one network for Europe

Requirements specification of the pilot projects in Greece and Cyprus

D8.1

Authors:

Distribution Level	PU
Responsible Partner	University of Athens
Checked by WP leader	Date:28.9.2021 Emmanouil Zoulias – UoA
Verified by the appointed Reviewers	Date: :21/9/2021 Ivelina Stoyanova (RWTH AACHEN) 27/9/2021 Anastasis Tzoumpas (UBITECH ENERGY)
Approved by Project Coordinator	Date:

Dissemination Level	PU	
PU	Public	
CO	Confidential, only for members of the consortium (including the Commission Services)	
CI	Classified, as referred to in Commission Decision 2001/844/EC	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Issue Record

Planned delivery date	30/9/2021
Actual date of delivery	29.9.2021
Status and version	0.4

Version	Date	Author(s)	Notes
0.5	13/9/2021	Emmanouil Zoulias-UoA Nenad Sijakovic-EnergoInfo Aleksandar Terzic-Energoinfo Markos Asprou-UCY Lenos Hadjidemetriou-UCY Therapontos Fivos UCY Dimitra Makrygiorgou –IPTO Christos Christodoulou – HEDNO	Draft creation for internal review
0.6	28/9/2021	Emmanouil Zoulias-UoA	Incorporation of the internal reviewers' comments

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

About OneNet

OneNet will provide a seamless integration of all the actors in the electricity network across Europe to create the conditions for a synergistic operation that optimizes the overall energy system while creating an open and fair market structure.

The project OneNet (One Network for Europe) is funded through the EU's eighth Framework Programme Horizon 2020. It is titled "TSO – DSO Consumer: Large-scale demonstrations of innovative grid services through demand response, storage and small-scale (RES) generation" and responds to the call "Building a low-carbon, climate resilient future (LC)".

While the electrical grid is moving from being a fully centralized to a highly decentralized system, grid operators have to adapt to this changing environment and adjust their current business model to accommodate faster reactions and adaptive flexibility. This is an unprecedented challenge requiring an unprecedented solution. For this reason, the two major associations of grid operators in Europe, ENTSO-E and EDSO, have activated their members to put together a unique consortium.

OneNet will see the participation of a consortium of over 70 partners. Key partners in the consortium include already mentioned ENTSO-E and EDSO, Elering, EDP Distribution/E-, RWTH Aachen University, University of Comillas, VITO, European Dynamics, UBITECH Energy, Engineering, and the EUI's Florence School of Regulation (Energy).

The key elements of the project are:

1. Definition of a common market design for Europe: this means standardized products and key parameters for grid services which aim at the coordination of all actors, from grid operators to customers;
2. Definition of a Common IT Architecture and Common IT Interfaces: this means not trying to create a single IT platform for all the products but enabling an open architecture of interactions among several platforms so that anybody can join any market across Europe; and
3. Large-scale demonstrators to implement and showcase the scalable solutions developed throughout the project. These demonstrators are organized in four clusters coming to include countries in every region of Europe and testing innovative use cases never validated before.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Table of Contents

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

List of Figures

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

List of Tables

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

List of Abbreviations and Acronyms

Acronym	Meaning
ABCM	Active Balancing and Congestion Management
aFRR	Automatic Frequency Restoration Reserve
ATC	Available Transfer Capacity
BaU	Business as Usual
BRP	Balancing Responsible Party
BSP	Balancing Service Provider
BUC	Business Use Case
CACM	capacity Allocation and Congestion Management
CEP	Clean Energy Package
CGM	Common Grid Model
CIM	Common Information Model
CM	Congestion management
DACF	Day Ahead Congestion Forecast
DAM	Day Ahead Market
DSF	Demand Side Flexibility
DSO	Distribution System Operator
EAC	Electricity Authority of Cyprus
EHV	Extra High Voltage
ESCO	Energy Service Company
FCA	Forward Capacity Allocation
FCR	Frequency Containment Reserve
FSP	Flexibility Service Provider
GL	Guideline
GUI	Graphical User Interface
HEDNO	Hellenic Electricity Distribution Network Operator
HERM	Harmonized Electricity Role Model
IGM	Individual Grid Model
IPTO	Independent Power Transmission Operator
mFRR	Manual Frequency Restoration Reserve
MO	Market operator
OHL	Overhead line
PCI	Projects of Common Interest
PMU	Phasor Measurement Unit
POI	Points of Interest
RES	Renewable Energy Sources
RfG NC	Requirements for Generators Network Code

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

RR	Replacement Reserve
RSC	Regional Security Coordinator
SUC	System Use Case
SUC	System Use Case
TSO	Transmission System Operator
WFS	Web Feature Service
WMS	Web Map Services

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Executive Summary

This deliverable D8.1 is setting the basis of the Southern cluster demonstrators in Greece and Cyprus. It reflects and consolidates the work been done through task 8.1., as this is linked with the initial development work in Tasks 8.2 and 8.3, as well as the work in the work packages WP2-WP6. The scope is to present the characteristics of the electricity markets in Greece and Cyprus, identify common elements and particularities, and illustrate the challenges facing the two countries with respect to the technical, strategic , and regulatory aspects. Especially for Greece, the target model is presented and the respective implementation in the Hellenic electricity market reform during 2020 is described. Balancing and congestion management are critical operations in both regions since the decarbonisation targets are high and system operators are called upon to manage an extensive volume of variable renewable generation

Additionally, the overall approach of the two platforms i.e. F-channel and ABCM are presented in detail. The respective data requirements and the IT/OT environment are described describing the interconnections among the various modules and the functionalities. Efficient forecasting of volatile generation and demand, frequency and voltage control, congestion management are in the centcentrere of interest for the two demonstrators where in close collaboration with system operators, respective network models are being developed. Furthermore, detailed Business Use Cases (BUCs) have been correlated with System Use Cases (SUCs) and products, while respective Key Performance Indicators (KPIs) are defined in to monitor and evaluate the efficiency of the developed tools. This schedule of activities has been developed for both demonstrators in close collaboration with WP2—WP4 where there are relative tasks for homogenising the demonstration approaches among all demo clusters. Then, the integration of the two platforms (i.e. F-Channel and ABCM) with the OneNet 'platform of platforms' has been outlined on a high-level conceptual architecture in cooperation with partners from WP5 and WP6. The details will be further elaborated in the next activities of the OneNet project.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

1 Introduction: Scope of the Southern cluster demonstrator

In the context of OneNet project, the Southern cluster demonstrator consists of the implementation of two pilot projects situated in Greece and Cyprus respectively. These countries and the respective pilots are currently facing different challenges The two pilot projects are addressing the specific needs of TSOs, DSOs market actors and consumers in both countries, market , and regulatory specificities, but at the same time presents an innovative common approach for TSO-DSO coordination for common services and flexibility.

In Greece, an advanced forecasting platform evaluating the needs and flexibilities for balancing and congestion management (F-platform) will be developed and implemented in the areas of Peloponnese and Crete. The Crete island has been recently interconnected with mainland Greece and consequently with the pan European interconnected electricity network (Figure 1). The high voltage level is 150kV for the time being in Crete and Peloponnese, while in the latter area two new projects of 400kV OHLs and new substations have been planned in the national TYNDP, and they are currently under construction. The Peloponnese area is a mountainous area with high wind capacity, thus there are a lot of wind parks installed while the current network capacity is insufficient for the installation of even more wind generation.

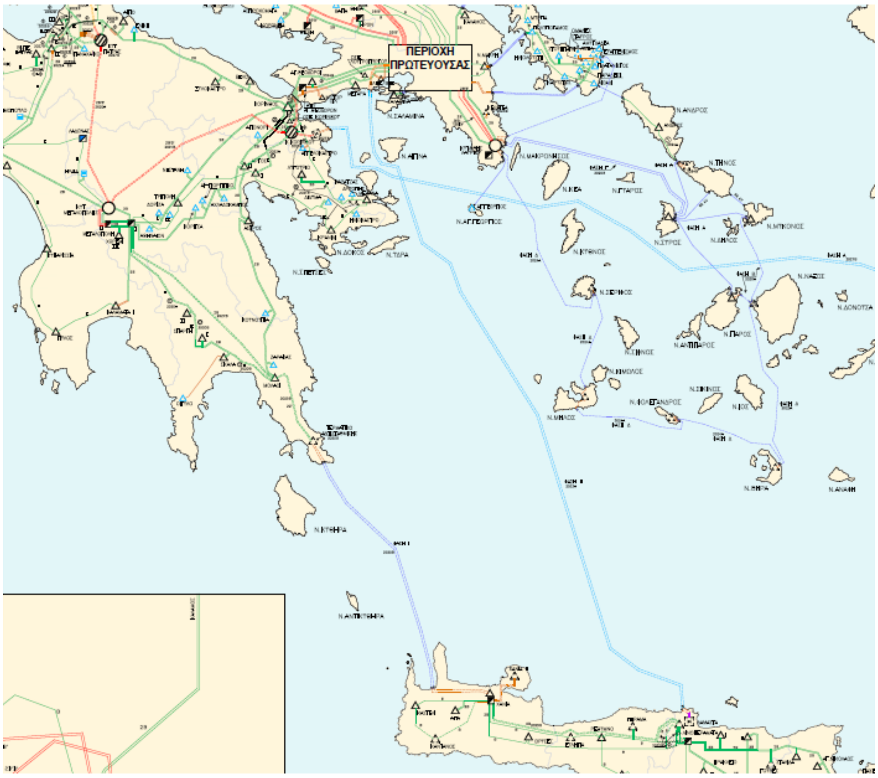

Figure 1. The interconnections of Crete with mainland, as depicted in the National TYNDP 2021-2030.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Crete island has been isolated from mainland Greece till the end of 2020. Due to the environmental regulation, diesel generation units have to be phased out the following years, that is why the TSO has included some years ago the AC interconnection with South Peloponnese primarily and with Attica through a second HVDC interconnection, at a later stage (scheduled for commissioning by the end of 2023).

The Cyprus electricity system (Figure 2) is a non-interconnected island, however, there are plans to be interconnected with Crete and Israel which is known as Euroasia Interconnector Project, co-funded under CEF as PCI. In that sense, the Cypriot system will be interconnected with the pan-European electricity backbone network and the Israeli network, linking Europe with the Middle-East area. Currently, the Cypriot electricity market has already been liberalised, with the possibility of multiple generations and retail supply firms operating in a competitive market. Nevertheless, the Electricity Authority of Cyprus (EAC) has held nearly 100% of retail supply and over 90% of generation. Intending to open the market to new entrants, Cyprus has been working on reorganizing the electricity market arrangements. The Cyprus Transmission System Operator (TSO) developed the Trading and Settlement Rules (TSR) to serve as the detailed market rules for this reorganised market. To face the challenges of variable renewable energy sources, energy efficiency, and distributed generation, TSOs and DSOs have to coordinate their efforts to maximize the flexibility resources and optimize system services.

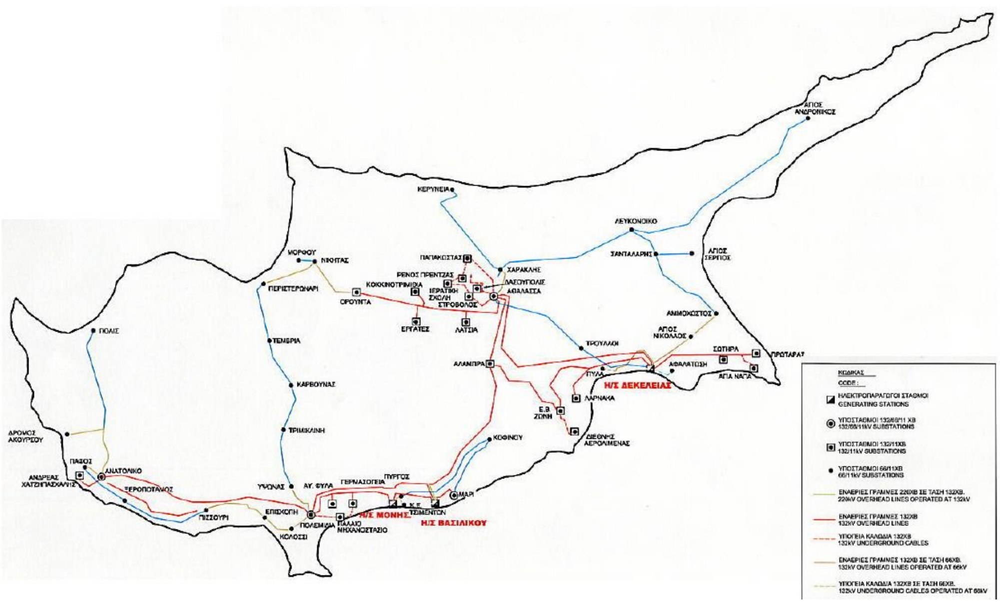

Figure 2. The electricity system of Cyprus (source: Electricity Authority of Cyprus).

The overall objective of the Southern demonstrator is to prescribe, develop, implement and evaluate two pilot projects in Greece and Cyprus dealing with balancing and congestion management challenges facing system

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

operators in the clean energy era, in compliance with the OneNet overall architecture. The TSOs and DSOs in both countries will share flexibility resources and coordinate their efforts to meet their augmenting regional challenges through grid services stemming from prosumers, aggregators, suppliers, producers, while at the same time they are optimizing the use of network assets and big data processing tools for network predictability and observability.

The Southern demonstrator will implement efficient forecasting algorithms, grid observability technologies, balancing and congestion management algorithms to evaluate specific strategies and market mechanisms, that will finally be incorporated in the OneNet platform, as this will be developed through the work of WP5 and WP6. The demonstrator results will be evaluated to provide recommendations for future market reforms in the region and harmonization for a pan-EU electricity market, supporting the activities in WP11, WP12 and WP13.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

2 The energy landscape in Greece and Cyprus: Current situation and challenges

2.1 The Hellenic electricity market

The following Figure 3 presents a high-level conceptual approach to the Transmission Grid and the Distribution Network of the Hellenic electricity system.

