 by characterizing various forms of distributed resource (DR) technologies and their associated interconnection issues. It provides background and rationale of the technical requirements of IEEE Std 1547-2003. It also provides tips, techniques, and rules of thumb, and it addresses topics related to DR project implementation to enhance the user's understanding of how IEEE Std 1547-2003 may relate to those topics. This guide is intended for use by engineers, engineering consultants, and knowledgeable individuals in the field of DR. The IEEE 1547 series of standards are cited in the Federal Energy Policy Act of 2005, and this guide is one document in the IEEE 1547 series. [26]

IEEE P1127a – Guide for the Design, Construction and Operation of Electric Power Substation for Community Acceptance and Environmental Compatibility

This guide identifies significant community acceptance and environmental compatibility items to be considered during the planning and design phases, the construction period, and the operation of electric supply substations, and documents ways to address these concerns to obtain community acceptance and environmental compatibility. On-site generation and telecommunication facilities are not considered. [97]

IEEE 802.16-2012 – Approved Draft Standard for LAN and MAN Part 16: Air Interface for Broadband Wireless Access Systems

This standard specifies the air interface, including the medium access control layer (MAC) and physical layer (PHY), of combined fixed and mobile point-to-multipoint broadband wireless access (BWA) systems providing multiple services. The MAC is structured to support multiple physical layer (PHY) specifications, each suited to a particular operational environment. The standard enables rapid worldwide deployment of innovative, cost-effective, and interoperable multivendor broadband wireless access products facilitate competition in broadband access by providing alternatives to wireline broadband access, encourages consistent worldwide spectrum allocations, and accelerates the commercialization of broadband wireless access systems. The standard is a revision of IEEE Std 02.16-2004, and consolidates material from IEEE Std 802.16eTM-2005, IEEE 802.16 004/Cor1-2005, IEEE 02.16fTM-2005, and IEEE Std 802.16gTM-2007, along with additional maintenance items and enhancements to the management information base specifications. This revision supersedes and makes obsolete IEEE Std 802.16-2004 and all of its subsequent amendments and corrigenda. [98]

IEEE 802.15.4g-2012 – Local and metropolitan area networks--Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs) Amendment 3: Physical Layer (PHY) Specifications for Low-Data-Rate, Wireless, Smart Metering Utility Networks

This Standard defines an amendment to IEEE 802.15.4. It addresses principally outdoor Low Data Rate Wireless Smart Metering Utility Network requirements. It defines an alternate PHY and only those MAC modifications needed to support its implementation. Specifically, the amendment supports all of the following:

- Operation in any of the regionally available license-exempt frequency bands, such as 700MHz to 1GHz, and the 2.4 GHz band.
- Data rate of at least 40 kbits per second but not more than 1000 kbits per second.
- Achieve the optimal energy-efficient link margin given the environmental conditions encountered in Smart Metering deployments.
- Principally outdoor communications • PHY frame sizes up to a minimum of 1500 octets • Simultaneous operation for at least 3 co-located orthogonal networks.
- Connectivity to at least one thousand direct neighbours characteristic of dense urban deployment Provides mechanisms that enable coexistence with other systems in the same band(s) including IEEE 802.11, 802.15 and 802.16 systems. [99]

IEEE 802.3-2005 – Standard for Information Technology – Telecommunications and Information Exchange between Systems – LAN and MAN – Part 3 (CSMA/CD)

IEEE 802.3 is a set of standards and protocols that define Ethernet-based networks. Ethernet technologies are primarily used in LANs, though they can also be used in MANs and even WANs. IEEE 802.3 defines the physical layer and the medium access control (MAC) sub-layer of the data link layer for wired Ethernet networks [100].

IEEE 802.11 -2012 – Standard for Information Technology – Telecommunications and Information Exchange Between Systems – LAN and MAN – Part 2: Logical Link Control

This standard is part of a family of standards for local area networks (LANs) and metropolitan area networks (MANs) that deals with the physical and data link layers as defined by the ISO Open Systems Interconnection Basic Reference Model. The functions, features, protocol, and services of the Logical Link Control (LLC) sublayer, which constitutes the top sublayer in the data link layer of the ISO/IEC 8802 LAN protocol, are described. The services required of, or by, the LLC sublayer at the logical interfaces with the network layer, the medium access control (MAC) sublayer, and the LLC sublayer management function are specified. The protocol data unit (PDU) structure for data communication systems is defined using bit-oriented procedures, as are three types of operation for data communication between service access points. In the first type of operation, PDUs are exchanged between LLCs without the need for the establishment of a data-link connection. In the second type of operation, a data link connection is established between two LLCs prior to any exchange of information-bearing PDUs. In the third type of operation, PDUs are exchanged between LLCs without the need for the establishment of a data link connection, but stations are permitted to both send data and request the return of data simultaneously. [45]

IEEE PC37.240 Standard for Cybersecurity Requirements for Substation Automation, Protection and Control System

This document provides technical requirements for substation cybersecurity. It presents sound engineering practices that can be applied to achieve high levels of cybersecurity of automation, protection and control systems independent of a voltage level or criticality of cyber assets. Cybersecurity includes trust and assurance of data in motion, data at rest and incident response. [58]