Platone

PLATFORM FOR OPERATION OF DISTRIBUTION NETWORKS

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PLATform for Operation of distribution NEtworks

D4.1 v1.0

Report on the definitions of KPIs and UCs

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Abstract

The Greek demo, aiming to test the Platone architecture and its benefits, has conceived five Use Cases, which are expounded in this report. In addition, appropriate Key Performance Indicators have been defined to measure the effectiveness of the Platone platforms as well as the new methodologies developed. This report, additionally, describes briefly the demo site, highlighting its objectives and detailing existing and Platone-related infrastructure (both hardware and software), so that an initial overview of the Greek demo and the work completed in the first year of Platone project is presented.

Keyword list

use cases – KPIs – DSOs – grid observability – state estimation tool – network tariffs –optimal dispatching – platform – congestion – voltage control – frequency support – ancillary services – PMU – data acquisition – data integration

Executive Summary

The Greek demo, led by the Greek DSO HEDNO, is amongst the three European pilots that will adopt the Platone architecture to evaluate its benefits and potential. HEDNO aims to prove Platone framework as a powerful data acquisition system, by integrating a large amount of data coming from heterogeneous data sources. Additionally, the Greek demo envisages Platone as the ideal environment to accommodate and test novel tools and services for use of the DSOs, Transmission System Operators (TSOs), customers and Aggregators. For this purpose, algorithms that address issues ranging from improvement of network observability and smart use of Distributed Energy Resources (DERs) to the provision of ancillary services to the TSO will be developed.

The Greek demo chose as the pilot site the area of Mesogeia located in the southeastern part of Attica, near Athens. The Mesogeia area is considered as the most suitable for demonstration purposes, since it combines parts of mainland and interconnected islands with significant DER penetration of various types and it provides a mix of rural, urban and suburban areas that include a great spectrum of customer types (households, small, medium and large industries). For the purposes of the demo, existing DSO infrastructure -both hardware and software- will be supplemented with devices (e.g. Phasor Measurement Units) to be installed, tools and services to mature under Platone's framework. The planned installation of the PMUs in appropriately selected network nodes and the integration of their measurements in Platone platforms, serve well the innovation concept of advanced data-driven state estimation that the project champions. In addition, state estimation techniques and models for optimal dispatch for the Day Ahead (DA) and Balancing Markets developed within the Greek demo by NTUA, will become new assets for HEDNO, enabling secure and efficient network operation.

The trial of Mesogeia is accomplished via five different Use Cases described by the use of the standardised IEC template (IEC 62559-2). The UC-GR-1 and the UC-GR-2 are dedicated to the assessment of state estimation methods for identification of operating state of the distribution network, with UC-GR-1 using conventional measurements, and UC-GR-2 considering additional PMUs' measurements. State estimation results are used, not only as a method to enhance forecasts of the network state for the models developed in UC-GR-3 and UC-GR-4, but also as real-time operation data for demonstration purposes. UC-GR-3 seeks to test a novel approach on optimal dispatching of DERs in distribution networks, adopting a variable network tariff, instead of the traditionally used flat network tariff, which will be shared for a 24-hour window in a Day Ahead basis to customers with flexible loads to incentivise certain behaviours. In a similar way, in UC-GR-4, the DSO communicates for a single-period of the Balancing Market a network tariff that reflects the state of the distribution grid as well as the frequency support request coming from the TSO. UC-GR-5 assesses the completion of the on-site installation of PMUs and examines how Platone acts as a visualisation tool and central data hub, providing data integration, verification and security for the various DSO data.

As part of the work of this deliverable, appropriate KPIs are identified to quantify the measurable impact of the methodologies developed. UC-GR-1 and UC-GR-2 employ a series of metrics to evaluate the precision of the state estimation of the distribution network achieved and, most importantly, the potential accuracy improvement that PMUs measurements may offer. The effect of methods described in UC-GR-3 and UC-GR-4 is measured based on the demand and generation curtailment -in terms of frequency of events and volume- against the Business-as-Usual scenario. In the same sense, the frequency support not provided to the TSO is used to compare the approach tested in UC-GR-4 with the Business-as-Usual scenario. KPIs that quantify the success of on-site installation and commissioning of PMUs, together with data integration and visualisation, highlight the end result of Platone in the Greek demo.

The definition of the Use Cases and KPIs has been an exacting and multi-stage work within WP4 for the first year of the project, which produced meaningful scenarios and ways to assess them. The use of established methodologies for the purpose of this task, as suggested and agreed by all project partners, gives confidence that the Greek demo will adequately test the Platone architecture, taking it a step further by exploring novel approaches for DSO operation.

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1 Introduction

The project "PLATform for Operation of distribution Networks – Platone" 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 a 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 become flexibility market players more easily. 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 [1], 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 three European trials (in Greece, Germany and Italy) and within the Distributed Energy Management Initiative (DEMI) in Canada. The Platone consortium aims to go for a commercial exploitation of the results after the project is finished. Within the H2020 programme "A single, smart European electricity grid" Platone addresses the topic "Flexibility and retail market options for the distribution grid".

The Greek demo, led by the Greek DSO HEDNO, aims to test the Platone architecture and systems developed within the project by means of five different Use Cases. More specifically, the Greek demo uses as core components the Platone DSO Technical Platform (DSOTP), and the Platone Blockchain Access Platform (BAP). DSOTP is the IT environment that includes all the tools and services that enable advanced monitoring and control of the grid. BAP is the platform that certifies measurements and customer data. HEDNO and NTUA elaborated the Use Cases so that, apart from testing the Platone architecture itself, they also showcase how the DSO can actually benefit from it. The scenarios defined in the Use Cases investigate whether the DSO achieves better observability of the distribution network via an advanced SE tool and whether adopting variable network tariffs, enables a more efficient operation of the distribution network or even the provision of ancillary services to the TSO by the end users of the distribution network. Explicitly defined Key Performance Indicators (KPIs) are used to measure the impact of the scenarios tested compared to the Business-as-Usual scenario.

1.1 Task 4.1

This document reports and analyses the outcomes of the Task 4.1, for which Use Cases and corresponding KPIs were defined for the Greek demo. HEDNO and NTUA explored potential Use Cases for the Platone demonstration site of Mesogeia to conclude in meaningful scenarios to be tested, that will allow the DSO to better manage and operate the network, improving the power quality and reducing generation and demand curtailment. Out of an extended list of potential KPIs, those that effectively measure the success of such scenarios were chosen. Further details of the methodology for Use Cases and KPIs definition are presented in Chapter 3 and 4 respectively.

1.2 Objectives of the Work Reported in this Deliverable

The objective of the work reported in this deliverable is to define the Use Cases that the Greek Demo developed for the purposes of testing a novel approach to distribution network operation for the DSO and how this can be realised via the Platone architecture. Also, the work described in this deliverable aims to analyse the models that the Use Cases were based upon by the use of specific scenarios and clearly defined KPIs that are going to measure their success.

1.3 Outline of the Deliverable

Following this introductory first chapter, Chapter 2 presents an overview of the Greek Demo in terms of objectives and then infrastructure, applications, tools and services of the pilot site (Mesogeia). Existing and Platone related assets are portrayed in separate subchapters to underline the originality achieved via the project. Chapter 3 describes the methodology used for the Use Cases definition, the actors involved in them, and the Use Cases themselves in full detail, dedicating one subchapter for each one. Chapter 3 finishes with a mapping of the Use Cases to provide a better understanding of not only the relationships between them, but also the Greek Demo overall. The methodology behind the definition of the KPIs as well as the Greek Demo KPIs themselves are presented in Chapter 4. Chapter 5 presents the conclusions of the deliverable.

1.4 How to Read this Document

This report presents the Use Cases and the KPIs defined for the Greek Demo. D5.2 [2], which is released in parallel, includes similar information for the German Demo. Further details regarding the Italian Demo like its Use Cases and specific KPIs will be found in the D3.3 [3], due for release in month 18 of the project.

D1.1 [4], which is released in parallel, compiles and compares the Use Cases in the three different Platone demos. D1.2 [5], which again is released in parallel, includes calculation methodology, data collection and baseline details for all Demos' KPIs and defines Project KPIs, which relate at least with two different demos and intend to measure the success of the Platone project as a whole. All information regarding Use Cases and KPIs are also available in the online repository GitHub [6].

The Platone architecture (platforms and their use in the demos) is described in detail in D2.1 [7], which is released in parallel.

2 Greek Demo Description

The Greek demo is led by the Greek DSO HEDNO and is situated in the Mesogeia area in the Attica region, which encompasses a mix of rural, urban and sub-urban areas servicing Athens as well as the islands Kea, Andros and Tinos. The area supplies approximately 225,000 customers in its LV and MV networks, varied from households to small, medium and large industries. The area benefits from installations of various forms of renewables, windfarms and PV including net metering and rooftop PVs as well. Part of this Mesogeia area will be the test site for the purposes of the Greek demo.

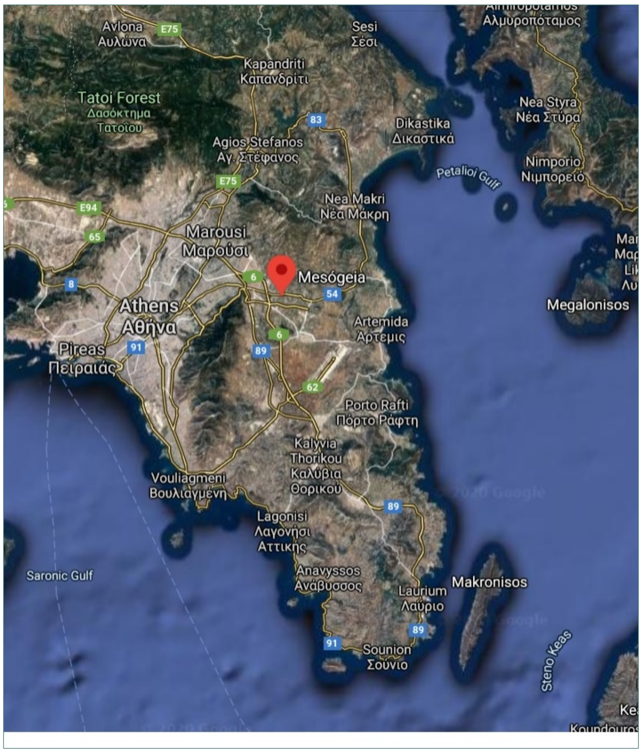

Figure 1: Mesogeia area

2.1 Demo Objectives – Platone

After completion of the first year of the Platone project, the Greek demo reviewed its potential and made its original objectives more concrete and detailed through the UC definition process. The Greek demo objectives are the following:

- To test the Platone architecture and explore its benefits for the Greek DSO (HEDNO).
- To improve grid operation through advanced grid observability.
- To achieve optimal dispatching, addressing local congestion and voltage level issues using novel approaches for flexibility mechanisms at DSO level.
- To investigate potential provision of ancillary services to the TSO by the users of the distribution network.
- To assess the penetration limits of DERs for better control and planning of the distribution network.

2.2 Infrastructure

2.2.1 Existing infrastructure

The test-bed for the Greek demo is a real-world distribution network operating in the geographical site of Mesogeia, which is located in the southeastern part of Attica region, as shown in Figure 1.

With regard to the existing metering infrastructure, the HV/MV substation of the test site, which is considered the slack bus for power flow purposes, is equipped with a SCADA system that provides voltage and current flow measurements at the top of the distribution feeders. In addition, there are dispersed metering devices throughout the network which support recording, storage and transmission towards HEDNO telemetry centres of measurement data (mainly referring to active/reactive power injection) obtained from all MV customers and selected LV customers. The abovementioned metering equipment serves PVs operating at MV and LV levels, and also includes 200 smart meters installed at LV consumers. The related measurement data have a 15-minute temporal resolution.

2.2.2 Low-Cost Phasor Measurement Units - Platone

The Low-Cost Phasor Measurement Unit is a low-cost device, developed by RWTH [8], that measures AC voltage and current signals and is therefore able to estimate phasors of those signals i.e. magnitudes and angles. It also estimates frequency and Rate of Change of Frequency (ROCOF) of the measured waveforms. These measurements are time stamped to accurate time synchronization with respect to the UTC time obtained via GPS protocol. The described output of the Low-Cost PMU is as defined in the standard IEEE C37.118.1 [9] (or updated version IEEE/IEC 60255-118.1 [10]).

2.2.2.1 Low Cost PMU hardware setup

The Low-Cost PMU is built of several fundamental components. The main components are the following:

- Data Acquisition Board. It converts a voltage signal in the required range to digital sampled values. A Low-Cost data acquisition board MCC USB 201 is used. It allows sampling up to 100 kHz (for all channels).
- Measurement computation unit. This unit acquires samples from the data acquisition board, performs phasor estimation, coordinates time synchronization and converts the output of the algorithm into desired format so that the measurements can be transmitted further. General-purpose board Raspberry Pi is used as the computation unit.
- GPS system. It includes necessary components such as antennas and adapters. They provide very precise time synchronization to the computation unit. It is necessary for PMU operation. It is also necessary to trigger precise data acquisition by data acquisition board.
- Mobile communication dongle or wired connection. For communication with other devices/instances, a USB-connected adapter that provides mobile communication is used. Otherwise, the communication can be wired through a direct Ethernet connection.

The Low-Cost PMU in such setup costs around 300-400€ (including associated equipment like cases, cabling, cable terminals and sockets). It is therefore considered a low-cost device when comparing to prices of commercial equipment with costs starting from several thousand EUR. The setup can provide measurement for maximum 8 signals. For better precision of phasor and frequency estimations and especially for better time synchronization in case of higher reporting rates, a lower number of signals in simultaneous use is recommended.

2.2.2.2 PMU measurement calculations

As mentioned, a PMU measurement (frame) includes a phasor of the measured signal (magnitude and angle), frequency, ROCOF and a UTC time tag.

Depending on the configuration, the Low-Cost PMU can estimate the frequency and ROCOF based on zero-crossing algorithm for the observation period. Then, phasor estimation is performed through taking the Discrete Fourier Transform (DFT) after flat top window conditioning. The measurement window is chosen to be 120 ms long (6 cycles for 50Hz). The setup is sufficient for reporting rates up to 1 Hz. For test results of this configuration with the hardware described above, please see [8].

For more frequent reporting rates, phasors, frequency and ROCOF are calculated using an interpolated-modulated-sliding DFT algorithm [11], which enables much higher reporting rates, theoretically up to the sampling frequency. Practically, the reporting rate is constrained mainly by strict requirements of time synchronization (e.g. in IEEE C37.118.1 [9] / IEEE/IEC 60255-118.1 [10]) of the resulting phasors, which is primarily determined by the limited capabilities of data acquisition board.

2.2.2.3 PMU upstream communication

Communication from PMU to other instances of Platone architecture (usually only unidirectional communication of the measurement) can be established using different communication protocols with messages defined according to IEEE C37.118.2 [12]. In Platone, communication protocol can be tailored to the component receiving data (e.g. Platone technical platform or directly a service hosted elsewhere). Communication can be realized for example through popular IoT protocols such as MQTT at session layer with JSON data structure for application/presentation layer, or through Sampled Values (SV) and associated IEC 61850 protocols as defined in IEC 61850-7-2 [13] and IEC 61850-9-2 [14] standards and extended in IEC 61850-90-5 [15] for the use with phasors. Since the communication is mainly with the designed platform, MQTT/JSON protocols with the content as defined by standards IEEE C37.118.1 / IEEE/IEC 60255-118.1 are used as the default communication solution. Finally, PMU measurements in the Platone framework could be also communicated through the Blockchain Access Platform component for the Use Cases that a higher level of security is considered as essential.