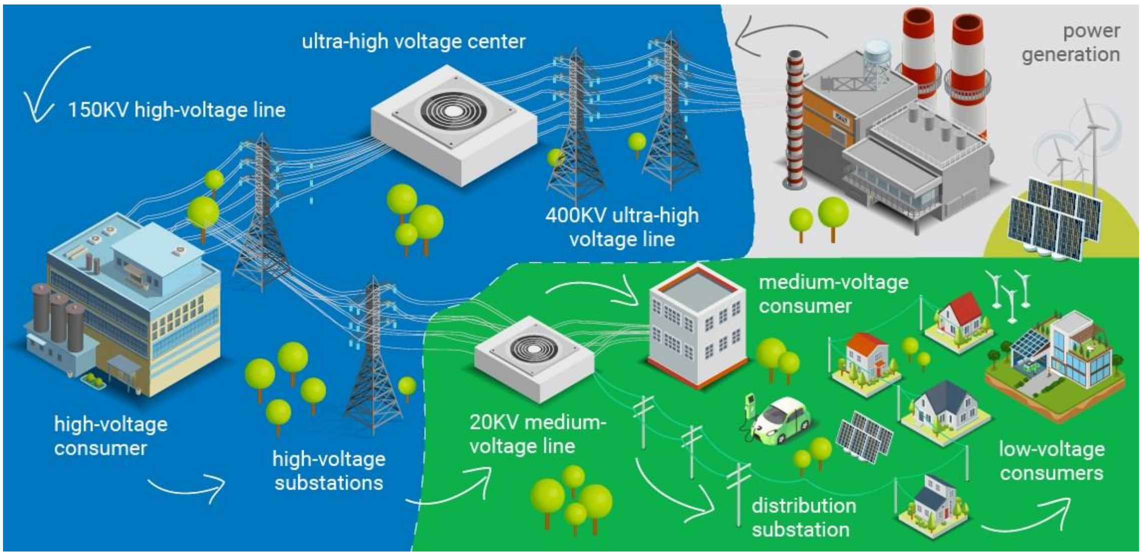

Figure 3. A high-level conceptual approach of the Hellenic electricity system

The transmission system operator in Greece is the Independent Power Transmission Operator S.A. (IPTO), which was established with Law 4001/2011 and was organized and operates as an Independent Transmission Operator as described in the EU Directive 2009/72/EC. The Company acts as Owner and Operator of the Hellenic Electricity Transmission System (HETS), following the provisions of Law 4001/2011, the National Grid Code and the Operation License. IPTO's compliance with the requirements applicable to the Independent Transmission Operator model was certified by the Regulatory Authority for Energy in December 2012. The role of IPTO is the operation, control, maintenance and development of the Hellenic Electricity Transmission System, to ensure the country's supply with electricity in an adequate, safe, efficient and reliable manner, as well as the operation of the electricity Balancing Market. Due to this critical role of the Company, IPTO is taking all the necessary measures and respective procedures have been set in place to ensure its independence, transparency in its operation, strict adherence to the "equal treatment" principle for all System Users and Participants in the Electricity Market, and respect of the confidentiality of the information which IPTO manages.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

The Hellenic transmission system has an overall length of approximately 12,384km for OHLs and cables, connecting an overall number of 361 substations in EHV (400kV) and HV(150kV) in the mainland Greece. Regarding the distribution network, HEDNO S.A. is responsible for the development, operation and maintenance of the Hellenic Electricity Distribution Network (HEDN) under economically advantageous terms and in accordance with the Management License. The role of HEDNO is to ensure its reliable, efficient and safe operation, taking due account of the environment and energy efficiency, as well as ensuring in the most cost-effective, transparent, direct and non-discriminatory way, access to the HEDN for Users (Consumers, Producers) and Suppliers in order to carry out their business operations.

The operation of distribution network management is a natural monopoly in the area where it runs as there is no competition. For this reason, these business operations are supervised and regulated by the independent Regulatory Authority for Energy (RAE). Regulating is achieved by approving the revenue that is allowed from such operation, while objectives are set for the improvement of both customer service and the efficiency of the company's operation, providing incentives for their achievement.

In addition to Law 4001/2011, which outlines the operation, development, maintenance and access of users to HEDN, the main Regulatory text which defines the above is the "Hellenic Electricity Distribution Network Code", which was approved by virtue of Decision 395/2016 reached by RAE. The content of the Code regulates the rights and obligations of the Hellenic Electricity Distribution Network Operator, as well as the rights and obligations of Network Users and Providers in addition to issues related to the development, operation, Network access, the services provided by the Network Operator and the financial reward thereof.

HEDNO is also responsible for the management of the Electricity Systems of the Non-Interconnected Islands (NIIs), i.e. the islands of Greece whose Electricity Distribution Network is not connected to the Transmission System or the Distribution Network of the Mainland, which includes the management of the production, market operation and the systems of these islands, following the "Non-Interconnected Islands Electrical System Management Code" provided for in Article 130 of Law 4001/2011.

The Distribution network consists of:

- 112.622 km of Medium Voltage Network (M.V.).
- 127.564 km of Low Voltage Network (L.V.).
- 240.186 Km of Network in total
- 163.431 Substations of Medium/Low Voltage.
  993 km High Voltage Network (H.V.) of which the 218 km are in Attica and the 775 km in the non-Interconnected islands
  241 High/Medium Voltage Substations

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

- 7.577,996 Customers (11.956 M.V. & 7.566,040 LV).

  44.133 GWH Customers' consumptions (11.861 in M.V. & 32.272 in LV).

In 2018 RAE proceeded with the implementation of "the Target Model" in the Greek wholesale electricity market, based on the European regulations, directives and guidelines. The Balancing, Intraday Day-ahead and Forward markets have been introduced as future targets .

Since August 2021, the ownership of the transmission network in Crete has been transferred from HEDNO to IPTO, and a specific transitory regulation framework for the smooth transition of the Crete electricity system into the National wholesale electricity market has been defined.

2.1.1 Integrated Energy Market and Target Model in general-European policies and targets

This chapter provides a brief overview of the electricity market structures that consist of the Target model, to provide the outline of the existing situation in Greece and Cyprus and the surrounding environment of the Southern cluster.

The European Union (EU) attempted to liberalize the existing energy market via an organized effort that started more than 20 years ago and aimed to create one integrated internal electricity market. This liberalized internal energy market has been established through four legislative packages. The fourth package, the so-called Clean Energy Package (CEP) builds further on the energy policy framework set by the previous three packages and paved the way for a gradual transition from fossil fuels to a carbon-free economy. In the Third Energy Package that was adopted in 2009, *EU* aimed at further liberalising and integrating Europe's energy markets. The most relevant network codes when talking about electricity markets are the market codes (CACM GL, FCA GL, SO GL and EB GL) as electricity markets are coupled to the system operation. These network codes describe the market design for the European internal electricity market, commonly called the "Target Model". Corresponding legislation includes (i) Directives (EU) 2009/72/EC, 2019/944 and 2019/943 that contain common rules for the internal market in electricity, (ii) Regulation (EC) 714/2009 that contains conditions for access to the network for cross-border exchanges in electricity,(iii) Regulation (EC) 713/2009 that foresees the establishment of the Agency for the Cooperation of Energy Regulators (ACER), (iv) Commission Regulation (EU) 2017/2195 that lays out detailed rules for the integration of balancing energy markets in Europe, (v) Commission Regulation (EU) 2017/1485 that sets harmonized rules for TSOs, DSOs and SGUs (significant grid users), in order to provide a legal framework for the operation of the interconnected transmission system, to maintain system security, and to achieve other Union-wide objectives, (vi) Commission Regulation (EU) 2015/1222 that establishes a guideline on Capacity Allocation and Congestion Management (CACM), and (vii) Commission Regulation (EU) 2016/1719 that establishes a guideline on forward capacity allocation (FCA) [1-9].

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

The Electricity Target Model aims to couple the different national markets into one European electricity market [9]. The aforementioned integration requires that electricity markets across Europe share a set of common features by determining the mechanisms for the function of a sequence of markets necessary for the proper function of the wholesale electricity market, namely the Forward and Futures Market, the Day-Ahead Market, the Intra-Day Market and the Balancing Market (Figure 3)

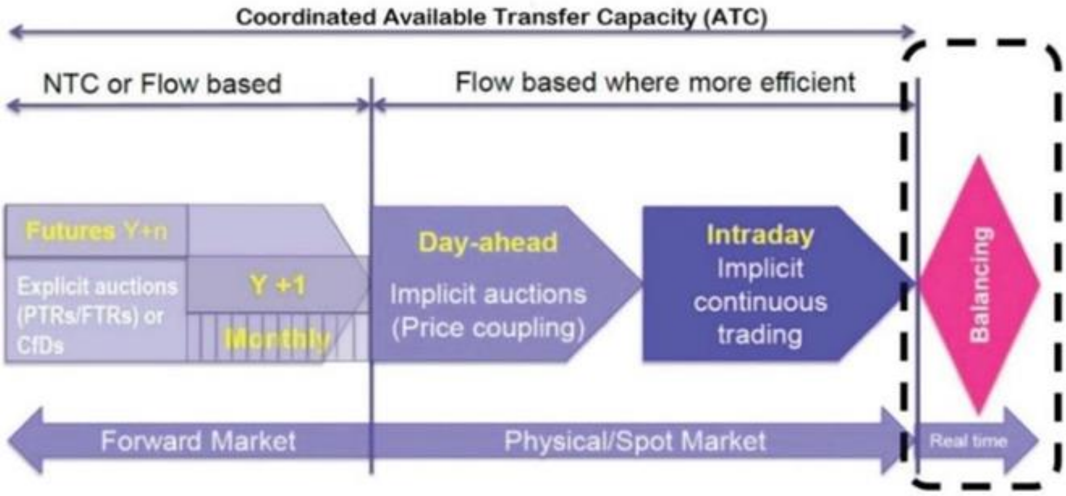

Figure 4: The electricity Target Model [9].

The Forward and Future markets respond to years before up to the day before delivery. Forwards and futures are contracts to deliver a satisfied amount of electricity at a certain time in the future for a price agreed upon today. Parties agree on a price for the sale of electricity in the future (e.g. year x+1 or x+2) [10]. The Forward market enables the market participants to limit their exposure to the more volatile Intra-Day Market by ensuring their position when the market price is susceptible to changes by indicating long-term future expectations of hourly market prices [9]. This risk-reducing behaviour is referred to as hedging. In Forward and Future markets, electricity can be traded between different market zones or within a market zone [11]. A financial exchange organizes trade using standardized products, or market parties can make bilateral over the counter (OTC) deals. The negotiated energy prices are denominated per bidding zone, which in most cases overlap with national borders. The Forward Capacity Allocation Guideline (FCA GL) regulates the allocation and calculation rules for cross-zonal transmission rights. The allocation of the transmission capacity between two market zones in Forwarding and Future markets happens explicitly. In such an explicit cross-border allocation, transmission capacity is traded apart from electric energy. This implies that market players first buy the right to use the transmission capacity between two market zones before buying or selling electricity in another zone. With respect to trading within a market zone, it is assumed that intra-zonal trading is never constrained by the transmission capacities [10].

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

In the Day-Ahead market electricity transactions with a physical delivery obligation in day (D) are auctioned in a day D-1, where all transactions of energy financial products with physical delivery are also declared. Therefore, electricity is traded one day before actual delivery [9]. The Day-Ahead market is of major importance as the market zone has to be in balance at the end of the day [11]. At Day-Ahead market closure, scheduled generation needs to equal forecasted demand plus/minus net export/import to/from other market zones. Electricity can be traded both with OTCs and at a power exchange level. Participation is mandatory for the producers and optional for all other participants [9]. At the end of the Day-Ahead market, each Balance Responsible Partner (BRP) submits a balanced portfolio to the TSO, called nominations, that are used to calculate the planned generation or consumption for every unit of the BRP [11]. In the Day-Ahead market, market zones can be coupled with each other by linking Day-Ahead spot markets into a virtual market, so that the lowest priced bids are accepted up to the point where congestion constraints limit further trade. All accepted bids are paid to the marginal offer [9].

After the Day-Ahead market is cleared, the Intra-Day market opens [12]. The Intra-Day market refers to electricity traded on the same day of delivery (D). This allows market participants to proceed with corrections when deviations from their offers in the Day-Ahead Market occur. It also permits the correction of the trading position as approaching real-time in the case of changes in demand or power plant outages and the submission of more accurate short-term forecasts for renewables [9]. The Intra-Day nominations are added to the day-ahead nominations of the BRPs [9]. The BRP's portfolio can be in imbalance after the Intra-Day market, in contrast to the Day-Ahead market where a balanced portfolio is required. These portfolio imbalances are dealt with in the balancing market [12].

Currently, trading in the Intra-Day market is done via continuous trading (as on a stock exchange) in some countries and via auctions in other countries. The Day-Ahead and Intra-Day markets, the market coupling and the cross-zonal Intra-Day market design are described in the Capacity Allocation and Management Guideline (CACM GL) [7]. Particularly, Commission Regulation (EU) 2015/1222 of 24 July 2015, defines the Target Model for the single European market for electricity in the Day-Ahead and Intra-Day timeframes. It describes the Target Model for the Intra-Day market as an implicit continuous trade-matching algorithm, allowing the coupling of Intra-Day markets at EU level, with first-come first-served allocation of capacity (Article 51) [13]. The CACM GL also foresees the implementation of a methodology to price cross-zonal Intra-Day capacity (Article 55). The Cross Border Intra-Day (XBID) Trading Solution applies to establish a common cross border implicit continuous Intra-Day trading solution across Europe, where all the cross-border capacities are allocated [9, 13]. To do so, ACER decided on 24 January 2019 to introduce three pan-European auctions for the pricing of capacity. The single Intra-Day coupling (continuous trading) will continue to run in-between these auctions, but it will be interrupted for the duration of the auctions [12]. In addition, the CACM GL offers the possibility for individual regions to

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

implement complementary auctions (Article 63), again with continuous trading running in-between these local auctions [12].

After trading in the Intra-Day market closes, the balancing mechanism is in place to ensure that supply equals demand in real-time [14]. The core scope of the Balancing market is to correct imbalances between input and output in the electricity system in real-time [15]. The TSOs need to act in real-time for the procurement of balancing capacity to cover the system's reserve requirements, as well as the procurement of energy volumes in order to balance differences between real-time production and demand.

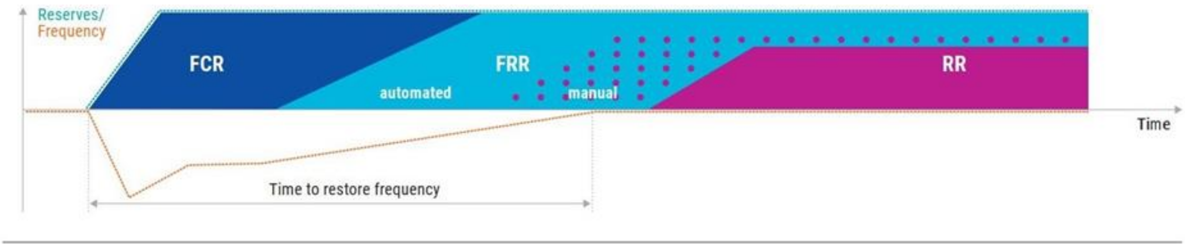

Figure 5: The Balancing Reserve Market [16].

In the Balancing Reserve Market, the TSO needs to contract three types of reserves (Figure 2). Frequency containment reserves (FCR, formerly called "primary reserves") are used to stabilize the frequency within the time frame of seconds utilizing automatically controlled and locally activated reserves [15]. Frequency restoration reserves (FRR, formerly called "secondary reserves") are used to restore the system balance, are active in the range of seconds up to 15 minutes and are controlled automatically and activated centrally [15-17]. Primary Reserves, used to almost instantly stabilize the grid frequency by activating locally controlled reserve capacity, Secondary Reserves, activated centrally within minutes' timeframe, and Replacement Reserves, activated locally for longer time-periods (hours) that are needed to restore system balance in cases where the two previous systems are not adequate to restore the balance between supply and demand. Besides the yearly contracts, non-contracted FRR can be offered in the reserve market Day-Ahead as free bids. Replacement reserves (RR) are used to restore the system balance when frequency restoration reserves are not able to do so (i.e., in case of major imbalances). Additionally, they allow the FRR units to return to their pre-imbalance status allowing them to be ready for the next short-term imbalance intervention. Replacement reserves are active in the range of minutes to hours, controlled manually and activated locally [17].