2.2.2.4 PMU use and benefits in Greek Demo

The generic purpose of PMU installation in the Platone Greek Demo is to increase network observability (for the details see UC descriptions in subchapter 3.3.). Phasors and frequency data are used for network visualisation, but also for integration into State Estimation (SE) applications. Phasor measurements from PMUs can be integrated in the SE tool through e.g. the single step hybrid WLS algorithm, two-step integration with conventional WLS or linear WLS formulation (for monitoring networks with PMUs only). For application in state estimation, even very low measurement reporting rates (e.g. every 5 minutes) can be very beneficial for improving the quality of the algorithm output. The results of SE can be further used by many services, for example related to electricity market or services deciding on the dispatch of generation resources and many other applications. The quality improvements brought to SE by PMU measurements therefore improves also the quality of subsequent SE-based services. PMUs can also serve as a measurement source for more frequently (sub-seconds) operating applications, aiming for more-real time operation.

2.3 Applications, tools and services

2.3.1 Existing Applications, tools and services

SCADA-DMS

SCADA-DMS is a core system for HEDNO's day to day operation as the Greek DSO. The services provided by HEDNO's SCADA-DMS include among others:

- alarm management
- topology information (with feeder traces and schematics)
- fault management
- power flow analysis
- outage management
- monitoring and extraction of quality indices
- load shedding
- asset management
- short-circuit analysis
- a virtual environment fed with details of real grids, which is used as a study environment for investigating distribution feeder optimisation, for protection coordination and for operator training simulation.

AMR (Automatic Meter Reading system)

HEDNO is responsible for installing, operating and maintaining the metering equipment necessary for the operation of the Distribution Network. To this end, HEDNO collects and validates metering data and provides the respective electricity retailers with the measured consumption data necessary for customer billing. Smart electronic meters are installed on some distribution grid buses, covering the MV systems and limited in LV systems, and are responsible for monitoring the transferred energy of these buses. Specifically, in the Mesogeia area there are 200 smart meters covering all the customers served by a specific substation.

GIS (Geographic Information System)

A Geographic Information System is designed to capture, analyse, manage and present the spatial or geographical network data. Moreover, it is a quite flexible system that can collaborate with other systems and technologies concerning the network functions and management operations, such as DMS-SCADA, SAP ERP system, CIS, etc. The visualised network status is directly displayed to the operators, so that it is helpful for the operating efficiency. Last but not least, the geographic information system is valuable for grid planning, optimising, repairing and maintaining strategies. The regions of Mesogeia, which include the Greek demo site and West Thessaloniki were the first to be equipped with a GIS, as the first stage of the system's rollout in the Greek Distribution Network. The GIS pilot in Mesogeia started in April 2017.

DSO Data Server

The DSO Data Server is a dockerised database of HEDNO that hosts DSO data (both network data and AMR data for MV and LV customers) mostly for data analytics and research purposes.

2.3.2 Tools and services - Platone

2.3.2.1 State Estimation Tool

The State Estimation tool (SE tool) filters the available measurement data, comprising actual measurements obtained from active metering devices and pseudo-measurements, i.e. data derived from load forecasting or RES scheduling for network observability accomplishment, in order to estimate the actual operational network state, identify measurements with gross errors (bad data), suppress measurement errors and reconcile inconsistent data. For the development of the SE tool, intricate issues such as the use of low accuracy pseudo-measurements or the occurrence of missing measurement data, should be taken into account and properly tackled with a view to maintaining the quality of state estimation output. In this way, a highly precise estimate of the network state can be acquired in real-time conditions and, thus, reliable real-time monitoring of the distribution network will be supported. Moreover, given that Distribution State Estimation (DSE) is regarded as an enabling function, i.e., it is not an application in and of itself, but it allows and assists the use of other DMS services and applications. The estimated network state will be used as an input to distribution management applications.

A rather challenging aspect of the research work, which has a degree of novelty, is the integration of measurement data obtained from PMUs into the SE tool. The installation of PMUs at selected buses is sure to upgrade the overall metering infrastructure of the network, since they record synchronized measurements of bus voltage phasors as well as a number of line current phasors—all of which are independent of each other and count as individual measurements. Yet, their proper utilization via the SE tool is characterized by difficulties, namely the intense discrepancies in update rates between conventional and PMU measurements and the so-called ill-conditioning issues, and, therefore, demands meticulous planning. The SE tool will ensure that the integration of PMU data will be smooth and all related technical complexities will be circumvented. In this way, the overall performance of the SE tool will be enhanced; the network state will be calculated with increased precision and high quality real-time operational standards for distribution management applications, will be met.

2.3.2.2 Algorithm for optimal DER control

The DER control algorithm will implement a novel approach to optimal dispatching of DERs in distribution networks. Traditional approaches use direct or indirect methods for controlling DERs in order to maximize social wellbeing, while keeping the network within physical limits. Direct methods mean that the DSO is directly controlling DERs, whereas indirect methods involve distributed or decentralised algorithms where the DSO exchanges signals with DERs until a consensus is reached. These methods, while able to achieve optimality, are not practical in the case where DERs participate in different electricity markets. Optimality cannot be defined in that case, as it depends on external variables such as market prices and system-wide conditions. To find a truly close to optimal dispatching strategy one would need to co-optimize the entire system.

The alternative approach used in the Greek demo is for the DSO to charge DERs for network usage according to the distribution network conditions. This means that the network usage price (or tariff) in the Greek demo is not flat, as it is in most countries now, but instead varies according to network conditions. Additionally, this network tariff is known before the DERs optimise their strategy and bid in the Day-Ahead (DA) market, i.e. the day before real-time operation. Thus, DERs know the cost of using the network in each time period and decide accordingly their optimal schedules, free of having to consider network restrictions such as those are incorporated and reflected in the network tariffs.

The goal of the DSO is to rearrange the network usage revenue they already receive, in such a way that the most efficient operation of the network possible is achieved. The network tariffs are subject to restrictions, such as how high or low they can be, and the DSO is not allowed to receive unlimited revenue from these tariffs. Both constraints are bound to limits set by the regulatory authorities. Optimality is still not guaranteed. Nevertheless, the ambition is that by rearranging this revenue to come from time periods and locations of the network where most often DERs create network limit violations, these DERs will adjust their schedules accordingly leading to a significant reduction in the negative side-effects of limit violations, such as demand or/and generation curtailment.

In the Greek demo, an algorithm that employs advanced techniques of mathematical programming to model the DER behaviour and design those network tariffs is developed. The DSO will use this algorithm to find the optimal tariffs for each day of operation and communicate them before the DA market closure to the Aggregators. Aggregators are entities that manage and operate multiple DERs and participate in electricity markets with their entire portfolio. The Aggregators receive the network tariffs, optimise their portfolio and direct setpoints to their DERs. Then, the DSO monitors the outcome and decides to intervene, most often via curtailment, where necessary.

The efficiency of the approach will be tested by measuring the incurred costs for the DSO, in the case where the method is employed, and will be compared with the baseline scenario, which is the Business-as-Usual approach of the flat network tariff. The costs in the Greek demo are mostly curtailment costs and the goal is to reduce both their frequency and volume.

2.3.2.3 Algorithm for ancillary services

Similar to the DER control algorithm, the ancillary services algorithm employs the same idea of variable network tariffs and is analogous in almost every aspect. The difference is that the latter is employed in a frequency response activation market context. This means that it does not apply to an entire day but for a short balancing period in which the Aggregators sell frequency response activation products.

When a frequency response activation arrives, the DSO imposes a short-duration network tariff to represent the state of the network to the Aggregators. The Aggregators take into account the network usage costs (in the form of the added network tariff) and decide their response accordingly. Again, we measure the effectiveness of the method by the reduction of forced curtailment with the method compared to the baseline case.

2.3.2.4 DSOTP and BAP

The DSOTP (DSO Technical Platform) and the BAP (Blockchain Access Platform) are both platforms of Platone framework that are developed by WP2. The Greek demo aims to test their functionalities and evaluate their benefits for the DSO. For this purpose, these platforms were placed as key components of all the Use Cases defined.

The DSOTP is based on work done in the H2020 project SOGNO and is capable of hosting different micro services for a DSO. It offers its own embedded services, data storage provision and, in addition, the potential of interfacing with external systems and services via Rest APIs. The Greek demo use the DSOTP as the central data hub to log DSO data from not only existing infrastructure (GIS, SCADA-DMS, AMR), but also new assets (PMUs). DSOTP will be the first DSO system to integrate PMU measurements, due to which HEDNO is expected to achieve advanced centralised monitoring and data logging for better and more efficient distribution network operation. The Greek demo also uses the DSOTP to interface with algorithms that NTUA is developing and which are described in subchapters 2.3.2.1, 2.3.2.2, and 2.3.2.3. Furthermore, the potential utilisation of a forecasting tool that the DSOTP has is examined for the testing of UC-3 and UC-4 and described in Chapter 3.

The BAP to be developed within Platone, based on blockchain and smart contracts technology, acts as a data encryption enabler for the Greek demo, to ensure data provenance and data immutability for the Greek DSO. In particular, for all Use Cases defined in the Mesogeia pilot, all data coming from the distribution network (e.g. voltage magnitudes, power flows, power injections from distributed generation units) will be certified and registered as blockchain transactions, and then provided to the DSOTP.

Further details of the DSOTP and the BAP as well as their use in the Italian and the German demo are included in D2.1 [7], which is released in parallel.

3 Use Cases - Greek demo

3.1 Methodology

For the definition of Platone Use Cases, a template, based on the Use Case Methodology defined in IEC 62559 [16], was distributed among demo leaders, in order to achieve a common approach between the three demos. This task was performed by E.DSO and is described thoroughly in D1.1 [4]. For the implementation of the Greek demo High level Use Cases were already described in the project's proposal and during the first year of the project these Use Case were re-evaluated and modified in order to describe more accurately the impact of Platone solutions implemented in the Mesogeia pilot site. Four Use Cases (UC-1-UC-4) are focused on the assessment of the tools and services, described in subchapter 2.3.2 of this document that will be developed for Platone and implemented within the Greek demo. On the other hand, UC-5 is an IT oriented Use Case associated to the actual implementation of the Platone platforms (DSOTP and BAP) and PMUs within the Greek demo. Platone platforms and PMUs are used in Use Cases as per Table 1 in subchapter 3.2.

3.2 Actors

For the implementation of the Use Cases, 14 actors of three different types, Person, System, Device, are participating. All actors involved in Greek demo and the corresponding Use Cases are described in the next table.

Table 1: Actors list

Actor Name	Actor Type	Actor Description	UC
Aggregator	Person	Entity that aggregates the flexibility offers on the market and provide them to DSO in case of needs for the grid.	GR-3, GR-4
AMR	System	Automatic Meter Reading system	all UCs
BAP	System	Blockchain Access Platform	all UCs
Commercial customer	Person	End user to denote a typical commercial electricity consumption with the capability of load flexibility provision through a contract with an Aggregator.	GR-3, GR-4
DMS	System	Distribution Management System	all UCs
DSO	Person	Distribution System Operator, the entity responsible for the safe and secure operation and management of the distribution system; for data management associated with the use of the distribution system; for procurement of flexibility services using optimization algorithms and the Platone DSO Technical Platform.	GR-1, GR-2, GR-3, GR-4
DSO Data Server	System	Database containing data from AMR, DMS & SCADA	all UCs
DSOTP	System	DSO Technical Platform	all UCs
GIS	System	Geographical Information System	all UCs

PMU	Device	Phasor Measurement Unit	GR-2, GR-3, GR-4, GR-5
RES	System	Renewable Energy Source	GR-3, GR-4
Residential customer	Person	End user to denote a typical residential electricity consumption with the capability of load flexibility provision through a contract with an Aggregator.	GR-3, GR-4
SCADA	Device	Supervisory Control And Data Acquisition system	all UCs
TSO	Person	Transmission System Operator	GR-4

3.3 Use Cases description

3.3.1 UC-GR-1 - Functions of the State Estimation tool given conventional measurements

Objective

The main objectives of the Use Case is to improve confidence in actual measurement data obtained throughout the network as well as available load forecasts and to capture the real-time operational network state.

Description

The DSO operates the distribution network. A measurement set, composed of actual and historical measurement data obtained from the dispersed metering devices (AMR, GIS, SCADA) installed throughout the network, is available for real-time operation purposes. The related measurements refer to power flows and voltage magnitudes at the top of distribution feeders, power injections from distributed generation units, and load pseudo-measurements for aggregated consumer demand at MV/LV transformer level. Given that the network model (topology) is known with a good degree of certainty, the State Estimation tool ensures that the network is observable based on the available measurement set and, subsequently, calculates the estimated state vector, that is, the voltage magnitudes and angles of all network buses.

Actors involved in the Use Case:

- AMR
- BAP
- DMS
- DSO
- DSO Data Server
- DSOTP
- GIS
- SCADA

Use Case Conditions

In order to implement the Use Case successfully, it is a prerequisite that the network model (topology) is known with a good degree of certainty and DSO systems (e.g. AMR, GIS, SCADA) are operational during the preparation and demonstration period.

Diagrams

The Use Case and Sequence diagrams, depicted below, can provide a good understanding of the procedures and processes of the Use Case implementation.

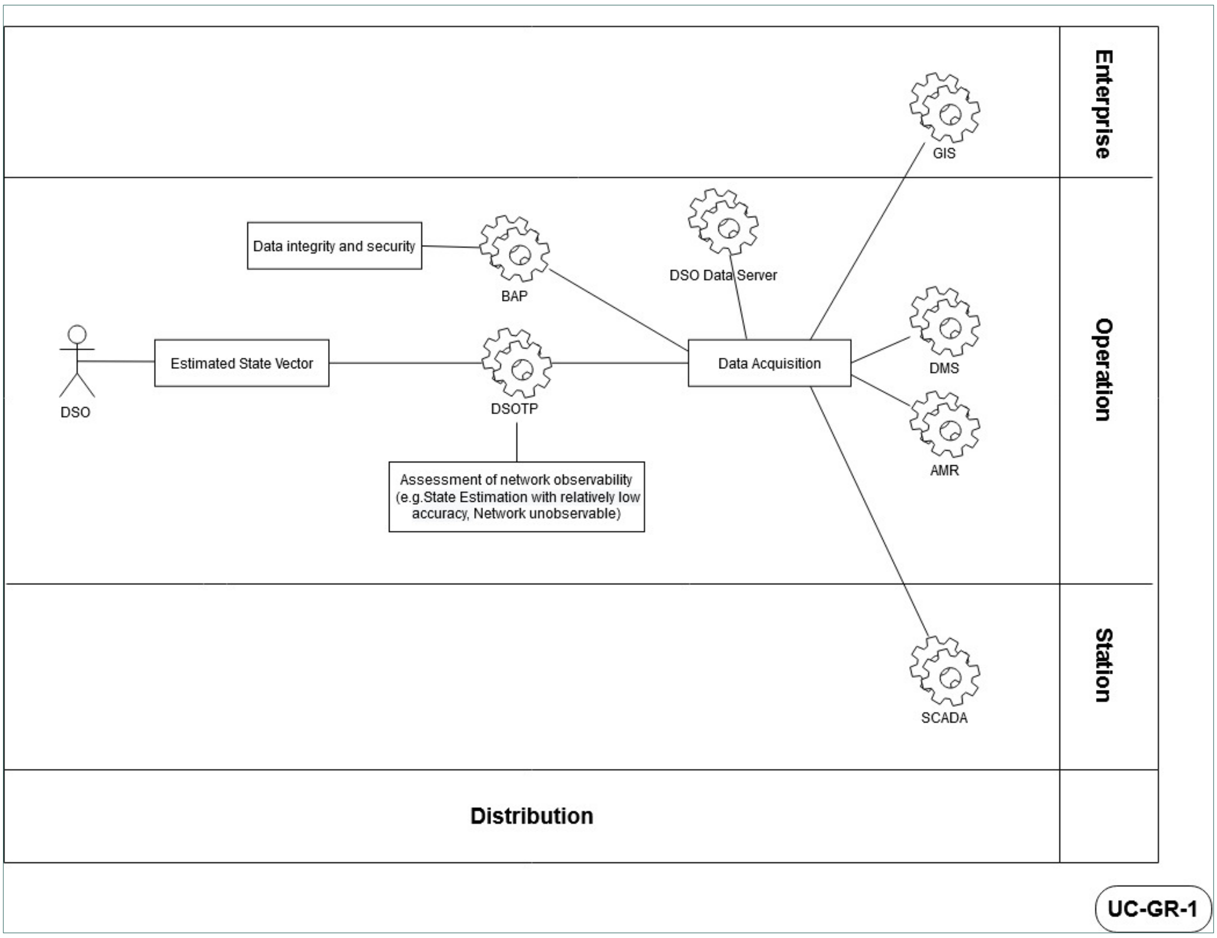

Figure 2: Use Case diagram UC-GR-1

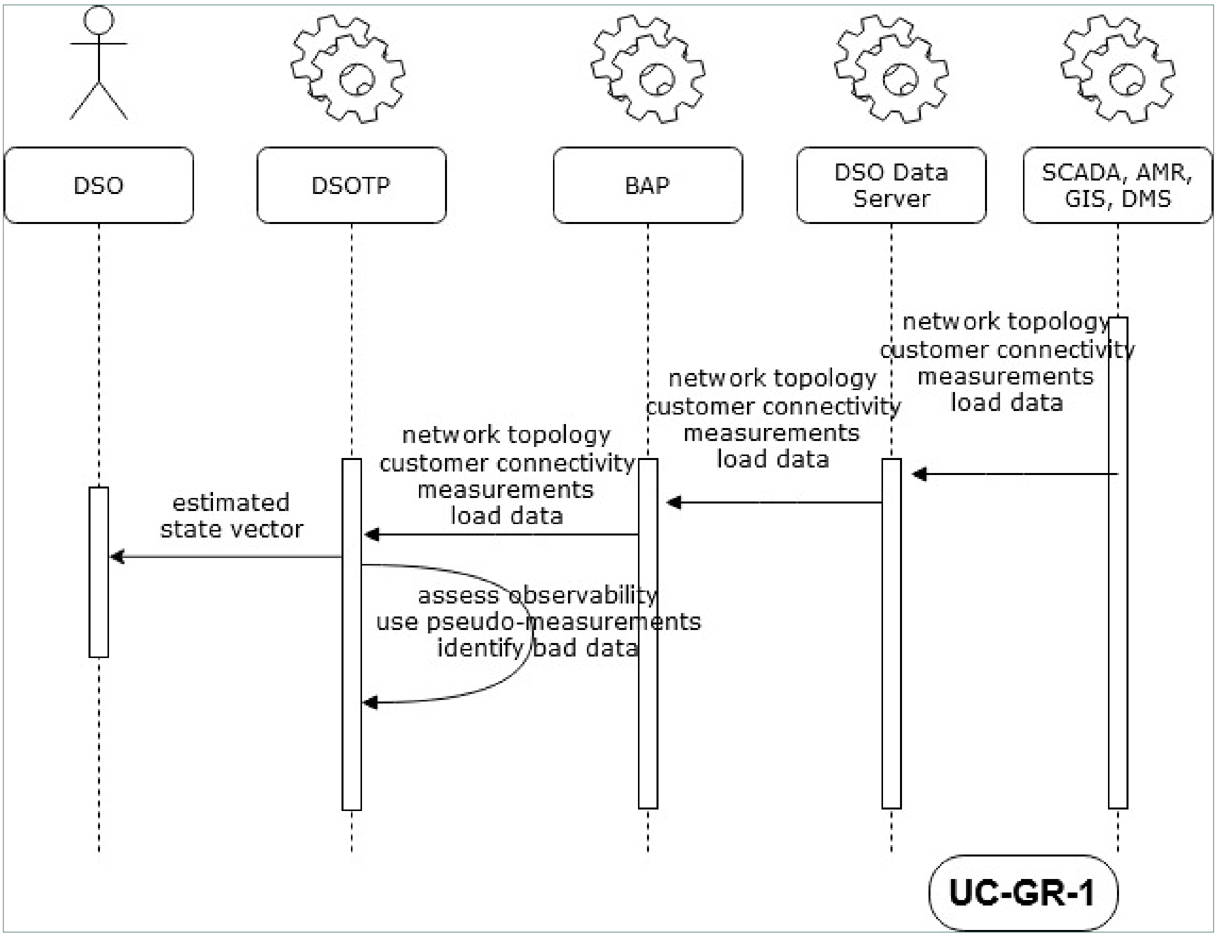

Figure 3: Sequence diagram UC-GR-1

Scenarios-Steps

For the implementation of UC-GR-1, two different scenarios are considered. Scenario 1 aims at the attainment of quality state estimation using accurate pseudo-measurements or indicating new measured points. Whereas, the objective of Scenario 2 is the fulfilment of observability using additional/alternative data to substitute for the missing ones.

Scenario 1: Attainment of quality state estimation

In this scenario, the State estimation accuracy is below a predefined threshold and accurate pseudo-measurements are used in order to improve the accuracy of the state vector. In the table below, there is a step-by-step analysis of this scenario.

Table 2: Steps of UC-1, Scenario 1: Attainment of quality state estimation

Step No.	Event.	Name of Process/ Activity	Description of Process/ Activity.	Service	Information Producer (Actor)	Information Receiver (Actor)
1	Measurements from the Distribution Network	Data Acquisition	Various field measurements that reflect the network state are communicated	REPORT	SCADA, DMS, GIS, AMR	DSO Data Server

2	Measurements from the Distribution Network	Data Acquisition	Various field measurements that reflect the network state are communicated	REPORT	DSO Data Server	BAP
3	Measurements from the Distribution Network	Data Verification	All data received gets verified and secured via blockchain technology	EXECUTE	BAP	BAP
4	Measurements from the Distribution Network	Data Acquisition	Verified and secured data is delivered to the DSOTP	REPORT	BAP	DSOTP
5	Measurements from the Distribution Network	Observability assessment	A numerical observability method is used in order to determine observability status	EXECUTE	DSOTP	
6	Measurements from the Distribution Network	Calculation of state vector	State estimation algorithm is carried out	EXECUTE	DSOTP	DSOTP
7	State vector with low accuracy	Data Acquisition	New measurements/pseudo-measurements integrated in the State Estimation tool	CHANGE	DSO Data Server	DSOTP
8	Measurements from the Distribution Network	Calculation of state vector	State estimation algorithm is carried out	EXECUTE	DSOTP	DSOTP
9	Measurements from the Distribution Network	Output of State Estimation tool	Estimated state vector is communicated	REPORT	DSOTP	DSO

Scenario 2: Fulfilment of observability

In the scenario 2, there are initially missing or inconsistent measurements, so the network is unobservable. In this scope, additional/alternative data are used to substitute for the missing ones in order to improve the accuracy of the state vector. In the table below, there is a step-by-step analysis of this scenario.

Table 3: Steps of UC-1, Scenario 2: Fulfilment of observability

Step No.	Event.	Name of Process/ Activity	Description of Process/ Activity.	Service	Information Producer (Actor)	Information Receiver (Actor)
1	Measurements from the Distribution Network	Data Acquisition	Various field measurements that reflect the network state are communicated	REPORT	SCADA, DMS, GIS, AMR	DSO Data Server
2	Measurements from the Distribution Network	Data Acquisition	Various field measurements that reflect the network state are communicated	REPORT	DSO Data Server	BAP
3	Measurements from the Distribution Network	Data Verification	All data received gets verified and secured via blockchain technology	EXECUTE	BAP	BAP
4	Measurements from the Distribution Network	Data Acquisition	Verified and secured data is delivered to the DSOTP	REPORT	BAP	DSOTP
5	Measurements from the Distribution Network	Observability assessment	A numerical observability method is used in order to determine observability status	EXECUTE	DSOTP	
6	Lack of observability	Data acquisition	Additional/alternative data to substitute for missing or inconsistent measurements, are integrated in the State Estimation tool	CHANGE	DSO Data Server	DSOTP
7	Measurements from the Distribution Network	Observability assessment	A numerical observability method is used in order to determine observability status	EXECUTE	DSOTP	

8	Measurements from the Distribution Network	Output of State Estimation tool	Estimated state vector is communicated	REPORT	DSOTP	DSO

3.3.2 UC-GR-2 - PMU data integration into State Estimation tool

Objective

In this Use Case, PMU measurements are used in order to reinforce network observability and controllability via improved state estimation performance. Furthermore, it is ensured that synchronised measurement data derived from PMUs are smoothly incorporated into the pre-existing system of conventional measurements.

Description

A measurement set, composed of actual and historical measurement data obtained from the dispersed metering devices (AMR, GIS, SCADA, PMUs) installed throughout the network, is available to the DSO for real-time operation purposes. The aforementioned data refer to a) synchronised measurements of bus voltage phasors and line current phasors (magnitude and angle) and b) conventional measurements of power flows and voltage magnitudes at the top of distribution feeders, power injections from distributed generation units, and load pseudo-measurements for aggregated consumer demand at MV/LV transformer level. Given that the network model (topology) is known with a good degree of certainty, the State Estimation tool ensures that the network is observable based on the available measurement set, reconciles the PMU data with the conventional measurements and, subsequently, calculates the estimated state vector, that is, the voltage magnitudes and angles of all network buses. Given the successful integration and use of the PMU data in the SE tool, the overall performance of the SE tool will be enhanced; the network state will be calculated with increased precision compared to conventional-measurements-only scenarios (UC-GR-1), and high quality real-time operational standards for distribution management applications will be met.

Actors involved in the Use Case:

- AMR
- BAP
- DMS
- DSO
- DSO Data Server
- DSOTP
- GIS
- PMU
- SCADA

Use Case Conditions

In order to implement the Use Case successfully, it is a prerequisite that the network model (topology) is known with a good degree of certainty and DSO systems (e.g. AMR, GIS, SCADA) are operational during the preparation and demonstration period. Furthermore, it is essential that PMUs are installed in the field and data retrieved from PMUs are available for the SE tool.

Diagrams

The Use Case and Sequence diagrams, depicted below, can provide a good understanding of the procedures and processes of the Use Case implementation.

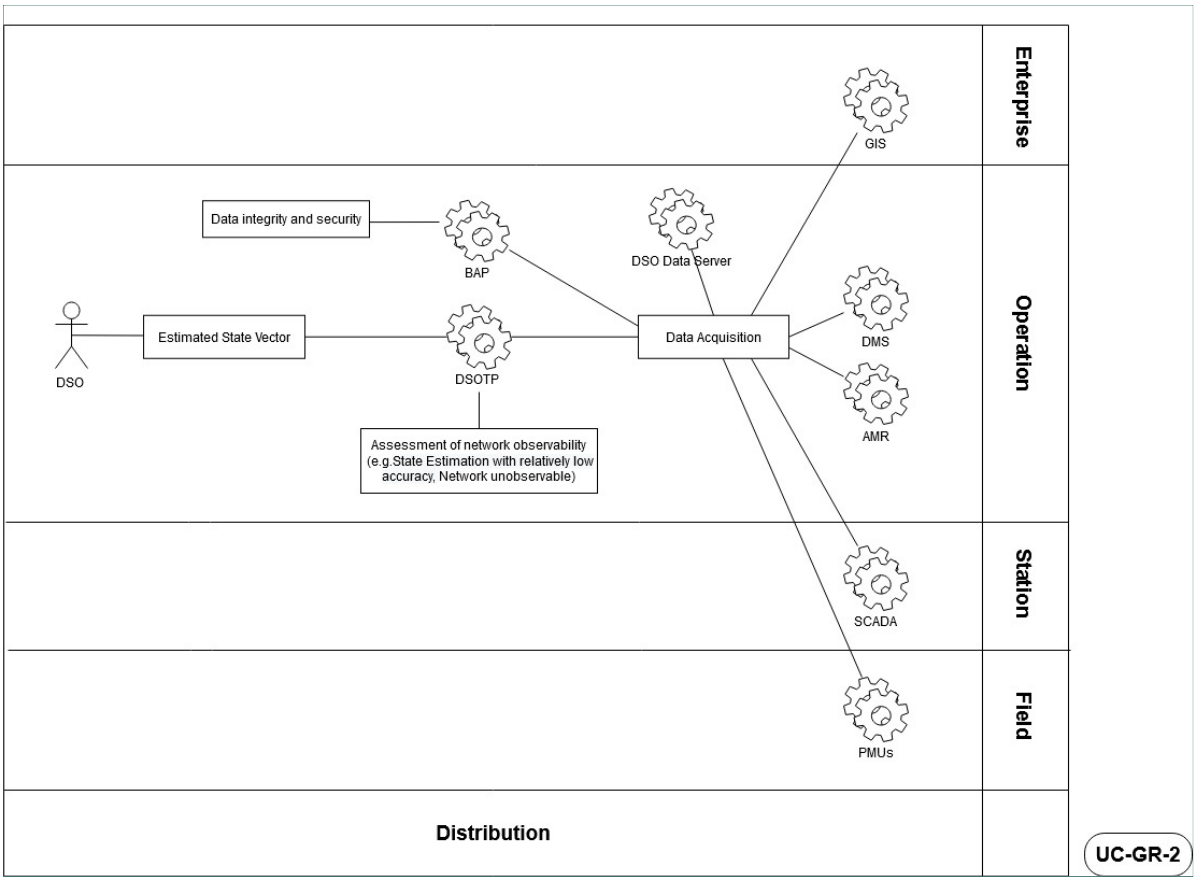

Figure 4 : Use Case diagram UC-GR-2

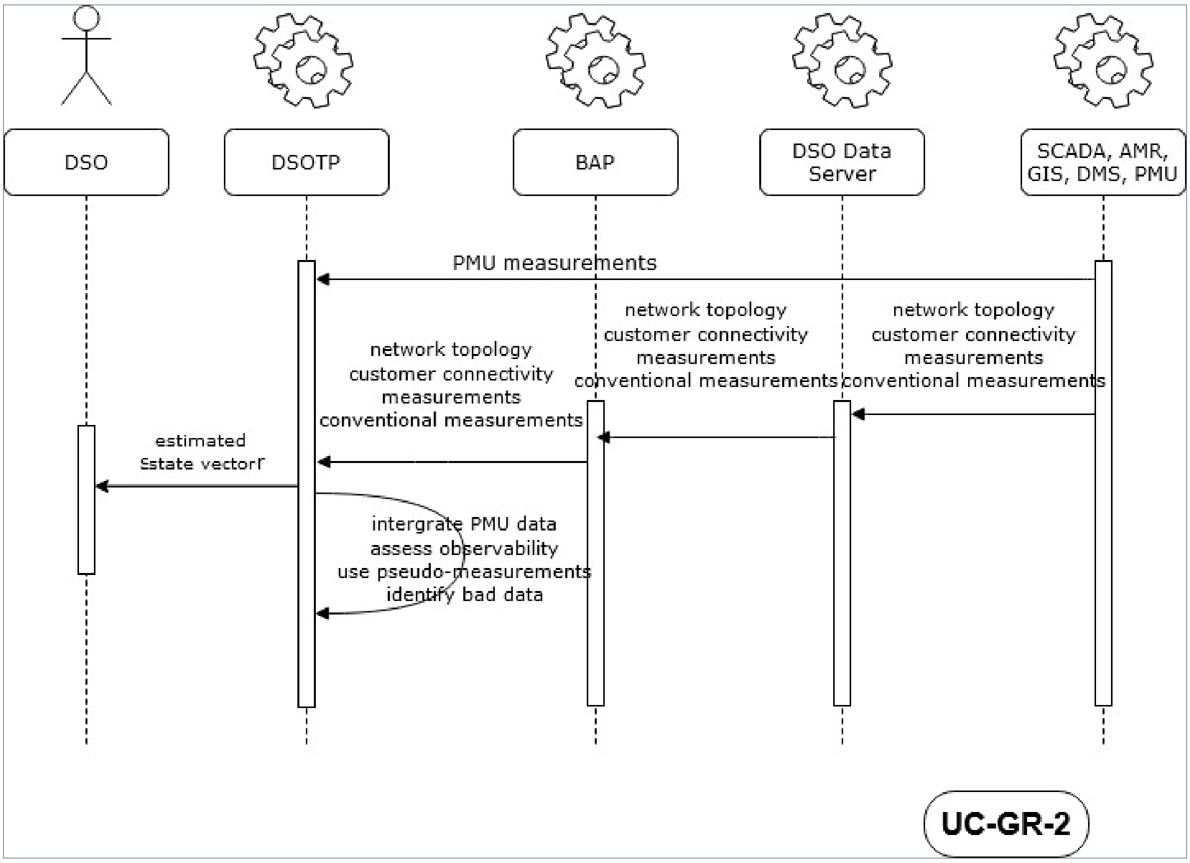

Figure 5 : Sequence diagram UC-GR-2

Scenarios-Steps

For the implementation of UC-GR-2, the scenario is focused on the PMUs data integration in the State estimation tool in order to achieve an estimation of high accuracy.