In balancing capacity markets, contracted Balancing Service Providers (BSPs) are paid an availability payment [16]. The TSO is responsible for settling the imbalances by setting tariffs to the contacted parties for imbalances in their portfolios [17,18,19]. Contracting is done one year ahead up to one day ahead of delivery in order to make sure that there will always be enough balancing energy available in real-time [12]. The BSPs contracted in the balancing capacity market then offer their balancing energy in the balancing energy markets [20]. The volume of activated energy depends on real-time imbalances [10]. The individual BRPs might face a real-time

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

imbalance. The BRP's imbalance is the net quarter- hourly difference between the BRP's total injections and offtakes [10]. The total imbalance in the control area is the net sum of all BRP imbalances [10, 21]. The TSO will maintain the system balance by activating reserves (Balancing Reserve Market). The number of reserves activated is referred to as the Net Regulation Volume (NRV). A positive NRV corresponds to upward regulation and a negative NRV corresponds to downward regulation [10, 19]. Imbalance pricing is designed in each country to incentivize BRPs to be balanced or help the electricity system to be balanced [5]. A main characteristic when calculating an imbalance price is the imbalance settlement period (hereafter ISP), which defines the frequency of the determination and publication of imbalance price signals sent to BRPs [5, 15, 16,17]. The EB GL regulation and recast electricity regulation provide clear provisions on the imbalance settlement and, among others, establish a harmonized time unit for which BRPs' imbalances have to be calculated - the ISP shall be harmonized to 15 minutes by 1 January 2021 [1, 19]. A core element of the EB GL regulation is the implementation of platforms for the exchange of balancing energy. . The following implementation projects are in the lead of its design and implementation: Trans- European Replacement Reserves Exchange (TERRE) for the RR platform, Manually Activated Reserves Initiative (MARI) for the mFRR platform, Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation (PICASSO) for the aFRR platform, and International Grid Control Cooperation (IGCC) for the IN platform [20-26].

Redispatch is needed when the market outcome (in this case the Day-Ahead or Intra-Day market) results in generation and consumption schedules that would lead to a potential violation of operational limits of a certain network element within a bidding zone. Typically, redispatch involves increasing or decreasing the output of a generator at the ends of a potentially congested line. The Clean Energy Package prescribes to organize redispatching by default in a market-based manner (Electricity Regulation, Art. 13). Currently, in most EU Member States generators are still legally obliged to participate in redispatch, and prices are regulated, or foregone opportunity costs from the wholesale market are paid to the owner of the redispatched resources.

Based on current policy targets, projections, and expectations, electricity is set to play a central role in the EU's economy [36]. The ambitious goals of decarbonization and energy-efficient actions include decreasing greenhouse gas emissions by 40% in 2030 and 95% in 2050 down to below 1990 levels, increasing the renewable energy share to at least 27% of final energy consumption in 2030, and attaining 27% energy savings by 2030 as compared to business-as-usual rates of growth [27]. In order to achieve this most efficiently, we need to make the energy system more flexible, and use the existing interconnections to their maximum capability, while preserving the secure operation of the system. At high-voltage levels, the current bidding zone configuration is under pressure. Grid expansion could not keep up with the impressive capacities of renewables installed, and consequently, among other problems, redispatch costs are high and still rising. In addition, at low-voltage levels, distribution networks would need to be expanded in order to deal with the increasing installation of PVs by consumers, electrification of transportation and heating [12]. It is also essential to find efficient ways of storing

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

excess energy and transporting it over long distances since renewable generation is often located far away from consumption centers. Consumers can play an important role in providing flexibility to the system through demand response. One big challenge is how to engage Consumers when many of them still find it difficult to switch suppliers or do not notice a price incentive to adjust their pattern of consumption. To that end, smart meters have been scheduled to reach nearly half of the EU's citizens by 2020. In such a rapidly shifting context, electricity system stakeholders are striving to keep up with the pace of innovation and anticipate the infrastructure and market arrangements necessary for future electricity delivery and services [27-30]. Legislators and regulators are confronted with the challenging task of creating the most effective actions to steer the electricity sector transition for the customers' benefit.

2.1.2 Electricity market status in Greece

The reformation of the electricity market in Greece started several years ago and was realized via various regulations and directives. Law 2773/1999 set the basis for the liberalization of the Greek electricity market and the regulation of some key points of the national energy policy [27,28]. It also introduced the Regulatory Authority of Energy (RAE) with the objective of monitoring and controlling the electricity market. Law 3426/2005 introduced some additions into Law 2773/1999 that accelerated the electricity market liberalization process [27,28]. In 2011, the Greek government introduced comprehensive new legislation in order to convert the third EU directive into national law and reform the electricity sector. Law 4001/2011 is the foundation of the modern Greek electricity market as it introduced the transition from the Independent System Operator model to the Independent Transmission Operator (IPTO) model [27,28]. Moreover, this Law strengthened the energy regulator (RAE), by granting it financial autonomy and a distinct legal personality. Some additional key provisions of this legislation are Law 4425/2016, which further strengthens the financial and operational independence of RAE and Laws 4336/2015, 4389/2016 and 4393/2016, which provide the framework for undertaking NOME auctions to enhance market competition [27,28]. Greece is set to apply all four markets deriving from the relevant legislation, namely the Forward market, Day-Ahead market, Intra-Day market and Balancing market [27,28]. In the new market structure of the Greek, the Hellenic Energy Exchange (HEnEx) manages the energy markets of physical delivery and the energy financial markets in accordance with the provisions of Law 4512/2018 and its delegated acts, while IPTO, the Greek TSO for electricity established in compliance with Law 4001/201, manages the Balancing Market. HEnEx complies with various European licenses, such as the Regulation on Wholesale Energy Market Integrity and Transparency (REMIT), the European Market Infrastructure Regulation (EMIR), the Markets in Financial Instruments Directive (MIFID II), the Market Abuse Regulation (MAR), and the Nominated Electricity Market Operator (NEMO) (Fig. 6). This framework is closely supervised by both national (RAE & Hellenic Capital Market Commission) and European regulators (ACER & ESMA). Hellenic Capital Market Commission is the authority responsible for granting a license to HEnEx, and in

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

parallel has the obligation to supervise the Forward market [28,29,33]. Based on the introduced legal framework, financial products trading in HEnEx, such as derivatives, options and futures, are subject to specific financial legislation. According to EMIR, the clearinghouse manages the settlement fund, which covers the likelihood of default of any market participant [5,28,29,32]. Furthermore, RES integration into the Balancing Market is also related to the effective implementation of the role of Aggregators in the system, functioning as virtual power plants, pooling RES production and/or electricity consumption of households and selling off their unused power during peak hours, when demand is high [9].

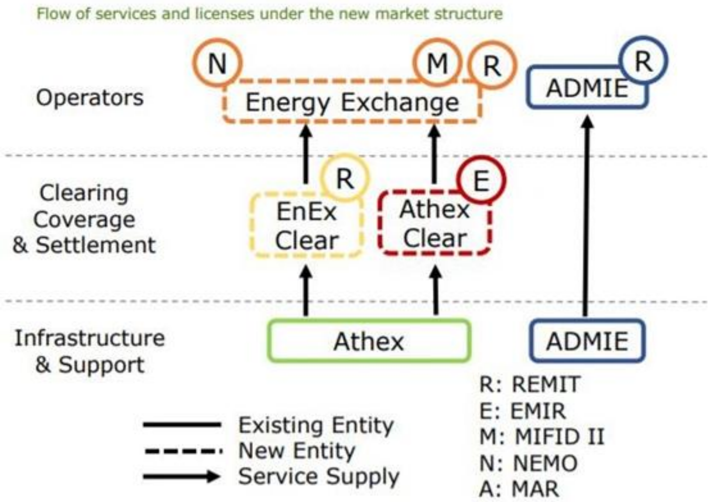

Figure 6: Services under the new market structure in Greece [27].

The most recent regulatory reform, related to the implementation of the electricity Target Model in Greece, is Law 1090/2018, published in the Official Government Gazette of the Hellenic Republic on 31/12/2018 [5,9]. Since 1 November 2020, the Target Model applies in Greece. Based on the adopted Target Model structure, the Greek Balancing Market includes the Balancing Capacity Market, the Balancing Energy Market and the Imbalance Settlements [9,34].

The new market design replaced the day-ahead mandatory pool system, which was in operation since 2005. The previous market design in Greece was based on a gross mandatory pool system that used a technical algorithm to determine prices and schedule for the entire energy market, in order to help encourage new entries by providing a guaranteed route to market and robust reference price. The system provided for co-optimization of energy and reserves to help maintain the security of supply. Multiple generation inputs were integrated into the Pool algorithm, including economic bids, cost data and technical characteristics of the generator units. In the aforementioned Central Dispatching Model, the scheduling process and dispatching bids included unit-based instead of portfolio-based participation [35, 36]. The unit-based system comprised of producer participation in the Day-Ahead market with one energy bid per generating unit, as well as participation in the Intra-Day market with separate purchasing and selling bids per generating unit [37]. Unit-

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

based participation entailed central scheduling performed by the IPTO in D-1 and real-time balancing conducted by IPTO, in order to dispatch the units to cover the load and reserves, and to centrally handle system imbalances in generation and demand. Forward, Day-Ahead and Intra-Day Markets fall under the authority of the Hellenic Energy Exchange (HEnEx) [28], (Fig. 7). The Greek wholesale power market also included the acquisition of Physical Transmission Rights (PTR) - explicit auctions, to serve cross-border exchanges with all the interconnected countries [9,38,39,40].

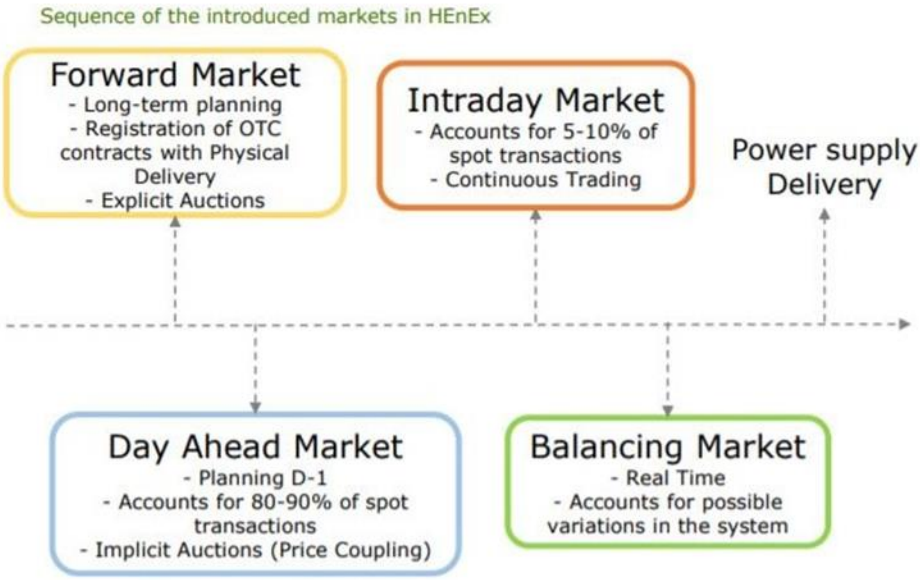

Figure 7: The new market structure in Greece [28].

Following law 4425/2016, as amended by law 4512/2018, the new market design comprises a series of wholesale markets, defined and discussed in detail in the following sentences. In particular, concerning the Forward market in Greece, it is operated by the Hellenic Energy Exchange (HENEX), with ATHEXClear performing transaction clearing, offers the possibility of trading both financially-settled and physically-settled forward contracts. The buyer of a forward contract has the obligation to buy a certain quantity of electricity, while the seller of such a contract has an obligation to sell a certain quantity of electricity at a certain price, and a predefined date [29,33,41]. Forward contracts in terms of the HEnEx function are designed to be Monthly, Quarterly, or Yearly Standardized Contracts. Participants in the Forward market are completely flexible to differentiate their position within that horizon. Consequently, the fundamentals are shaped for the entire exploitation of price fluctuations, leading to a significant diversification of costs. In the case of bilateral trading, all forward contract specifications are included in a bilateral OTC contract [29,33]. The rules regarding the operation of the Forward market are approved and monitored by the Hellenic Capital Markets Commission.

In the same framework, the day-ahead market is an hourly spot market balancing demand and supply via electricity prices, reflecting the highest generation bid needed to balance the lowest willingness to pay of load

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

representatives. This market allows participants to submit electricity transaction orders with the obligation of physical delivery on the next day. Participants can also declare the energy quantities corresponding to forward-market product transactions in the day-ahead market, irrespective of commitments through the forward products wholesale market or outside it. The delivery day (D) consists of twenty-four purchased time units [28,29,33]. Gate opening is at 10:30 (D-1) and lasts for 150 minutes since Gate closure time is at 13:00 (D-1) [29]. The product traded is an hourly contract that specifies the size (MWh) and value (Euro/MWh). Hourly bids are the most common type of bids in power exchanges, and the essential information required on each bid includes participant's details, type of bid (sale or buy), an hour of the day, quantity, and price [28,29,33]. Market participants in the HEnEx, submit their bids throughout the transaction system, determining the quantity and the price they are willing to sell or buy. After receiving the bids, a verification and validation process is performed. Each sale bid specifies the quantity and its minimum price, at which the seller is willing to supply electricity [24,28,29,33]. On the other hand, each buy bid specifies the desired quantity and the maximum price, at which buyers are willing to pay. The anonymously submitted bids are collected in the transaction system until the predetermined closure time and followed by a specific procedure of auction algorithm computation, a clearing price is determined for every hour. The clearing or matching price for every hour is settled when demand and supply curves aggregated and intersected. In that way, demand is covered for 24 hours, 7 days per week [29,32, 33]. Following ACER 04/2017 decision, the DAM market-clearing price floor is set at -500 EUR/MWH and the cap at 3000 EUR/MWh. In addition, a mechanism applies that increases the price cap by 1000 EUR/MWh when the price exceeds a certain threshold fraction.

The implementation of the Intra-Day market in HEnEx will take place in two phases [29, 32, 33]. During the first phase, auction sessions are implemented in Greece while during the second phase, trading will occur both internally and at the borders. The design of the Greek Intra-Day market will be adapted to implement pan-European continuous Intra-Day Trading through the already agreed Intra-Day solution [31]. This procedure allows transactions in which orders may be executed as soon as they are placed in the frame of the Intra-Day market. The Intra-Day market functions as an extension of Day-Ahead fine tuning, since participants can update their trading position based on their risk profile as approaching real-time and submit more accurate short-term forecasts for RES [31, 32]. The Intra-Day market-clearing price floor is set at -500 EUR/MWH and the cap at 3000 EUR/MWh. In the regional Intra-Day auctions and the continuous Intra-Day trading, the price bounds will be set at -9999 and +9999 EUR/MWh. For the non-coupled Intra-Day market, the bidding and clearing limits (+3.000 €/MWh and - 500 €/MWh) refer to the LIDAs, currently in place. According to RAE Decision 440/2019, the technical price limits of the CRIDAs should be aligned with the ones to be adopted in the SIDC, i.e. +9.999 €/MWh and -9.999 €/MWh respectively (ACER's Decision No 5/2017). Currently, the Intra-Day market performs three intra-day auctions per day (termed LIDAs). The Greek Intra-Day market is not yet coupled with neighbouring markets in intra-day. The Regulator plans to facilitate the introduction of intra-day trading also for the borders

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

with non-EU countries. The liquidity of the Intra-Day market transactions has been limited during the first months of market operation, due to the lack of regional integration of IDM, which will increase market liquidity. The introduction of additional participation in the market (i.e. traders, demand response, storage, etc.) is the selected approach to increasing intra-day trading liquidity.