Scenario 1: PMU data integration

In the table below, there is a step-by-step analysis of the scenario.

Table 4: Steps of UC-2, Scenario 1: PMU data integration

Step No.	Event.	Name of Process/ Activity	Description of Process/ Activity.	Service	Information Producer (Actor)	Information Receiver (Actor)
1	Measurements from the Distribution Network	Data Acquisition	Various field measurements that reflect the network state are communicated	REPORT	SCADA, DMS, GIS, AMR, PMUs	DSO Data Server
2	Measurements from the Distribution Network	Data Acquisition	Various field measurements that reflect the network state are communicated	REPORT	DSO Data Server	BAP
3	Measurements from the Distribution Network	Data Verification	All data received gets verified and secured via blockchain technology	EXECUTE	BAP	BAP
4	Measurements from the Distribution Network	Data Acquisition	Verified and secured data is delivered to the DSOTP	REPORT	BAP	DSOTP
5	Measurements from the Distribution Network	PMU Data Acquisition	PMU measurements that reflect the network state are communicated	REPORT	PMU	DSOTP
6	Measurements from the Distribution Network	PMU data integration	PMU and conventional measurements integrated into a unified measurement set	EXECUTE	DSOTP	DSOTP
7	Measurements from the Distribution Network	Observability assessment	A numerical observability method is used in order to determine observability status	EXECUTE	DSOTP	DSOTP

8	Measurements from the Distribution Network	Calculation of the state vector	State estimation algorithm is carried out	EXECUTE	DSOTP	DSOTP
9	Measurements from the Distribution Network	Output of State Estimation tool	Estimated state vector is communicated	REPORT	DSOTP	DSO

3.3.3 UC-GR-3 - Distribution Network limit violation mitigation

Objective

To use network tariffs in order to incentivise a more efficient operation of the network while respecting operation limits (voltages, lines overload).

Description

RES systems and customers with flexible loads are connected to the distribution network with the flexible loads considered aggregated for the scope of the UCs regarding their management in the MV level. State of the network is known with a good degree of certainty based on the state vector that the State Estimation tool produces using the available measurements and the topology data from the AMR, GIS, SCADA and PMUs. The DSO communicates network tariffs in a day-ahead context. These tariffs appropriately reflect the potential of the network exceeding its physical limits resulting in violations and/or curtailment of demand/generation. Compared to the Business-as-Usual scenario of the flat network tariffs, the DSO aims at reducing such negative effects by the use of variable day-ahead network tariffs, which incentivise the appropriate actions of the -assumed as- rational users of the distribution network.

Actors involved in the Use Case:

- Aggregator
- AMR
- BAP
- Commercial Customers
- DMS
- DSO
- DSO Data Server
- DSOTP
- GIS
- PMU
- RES
- Residential Customers
- SCADA

Use Case Conditions

Customers' consent required for participation in the flexibility mechanism, so it is assumed that the customers are rational and part of the load is flexible. Moreover, it is assumed that there is a good degree of certainty in the estimation of the network state.

For the implementation of the Use Case, the technical conditions that need to be fulfilled are the installation of smart metering, the existence of smart appliances for load shifting and the normal operation of DSO systems (e.g. AMR, GIS, SCADA) during the preparation and demonstration period.

Lastly, on the regulatory aspect of this Use Case, it is required that a dynamic network charging scheme is allowed.

Diagrams

The Use Case and Sequence diagrams, depicted below, can provide a good understanding of the procedures and processes of the Use Case implementation.

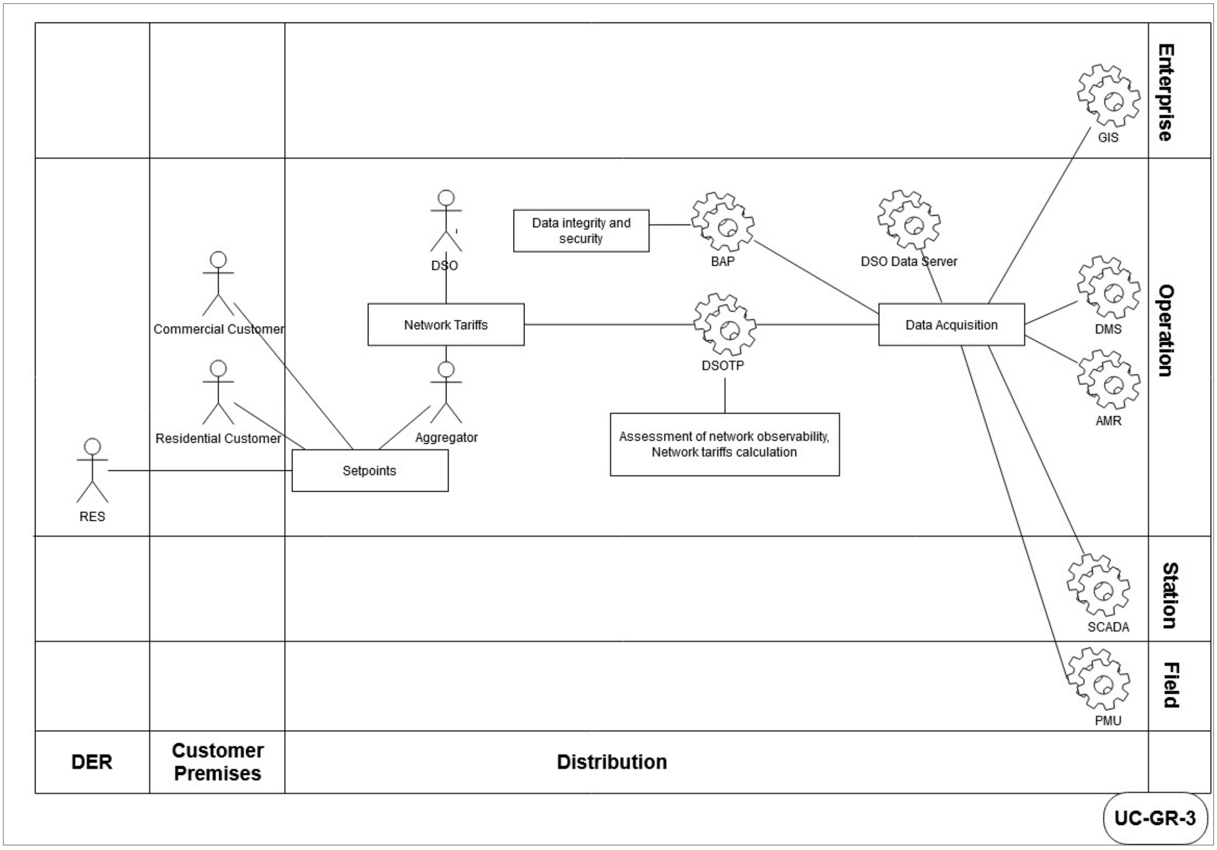

Figure 6 : Use Case diagram UC-GR-3

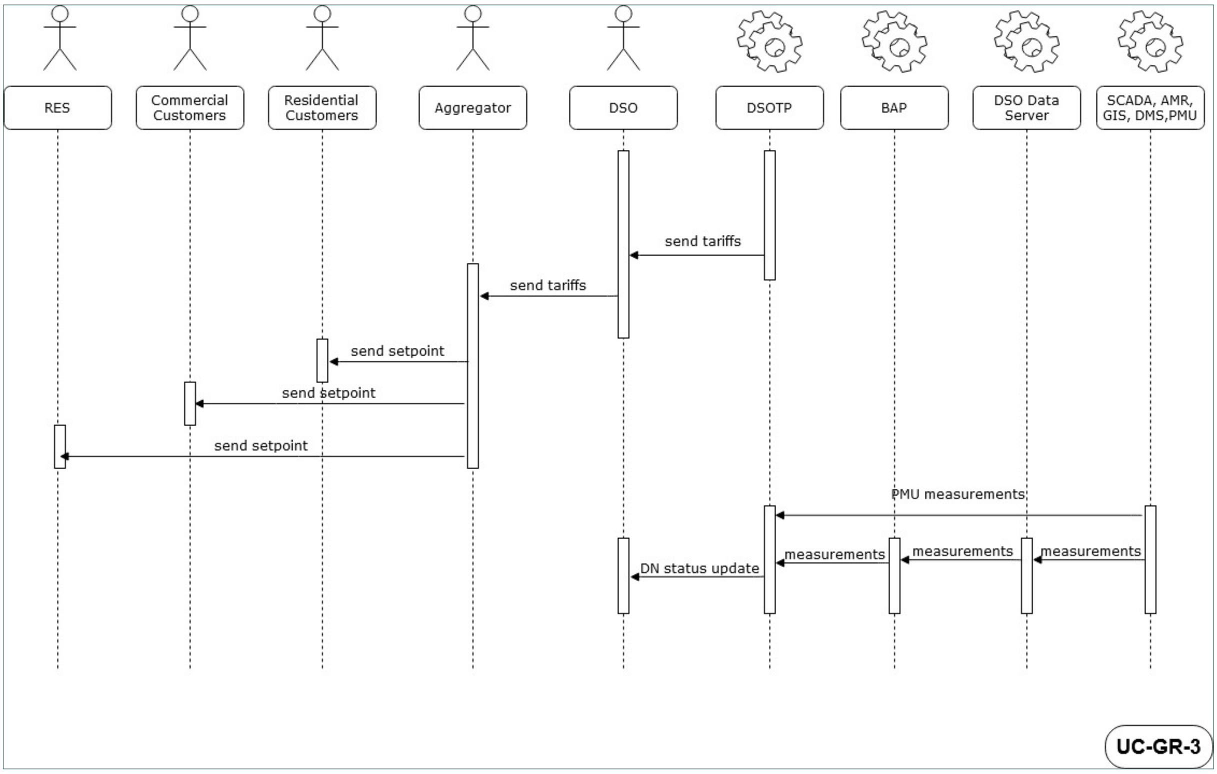

Figure 7 : Sequence diagram UC-GR-3

Scenarios-Steps

The scenario implemented within the UC-GR-3 assesses the network limit violations occurring in a distribution network and investigates their mitigation by the use of variable day-ahead network tariffs.

Scenario 1: Network limit violations mitigation by the use of day-ahead network tariffs

In the table below, there is a step-by-step analysis of the scenario.

Table 5: Steps of UC-3, Scenario1: Network limit violations mitigation by the use of day-ahead network tariffs

Step No.	Event.	Name of Process/ Activity	Description of Process/ Activity.	Service	Information Producer (Actor)	Informatio n Receiver (Actor)
1	none (daily process)	Tariffs retrieval	Day-ahead tariffs that reflect the expected state of the network sent to the DSO	CREATE	DSOTP	DSO
2	Tariffs retrieval	Tariffs communica tion	Tariffs are communicated to the Aggregator	REPORT	DSO	Aggregator
3	Tariffs communicati on	Setpoint sent to Residential Customer	Sending setpoint to the flexibility load	CREATE	Aggregator	Residential consumer

4	Tariffs communication	Setpoint sent to Commercial Customer	Sending setpoint to the flexibility load	CREATE	Aggregator	Commercial consumer
5	Tariffs communication	Setpoint sent to RES	Sending setpoint to the RES producer	CREATE	Aggregator	RES
6	none	Data Acquisition	New Distribution Network state (Distribution Network state updated following the Aggregator's response)	REPORT	PMU	DSOTP
7	none	Data Acquisition	New Distribution Network state (Distribution Network state updated following the Aggregator's response)	REPORT	SCADA, DMS, GIS, AMR	DSO Data Server
8	New Distribution Network state	Data Acquisition	New Distribution Network state	REPORT	DSO Data Server	BAP
9	New Distribution Network state	Data Verification	All data received gets verified and secured via blockchain technology	EXECUTE	BAP	BAP
10	New Distribution Network state	Data Acquisition	Verified and secured data is delivered to the DSOTP	REPORT	BAP	DSOTP
11	New Distribution Network state	Data Acquisition	New Distribution Network state	REPORT	DSOTP	DSO

3.3.4 UC-GR-4 - Frequency support by the distribution network

Objective

To achieve better operating conditions of the distribution network in the case of a frequency restoration reserve activation request by the TSO.

Description

RES systems and customers with flexible loads are connected to the distribution network with the flexible loads considered aggregated for the scope of the UCs regarding their management in the MV level. State of the network is known with a good degree of certainty based on the available measurements and the topology via the AMR, GIS and SCADA data. A frequency support activation request from the TSO arrives to the Aggregator representing the customers with flexible loads. The request is also communicated to the DSO Technical Platform via an API and the information is shared with the appropriate tools and services. The DSO calculates and communicates to the Aggregator the appropriate network tariffs that reflect the situation of the network. The flexible loads react to these tariffs and respond to the frequency support request appropriately.

Actors involved in the Use Case:

- Aggregator
- AMR
- BAP
- Commercial Customers
- DMS
- DSO
- DSO Data Server
- DSOTP
- GIS
- PMU
- RES
- Residential Customers
- SCADA
- TSO

Use Case Conditions

For the scope of this Use Case, the TSO is a simulated entity.

Customers' consent required for participation in the flexibility mechanism, so it is assumed that the customers are rational and part of the load is flexible. Moreover, it is assumed that there is a good degree of certainty in the estimation of the network state.

For the implementation of the Use Case the technical conditions that have be fulfilled are the installation of smart metering, the existence of smart appliances for load shifting as well as the DSO systems (e.g. AMR, GIS, SCADA) being operational during the preparation and demonstration period.

Lastly, on the regulatory aspect of this Use Case, it is required that a dynamic network charging scheme is allowed.

Diagrams

The Use Case and Sequence diagrams, depicted below, can provide a good understanding of the procedures and processes of the Use Case implementation.

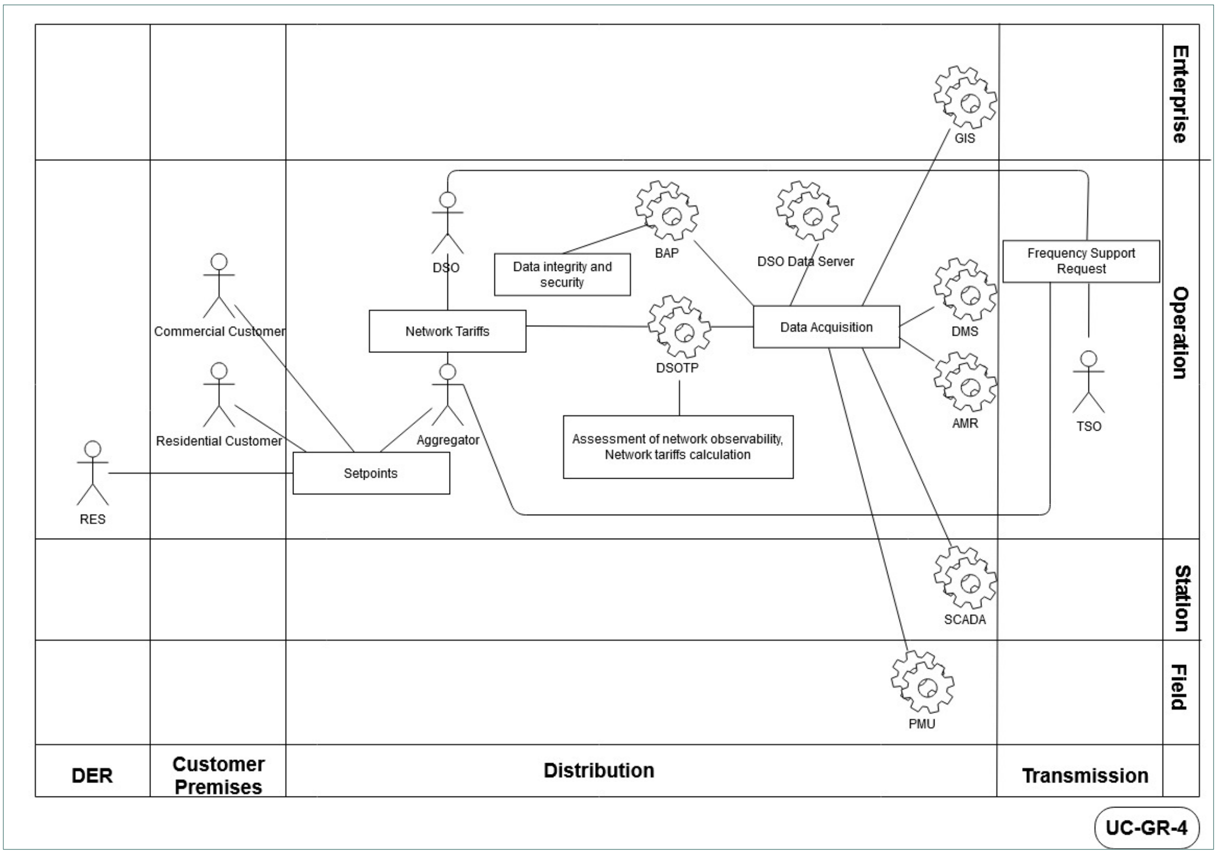

Figure 8 : Use Case diagram UC-GR-4

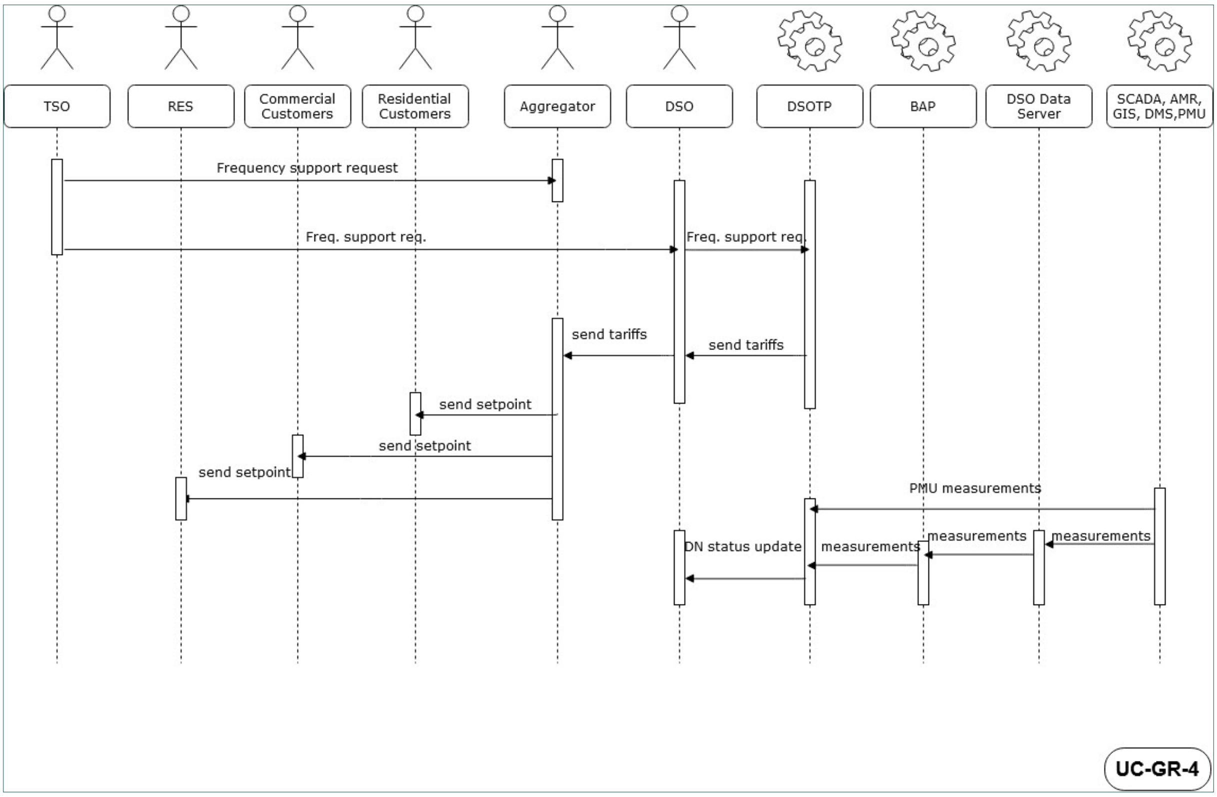

Figure 9 : Sequence diagram UC-GR-4

Scenarios-Steps

In the scenario implemented within the UC-GR-4 a frequency support request from the TSO needs to be resolved while the DSO ensures the network state with the use of variable network tariffs.

Scenario 1: Frequency support request resolved

In the table below, there is a step-by-step analysis of the scenario.

Table 6: Steps of UC-4 Scenario 1: Frequency support request resolved

Step No.	Event.	Name of Process/ Activity	Description of Process/ Activity.	Service	Information Producer (Actor)	Information Receiver (Actor)
1	TSO needs frequency support	Frequency support request	Frequency support request sent to the Aggregator	CREATE	TSO	Aggregator
2	TSO needs frequency support	Frequency support request	Frequency support request communicated to the DSO	CREATE	TSO	DSO
3	DSO receives frequency support request from TSO	Frequency support request	Frequency support request sent to the DSOTP	REPORT	DSO	DSOTP
4	Frequency support request received by DSOTP	Tariffs retrieval	Tariffs are sent to the DSO	CREATE	DSOTP	DSO
5	Tariffs retrieval	Tariffs communica tion	Tariffs are communicated to the Aggregator	REPORT	DSO	Aggregator
6	Tariffs communicati on	Setpoint sent to Residential Customer	Sending setpoint to the flexibility load	CREATE	Aggregator	Residential consumer
7	Tariffs communicati on	Setpoint sent to Commercial Customer	Sending setpoint to the flexibility load	CREATE	Aggregator	Commercial consumer
8	Tariffs communicati on	Setpoint sent to RES	Sending setpoint to the RES producer	CREATE	Aggregator	RES
9	none	Data Acquisition	New Distribution Network state (Distribution Network	REPORT	PMU	DSOTP

			state updated following the Aggregator's response)			
10	none	Data Acquisition	New Distribution Network state (Distribution Network state updated following the Aggregator's response)	REPORT	SCADA, DMS, GIS, AMR	DSO Data Server
11	New Distribution Network state	Data Acquisition	New Distribution Network state	REPORT	DSO Data Server	BAP
12	New Distribution Network state	Data Verification	All data received gets verified and secured via blockchain technology	EXECUTE	BAP	BAP
13	New Distribution Network state	Data Acquisition	Verified and secured data is delivered to the DSOTP	REPORT	BAP	DSOTP
14	New Distribution Network state	Data Acquisition	New Distribution Network state	REPORT	DSOTP	DSO

3.3.5 UC-GR-5 - PMU integration and Data Visualisation for Flexibility Services Management

Objective

The objectives of UC-GR-5 are to increase network observability and to integrate data coming from different sources in the DSO Technical Platform.

Description

The DSO operates the distribution network and handles the data sources coming from various systems such as SCADA/DMS, AMR, and GIS. Data coming from various sources get integrated into the Open DSO Technical Platform providing an adequate level of network observability. Low Cost PMUs are deployed in Mesogeia area in critical network points and nodes where there is limited observability or a requirement to have an increased awareness such as DER and prosumers bidirectional power flows. Also, PMU data are integrated in the DSO Technical Platform following a data collection plan that serves the functionalities of the flexibility tools and services. Measurements from PMUs enhance network awareness in terms of data granularity and number of nodes observed in a cost-effective manner. In addition, the DSO Technical Platform performs the correlation of the data coming from different sources and systems during real time, providing to the DSO the technical capacity for flexibility mechanisms support and a User Interface (UI) where the aforementioned is visualised. All data except for PMUs measurements is verified and secured by the use of blockchain technology to be developed in the Blockchain Access Platform (BAP) of the project.

Actors involved in the Use Case:

- AMR
- BAP
- DMS
- DSO Data Server
- DSOTP
- GIS
- PMU
- SCADA

Use Case Conditions

PMUs are provided for deployment in Mesogeia area.

Diagrams

The Use Case and Sequence diagrams, depicted below, can provide a good understanding of the procedures and processes of the Use Case implementation.

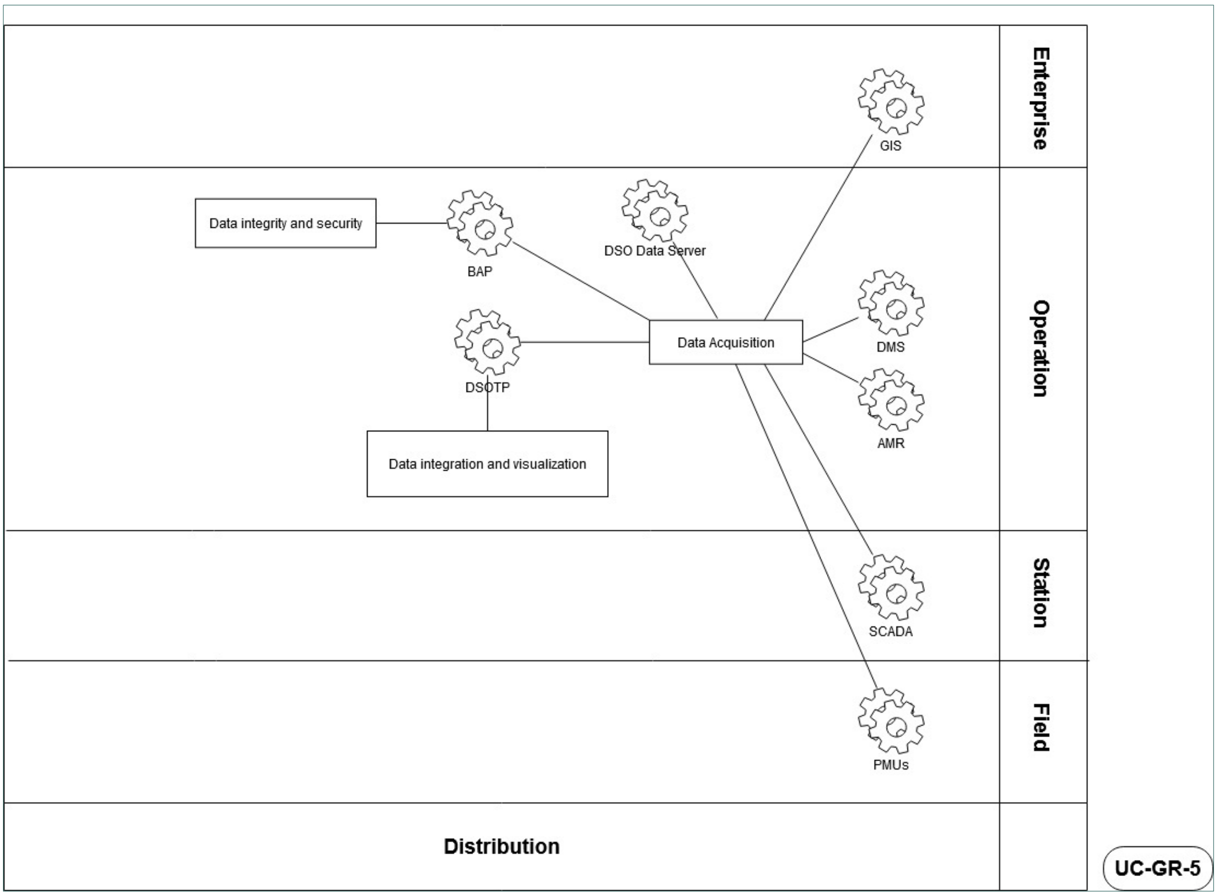

Figure 10 : Use Case diagram UC-GR-5

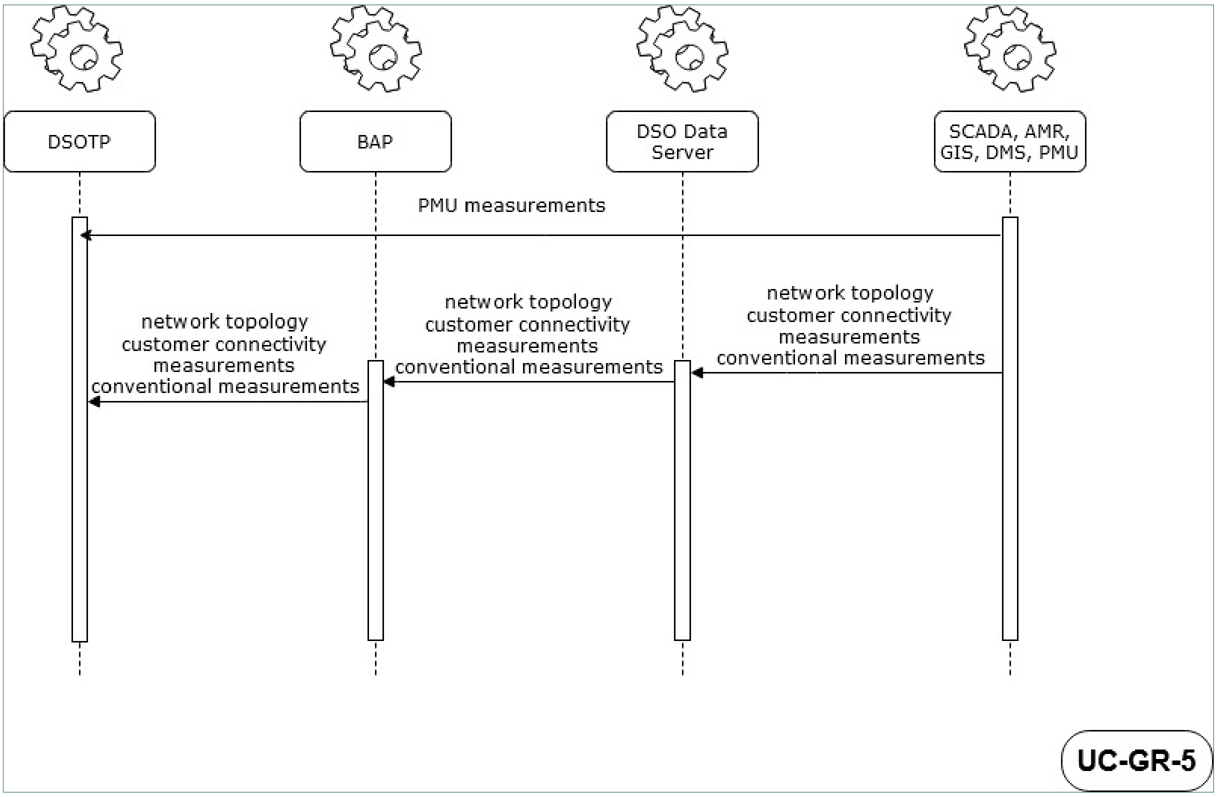

Figure 11 : Sequence diagram UC-GR-5

Scenarios-Steps

The scenario implemented for the UC-GR-5 appraises the integration and visualisation of data from various data sources as well as services' outcomes in the DSOTP.