Balancing market is critical for the safety of the system as it has not only economic but also physical effects. Today it has a small market share (up to 5%) but will increase as the penetration of RES increases. RES units will not participate in the balancing market before the fourth quarter of 2021. This is related to the fact that RAE wants to assess the liquidity of the Intra-Day Market after collecting registered data of twelve months of continuous Intra-Day transactions, setting a time limit of at least the third quarter of 2021. The balancing market in Greece is based on the unit based/central dispatching model. In Greece, The System Operator, selects the bids (which are given per production unit) with the lowest price on the basis of on an optimization algorithm, and issues corresponding orders to each production unit selected for the provision of each service. Specifically, in the first stage, it is ensured that the system has sufficient capacity to provide balancing services in accordance with the Operator's estimates and then, when necessary, the required orders are issued to the entities that provide balancing services. Entities that provide balancing services submit bids to the market per unit, per load zone and per interconnection border. The balancing market is implemented through three separate markets, namely the Balancing Capacity Market, the Balancing Energy Market, and the Imbalances Settlement Market [33,34], Fig. 5.

Figure 8: The balancing market structure in Greece [33]

In the framework of the Balancing Capacity Market, the System Operator determines the number of required reserves for each balancing capacity product that deems necessary for each allocation period and participants submit bids for these products, provided they have the technical capacity to provide them [33, 34]. Participation in the Balancing Capacity Market takes place prior to real-time. The market design has prescribed the three key

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement No 957739

balancing capacity products, upward and downward Frequency Containment Reserve (FCR), upward and downward manual (non-automatic) Frequency Restoration Reserve (mFRR), and upward and downward automatic Frequency Restoration Reserve (aFRR) [33-35]. Participants are compensated for the balancing capacity quantity that corresponds to them from the market clearing on a pay-as-bid basis every 30 minutes and participants are required to commit the respective capacity in order to maintain a safe margin for System balancing in real-time. The dispatch and balancing market settlement period are 15 minutes, compared to the current imbalances settlement scheme which is one hour [33-35].

In the context of the Balancing Market reform towards the participation of IPTO in the MARI platform, the local mFRR balancing energy product characteristics have to be amended in order to be fully compliant with the standard mFRR balancing energy product according to ACER Decision No 11/2020. Furthermore, for the participation in the PICASSO platform, the local aFRR balancing energy product has to be equally fully compliant with the standard aFRR balancing energy product according to ACER Decision No 11/2020, especially regarding the full activation time, which has to be amended from 7.5 minutes to 5 minutes from 18.12.2024. The minimum bid size for balancing is 1 MW. The volumes of FCR, aFRR and mFRR reserves are awarded to the market participants through the ISP, based on the requirements published by the TSO on a 30-min granularity. The participants submit volume-price balancing capacity offers per reserve product, provided that they are eligible, technically and operationally, and have capacity available for reserves. The offerors are dispatchable generating units. Demand response, electricity storage systems and RES are not yet eligible to offer reserves; however, regulatory, technical and operational preparations are ongoing to allow such participation in the reserve offerings by Q1 2022 (for DSR and RES, whereas for storage regulation is pending).

In the context of the Balancing Energy Market, all entities that can provide balancing services are required to submit bids to the market for the necessary balancing energy products, the amount of which has been determined by the System Operator. Close to real-time, the operator estimates, where activation of Upward or Downward manual Frequency Restoration Reserve (mFRR) is necessary and then issues the corresponding orders based on the lowest priced bids [44]. In real-time, the entities that can provide aFRR, receive automatic orders for activation of the lowest priced bids in order to ensure the balance of the system, under the limitation of protecting the safe operation of the system. This is a process similar to Automatic General Control (AGC). Energy is compensated at a marginal price per balancing energy product, except for reallocation cases, when it is compensated at the bid price and every 15 minutes. Imbalances Settlement takes place to post real-time and aims at the compensation or charge of the energy arising from any imbalances of the participants in the Balancing market from the last schedule of the market and/or the dispatch orders. The Imbalance Settlement Procedure defines the remunerations and, generally, the settlement for balancing energy, balancing capacities and imbalances. The remuneration basis results from the RTBM algorithm that implements the Balancing Energy Market. The imbalance settlement period has already been set to 15 minutes since 1st November 2020. [34].

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

The core of the Balancing Market is the Integrated Scheduling Programming (ISP) which is a process carried out by the System Operator to shape the dispatch schedule of units and allocate the balancing capacity to the entities that provide it [34]. The ISP is carried out on a schedule three times, i.e. once immediately after the clearing of the Day-Ahead market and two more times after the clearing of each one of the two Intra-Day auctions carried out in the framework of the Intra-Day market [34]. It may also be carried out on demand, each time the Operator deems that there are significant changes during the operation of the system. The ISP clearing takes place for 30-minute dispatch periods. The results of the ISP clearings are not binding for its first execution. They are binding for the first 24 dispatch periods of the dispatch day for the clearing after the first Intra-Day auction and are binding for the last 24 dispatch periods of the dispatch day for the clearing after the second Intra-Day auction. Participants, before the clearing of the first ISP, submit bids both for the balancing capacity and for the balancing energy, for each 30-minute dispatch period. The minimum limit for bidding prices in the balancing capacity is zero. The maximum limit for these prices is currently +3000 EUR/MW/hour, which is likely to increase up to +9999 EUR/MW/hour after the operation of continuous and complementary regional intra-day trading. The result of the ISP procedure is a commitment schedule of the power plants, the awarded capacities and an indicative generation schedule. The balancing capacity quantities allocated to each participant as above during the next two scheduled clearings of the ISP are committed and compensated in the framework of the Balancing Capacity Market, regardless of whether in real-time the entities provide balancing energy or not [34].

For the clearing of the Balancing Energy Market, the Operator converts the 30-minute energy bids of the participants into 15-minute bids.Participants may submit only improved bids in relation to the bids submitted at the first ISP, namely bids with a lower price in the case of a production unit or bids with a higher price in the case of load [34]. The last available 15-minute energy bids received to participate in the real-time balancing energy market, as mentioned above. At this point, it should be noted that the design of the Balancing Market has taken into consideration all potential balancing energy supply sources, namely conventional units, RES units, and load, in the case of aggregators, which can provide balancing capacity and energy products after the conduct of the relevant pre-selection tests [34]. Finally, the Imbalances Settlement takes place when the required metering data are available, closing the cycle of Balancing Market processes [34].

2.1.3. Identified challenges in the market structure, TSO-DSO-consumer coordination and future steps

In order for Greece to achieve all the related to the Clean Energy Package goals, several challenges that the current electricity system and market face have to be tackled. Domestic market liberalisation is a major challenge for the Greek energy system. Unless further measures for market liberalisation are taken, effective

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

competition is not conceivable in Greece, and the benefits for the consumers from the electricity markets will be significantly diminished. Another point of concern that needs to be addressed is the 2030 target of the installed RES electricity units [41]. Unfortunately, chronic problems related to the implementation of RES projects in Greece for more than two decades still persist. Such problems involve the very long and tortuous RES licensing procedures, the uncertain future of the special RES account and its resources that financially support the RES growth, and the lack of electrical interconnections with RES-rich regions, such as islands, etc. In addition to those problems, new challenges for renewables have emerged, such as the new auction-based Feed-in-premium (FiP) system, which still requires significant improvements in its design and operation, the continuously postponed application of the complete Target Model and the regional electricity market coupling, which prevent the full and equitable participation of new RES projects in the electricity market, the rapid and very significant changes that many RES technologies and integrated RES schemes are undergoing worldwide, for which a coherent regulatory framework is missing in Greece (e.g. for energy storage, for offshore/floating wind, etc.).

Up to the present time, Greece's market has entered a transitional stage, where RES producers obtain only a balancing responsibility for the deviations they cause in the balancing market. The final stage of the participation of RES units in the Target Model is most likely to begin at the end of 2021. At this stage, RES producer's participation in all relevant markets will be mandatory whereas a full balancing obligation will be required, leading to increased risk thus costs for the power fluctuation they induce. Moreover, their operating costs will rise, as a result of their compliance with the obligations set by Target Model. RES aggregator's aim is the commercially successful operation of the connected RES units they represent, in order to reduce the fluctuations between the forecast and actual production of RES units and consequently maintain the deviation charges imposed on RES producers, at a low level. Furthermore, currently it is mostly traditional units that provide stable energy generation, but as they are fading out, questions arise regarding RES unit's capability to autonomously maintain this stability and bear its cost. While all these problems and obstacles impose additional difficulties and requirements for the successful implementation of new RES projects, the existing policies that support the increase in RES penetration by 2030, are sketchy and insufficient. Finally, the lack of sufficient electricity interconnections with the mainland, in geographically isolated regions, ends up depriving the Greek consumers of actively participating in the EU energy transition process.

Another key point that the Greek electricity system has to address is the participation of consumers in the energy system both through their generation assets and the flexibility in their load operation. [36,37]. However, current market rules often do not allow consumers to benefit from these new opportunities. In order to enable consumers to benefit financially from those new opportunities, they must have access to smart systems as well as electricity supply contracts with dynamic prices linked to the spot market. In addition to consumers adjusting their consumption to price signals, new demand services are currently emerging whereby new market actors offer to manage the electricity consumption of a number of consumers by paying them compensation for their

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

flexibility [36,37]. The new market design aims at ensuring that supply prices are free of any public intervention and only with duly justified exceptions. However, self-generation is still hampered by a lack of common rules for 'prosumers'. Appropriate rules could remove these barriers, e.g. by guaranteeing consumers' rights to generate energy for their own consumption and sell surplus into the grid, while taking into account the costs and benefits for the system as a whole (e.g. appropriate participation in grid costs) [32]. Another key driver to competition and consumer engagement is information. Studies have shown that consumers complain about a lack of transparency in electricity markets, reducing their ability to benefit from competition and actively participate in markets. Consumers do not feel informed enough about alternative suppliers, the availability of new energy services and complain about the complexity of offers and procedures for switching suppliers. The increased use of new technologies (notably smart metering systems) will generate a range of energy data carrying high commercial value, while data protection measures will be taken. Therefore, we need new synergies, new levels of cooperation among the energy actors so to really operate the electrical infrastructure as One Network.

OneNet aims at creating unique synergies between all the players at the European level proposing new and standardized products and services (WP2 and 3)_and enabling them through an open, interoperable, scalable and standardized IT architecture. A key element of the structure of this project is the creation of GRIFOn (GRId FOrum), a platform for all the stakeholders that will be used to create a constant dialogue between the project and all the other stakeholders.

As far as the Greek demo is concerned, the proposed "TSO-DSO Flexibility Channel" (F-Channel) is a digital platform that can demonstrate the setting-up of flexibility market with various common products for TSO-DSO coordination (Fig. 9). The core technologies of the digital platform will be the forecasting module (ensuring predictability of the highly volatile RES generation and demand) and the coordination module, which will consider the existing functionality and data of IPTO-HEDNO key systems (such as the control system, asset register, GIS) and develop a flexibility platform for providing grid services (frequency and non-frequency) for the balancing and congestion management challenges, realizing the use cases presented in the coordination schemes of Active System Management proposal by ENTSOe. Forecasting and Coordination modules will consider all the various stakeholders participating in existing or near future markets in Greece. These modules will also incorporate "prosumers" (self-consumption legislation already being established in Greece), "aggregators" and their forms of participation in the energy mix and flexibility provision, flexibility providers/storage owners / EV charging station operators (grid storage and EV regulation is currently being formulated by the Greek NRA).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

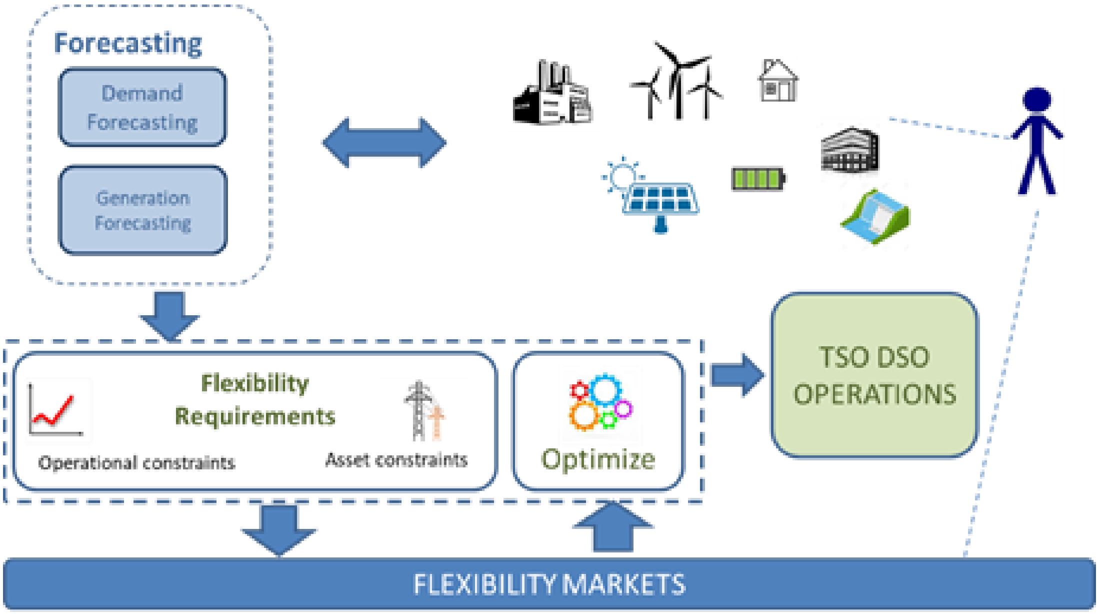

Figure 9: F-channel architecture.