Scenario 1: Data integration and visualisation in the DSOTP (User Interface)

In the table below, there is a step-by-step analysis of the scenario.

Table 7: Steps of UC-5 Scenario 1: Data integration and visualisation in the DSOTP (User Interface)

Step No.	Event.	Name of Process/ Activity	Description of Process/ Activity.	Service	Information Producer (Actor)	Information Receiver (Actor)
1	none (continuous process)	Data Acquisition	Various field measurements that reflect the network state are communicated	REPORT	SCADA, DMS, GIS, AMR	DSO Data Server
2	none-continuous process	Data Acquisition	PMU data are retrieved by and integrated in the DSOTP	REPORT	PMUs	DSOTP

3	none-continuous process	Data Acquisition	Various field measurements that reflect the network state are communicated	REPORT	DSO Data Server	BAP
4	none-continuous process	Data Verification	All data received gets verified and secured via blockchain technology	EXECUTE	BAP	BAP
5	none-continuous process	Data Acquisition	Verified and secured data is delivered to the DSOTP	REPORT	BAP	DSOTP
6	none-continuous process	Data Visualisation	Data and services' outcomes are visualised (User Interface)	EXECUTE	DSOTP	DSOTP

3.4 Use case mapping

This chapter aims to provide a better understanding of the relationships between the Use Cases defined in the Greek demo.

In UC-GR-3, network tariffs are used to incentivise a behaviour of DERs' owners (owning either a RES or a flexible load) that is as close to an optimal dispatch and scheduling method as possible. As it is typical for optimal scheduling methods for distribution networks based on optimisation, necessary information includes knowledge of the active and reactive power injections on each node of the network. This is because a physical model of the network is employed, usually some variation of the power flow model. In UC-GR-3 (but also UC-GR-4), the network tariffs are calculated a-priori, meaning the day ahead of the real time operation based on forecasts for the power injections on each node.

However, past data, on the same networks where the method is applied, can be very helpful in performing the aforementioned projections, as it is common in such problems. Given, that most distribution networks at MV level do not have dedicated measurement devices to obtain data on power injections, a very successful alternative is the use of state estimation techniques to infer this information. This creates a natural point of connection between UC-GR-1-2 on one hand and UC-GR-3-4 on the other. Past data coming from state estimation can improve the power injection forecasts the latter two Use Cases rely on. In addition, an online state-estimation tool can provide the real-time operation data when UC-GR-3-4 are demonstrated to provide results on the success of the method, in the manner outlined in the description of the KPIs.

Regarding UC-GR-3 and UC-GR-4, there are related, as stated in Chapter 2, methodologically. The latter's ambition is to perform a task similar to the former's but in a different market context, that of a short spanning reserve activation market. The different market context implies different time horizons, limitations and concerns. For example, reserve markets can reach higher prices than the DA markets. Therefore, network tariff limitations should also differ between the two Use Cases. Moreover, UC-GR-3 utilises a scheduling-like approach that spans to a 24-hour period, whereas UC-GR-4 is concerned on a single time period, which is more of a dispatching problem.

UC-GR-5 is an overarching Use Case, in the sense that it does not investigate a specific method or scenario, but it is a study applicable to all previous Use Cases. It explores the actual PMUs' installation, and also how Platone platforms empower the Greek demo in terms of data integration and security, and data visualisation. UC-GR-5 intends to verify and measure tangible outcomes of the Platone architecture in the case of the Greek demo.

4 Key Performance Indicators - Greek demo

The following subchapters give detailed description of the key performance indicators (KPIs) defined in order to evaluate and assess the results of Platone solution in the Greek demo.

4.1 Methodology

In order to evaluate the results of the solutions proposed and implemented within Platone, it is necessary to quantify the tangible and measurable impacts of the project. As it is described in the D1.2 [5], which is released in parallel with this deliverable, a productive coordination process among the project partners took place in order to analyse and discuss KPIs from other projects and KPIs proposed by the demo leaders of Platone project.

Following the procedure described above and within the scope of UC-GR-3 and UC-GR-4 a project KPI was identified (KPI_PR_07) evaluating the impact of the Platone implementation by HEDNO on the Hosting Capacity of the Distribution Network.

For the Greek demo KPIs, a "per Use Case" approach was followed. The discussion initiated internally with the Greek demo partners HEDNO, NTUA and RWTH and provided feedback for the definition of Project KPIs within WP1. The demo specific KPIs of all three Platone demos were described using a common template that was also used for Project KPIs defined in D1.2 [5].

The main objectives of the first two Use Cases of the Greek demo are to increase network observability via a State Estimation tool (UC-GR-1) and then enhance it by incorporating PMU measurements in the state estimation process (UC-GR-2). As a result, six statistical KPIs (KPI_GR_01-KPI_GR_06) were defined for the evaluation of the State Estimation tool's performance for both Use Cases.

UC-GR-3 and UC-GR-4 address the procurement of flexibility by the DSO and TSO respectively, using a novel network tariff scheme. The motivation behind the definition of KPIs for these Use Cases is to evaluate the impact of this flexibility procurement on the distribution network. Thus, seven different KPIs are proposed. KPI_GR_07 and KPI_GR_08 are referring to the amount of energy curtailed in generation and demand respectively, while KPI_GR_09 and KPI_GR_10 measure the number of occurrences of these curtailments. Furthermore, the number of the network limit violations, (KPI_GR_11) is measured during the implementation of both Use Cases. Especially for UC-GR-4, another KPI, (KPI_GR_12) was defined with the aim to assess the fulfilment of the frequency support request of the TSO. All the KPIs regarding UC-GR-3 and UC-GR-4, i.e. KPI_PR_07 and KPI_GR_07- KPI_GR_12, aim to assess the novel approach of variable network tariffs, which is proposed within Platone, against the Business-as-Usual scenario of flat network tariffs currently applied by HEDNO.

Lastly, the three KPIs (KPI_GR_13 - KPI_GR_15) dedicated to UC-GR-5 assess the actual integration of Platone platforms and PMUs within the Greek demo.

In Table 8, there is a list of the KPIs defined for the implementation of the Greek demo and the related Use Cases, while more details about each of the KPIs are presented in the following subchapters. The main information provided for each KPI is:

- Name
- ID- "KPI_PR_XX" for project KPIs, "KPI_GR_XX" for Greek demo KPIs
- Objectives
- Description
- Formula
- Unit
- Target/Threshold
- Measurement process
- Reporting period
- Reporting Audience and Access Rights

It should be noted that further details about the calculation methodology, the data collection and the baseline for each KPI were provided by the Greek demo to be presented in D1.2 [5].

Table 8 KPIs in the Greek Demo

KPI ID	KPI name	Related UC(s)
KPI_PR_07	Distribution Network Hosting Capacity	GR-3, GR-4
KPI_GR_01	Relative root mean square error (RRMSE)	GR-1, GR-2
KPI_GR_02	Relative percentage error (RPE)	GR-1, GR-2
KPI_GR_03	Accuracy metric for complex phasor voltage estimation (MaccV)	GR-1, GR-2
KPI_GR_04	Convergence metric in terms of objective function	GR-1, GR-2
KPI_GR_05	Convergence metric in terms of estimated voltage magnitude	GR-1, GR-2
KPI_GR_06	Convergence metric in terms of estimated voltage angle	GR-1, GR-2
KPI_GR_07	Generation curtailment	GR-3, GR-4
KPI_GR_08	Demand curtailment	GR-3, GR-4
KPI_GR_09	Generation curtailment occurrences	GR-3, GR-4
KPI_GR_10	Demand curtailment occurrences	GR-3, GR-4
KPI_GR_11	Network limit violation occurrences	GR-3, GR-4
KPI_GR_12	Frequency support not provided	GR-4
KPI_GR_13	PMUs field installation and integration	GR-5
KPI_GR_14	Data visualisation	GR-5
KPI_GR_15	Visualised outputs of tools and services and network response handling	GR-5

4.2 Basic KPI information

This subchapter presents the KPIs in the Greek demo as per the methodology described in subchapter 4.1

4.2.1 KPI_PR_07- Distribution Network Hosting Capacity

BASIC KPI INFORMATION			
KPI Name	Distribution Network Hosting Capacity	**KPI ID**	KPI_PR_07

Strategic Objective(s)	To ensure reliable and secure power supplies in the context of increasing DER penetration. To unlock flexibility to address local congestion and voltage level issues.
Greek demo objective(s)	To test the Platone architecture and explore its benefits for the Greek DSO (HEDNO). To assess the penetration limits of DERs for the better control and planning of the distribution network.
DEMO where KPI applies	☐IT ☒GR ☒DE
Owner	HEDNO
KPI Description	This indicator measures the potential increase of hosting capacity for distributed energy resources with solutions proposed by Platone compared to the baseline scenario where DSO has no flexibility tools and services. The indicator gives a statement about the additional DERs that can be installed in the network, thanks to innovative grid services, without the need for conventional reinforcements (i.e. new grid lines).
KPI Formula	$$HC = \frac{HC_{R\&I} - HC_{BaU}}{HC_{BaU}} * 100$$ $\mathrm{HC}_{\mathrm{BaU}}$: Hosting Capacity of Business-as-Usual scenario (kW). $\mathrm{HC}_{R\&I}$: Hosting Capacity of Research & Innovation scenario (kW).
Unit of measurement	%
Target / Thresholds	Achieving any increase is considered as a success (as the proposed method has no implementation costs); a 10% increase in hosting capacity is a reasonable goal as it is enough to relieve pressure for additional DER installations in this part of Mesogeia.
Measurement Process	Two cases are tested, one with the use of the Algorithm for optimal DER control and one without. An acceptable curtailment threshold is used to characterise whether the capacity limit is reached or not. Hosting capacity is increased incrementally for both cases until the capacity limit is reached. We measure at which hosting capacity the limit is reached for both cases.
Reporting Period	M48
Reporting Audience and Access Rights	☐Public ☐Platone ☒ Demo ☐Other

4.2.2 KPI_GR_01 - Relative root mean square error (RRMSE)

BASIC KPI INFORMATION			
KPI Name	Relative root mean square error (RRMSE)	**KPI ID**	KPI_GR_01
Strategic Objective	To improve grid operation through advanced observability approach.		
Greek demo objective(s)	To test the Platone architecture and explore its benefits for the Greek DSO (HEDNO). To improve grid operation through advanced grid observability.		
Owner	HEDNO		
KPI Description	RRMSE is a unitless metric for the evaluation of state estimation accuracy in terms of bus voltage magnitudes. It captures the average 2-norm relative error in estimating bus voltage magnitudes.		
KPI Formula	$$RRMSE = \sqrt{1/_n \sum_{i=1}^{n} (\frac{V_i^{true} - V_i^{est}}{V_i^{act}})^2} * 100$$ n: number of network buses, V_i^{est}, V_i^{true} estimated and true voltage magnitude of i-th bus		
Unit of measurement	%		
Target / Thresholds	<1%; The KPI indicates how close to the reality the estimated grid state was in terms of bus voltage magnitudes. The average 2-norm relative error between the actual and the estimated magnitudes should be as low as possible and certainly below 1%. By meeting this target value, the average performance of the state estimation will be precise enough to support real-time decision making and operation planning.		
Measurement Process	Available measurements (referring to power flows and voltage magnitudes at the top of distribution feeders, power injections from distributed generation units, load pseudo-measurements for aggregated consumer demand at MV/LV transformer level or/and synchronized measurements of voltage/current phasors obtained from PMUs) from the Distribution Network are used as an input for the grid state estimation. The State Estimation tool processes the data and computes the voltage magnitudes of all buses of the test grid. Actual bus voltage magnitudes from the Distribution Network are compared against the calculated ones and the average 2-norm relative error between the two is calculated to evaluate the accuracy of the state estimation algorithm.		
Reporting Period	M48		
Reporting Audience and Access Rights	☐Public ☐Platone ☒ Demo ☐Other		

4.2.3 KPI_GR_02 - Relative percentage error (RPE)

BASIC KPI INFORMATION			
KPI Name	Relative percentage error (RPE)	**KPI ID**	KPI_GR_02
Strategic Objective	To improve grid operation through advanced observability approach.		
Greek demo objective(s)	To test the Platone architecture and explore its benefits for the Greek DSO (HEDNO). To improve grid operation through advanced grid observability.		
Owner	HEDNO		
KPI Description	RPE is a unitless metric for the evaluation of state estimation accuracy in terms of bus voltage magnitudes. It captures the relative error in estimating voltage magnitude per individual bus.		
KPI Formula	$$RPE_i = \frac{V_i^{true} - V_i^{est}}{V_i^{true}} * 100$$ V_i^{est}, V_i^{true} estimated and true voltage magnitude of i-th bus		
Unit of measurement	%		
Target / Thresholds	<1%. The KPI_GR_02 again indicates how close to the reality the estimated grid state was, in terms of bus voltage magnitudes. It is different to the KPI_GR_01 in its per-individual-bus approach. The relative percentage error between the actual and the estimated voltage magnitude for each individual bus should be as low as possible and certainly below 1%. By satisfying this precision threshold, the State Estimation tool will be accurate enough in order to support the quality standards according to the Hellenic regulatory framework (Hellenic Electricity Distribution Network Code [17]), where it is stated that the average voltage at any MV bus should not exceed ±5% of the nominal voltage, e.g. 20 kV. In this way, the worst-case estimation error of 1% will be kept considerably lower than the maximum permissible voltage fluctuation, thus, possible voltage violation will be reliably detected.		
Measurement Process	Available measurements (referring to power flows and voltage magnitudes at the top of distribution feeders, power injections from distributed generation units, load pseudo-measurements for aggregated consumer demand at MV/LV transformer level or/and synchronized measurements of voltage/current phasors obtained from PMUs) from the Distribution Network are used as an input for the grid State Estimation. The State Estimation tool processes the data and computes the voltage magnitudes of all buses of the test grid. Actual bus voltage magnitudes from the Distribution Network are compared against the calculated ones and the relative percentage error between the two per individual bus is calculated to evaluate the accuracy of the state estimation algorithm.		
Reporting Period	M48		

Reporting Audience and Access Rights	☐Public ☐Platone ☒ Demo ☐Other

4.2.4 KPI_GR_03 - Accuracy metric for complex phasor voltage estimation (MaccV)

BASIC KPI INFORMATION			
KPI Name	Accuracy metric for complex phasor voltage estimation (MaccV)	**KPI ID**	KPI_GR_03
Strategic Objective	To improve grid operation through advanced observability approach.		
Greek demo objective(s)	To test the Platone architecture and explore its benefits for the Greek DSO (HEDNO). To improve grid operation through advanced grid observability.		
Owner	HEDNO		
KPI Description	MaccV is a metric for the evaluation of state estimation accuracy in terms of complex phasor voltages. It captures the effect of both bus voltage magnitude and angle errors by combining them in a common 2-norm formula.		
KPI Formula	$$Macc_V = \sqrt{\sum_{i=1}^{n} \left\| \tilde{V}_i^{true} - \tilde{V}_i^{est} \right\|^2}$$ n: number of network buses, $\tilde{V}_i^{true}$, $\tilde{V}_i^{est}$: true and estimated complex phasor voltage of i-th bus		
Unit of measurement	pu		
Target / Thresholds	<0.2. The KPI indicates how close to the reality the grid state estimation was in terms of bus voltage phasors, i.e., both bus voltage magnitudes and angles. For a network comprising 350 buses, the error between the actual and the estimated complex phasor voltages as expressed by the KPI's formula should be as low as possible and certainly below 0.2, assuming that the worst-case estimation error of 1% occurs for all estimated bus voltages.		
Measurement Process	Available measurements (referring to power flows and voltage magnitudes at the top of distribution feeders, power injections from distributed generation units, load pseudo-measurements for aggregated consumer demand at MV/LV transformer level or/and synchronized measurements of voltage/current phasors obtained from PMUs) from the Distribution Network are used as an input for the grid state estimation. The State Estimation tool processes the data and computes the complex phasor voltage (magnitude and angle) of all buses of the test grid. Actual complex phasor voltages from the Distribution Network are compared against the calculated ones and the error between the two is calculated to evaluate the accuracy of the state estimation algorithm.		
Reporting Period	M48		

Reporting Audience and Access Rights	☐Public ☐Platone ☒ Demo ☐Other

4.2.5 KPI_GR_04 - Convergence metric in terms of objective function

BASIC KPI INFORMATION			
KPI Name	Convergence metric in terms of objective function	**KPI ID**	KPI_GR_04
Strategic Objective	To improve grid operation through advanced observability approach.		
Greek demo objective(s)	To test the Platone architecture and explore its benefits for the Greek DSO (HEDNO). To improve grid operation through advanced grid observability.		
Owner	HEDNO		
KPI Description	$Mconv_{obj}$ is a metric for the evaluation of the ability of the state estimation algorithm to converge to a solution. It quantifies the relative change in objective function ($Mconv_{obj}$) which occurs at the final iteration.		
KPI Formula	$$Mconv_{obj} = \left\|1 - \frac{J^{kterm}}{J^{kterm-1}}\right\|$$ J: value of objective function; $kterm$: the ascending number of the terminal iteration of state estimation algorithm.		
Unit of measurement	unitless		
Target / Thresholds	<<1; Since the KPI assesses the ability of the state estimation algorithm to converge to a solution, the target value for the relative change in the objective function which occurs at the final iteration, is any value below 1. The closer to zero the value is, the better.		
Measurement Process	Available measurements (referring to power flows and voltage magnitudes at the top of distribution feeders, power injections from distributed generation units, load pseudo-measurements for aggregated consumer demand at MV/LV transformer level or/and synchronized measurements of voltage/current phasors obtained from PMUs) from the Distribution Network are used as an input for the grid state estimation. The State Estimation tool processes the data and computes the complex phasor voltage (magnitude and angle) of all buses of the test grid. The relative change in the objective function which occurs at the final iteration of the state estimation process is calculated.		
Reporting Period	M48		
Reporting Audience and Access Rights	☐Public ☐Platone ☒ Demo ☐Other		

4.2.6 KPI_GR_05 - Convergence metric in terms of estimated voltage magnitude

BASIC KPI INFORMATION			
KPI Name	Convergence metric in terms of estimated voltage magnitude	**KPI ID**	KPI_GR_05
Strategic Objective	To improve grid operation through advanced observability approach.		
Greek demo objective(s)	To test the Platone architecture and explore its benefits for the Greek DSO (HEDNO). To improve grid operation through advanced grid observability.		
Owner	HEDNO		
KPI Description	$Mconv_V$ is a metric for the evaluation of the ability of state estimation algorithm to converge to a solution. It quantifies the maximum relative change in estimated voltage magnitudes which occur at the final iteration.		
KPI Formula	$$Mconv_V = \max_i \left\| 1 - \frac{V_i^{kterm}}{V_i^{kterm-1}} \right\|$$ V_i: voltage magnitude of i-th bus, $kterm$: terminal iteration of state estimation algorithm		
Unit of measurement	unitless		
Target / Thresholds	<<1%; Since the KPI assesses the ability of the state estimation algorithm to converge to a solution in regards with voltage magnitudes, the target value for the relative change in estimated voltage magnitudes which occur at the final iteration, is any value below 1%. The closer to zero the value is, the better		
Measurement Process	Available measurements (referring to power flows and voltage magnitudes at the top of distribution feeders, power injections from distributed generation units, load pseudo-measurements for aggregated consumer demand at MV/LV transformer level or/and synchronized measurements of voltage/current phasors obtained from PMUs) from the Distribution Network are used as an input for the grid state estimation. The State Estimation tool processes the data and computes the complex phasor voltage (magnitude and angle) of all buses of the test grid. The relative change in voltage magnitude which occurs at the final iteration of the state estimation process is calculated per individual bus and the maximum relative change among all buses is reported for this KPI in a worst-case scenario approach.		
Reporting Period	M48		
Reporting Audience and Access Rights	☐Public ☐Platone ☒ Demo ☐Other		

4.2.7 KPI_GR_06 - Convergence metric in terms of estimated voltage angle

BASIC KPI INFORMATION			
KPI Name	Convergence metric in terms of estimated voltage angle	**KPI ID**	KPI_GR_06
Strategic Objective	To improve grid operation through advanced observability approach.		
Greek demo objective(s)	To test the Platone architecture and explore its benefits for the Greek DSO (HEDNO). To improve grid operation through advanced grid observability.		
Owner	HEDNO		
KPI Description	$Mconv_\delta$ is a metric for the evaluation of the ability of state estimation algorithm to converge to a solution. It quantifies the maximum change in estimated voltage angles which occur at the final iteration.		
KPI Formula	$$Mconv_\delta = \max_i \left\|\theta_i^{kterm} - \theta_i^{kterm-1}\right\|$$ θ_i: voltage angle of i -th bus, $kterm$: the ascending number of the terminal iteration of state		
Unit of measurement	unitless		
Target / Thresholds	<<1%; Since the KPI assesses the ability of the state estimation algorithm to converge to a solution in regards with voltage angles, the target value for the relative change in estimated voltage angles which occur at the final iteration, is any value below 1%. The closer to zero the value is, the better		
Measurement Process	Available measurements (referring to power flows and voltage magnitudes at the top of distribution feeders, power injections from distributed generation units, load pseudo-measurements for aggregated consumer demand at MV/LV transformer level or/and synchronized measurements of voltage/current phasors obtained from PMUs) from the Distribution Network are used as an input for the grid state estimation. The State Estimation tool processes the data and computes the complex phasor voltage (magnitude and angle) of all buses of the test grid. The relative change in voltage angle which occurs at the final iteration of the state estimation process is calculated per individual bus and the maximum relative change among all buses is reported for this KPI in a worst-case scenario approach.		
Reporting Period	M48		
Reporting Audience and Access Rights	☐Public ☐Platone ☒ Demo ☐Other		

4.2.8 KPI_GR_07 - Generation curtailment

BASIC KPI INFORMATION			
KPI Name	Generation curtailment	**KPI ID**	KPI_GR_07
Strategic Objective	To ensure reliable and secure power supplies in the context of increasing DER penetration. To unlock flexibility to address local congestion and voltage level issues.		
Greek demo objective(s)	To test the Platone architecture and explore its benefits for the Greek DSO (HEDNO). To achieve optimal dispatching addressing local congestion and voltage level issues using novel approaches for flexibility mechanisms at DSO level. To investigate potential provision of ancillary services to the TSO by the users of the distribution network.		
Owner	HEDNO		
KPI Description	The indicator compares the amount of energy from Renewable Energy Sources (RES) that is not injected to the grid (even though it is available) due to operational limits of the grid, between the Variable Network Tariff scenario and the Business-as-Usual scenario.		
KPI Formula	$$\Delta C_{RES} = \frac{\sum_{t\in T}\sum_{i\in I} E_{g\,i,t}^{BaU} - \sum_{t\in T}\sum_{i\in I} E_{g\,i,t}^{R\&I}}{\sum_{t\in T}\sum_{i\in I} E_{g\,i,t}^{BaU}} * 100$$ $E_{g\,i,t}^{BaU}$: energy curtailment of the i-th RES facility at period t in Business-as-Usual - Flat Network Tariff scenario (kWh) $E_{g\,i,t}^{R\&I}$: energy curtailment of the i-th RES facility at period t in the Variable Network Tariff scenario (kWh) I: set of RES facilities under consideration T: set of time intervals of the period under consideration (excluding periods of scheduled maintenance and outages).		
Unit of measurement	%		
Target / Thresholds	Reduction by 20%; The use of variable network tariff instead of flat network tariff by the DSO will incentivise certain behaviours from the DERs' owners, which will lead to an optimal dispatch with the least possible RES generation curtailed. A variable network tariff could potentially resolve all cases, which would theoretically mean that no RES generation curtailment would be needed at all, if it were a true locational marginal price. However, since the network tariff is subject to regulatory constraints and there are technical constraints regarding the efficient network use, the reduction of RES generation curtailment is expected to be 20%.		

Measurement Process	Available measurements (referring to power flows and voltage magnitudes at the top of distribution feeders, power injections from distributed generation units, load pseudo-measurements for aggregated consumer demand at MV/LV transformer level or/and synchronized measurements of voltage/current phasors obtained from PMUs) from the Distribution Network are used as an input for the grid state estimation. The State Estimation tool processes the data and provides an accurate grid state estimation. The Algorithm for optimal DER control calculates on day (d-1) a per-hour network tariff value for day d in a Day-Ahead context to be communicated to the Aggregators by the DSO. The Aggregators schedule their resources at optimal cost, accordingly. On day (d), the DSO operates the network and measures the RES generation curtailment that was required for the safe and stable operation of the distribution network. The amount of RES generation curtailed in kWh is compared with the Business-as-Usual - Flat Network Tariff scenario on the same test data. The period T examined can be one day, one month or one year depending of the reporting requirements.
Reporting Period	M48
Reporting Audience and Access Rights	☐Public ☐Platone ☒ Demo ☐Other

4.2.9 KPI_GR_08 - Demand curtailment

BASIC KPI INFORMATION			
KPI Name	Demand curtailment	**KPI ID**	KPI_GR_08
Strategic Objective	To ensure reliable and secure power supplies in the context of increasing DER penetration. To unlock flexibility to address local congestion and voltage level issues.		
Greek demo objective(s)	To test the Platone architecture and explore its benefits for the Greek DSO (HEDNO). To achieve optimal dispatching addressing local congestion and voltage level issues using novel approaches for flexibility mechanisms at DSO level. To investigate potential provision of ancillary services to the TSO by the users of the distribution network.		
Owner	HEDNO		
KPI Description	The indicator compares the amount of energy consumption that needs to be curtailed due to operational limits of the grid, between the Variable Network Tariff and the Business-as-Usual scenario.		
KPI Formula	$$\Delta C_{DEMAND} = \frac{\sum_{t\in T}\sum_{i\in I} E_{d_{i,t}}^{BaU} - \sum_{t\in T}\sum_{i\in I} E_{d_{i,t}}^{R\&I}}{\sum_{t\in T}\sum_{i\in I} E_{d_{i,t}}^{BaU}} * 100$$ $E_{d_{i,t}}^{BaU}$: demand curtailment of the i-th flexible customer facility at period t in Business-as-Usual –Flat Network Tariff scenario (kWh); $E_{d_{i,t}}^{R\&I}$: demand curtailment of the i-th flexible customer facility at period t in the Variable Network Tariff scenario (kWh); I: set of flexible customers under consideration; T: set of time intervals of the period under consideration.		
Unit of measurement	%		
Target / Thresholds	Reduction by 20%; The use of variable network tariff instead of flat network tariff by the DSO will incentivise certain behaviours from the DERs' owners, which will lead to an optimal dispatch with the least possible demand curtailed. A variable network tariff could potentially resolve all cases, which would theoretically mean that no demand curtailment would be needed at all, if it were a true locational marginal price. However, since the network tariff is subject to regulatory constraints and there are technical constraints regarding the efficient network use, the reduction of demand curtailment is expected to be 20%.		

Measurement Process	Available measurements (referring to power flows and voltage magnitudes at the top of distribution feeders, power injections from distributed generation units, load pseudo-measurements for aggregated consumer demand at MV/LV transformer level or/and synchronized measurements of voltage/current phasors obtained from PMUs) from the Distribution Network are used as an input for the grid state estimation. The State Estimation tool processes the data and provides an accurate grid state estimation. The Algorithm for optimal DER control calculates on day (d-1) a per-hour network tariff value for day d in a Day-Ahead context to be communicated to the Aggregators by the DSO. The Aggregators schedule their resources at optimal cost, accordingly. On day (d), the DSO operates the network and measures the demand curtailment that was required for the safe and stable operation of the distribution network. The amount of demand curtailed in kWh is compared with the Business-as-Usual - Flat Network Tariff scenario on the same test data. The period T examined can be one day, one month or one year depending of the reporting requirements.
Reporting Period	M48
Reporting Audience and Access Rights	☐Public ☐Platone ☒ Demo ☐Other

4.2.10 KPI_GR_09 - Generation curtailment occurrences

BASIC KPI INFORMATION			
KPI Name	Generation curtailment occurrences	**KPI ID**	KPI_GR_09
Strategic Objective	To ensure reliable and secure power supplies in the context of increasing DER penetration. To unlock flexibility to address local congestion and voltage level issues.		
Greek demo objective(s)	To test the Platone architecture and explore its benefits for the Greek DSO (HEDNO). To achieve optimal dispatching addressing local congestion and voltage level issues using novel approaches for flexibility mechanisms at DSO level. To investigate potential provision of ancillary services to the TSO by the users of the distribution network.		
Owner	HEDNO		
KPI Description	The metric compares the number of occurrences of generation curtailment for the mitigation of network limit violations between the Variable Network Tariff scenario and the Business-as-Usual scenario.		
KPI Formula	$$\Delta Nc_{RES} = \frac{Nc_{RES}^{BaU} - Nc_{RES}^{R\&I}}{Nc_{RES}^{BaU}} * 100$$ $Nc_{RES} = \sum_{t \in T} k_t$, number of occurrences of RES generation curtailment; k_t: binary variable indicating if generation curtailment occurred anywhere at period t; T: set of time intervals of period under consideration; Nc_{RES}^{BaU}: Number of occurrences of RES generation curtailment in Business-as-Usual - Flat Network Tariff scenario; $Nc_{RES}^{R\wedge I}$: Number of occurrences of RES generation curtailment in Variable Network Tariff scenario.		
Unit of measurement	%		
Target / Thresholds	Reduction by 20%; The use of variable network tariff instead of flat network tariff by the DSO will incentivise certain behaviours from the DERs' owners, which will lead to an optimal dispatch with the least possible RES generation curtailment occurrences. A variable network tariff could potentially resolve all cases, which would theoretically mean that no RES generation curtailment would be needed at all. However, since the network tariff is subject to regulatory constraints and there are technical constraints regarding the efficient network use, the reduction of RES generation curtailment occurrences is expected to be 20%.		