In the Greek demo, the scenarios tested will be two-folded: (i) situation as is, dry-run testing of forecasting in various timeframes, balancing and congestion management processes, linking with the ongoing processes in IPTO and HEDNO, i.e. balancing/DAM, flexibility auctions, RES aggregators participation (ii) examining near future scenarios of market reforms (ID market) and business prospects for flexibility services stemming from prosumers, DERs, storage owners, EV charging station owners, new aggregator profiles as well as extensive scenarios i.e. local markets, planning of new investments and interconnections (islands, cross-border), regulatory reforms for sector coupling strategy (Figure 10) . It is worth mentioning that all the aforementioned scenarios will take place in the area of the Crete AC interconnection (Peloponnese – Crete). The latter poses significant challenges in the system operation: the transmission network of Crete (HEDNO operated) will be bridged with the mainland transmission backbone (IPTO operated) in 2020, while the second HVDC interconnection is expected to be commissioned in 2022. High-RES penetration already exists and is expected to augment in the area.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

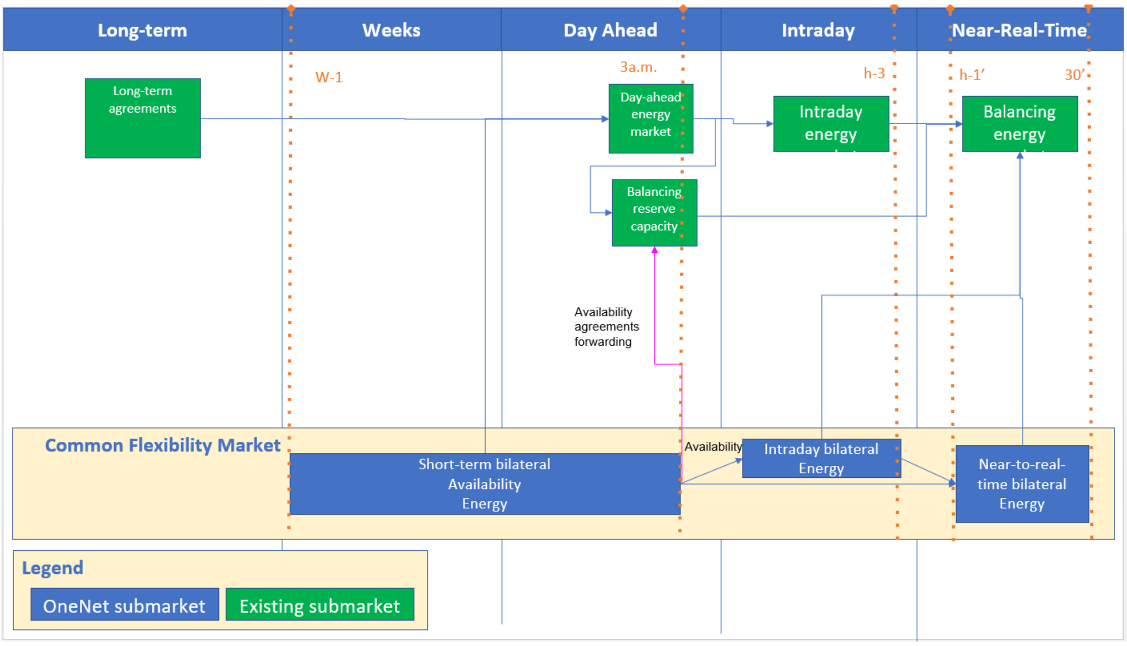

Figure 10: High – level visualization of the pilot in Greece.

2.2 The Cypriot electricity market

1.1.1 Analysis of history of energy regulatory aspects within Cyprus- philosophy and rationale behind these

The establishment of the Cyprus Energy Regulatory Authority (CERA) and the appointment of the Transmission System Operator (TSO) during 2004 constitute two very important events in the field of Energy, a field that before to the entry of Cyprus into the European Union (EU), had a purely monopolistic character. It was and still is among the basic priorities of Cyprus to get fully harmonised with the 'Acquis Communitaire' in the field of Energy. This process passes through a series of actions, the most important being the one that aims at a healthy competition with the abolition of monopolistic attitudes and conduct. One of the urgent priorities of CERA was the opening of the Electricity Market. This was achieved and the Electricity Market was liberalised by 35% on 1st May 2004.

During 2005, the Electrical Energy Sector in Cyprus has its own historical landmark. In this period the important event was the issue of New Licences for the Construction and Operation of Power Stations for the Generation of Electricity. With this development, the monopoly regime which existed for more than half-century comes to an end. Now the regulation exists and it is only up to the Projects to materialise in order that their unhindered access to the Electricity Network may follow. This will allow Eligible Consumers the free choice of their Supplier which is the essence of free competition in the Energy Market. CERA is also giving due importance

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

to the matter of rational and gradual liberalisation of the Electricity Market in order not to upset the smooth operation of the Market. The securing of the quality and reliability of Electrical Energy was amongst the top priorities of CERA while creating favourable conditions to promote the use of Renewable Sources of Energy. Furthermore, new Regulations were prepared by CERA and approved by Parliament safeguarding consumers' rights, namely the Regulations on the Procedure for Submitting Complaints, and the Performance Indicators Regulations. During 2006, the Electrical Energy Sector takes further important steps in regulating the Market. Regulatory Decisions were issued by CERA on the Methodology of Electricity Tariffs. At the same time, in-depth discussions, meetings and deliberations are constantly in process with all parties involved in the Energy Sector on various important itemised issues among which were:

- The unbundling of the EAC accounts to establish the actual cost of the services rendered by EAC, the vertically integrated electricity undertaking, minimise the possibility of cross-subsidies between its activities resulting in eventual lowering of the prices of electricity,
- The Market Rules, which were prepared by the TSO and submitted to CERA for approval. CERA gave unofficial approval but requested their simplification,
- The Transmission and Distribution System Rules, already revised once, being further revised,
- The connection and use charges of the Transmission and Distribution System.

In 2007, CERA encouraged the increased subsidies for the production of electrical energy from the photovoltaic systems and set the target to increase the penetration of RES by 6% by the year 2010, a target that was achieved. Further, for the first time and by considering the 3rd Energy Package, a new and difficult target was set for Cyprus, the generation of 13% of energy production from RES (while other European Countries need to achieve 20% energy production). In 2007, The Electrical Energy Sector takes further important steps in regulating the market. In particular, new regulatory decisions were issued by CERA on the methodology of Electricity Tariffs and the connection charges of the transmission and the distribution systems.

With effect from first of January 2009 the electricity market was further liberalised including all "non-domestic" consumers which are free to select their Supplier. However, there are no other Suppliers now. Therefore, the sole supplier is the Electricity Authority of Cyprus (EAC). In the attempt of CERA to establish the basis for the operation of the Cyprus electricity market, in the period 2010-2011, and for the first time, a regulation was established regarding the Fees for the Use of the Transmission and the Distribution Network as well as the charges for Ancillary Services. Moreover, the Regulatory Decision on the Methodology for the supply and compensation of Ancillary Services and Long-Term Capacity Reserve has been approved and published.

In 2012, a very important development was the harmonisation of national legislation with the 3rd Energy Package of the European Union. The House of Representatives approved the harmonisation amending legislation. As a result, on 28/12/2012, the Amendment Laws 211(I)/ 2012 and 219(I)/ 2012 on Regulating the

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Electricity Market Laws of 2003 to 2008 were published and came into force. From 1st of January 2014 the market is fully liberalised and all consumers of electrical energy are able to choose their Supplier. However, currently there is no other Supplier in Cyprus apart from EAC.

In 2015, the energy sector in Cyprus underwent fundamental transformations in its structure and organization, institutional framework and the diversification of its energy mix. In order to open up the market to new participants, CERA has proposed the Net-Pool model [44] as being the most appropriate trading arrangement approach for the Cyprus electricity market, setting mid-2016 as the milestone for its commercial operation [44]. The formulation of a Net-Pool incorporates both, a bilateral contracts market and a central Day Ahead Market while the organization of an IntraDay Market was postponed for future organization. The proposed design included also a real-time Balancing mechanism that provides the TSO with the ability to purchase the required operational reserves, activate balancing services, and settle imbalances.

In the light of the delay in the implementation of the Net-Pool model for the electricity market of Cyprus, CERA has proposed transitional arrangements of the electricity market in Cyprus prior the full implementation of the new Electricity Market Model. The transitional period will be based on bilateral contracts between producers and suppliers for the supply of a standard quantity of electricity (kWh) on a monthly basis. The transitional period of the electricity market in Cyprus started on 1 September 2017 and will be in force until the full implementation of the new Electricity Market Model. During 2017, a set of new decisions were also issued concerning:

- The implementation of provisions for the prohibition of abusive practices on the wholesale energy market and the imposition of sanctions in case of violation of the provisions,
- The imposition of Public Service Obligations (PSO) on electricity suppliers concerning the implementation of reduced tariffs for specific categories of vulnerable consumers,
- The implementation of a binding timetable for the full commercial operation of the new electricity market model,
- Guidelines to the Owner of the Transmission System for the allocation of resources to the TSO,
- Implementation of the transitional arrangements of the electricity market in Cyprus prior to the full implementation of the new electricity market model.

1.1.2 Technical function of the Cyprus energy market

The "Trading and Settlement Rules" (Market Rules) were officially published and placed into force on 30 January 2009. In general, the Trading and Settlement Rules enable the Cyprus TSO to fulfil its obligations under the Law, regulate the means by which Participants may trade Energy, allow the calculation and settlement of payments in respect of Energy and specify the way in which settlement and billing shall be carried out. The

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Trading and Settlement Rules provide all necessary information concerning the operation of the electricity market in the country and the balancing operation rules. In accordance with CERA's Regulatory Decision 01/2015, CERA has given instructions to the Cyprus TSO, to proceed immediately to the preparation of the specifications for the supply of the required systems and other arrangements needed for the proper functioning of the Electricity Market as soon as possible. It has also given instructions to the Cyprus TSOto draft the new Trading and Settlement Rules and the revision, where necessary, of the Transmission and Distribution Rules for the full implementation of the Regulatory Decision. TSO has set under Public Consultation, a text modifying the Trading and Settlement Rules on the basis of the Regulatory Decision 01/2015 [39] and afterward discussions followed within the Advisory Committee according to the provisions of the Law. By Decision 84/2017, 12 May 2017, the Members of CERA decided to approve the proposed amended Trading and Settlement Rules submitted by the Cyprus TSO. Specifically, the members of CERA approved the adoption of deviations in the proposed revised Trading and Settlement Rules, in relation to the provisions of the Regulatory Decision 01/2015 regarding the new Net-Pool Electricity Market arrangements in Cyprus, some of which are set out below:

- Monthly offers accepted for reserve availability (in €/MW) to be paid the Marginal Reserve Price instead of their Pay as Bid
- Define maximum caps for reserve offers
- Bilateral contract entries can be made until 09:00 H-1, instead of 13:00 H-2
- Allow up to 10 energy purchase offers by suppliers for each trading period
- RES units and RES aggregators (except for RES units under National Grant Schemes) can provide operational reserves
- Balancing market to work up to real-time

1.1.3 Development and philosophy of market design

In brief, the above-market design is aiming at creating the environment and enable market participants to operate in the electricity sector of Cyprus. Special arrangements and mechanisms have been included in the design to allow RES generators (not operating under government support schemes) to benefit by their direct participation in the competitive electricity market either through a day ahead market (DAM) or through bilateral contracts with suppliers.

Specifically, bilateral physical forward contracts are notified and corresponding schedules are nominated on a half-hourly basis to the Market Operator (MO) on the day ahead of real-time. Orders in the DAM are unit based in the case of generators (or per RES plant or per aggregators of smaller size RES plant). Suppliers submit demand orders based on individually forecast half-hourly demand. Orders in the DAM correspond to residual quantities not already covered by the nominated bilateral contracts.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

The DAM is centrally managed by the MO by processing matching bid curves in order to optimise dispatch. Contracts resulting from the DAM are between market participants and the MO at the DAM clearing price. Through a centralised approach, the crucial ancillary services are allocated using a co-optimising Integrated Scheduling Process (ISP) prior to gate closure on the day ahead of real-time. A real-time Balancing mechanism is used for optimised real-time dispatch actions.

The Market Arrangements provide for a centrally organized Day Ahead Market, compatible with Regional Price Coupling principles (PCR) and an Intra-Day Market. An integrated Daily Unit Scheduling Process is also provided, matching with a real-time Balancing Market. Development of a Forward market is also foreseen, based on Over-the-Counter (OTC) transactions. Over-the-Counter forward products are bilateral contracts, negotiated and concluded between market players, in some case with the mediation of a broker. These contracts are not referring to standardized products transacted in an organized marketplace, e.g. a Power Exchange. Although in the market arrangements, a platform for the transaction of these contracts might be developed later by the Market Operator.

Subsequently, CERA instructed the Cyprus TSO as the competent and responsible organisation. It is prepared , the new Trading and Settlement Rules (known as the Market Rules) and take all necessary steps leading to the implementation of the market according to the agreed plan and timetable. Cyprus TSO set under Public Consultation a text modifying the Market Rules and discussion within the Advisory Committee followed. By Decision 84/2017, 12 May 2017, the Members of CERA decided to approve the proposed amended Trading and Settlement Rules submitted by the Cyprus TSO.

On 27 January 2017, CERA set the implementation of a Binding Timetable for the full commercial operation of the new Electricity Market Model. Specifically, CERA decided to instruct the Cyprus TSO to be staffed, by 30 June 2017, by applying the provisions of article 60(1)(c) of the Law Regulating the Electricity Market, to meet its needs and become competent in the exercise of its responsibilities. Then CERA should proceed immediately with the necessary actions for the completion of the works needed for the full commercial operation of the new Electricity Market Model, until the EAC Board of Directors places appropriate permanent staff.

Moreover, CERA decided that by 1 July 2017 [40] to initiate the implementation of the timetable, as proposed by the Cyprus TSO and complete within 24 months for the full commercial operation of the new Electricity Market Model. Also, CERA has set the 1st of July, 2019 as the latest date that the new Electricity Market Model to be fully operated. Unfortunately, further delays that have postponed the operation of the Cyprus Electricity Market. According to CERA president, the Electricity Market in Cyprus will be fully operational by the beginning of 2022. The implementation of the transitional arrangements of the electricity market in Cyprus prior to the full implementation of the new Electricity Market Model is also decided, it should be noted that the transitional period will be based on bilateral contracts.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

1.1.3.1 Factors influencing the market design

By 2022, the electricity market of Cyprus will operate with the Net-Pool market model. The operation of a centrally managed Day-Ahead Market (DAM) through which licensed participants may buy and sell energy to supplement any bilateral contracts they have entered and the subsequent application of an integrated scheduling process. Participation in the DAM for the residual quantities (i.e. quantities that have not been contracted at the forward stage or contracted as Replacement Reserve) is mandatory for all generating units. The DAM is a market where energy products with physical delivery are traded, meaning that only participants with physical injection and offtake points can submit orders to this market. With a view to fostering liquidity in the DAM, especially with regard to RES absorption, CERA should require X percentage of the country's consumption needs to be covered through the DAM. As Cyprus's electricity market will be newly established, there are several factors that will influence its design. Some of these factors are analyzed below.

Dominant player in the market

The Electricity Authority of Cyprus (EAC) has currently an almost 100% share of the Cyprus market. This constitutes a major issue that should be taken into account when designing all segments of the new wholesale market. In this respect, and with a view to avoiding placing barriers to the entry of new suppliers, the requirement of X percentage of the country's consumption through DAM will be initially placed only to the Dominant Participant's supply volumes. As competition emerges, CERA will examine the possibility for introducing relevant obligations to the supply volumes of those independent suppliers who have gained a considerable market share.