Measurement Process	Available measurements (referring to power flows and voltage magnitudes at the top of distribution feeders, power injections from distributed generation units, load pseudo-measurements for aggregated consumer demand at MV/LV transformer level or/and synchronized measurements of voltage/current phasors obtained from PMUs) from the Distribution Network are used as an input for the grid state estimation. The State Estimation tool processes the data and provides an accurate grid state estimation. The Algorithm for optimal DER control calculates on day (d-1) a per-hour network tariff value for day d in a Day-Ahead context to be communicated to the Aggregators by the DSO. The Aggregators schedule their resources at optimal cost, accordingly. On day (d), the DSO operates the network and measures the number of cases that curtailed RES generation for the safe and stable operation of the distribution network. The number of occurrences when RES generation was curtailed is compared with the Business-as-Usual - Flat Network Tariff scenario on the same test data. The period T examined can be one day, one month or one year depending of the reporting requirements.
Reporting Period	M48
Reporting Audience and Access Rights	☐Public ☐Platone ☒ Demo ☐Other

4.2.11 KPI_GR_10 - Demand curtailment occurrences

BASIC KPI INFORMATION			
KPI Name	Demand curtailment occurrences	**KPI ID**	KPI_GR_10
Strategic Objective(s)	To ensure reliable and secure power supplies in the context of increasing DER penetration. To unlock flexibility to address local congestion and voltage level issues.		
Greek demo objective(s)	To test the Platone architecture and explore its benefits for the Greek DSO (HEDNO). To achieve optimal dispatching addressing local congestion and voltage level issues using novel approaches for flexibility mechanisms at DSO level. To investigate potential provision of ancillary services to the TSO by the users of the distribution network.		
Owner	HEDNO		
KPI Description	The metric compares the number of occurrences of demand curtailment for the mitigation of network limit violations between the Variable Network Tariff scenario and the Business-as-Usual scenario.		
KPI Formula	$$\Delta Nc_{DEMAND} = \frac{Nc_{DEMAND}^{BaU} - Nc_{DEMAND}^{R\&I}}{Nc_{DEMAND}^{BaU}} * 100$$ $Nc_{DEMAND} = \sum_{t \in T} m_t$, number of occurrences of demand curtailment; m_t: binary variable indicating if demand curtailment occurred anywhere at period t; T: set of time intervals of period under consideration; Nc_{DEMAND}^{BaU}: Number of occurrences of demand curtailment in Business-as-Usual - Flat Network Tariff scenario; $Nc_{DEMAND}^{R\&I}$: Number of occurrences of demand curtailment in the Variable Network Tariff scenario.		
Unit of measurement	%		
Target / Thresholds	Reduction by 20%; The use of variable network tariff instead of flat network tariff by the DSO will incentivise certain behaviours from the DERs' owners, which will lead to an optimal dispatch with the least possible demand curtailment occurrences. A variable network tariff could potentially resolve all cases, which would theoretically mean that no demand curtailment would be needed at all. However, since the network tariff is subject to regulatory constraints and there are technical constraints regarding the efficient network use, the reduction of demand curtailment occurrences is expected to be 20%.		

Measurement Process	Available measurements (referring to power flows and voltage magnitudes at the top of distribution feeders, power injections from distributed generation units, load pseudo-measurements for aggregated consumer demand at MV/LV transformer level or/and synchronized measurements of voltage/current phasors obtained from PMUs) from the Distribution Network are used as an input for the grid state estimation. The State Estimation tool processes the data and provides an accurate grid state estimation. The Algorithm for optimal DER control calculates on day (d-1) a per-hour network tariff value for day d in a Day-Ahead context to be communicated to the Aggregators by the DSO. The Aggregators schedule their resources at optimal cost, accordingly. On day (d), the DSO operates the network and measures the number of cases that curtailed demand for the safe and stable operation of the distribution network. The number of occurrences when demand was curtailed is compared with the Business-as-Usual - Flat Network Tariff scenario on the same test data. The period T examined can be one day, one month or one year depending of the reporting requirements.
Reporting Period	M48
Reporting Audience and Access Rights	☐Public ☐Platone ☒ Demo ☐Other

4.2.12 KPI_GR_11- Network limit violation occurrences

BASIC KPI INFORMATION			
KPI Name	Network limit violation occurrences	**KPI ID**	KPI_GR_11
Strategic Objective	To ensure reliable and secure power supplies in the context of increasing DER penetration. To unlock flexibility to address local congestion and voltage level issues.		
Greek demo objective(s)	To test the Platone architecture and explore its benefits for the Greek DSO (HEDNO). To achieve optimal dispatching addressing local congestion and voltage level issues using novel approaches for flexibility mechanisms at DSO level. To investigate potential provision of ancillary services to the TSO by the users of the distribution network.		
Owner	HEDNO		
KPI Description	This indicator evaluates the difference between the number of network limit violation occurrences under a 24-hour timeframe in the Variable Network Tariff scenario and the equivalent one in the Business-as-Usual scenario.		
KPI Formula	$$NV = \frac{N^{BaU}_{total_{violations}} - N^{R\&I}_{total_{violations}}}{N^{BaU}_{total_{violations}}} * 100$$ $N^{BaU}_{total_{violations}} = N^{BaU}_{RES} \cup N^{BaU}_{demand}$: Total number of network limit violation occurrences in Business-as-Usual - Flat Network Tariff scenario; $N^{R\&I}_{total_{violations}} = N^{R\&I}_{RES} \cup N^{R\&I}_{demand}$: Total number of network limit violation occurrences in Variable Network Tariff scenario; Nc_{RES}: number of occurrences of RES generation curtailment; Nc_{demand}: number of occurrences of demand curtailment.		
Unit of measurement	%		
Target / Thresholds	Reduction by 20%; The use of variable network tariff instead of flat network tariff by the DSO will incentivise certain behaviours from the DERs' owners, which will lead to an optimal dispatch with the least possible network limit violations. Since the network tariff is subject to regulatory constraints and there are technical constraints regarding the secure and efficient network use, the reduction of network limit violations is expected to be 20%.		

Measurement Process	Available measurements (referring to power flows and voltage magnitudes at the top of distribution feeders, power injections from distributed generation units, load pseudo-measurements for aggregated consumer demand at MV/LV transformer level or/and synchronized measurements of voltage/current phasors obtained from PMUs) from the Distribution Network are used as an input for the grid state estimation. The State Estimation tool processes the data and provides an accurate grid state estimation. The Algorithm for optimal DER control calculates on day (d-1) a per-hour network tariff value for day d in a Day-Ahead context to be communicated to the Aggregators by the DSO. The Aggregators schedule their resources at optimal cost, accordingly. On day (d), the DSO operates the network and measures the number of cases that there has been a network limit violation. A limit violation occurrence is equivalent to a generation and/or demand curtailment occurrence as every time a limit violation is bound to happen, curtailment is decided to prevent it. The number of occurrences of network limit violations on a day is compared with the Business-as-Usual - Flat Network Tariff scenario on the same test data.
Reporting Period	M48
Reporting Audience and Access Rights	☐Public ☐Platone ☒ Demo ☐Other

4.2.13 KPI_GR_12 - Frequency support not provided

BASIC KPI INFORMATION			
KPI Name	Frequency support not provided	**KPI ID**	KPI_GR_12
Strategic Objective	To ensure reliable and secure power supplies in the context of increasing DER penetration. To support cooperation with the TSO. To improve customers' engagement and facilitate their fair participation to market.		
Greek demo objective(s)	To test the Platone architecture and explore its benefits for the Greek DSO (HEDNO). To investigate potential provision of ancillary services to the TSO by the users of the distribution network.		
Owner	HEDNO		
KPI Description	This indicator evaluates the difference between the power deficit between the TSO's request for the frequency support and customers' response, due to operational limits of the grid in the Variable Network Tariff scenario and the Business-as-Usual scenario.		
KPI Formula	$$\Delta P_{FSNP} = \frac{P_{FSNP}^{BaU} - P_{FSNP}^{R\&I}}{P_{FSNP}^{BaU}} * 100$$ $FSNP$: Frequency Support Not Provided; P_{FSNP}^{BaU}: Power deficit between the TSO's request for frequency support and customers' response in the Business-as-Usual – Flat Network Tariff scenario (kW); $P_{FSNP}^{R\&I}$: Power deficit between the TSO's request for frequency support and customers' response in the Variable Network Tariff scenario (kW).		
Unit of measurement	%		
Target / Thresholds	Reduction by 20%; The use of variable network tariff instead of flat network tariff by the DSO will incentivise certain behaviours from the DERs' owners (users of the distribution network), so that they can provide frequency support to the TSO. Given that the network tariff is subject to regulatory constraints and there are technical constraints regarding the secure and efficient network operation, the frequency support that the DERs' owners did not manage to provide is expected to be reduced by 20%.		

Measurement Process	In a continuous manner, available measurements (referring to power flows and voltage magnitudes at the top of distribution feeders, power injections from distributed generation units, load pseudo-measurements for aggregated consumer demand at MV/LV transformer level or/and synchronized measurements of voltage/current phasors obtained from PMUs) from the Distribution Network are used as an input for the grid state estimation. The State Estimation tool processes the data and provides the Algorithm for ancillary services with an accurate grid state estimation. When a frequency response activation arrives by the TSO, the DSO is imposing a short-duration network tariff, which the Algorithm for ancillary services computes to represent the state of the network to the Aggregators and incentivise certain behaviours to satisfy the TSO's request. The Aggregators take into account the network usage costs, which are applicable in a short balancing period and not in an entire day and decide their response accordingly. The amount of frequency support eventually not provided to the TSO in KW for a certain frequency support request is compared with the Business-as-Usual - Flat Network Tariff scenario by the use of historical data.
Reporting Period	M48
Reporting Audience and Access Rights	☐Public ☐Platone ☒ Demo ☐Other

4.2.14 KPI_GR_13 - Field installation and data integration of PMUs

BASIC KPI INFORMATION			
KPI Name	PMUs field installation and integration	**KPI ID**	KPI_GR_13
Strategic Objective	To improve grid operation through advanced observability approach.		
Greek demo objective(s)	To test the Platone architecture and explore its benefits for the Greek DSO (HEDNO).		
Owner	HEDNO		
KPI Description	Indicates the number of PMUs actually installed in the field and integrated in the DSO Technical Platform.		
KPI Formula	$$PMU_{sum} = n$$ n: number of PMU installed		
Unit of measurement	unitless		
Target / Thresholds	30; The target value for the number of PMUs installed in selected nodes is proportional to the size of the test site, and it is set considering the impact on enhancing state estimation algorithm the PMUs are supposed to have.		
Measurement Process	PMUs will be installed and commissioned in selected nodes of the test grid. PMUs' measurement data will be integrated in the DSO Technical Platform. As long as a PMU is physically installed and its measurement data is read by the DSO Technical Platform, it will be counted as a successful PMU field installation and integration for the purposes of this KPI.		
Reporting Period	M48		
Reporting Audience and Access Rights	☐Public ☐Platone ☒ Demo ☐Other		

4.2.15 KPI_GR_14- Data visualisation

BASIC KPI INFORMATION			
KPI Name	Data visualisation	**KPI ID**	KPI_GR_14
Strategic Objective	To improve grid operation through advanced observability approach.		
Greek demo objective(s)	To test the Platone architecture and explore its benefits for the Greek DSO (HEDNO).		
Owner	HEDNO		
KPI Description	This KPI indicates the number of data sources (e.g. AMR, GIS, SCADA-DMS, DSO data server) that will be visualised in the open DSO Technical Platform.		
KPI Formula	$$DS_{vis} = m$$ DS are the data sources used for the testing of the Greek demo Use Cases within Platone		
Unit of measurement	unitless		
Target / Thresholds	4, as the data from 4 different data sources will be required for testing the tools and services the Greek demo develops within Platone.		
Measurement Process	The data from a HEDNO data source (e.g. AMR, GIS, SCADA-DMS, DSO data server) is visualised in the DSO Technical Platform to be counted as a successful data visualisation for the purposes of this KPI.		
Reporting Period	M48		
Reporting Audience and Access Rights	☐Public ☐Platone ☒ Demo ☐Other		

4.2.16 KPI_GR_15- Visualised tools and services

BASIC KPI INFORMATION			
KPI Name	Visualised tools and services	**KPI ID**	KPI_GR_15
Strategic Objective	To improve grid operation through advanced observability approach.		
Greek demo objective(s)	To test the Platone architecture and explore its benefits for the Greek DSO (HEDNO).		
Owner	HEDNO		
KPI Description	This KPI indicates the number of tools and services visualised, outputs of which, allow the DSO to operate the distribution network more efficiently by the use of the DSO Technical Platform.		
KPI Formula	$$T_{vis} = k$$ T are the tools (algorithms) developed within Platone		
Unit of measurement	unitless		
Target / Thresholds	3, as there will be three tools and services developed by the Greek demo within Platone		
Measurement Process	As long as the outputs of the tools and services developed by the Greek demo within Platone are visualised in the DSO Technical Platform, the related tool will be counted as a successfully visualised tool for the purposes of the KPI. The tool will be then considered as a new add-on for the DSO's day to day operation.		
Reporting Period	M48		
Reporting Audience and Access Rights	☐Public ☐Platone ☒ Demo ☐Other		

5 Conclusion

The present report documents the Use Cases and the KPIs identified for the Greek demo. What became evident after the completion of this piece of work is that the Use Case definition requires thorough and in-depth investigation, since it formulates the solid base upon which the demo is built. Utilising established methodologies like the one outlined in IEC 62559 results in clearly defined Use Cases and detailed elaboration of the relationships between them provides a coherent demo narrative. The Use Cases developed by the Greek demo adequately test the Platone architecture and, additionally, they explore new approaches for the DSO operation. The methods examined envisage transforming the DSO into a market enabler and a smarter manager of their own assets, in order to achieve the most efficient possible use of the distribution network for the common good.

The KPIs selected and presented in this document are effectively measuring the solutions proposed and will provide an appropriate field of discourse once the trial's implementation takes place. Some of them are of special interest considering their potential impact for the DSOs as well as other stakeholders of the power industry. For example, the increase of Network Hosting Capacity would mean higher RES penetration and/or avoidance of grid reinforcement, while the decrease in network limit violation occurrences would be translated in better distribution network operation which successfully meets the needs of the grid's users. The frequency support KPI matches well with the currently promoted and essential TSO-DSO cooperation. Also, the effect of PMUs in accuracy metrics for the State Estimation algorithm is another stimulating topic that will come out from the project. The Use Cases and the KPIs in the Greek demo are designed in such a way that they can be adapted in various different conditions (i.e. different demo site, customers, etc.).

6 List of Tables

7 List of Figures

8 List of References

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9 List of Abbreviations

Abbreviation	Term
AMR	Automatic Meter Reading system
BAP	Blockchain Access Platform
BAU	Business-as-Usual
CIS	Customer Information System
DA	Day-Ahead
DER	Distributed Energy Resource
DFT	Discrete Fourier transform
DMS	Distribution Management System
DSE	Distribution State Estimation
DSO	Distribution System Operator
DSOTP	DSO Technical Platform
GIS	Geographical Information System
GPS	Global Positioning System
IoT	Internet of Things
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
LV	Low Voltage
MQTT	Message Queuing Telemetry Transport
MV	Medium Voltage
PMU	Phasor Measurement Unit
PV	Photovoltaic
RES	Renewable Energy Sources
ROCOF	Rate of Change of Frequency
SAP ERP	SAP Enterprise Resource Planning
SCADA	Supervisory control and data acquisition
SE tool	State estimation tool
SV	Sampled Values
TSO	Transmission System Operator
UC	Use Case
UI	User Interface
UTC	Universal Time Coordinated
WLS	Weighted least squares