Participation of RES to the market

RES under the National Grants' Plans (NGPs) will continue to participate in the market through EAC. Though, at a later stage, CERA may shift corresponding responsibility to other suppliers as well. New RES plants operating outside NGPs may either contract on a bilateral basis at the forward stage or bid in the DAM pool. RES plants operating outside any support scheme with installed capacity above 1 MW may either directly participate (per plant) into the market arrangements or through an aggregator. An upper limit determined by CERA is introduced to the aggregated quantities. RES plants operating outside any support scheme with installed capacity lower than 1 MW may only participate through an aggregator.

Design of an Intra-day Market

The design of an intra-day market is not examined yet in the case of Cyprus therefore it will affect and influence the overall design of the market. It is expected that after the market has begun its operation, intra-day trading will be required by market participants with a view to minimizing their exposure to imbalances. In

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

any case intra-day trading should be possible the latest within 24 months from the date the market starts operation under the new arrangements.

Penetration of new technologies in the market

An important issue that will influence the design of the market is the installation of new assets in the Cyprus power system such as storage facilities. The electricity market should take into consideration these assets as they will play a critical role in the system operation. That is to say, they will provide additional flexibility while deferring capital intensive upgrades (OHLs, substations, transformers), Currently, there are no grid or market regulations for these technologies, therefore their participation will certainly require minor adjustment of the market design.

Cross border trading

As Cyprus is an isolated system, no arrangements are foreseen for cross-border trading at any stage of the market (forward, day-ahead, intra-day or real-time). However, in the possibility of the interconnection of the Cyprus power system with Israel and Greece, the design of the market will be influenced and appropriate market information systems should be developed. Considering that both Greece and Cyprus are EU member states the provisions of the Target Model should be implemented with regard to cross-border trading, as these are applied under the ENTSO-E Network Codes on Capacity Allocation and Congestion Management (CACM NC), the Electricity Balancing (EB NC) and the Forward Capacity Allocation (FCA NC). The design under these codes is quite advanced and therefore the market arrangements foreseen for Cyprus will have to be accordingly adapted.

1.1.4 Overview of market actors and their expectations

The Parties, and their respective roles in the future Market of Cyprus, are the following[1]:

Transmission System Operator (TSO): As far as it concerns the market operation, the TSO carries the responsibility to submit transmission system meter readings for settlement purposes. The TSO is also responsible to forecast load and RES output at the national level, check the feasibility of scheduling, manage network constraints and procure balancing energy and ancillary services from, and on behalf of, market participants. The TSO can therefore levy Market Participants charges for network and system operation services (following CERA's approval). This entity is legally distinct from the transmission owner.

Market Operator (MO): The MO would be a licensed entity responsible for the operation and settlement activities of the centrally managed markets i.e. the DAM and later the IDM. The roles of the TSO and MO could be carried out by the same commercial entity but this need not be necessarily the case. The MO function, as

[1] Cyprus Transmission System Operator, Trading and Settlement Rules, version 2, May 2017.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

provided under the Law, is assigned to the Cyprus TSO and therefore, should be strictly monitored by CERA with a view to securing independency from the incumbent**.** The MO will be responsible for the registration of all bilateral, Over the Counter (OTC), forward contracts between Market Participants, including the reception of technical declarations and nominations which will then be passed to the TSO. The MO will be responsible for the operation and settlement of the DAM. It further undertakes the financial settlement following the integrated scheduling process and the real-time balancing mechanism as well as the imbalance and other market uplift settlements.

Distribution System Operator (DSO): The DSO will undertake to inform the MO of the meter readings required for settlement purposes and shall undertake to perform the profiling calculations and submit them to the MO for market settlement purposes. In addition, the DSO may outsource metering certification services. The DSO shall not trade in energy or own generating capacity. The DSO does not have any account for settlements under the Market Rules.

Thermal Generators: Thermal generators with nominal installed capacity above 5 MW should notify any bilateral energy contracts they hold to the MO, submit declarations of their technical data, nominate physical delivery on a day-ahead basis, submit orders to the DAM, submit balancing reserve and balancing energy offers and hold appropriate accounts for the settlements performed by the MO.

RES plants operators operating outside National Grants' Plans (NGPs): RES plants operators operating outside NGPs with installed capacity above 1 MW can either participate through an aggregator or individually. In the latter case, RES operators should notify any bilateral energy contracts they hold, per plant, to the MO, submit declarations of their technical data, forecast and nominate generation scheduling on a day-ahead basis, submit orders to the DAM, and hold appropriate accounts for the settlements performed by the MO.

Aggregator of RES plants: Aggregators of RES plants operating outside NGPs for an aggregated size of RES plants from 1 MW up to 20 MW each, should notify the MO of any bilateral energy contracts they hold on a cumulative basis, submit declarations of the technical data of the RES power plants. They represent, forecast and nominate physical delivery on a day-ahead basis on a cumulative basis, submit orders to the DAM on a cumulative basis, and hold appropriate accounts for the settlements performed by the MO.

Retail Suppliers: Retail suppliers should notify their bilateral energy contracts to the MO, submit meter representation declarations, nominate on a day-ahead basis their offtake quantities, place orders to the DAM and balancing energy and reserve offers for the dispatchable load they represent (such offers are optional) and hold appropriate accounts for the purposes of the settlements performed by the MO.

Wholesale Suppliers: Wholesale suppliers should notify their bilateral energy contracts to the MO up to D-2. Wholesale suppliers need no account under the Market Rules.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Balance Responsible Parties (BRPs): are entities that undertake the financial settlement towards the MO with regard to the imbalances registered for a group of market participants.

1.1.5 Cross-border cooperation between other transmission systems

At present, the electricity system of Cyprus operates without cross-border links. An interconnection project through an underwater cable with Greece and Israel is currently under study, the so-called “EuroAsia Interconnector Project”, which is promoted as a Project of Common Interest (PCI). The EuroAsia Interconnector was proposed for the electricity interconnection between Israel, Cyprus and Greece. It was approved by the European Commission and was included in the EU list as a Cluster consisting of three distinct projects: Israel - Cyprus, Cyprus - Crete and Crete - Attica. The project consists of a DC subsea cable (HVDC) 600 kV with a total capacity of 2000 MW, and the required electrical equipment, i.e. power plants to convert the electrical current from DC to alternating current (AC) and vice versa, and for its transmission from and to the countries concerned. The total length of the submarine cable is estimated at around 820 nautical miles/ about 1518 km (329 miles between Cyprus and Israel, 879 km between Cyprus and Crete, and 310 km between Crete and Attica). It is estimated that the laying of the cable on the seabed in some places between Cyprus and Israel will exceed the depth of 2000 meters and 2500 meters between Cyprus and Greece.

With the implementation of this project, Cyprus will cease to be a system isolated from the European network, which is one of the main pillars set by the EU. It is also expected to contribute positively to the achievement of EU goals for the integration of the internal electricity market, security of supply, energy efficiency and better backup supply in emergencies.

1.1.6 Regulatory issues for flexibility provision

Regulations in Cyprus are in the right direction, trying to follow the European Commission recommendations by complying with the third and clean energy package. There are several upcoming factors that are expected to affect the regulations when considering flexibility (i.e., operation of the electricity market, interconnection of Cyprus with Israel and Greece, and increase penetration of renewable energy sources).

From the regulator, there is the willingness to implement increased flexibility and there are several regulations that are formulated in this direction. However, the current situation in Cyprus, having an isolated power system, with no actual operation of the electricity market, and relatively low penetration of renewable energy sources (compared to another European market) does not favour the flexibility regulations for the case of Cyprus. In this sense, Cyprus electricity market and the regulations related to the market are in a transition period and the regulator wants to implement increased flexibility and is in the process of doing so, but they are looking for recommendations that allow them to do it more effectively. In particular, the flexibility of a system

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 957739

is directly related to the increased penetration of renewable energy sources (something that is not the case today in Cyprus). Thus, some recommendations for implementing increased flexibility in the Cyprus power system are:

- Provide incentives for investment in increasing the flexibility provided of thermal generation. This will reduce the must run requirements and increase the space for the integration of renewable energy into the market
- Provide incentives for the provision of ancillary services from distributed renewable energy in the grid codes
- Participation of renewable energy in the market as ancillary services
- Net-metering scheme should be upgraded to Net-Billing scheme where renewable electricity that is fed into the grid is sold either at market price or at a feed-in tariff below marginal generation cost

1.1.7 Future evolution of flexibility in Cyprus Electricity sector

A long-term forecast of annual maximum generation (MWh) for the years 2021-2028 was prepared by the TSO and approved by the CERA, as shown in Figure 11. The maximum generation is expected to increase considerably in the next 7 years having around 2000 GWh more generation than today.

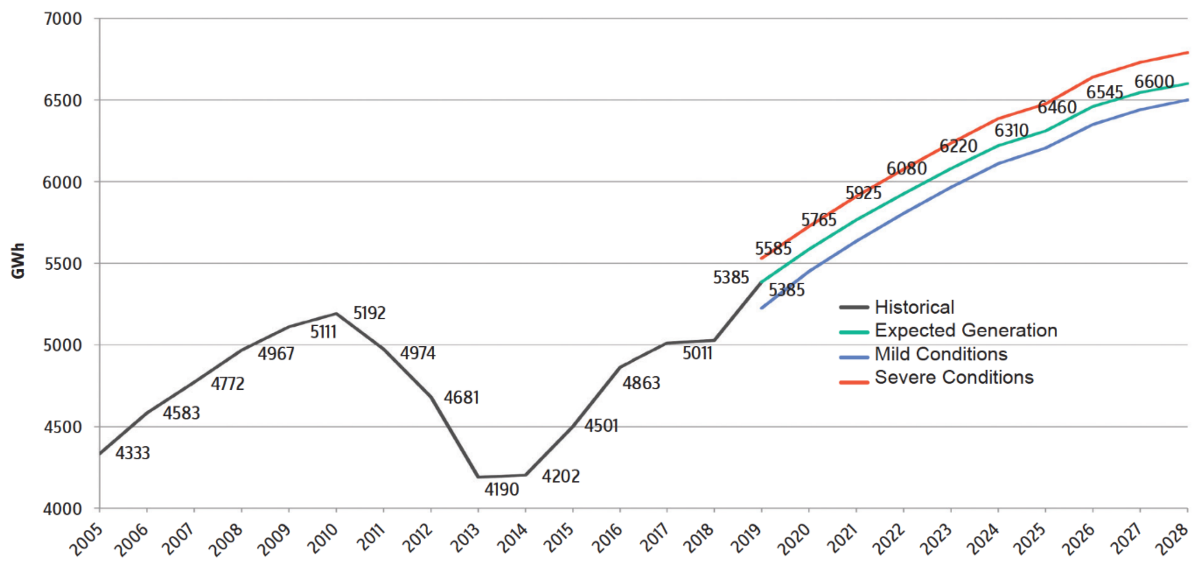

Figure 11. Long-term load forecast until 2028 [42]

Considering that the power system of Cyprus is isolated, and the generation is strongly dependent on oil power plants. Therefore, the flexibility of the Cyprus power system should be considerably increased to accommodate such a large increase in demand in the next years. The installed power generation capacity in Cyprus is approximately 1740 MW of which 1478 MW are provided by the Electricity Authority of Cyprus.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

According to the National Energy Renewable Action Plan (NREAP) that was set in 2010, Cyprus must produce at least 16% of electricity from Renewable Energy Sources by 2020 to meet the objective of 13% of reduction of CO2 from its entire energy system (heating, cooling, and transport) for complying with the EU requirements (Cyprus takes an exemption from the 20% target of RES). Currently, RES contribution to the total electricity consumption is below 12% with 229,1 MW and 157,5 MW total installed capacity of wind and PV systems respectively [43]. Total RES contribution is expected to increase dramatically, as the weather conditions are favourable (especially for solar technologies). However, the flexibility of the small network of Cyprus must be enhanced prior to any further RES integration since inflexibility signs have already emerged. Actually, the maximum allowable installed capacity in the Cyprus power grid is 650 MW for photovoltaic and 175 MW for wind parks. This results in 21.73% of RES penetration. The maximum installed capacity was calculated by TSOC, Cyprus DSO, Transmission system owner and KIOS Center of Excellence in order to maintain the grid stability. Therefore, the flexibility of the Cyprus power system is limited preventing the high penetration of RES. The Cyprus TSO already curtails wind energy to maintain generation and demand balance during low demand periods while currently the wind penetration is below 5%. The issue can be mitigated by improving the wind forecasting technics, as the current methods that are being utilized by the TSO have a normalised error above the nominal limits. Furthermore, grid storage could be a favorable solution for increasing the penetration of RES in the islanded power system of Cyprus. The main key factors that are expected to increase the flexibility of Cyprus power system are:

- The interconnection of the Cyprus system with Israel and Greece through EuroAsia Interconnector

  Such interconnection is expected to increase the Cyprus power system flexibility since a 2 GW HVDC link will be used for connecting the three systems. In the view of this interconnection, the curtailment of the RES power output is expected to be avoided.

- The operation of the electricity market following a Net-Pool Market model

  The operation of the electricity market in 2022 is expected to increase the flexibility of the system with the participation of more suppliers into the Cyprus electricity market. The model that will be used in the Cyprus electricity market complies with the third energy package proposed by the European Commission. The regulatory framework should be formulated in order to support ancillary services, storage, and demand response management that will certainly contribute to the increase of the market flexibility. Special incentives should be also provided to encourage the prosumers or aggregators to participate in the market.

The aforementioned key factors are not expected to be implemented immediately but it is believed that in a 10-year horizon, the Cyprus power system flexibility will be increased considerably.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

3 Description of the platforms, requirements, and scenarios in the pilot projects

3.1 Flexibility channel (F-channel) platform

F-channel is foreseen as a web based, client server application which will enhance Active Power Management for TSO-DSO coordination using Artificial Intelligence (AI) methods and cloud-computing approach

3.1.1 F-channel approach

The availability of climatic data models in recent years opened the possibility for continuous prediction of various parameters relevant to the power system needs. Predicting wind speed and solar insolation patterns throughout the yearly season with a very high geo resolution is possible through AI methods and usage of cloud computing techniques/environment. Also worth noting are demand response forecasting, as well as recent attempts in modelling icing on powerlines and wind turbines with the usage of historical climatic data models which can contribute a lot to the power grid operational planning, its flexibility and reliability estimations and smooth operations.

For purpose of this project similar approach shall be used. Historical weather data in the hourly resolution shall be analyzed and appropriate predictions for energy output for each particular predefined **Point of Interest** (**POI)** shall be given. Once the model is established sensitivity shall be tested against real-time data and adjustments using AI algorithms are to be applied for optimizing the efficiency of the model. On top of it model will be using the most advanced NWP – Numerical Weather Predictions based weather forecasts provided by the external professional weather forecast provider in order to fine tune and further improve forecasting outcomes. In further stages integration with real-time weather data shall be analyzed and a possibility to make a sustainable solution for industrial partners will be analyzed and proposed.

Active System Management (ASM) approach and regulatory framework

The constant increase in distributed renewable generation and in storage, and the expected rise of active customers engaging in demand response and electric mobility, trigger a key question to be addressed to support the energy transition: how to integrate the flexibility services provided by these new assets and actors into the energy market and use their services for congestion management and further in balancing while ensuring efficient and reliable system operation and enabling the market uptake for flexibility resources? In this we will will focus on the second part of this question , i.e. the issue of balancing and congestion management. Network

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

codes and Guidelines provide the first basis for congestion management and balancing (especially SO GL and EB GL). Furthermore, it is expected that the Clean Energy Package (Electricity Directive, article 32.1) gives the possibility to the DSOs to procure non-frequency ancillary services and manage congestion on their grid. DSOs shall procure these services in a transparent and market-based approach, when this represents the most cost-effective way to do it.

Ancillary services are services provided to DSOs and TSOs to keep the operation of the grid within acceptable limits for the security of supply and are delivered mainly by third parties (i.e. control power for frequency control, reactive power for voltage control, black-start capabilities) or by the TSOs and DSOs themselves (topology changes and integrated network components) [44]. Ancillary services are classified as:

a) frequency ancillary services (mainly for balancing);
b) services for congestion management;
c) non-frequency ancillary services such as voltage control and grid restoration, among others.

In the Active System Management (ASM) report [44], active power management is analysed from the perspective of a close collaboration of TSOs and DSOs. The congestion management is also analysed in both distribution and transmission grids, when such services are provided in a market-based approach by flexibilities owned and operated by third parties [44]. In the scope of the Greek demo, flexibility is considered as the modification of generation injection and/or consumption patterns in reaction to an external signal (price signal or activation) to provide a service within the energy system [44]. The respective regulatory framework will be analysed from national point of view in Greece where the demonstration will take place, includes the following:

a) Article 32.1 of Electricity directive (CEP), DIRECTIVE (EU) 2019/944
b) SOGL
c) EBGL
d) CACM
e) RfG NC
f) Demand Connection NC

3.1.2 Proposed system layout and architecture

The simple proposed system layout is given in Figure 12. A special care shall be taken in establishing data exchange between weather (energy) forecasting modules and planning (grid analysis) module, in order to address the weather-induced variability in RES generation and demand in the best possible way.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

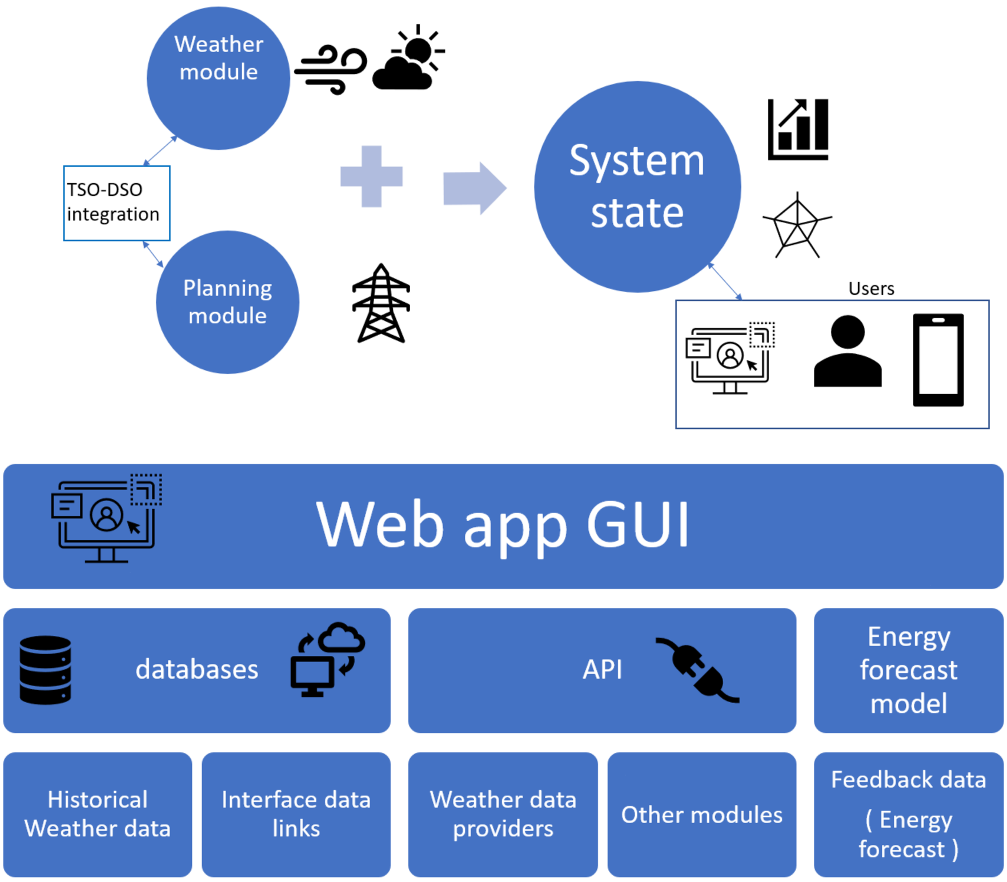

Figure 12 – (a) Proposed system layout for the F-channel(b)Cloud computing engine

Based on needed computing resources for Energy forecasts, a cloud computing engine shall be considered for this project and further used for modelling purposes if needed. On the following diagram basic architecture of the proposed Web app is given:

A similar computing engine will be developed for grid analysis and calculation purposes as well. Regarding data storage, databases and storage accounts are required. Allocated computing resources shall be split into two groups: continuously and per computation/transaction allocation. Power grid, as well as any necessary market data would be stored on the dedicated protected server, physically located in Energo Info Group (EIG) premises or other partner's premises, upon agreement, but still power system analysis calculation would be performed on the server engines as well, making the app very fast and capacity wise "light" at the same time.

The calculation engine will be robust enough to handle transmission, distribution and any customized micro grid topology with its calculations.

Database is to be structured in traditional RDBM Rational model. Geographical component - spatial shall be implemented since main datasets are geographically oriented. This provides easier representation, aggregation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

and query of all datasets. Display of geospatial data is to be provided by developed middleware supporting Web Map Services (WMS) and Web Feature Service (WFS).

Special care is addressed to the security of server infrastructure. Server access codes to the development environment shall be encrypted with SSH keys. Furthermore, access shall be restricted to specified IP address ranges. Access to the web app on the user side is to be limited to verified accounts created by administrator.

3.1.3. AI algorithms and methods

Initially, historical weather data in 1-hour resolution shall be used to obtain behaviour patterns of climatic parameters (daily, monthly, season) throughout the region of interest. For this purpose, various ERA5 climatic datasets shall be used and AI algorithms applied in combination with terrain orography data. This data shall provide a starting point for creating various case studies i.e. all RES locations can be monitored through time and critical scenarios shall be identified based on AI algorithms. Since ERA5 [45] models can provide various wind speed parameters (2m height, 100 m height, wind gust) these variables shall be tested and adjusted accordingly to reduce bias compared against operational data. Modeled results shall be compared with operational data from TSO/DSO and appropriate model calibration shall be provided based on deep learning AI algorithms.

In the second stage of project, implementation model must be linked with forecast weather API with various climatic parameters relevant to production being acquired. Stakeholder's data shall be implemented based on customized interface. Usage of forecasted data enables calculation of line rating, based on wind and temperature. All relevant calculations shall be done using highly optimized, vectorized CPU-oriented procedures. Core functionalities are to be implemented using Python and C programming language with GUI interface made in Flask environment.

Calculation models shall comply with all relevant standards and procedures. For instance, wind production forecast is done in compliance with IEC 61400 series, conductor ampacity is calculated in compliance with *IEC TR 61597 – Overhead electrical conductors - Calculation methods for stranded bare conductors.* In further stages of project, upon feedback with site measurements, models can be adjusted accordingly.

DISTRIBUTION AND MICRO GRID POINTS-OF-INTEREST (POIs)

F-channel will model transmission system, the distribution system and microgrid levels, with the customizable aggregations on the DSO, TSO, and Balancing Group topological aggregation level layer allowing DSO-TSO coordination in the field of flexibility and congestion management services through improved short term power system planning in both system operators. At the same time allowing prosumer's active inclusion

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

and role as an equal market participant. Full utilization of the vertical data and services flow would cover all vertically connected entities:

Individual unit <–> Prosumer <-> Aggregator <-> (DSO <-> TSO <-> RSC)

3.1.4 Data requirements

Under Task 8.2, the following set of data was collected and processed for F-channel development and implementation:

Network models data

Network models of transmission system have been submitted by IPTO. The network models of the distribution system will be modelled with available data and proper equivalents will be used for the simulation purposes.

Geospatial data

GPS coordinates, locations of power system elements including detailed routing and positions of each tower for the analyzed Wind Power Plants (WPPs) and Overhead Lines (OHLs):

- Substations (GPS coordinates describing the SS area),
- Wind parks (GPS coordinates describing the WPP area),
- Solar parks(GPS coordinates describing the SPP area),
- 400 kV HVAC lines (GPS coordinates of at least starting and ending point of a line).
- 220 kV HVAC lines (GPS coordinates of at least starting and ending point of a line),
- 150 kV HVAC lines (GPS coordinates of at least starting and ending point of a line),
- 110 kV HVAC (GPS coordinates of at least starting and ending point of a line),
- 35 kV HVAC lines (GPS coordinates of at least starting and ending point of a line),
- 20 kV HVAC lines (GPS coordinates of at least starting and ending point of a line),
- 10 kV HVAC lines (GPS coordinates of at least starting and ending point of a line),
- HVDC lines and cables of interest (GPS coordinates of at least starting and ending point of a line)

Power system GPS data, as well as GPS data on selected Points of Interest will be used for GIS visualization, localization of weather , and energy forecasts.

Data description:

- **GPS points for OHLs and cables**: start and end-point together with the corresponding substation names. It is necessary to indicate if the circuit is single or double and if parallel lines are connecting the same POIs. Conductor type and characteristics (diameter, weight, rated ampacity), as well as type of conductor bundle arrangement (2 - bundle, 3 - bundle, etc)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

- **GPS points for substations**: defining end-points of the substation surface, describing surface of the plant.
- **GPS coordinates of each WP tower** of the analyzed wind parks.
- **GPS coordinates of each OHL tower** (or preselected number of towers) of the analyzed OHL.
- **List of proposed interconnection lines (TSOs)**

Technical data for wind turbines

After selecting proper POIs, TSOs and DSOs should provide technical specification for each wind turbine type installed in the system if it is available. Otherwise, generic standard data will be used instead by TSOs and DSOs (Tables 1-5).

Table 1. Technical data for wind turbines

	Turbine 1	Turbine 2	Turbine 3	Turbine n
Turbine type				
Longitude				
Latitude				
Altitude				
Rotor diameter				
Tower height				
Rotor height				
A-factor				
Form factor, c				
Annual average wind speed				
Vertical average shear component				
Extreme wind speed (10 min average)				
Survival wind speed (3 sec average)				
Automatic stop limit (10 min average)				
Rated power				
Rotor speed				

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Rated wind speed (30 sec average)				
Cut in wind speed (3 sec average)				
Cut out wind speed (10 min average)				
Restart wind speed (10 min average)				
Power curves				

Table 2. Technical data for solar parks

	PV panels section 1	PV panels section 2	PV panels section 3	PV panels section n
Longitude				
Latitude				
Altitude				
Power conversion factor				
Tracking or static panels				
Panel´s tilt angle				

Table 3. Technical data for selected overhead lines

	Tower 1	Tower 2	Tower 3	Tower n
Longitude				
Latitude				
Altitude				
Tower type				
Tower total height				
Wire height				

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Also it is important to provide the overhead line route cross-section (in pdf preferably) for the OHLs that will be covered by novel forecasting.

Table 4. List of proposed critical lines (DSOs and TSOs)

Substation 1 name	Substation 2 name	Voltage level	Number of circuits	Parallel OHL index

Table 5. General list of all VRE production units (DSOs and TSOs

Type	Voltage Level	Installed capacity	Longitude	Latitude	Altitude

Historic energy data

- Historic production data for wind and solar for each of the concerned plants: hourly production for the last 10 years (or any other available period)
- Historic energy data for consumption (for defined SSs): hourly consumption for the last 10 years (or any other available period)

Historic weather data

Historic weather data measured and forecasted data related to the energy production/consumption of the analyzed points of interest in Greece. These data (measured and forecasted) for the last 10 years (or any other available period) can be provided by Greek authorities and/or TSO and DSO.

Copernicus Climate Change Service reanalysis data. Copernicus datasets are implemented and maintained by European Centre for Medium-Range Weather Forecasts – ECMWF and represent data available for the general and scientific public [45].

For the selected POIs the following historic data will be collected where available, as in Following Table 6

Table 6. Historic data fpr the selected POI

• Pressure/Wind speed 10m; • Pressure/Wind speed 100m; • Pressure/Wind; • Clouds; • Convective clouds;	• 850 mb temperature; • Visibility; • Soil wetness; • Snow; • Snow depth;

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

• Low clouds; • Rain; • Temperature; • Soil temperature; • 500 hPa temperature; • 700 hPa temperature;	• Rain/Snow; • Daily precipitation (acc); • Daily snow (acc); • 500 hPa wind; • Solar radiation

Energy policy information

Information on applicable EU Directives and Regulations that are of interest for TSO DSO coordination [44]. The data is pre-processed, and in cases where appropriate, stored on a dedicated database on the production server. Allocated computing resources are split into two groups: (i) Continuously allocated and (ii) allocated per computation/transaction. Power system analysis calculations during the demonstration/test period will be performed on cloud as well as other AI algorithms-based calculations.

3.2 Active Balancing and Congestion Management (ABCM) platforms

3.2.1 Cyprus demo description

The Cyprus demo aims to demonstrate an effective collaboration between the different actors of the Cyprus power system namely the TSO, DSO, Market Operator, and prosumer/aggregator. This will be enabled by the exchange of crucial information through the OneNet system and the innovative control and monitoring tools that will be developed in the context of Task 8.3. Among others the Cyprus demo will:

- allow aggregators and prosumers to provide active power, reactive power and power quality flexibility services to the power grid
- enable higher penetration of RES without risking the stability and integrity of the system
- showcase that the effective collaboration of the critical actors of the power system through the OneNet System can benefit the grid

The above objectives become more important if one considers the existing situation for the Cyprus power system. More specifically the Cyprus power system is islanded, and its reliability and integrity can be compromised with the high penetration of variable renewable sources. Furthermore, the high concentration of PVs in specific regions of the distribution grid often leads to local congestion problems in the distribution level due to the high volumes of reverse power flow, while the only flexibility resources are the conventional generation plants.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

The Cyprus demo will build on the aforementioned challenges and will showcase that through the effective collaboration of the Cyprus TSO, the Cyprus DSO, and the future Market Operator, any challenges that might appear in the Cyprus power system can be overcome effectively. In this attempt, the University of Cyprus will lead and coordinate the Cyprus demonstration activities, while the Cyprus TSO and the Cyprus DSO are actively participated by providing measurements, topology data, and historical data, for the Cyprus transmission and distribution grid.

The general architecture of the Cyprus demo is shown in Figure 13, in which all the main actors and the integrated platforms to the Cyprus demo are illustrated. The two main platforms of the Cyprus demo are the Active Balancing and Congestion Management platforms for the DSO and the TSO (ABCM-D and ABCM-T). These two platforms will be developed through Task 8.3 of the OneNet project and are intended to play a crucial role to the coordination of the Cyprus TSO, DSO, Market, and the flexibility service providers (FSPs) such as aggregators, prosumers, and large generation plants. The main functionalities of the ABCM-T platform are the real-time monitoring of the transmission level through the use of PMU measurements, the pre-qualification of certain products and services procured by the large FSPs located at the transmission level in order to ensure the operation of the transmission level within the proper limits, and the evaluation of the FSPs' response in case of a disturbance. In the same way, the ABCM-D platform will be designed for providing the capabilities to the DSOs to: (1) monitor in real-time the operating condition of the distribution grid through SCADA and smart meters measurements, (2) prequalify any products and services procured to the market by the FSPs located at the distribution level in order to ensure the safe operation of the distribution grid, (3) coordinate the flexibility services provided by the FSPs in the distribution grid, (4) evaluate online the response of the FSPs during and after the provision of services for frequency balancing and congestion management. The functional requirements of the two platforms are described in detail in Section 3.2.2.

Based on the overall architecture of Figure 13, the two platforms will be located at the TSO and DSO control center and will have direct communication with the OneNet system which will facilitate the seamless exchange of information with the TSO, DSO, Market and FSPs. In this sense, the OneNet system will play a crucial role to the coordination of the different actors in the demo. The flow of the information exchanged between the OneNet system, and the main actors of the Cyprus demo are described in Section 5.3.2. Since in Cyprus there is not any operational market yet, the Cyprus demo will have a fictitious market which will include the TSO market and a DSO local market. The two markets will be built according to pre-existing market setups and no new market designs will be developed in this demo.

The whole demonstration setup will be built in a controlled hardware in the loop (HiL) environment using the digital twin of the Cyprus transmission and distribution systems. The digital twin systems will be developed in the real-time simulator using the information provided by both Cyprus TSO and DSO. The controlled HiL

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

environment provides the opportunity to test several scenarios that are under the two Business Use Cases of the demo which are (1) Active power flexibility and (2) Reactive power flexibility and power quality.

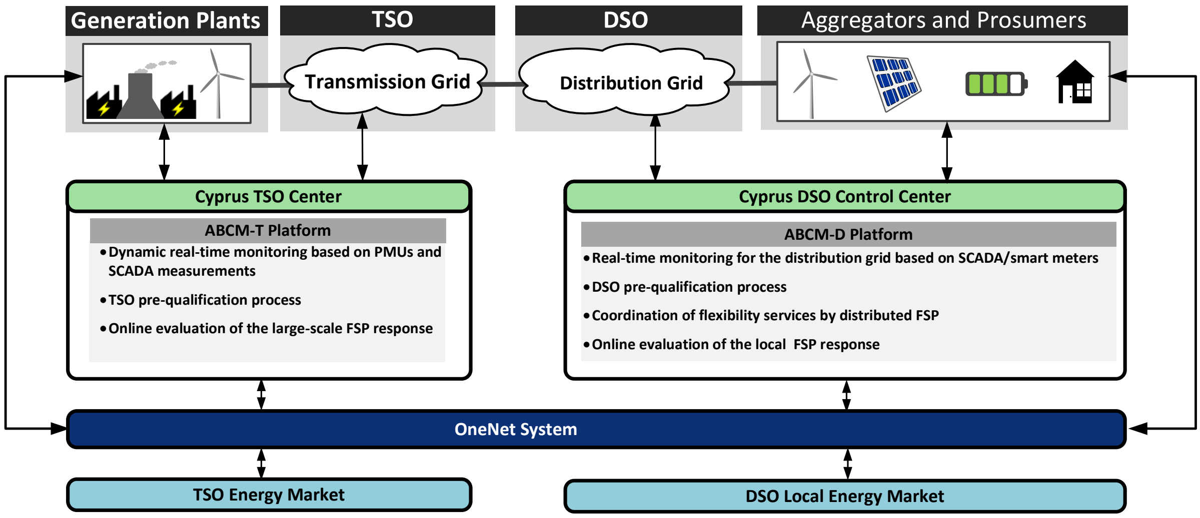

Figure 13: Cyprus demo general architecture

3.2.2 Functional requirements for the ABCM platforms

The Cyprus demo aims to facilitate the effective collaboration between TSO, DSO and the market operator enabling the participation of small/medium-scale flexible resources (i.e., photovoltaic, energy storage, etc.) to enhance the system flexibility. This concept can be realized by the effective information exchange between different entities (i.e., TSO, DSO, TSO Market, DSO local Market, large-scale generation plants, small/medium scale flexible services providers (aggregators or prosumers)) through the OneNet system. Furthermore, the main focus of the Cyprus demo is at the operational level of both the transmission and the distribution grids and thus, a dedicated active balancing and congestion management (ABCM) platform is needed to advance the operational capabilities of the of two operators (TSO and DSO). Due to the different characteristics, specifications, and requirements for each system (transmission and distribution), the ABCM platform is separated into two individual platforms, ABCM-T and ABCM-D, and each one is adequate for the Transmission and Distribution grid respectively. In the following sub-section, the main functional requirements are stated for each platform.

3.2.2.1 ABCM-T platform functional requirements

The ABCM-T platform will be developed within the OneNet project to facilitate effective operational capabilities for the TSO towards the seamless coordination of the transmission and the distribution grids through the energy market and will be demonstrated in the Cyprus demonstration. The ABCM-T platform should ensure the following functional requirements:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

- The platform should be able to receive measurements in real-time (every 20 ms) from actual or virtual (implemented within the digital twin) Phasor Measurement Units (PMUs) and store these measurements in a database.
- The platform should be able to receive measurements conventional measurements (SCADA measurements) from the digital twin of the power system on the scale of seconds (i.e., every 5 s) and store these measurements in a database.
- The platform should be able to send coordination signals to the flexible actuators located within the digital twin of the power system to control their operation according to the TSO decisions.
- The platform should facilitate the online monitoring of the transmission grid considering real-time measurements from both PMUs and conventional SCADA meters to enhance the situational awareness of the TSO.
- The platform should facilitate post-analysis functionalities for events. In this case, the user should select a specific time window (where there is an indication for an event) and the platform should use monitoring algorithms based on historical data to provide high-resolution situational awareness for the particular event.
- The platform should be able to use real-time monitoring and historical measurement to pre-qualify the operation of the transmission grid at each primary substation level (HV/MV interfaces) for a specific time window ahead (i.e., 3 hours ahead). This pre-qualification process will define the maximum location-based limits for specific services.
- The platform should be able to be used for evaluating the response of large-scale Flexible Services Providers (FSPs) located at the transmission grid and validate if their response corresponds to the awarded bids cleared by the market.
- The platform should be equipped with a human machine interface (HMI) to allow the TSO to observe the operation of the transmission grid in real-time and considering post-event-analysis
- Through the HMI, the operator should be able to validate the location-based pre-qualification limits and the evaluation report for the response of the FSPs before publishing these to the market operator and the market participants.
- The ABCM-T platform will facilitate the required communication between the TSO and the rest entities (i.e., TSO market, FSPs participate in the TSO market) in a standardized manner through the OneNet system. Therefore, the ABCM-T platform should be compatible with the OneNet system to facilitate the communication and data exchange between different entities.

3.2.2.2 ABCM-D platform functional requirements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

For the purposes of the Cyprus demo, another platform should be developed within the OneNet project to facilitate advanced operational capabilities for the DSO towards the seamless coordination of the transmission and the distribution grids through the energy market. This platform, entitled ABCM-D, will be tailored made for the needs of the DSO to monitor the operation of the system, procure products into the market, define location-based limits, evaluate the response of local FSPs and coordinate online the flexibility services. The ABCM-D platform should ensure the following functional requirements:

- The platform should be able to receive measurements from actual or virtual (emulated within the digital twin) smart meters in the scale of minutes (i.e., every 15 minutes) and store these measurements in a database.
- The platform should be able to receive measurements conventional measurements (SCADA measurements) from the digital twin of the distribution grid in the scale of seconds (i.e., every 5 s) and store these measurements in a database.
- The platform should be able to send coordination signals to virtual flexible actuators located within the digital twin or to actual flexible actors (connected to the grid or connected through HIL with the digital twin) to control their operation according to the DSO decisions.
- The platform should facilitate the online monitoring of the distribution grid considering real-time measurements from both smart meters at the end-users and conventional SCADA meters to enhance the situational awareness of the DSO.
- The platform should be able to use real-time monitoring and historical measurement to pre-qualify the operation of the distribution grid at each secondary substation level (MV/LV interfaces) for a specific time window ahead (i.e., 3 hours ahead). This pre-qualification process will define the maximum location-based limits for specific local services.
- The platform should be able to be used for evaluating the response of small/medium-scale Flexible Services Providers (FSPs) located at the distribution grid and validate if their response corresponds to the awarded bids cleared by the local market.
- The platform should be able to automatically coordinate the operation of the flexibility services to ensure the adequate and high power quality operation of the distribution grid.
- The platform should be equipped with a human machine interface (HMI) to allow the DSO to observe the operation of the distribution grid and to coordinate the operation of the system.
- Through the HMI, the operator should be able to validate the location-based pre-qualification limits and the evaluation report for the response of the FSPs before publishing these to the local market operator and the participants in the DSO local market.
- The ABCM-D platform will facilitate the required communication between the DSO and the rest entities (i.e., DSO local market, FSPs participate in the DSO market) in a standardized manner through the

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

OneNet system. Therefore, the ABCM-D platform should be compatible with the OneNet system to facilitate the communication and data exchange between different entities.

3.2.3 ABCM platform architecture

As it is already mentioned, the ABCM platform actually considers two individual platforms, ABCM-T and ABCM-D, and each one is adequate for the Transmission and the Distribution system operator respectively. The ABCM-T platform considers the specific characteristics, specifications, and requirements of the TSO while the ABCM-D platform is tailored made for the needs of the DSO. Therefore, a different architecture is defined for each platform as it is presented in the following sub-sections.

3.2.3.1 ABCM-T platform architecture

The architecture of the ABCM-T platform that will be developed for the effective management of the transmission grid in the Cyprus demo is presented in Figure 14. The platform will interact in real-time with the digital twin of the Cyprus power system considering hardware in the loop (HIL) environment. The ABCM-T platform will also be compatible with the OneNet system to facilitate a standardized communication and data exchange with the different entities (i.e., TSO energy market, large-scale FSP, etc.) in the demonstration.

The ABCM-T platform needs to receive measurements from actual and virtual PMUs through the IEEE C37.118 protocol. Therefore, an industrial Phasor Data Concentrator (PDC) (SEL-5073) will be integrated into the ABCM-T platform in order to receive the synchronized measurements every 20 ms by the PMUs, time align the measurements, and store them in the PDC database. An Application Programming Interface (API) will be developed to allow the ABCM-T platform to retrieve PMU measurements (either last value or historical data) to be used by different applications of the platform (i.e., TSO real-time monitoring application, TSO pre-qualification, etc.).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

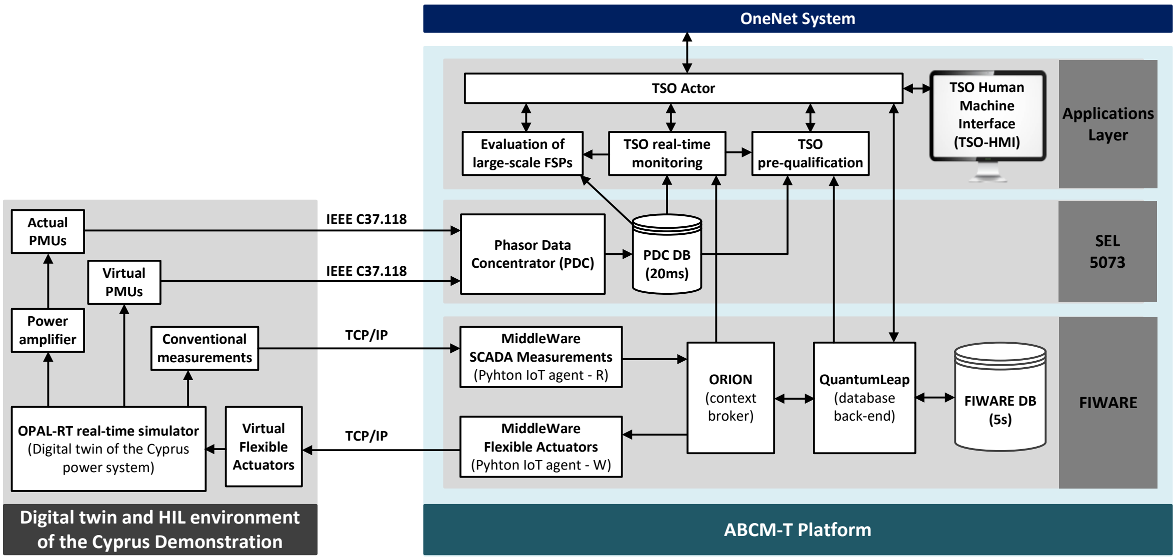

Figure 14: ABCM-T platform architecture

The ABCM-T platform will also receive conventional SCADA measurements and coordinate the flexible resources that are virtually implemented within the digital twin of the Cyprus power system. The measurement and coordination signals will be exchanged between the digital twin and the platform through TCP/IP protocol every 5 s. Two middleware will be developed as FIWARE IoT agents to allows the information exchange between the digital twin and the ABCM-T platform, to obtain measurement (read) or send coordination signal (write). The middleware will be integrated into an open-source platform (power by FIWARE), where a context broker (ORION) will manage the information and its availability while QuantumLeap will be used for storing, querying and retrieving data to/from historical data.

An application layer will also be developed on top of the two back-end systems (PDC and FIWARE), where all the applications/tools for enabling the system use cases of the demonstration will be developed. These applications will obtain PMU or conventional measurements (last value or historical measurements) to enable (a) the real-time monitoring of the transmission grid, (b) the TSO pre-qualification process, and (c) the evaluation of the FSP response. The TSO actor will interact with these applications through a Human Machine Interface (TSO-HMI) either to monitor the operation of its system, procure services, define location-based pre-qualification limits, or prepare a report for the adequate response of market participants. The TSO will be able to communicate or exchange information with other entities (i.e., market operators, participants to the market, etc.) in a harmonised manner through the OneNet system.

3.2.3.2 ABCM-D platform architecture

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

An additional platform needs to be developed for the DSO, entitled ABCM-D platform, to enable the effective management of the distribution grid in the Cyprus demo is presented in Figure 15. Even though there are similar characteristics between the ABVM-T and the ABCM-D platform, the unique characteristics of each system (transmission and distribution grid) and the different role of the operator (TSO and DSO) requires a different platform to support the role of the DSO in this TSO-DSO-Market-FSP collaborative framework that will be demonstrated in the Cyprus demo of the OneNet project. Thus, the ABCM-D platform will interact in real-time with the digital twin of the Cyprus power system considering a HIL environment. In this case, the platform will receive actual and virtual smart meters and virtual conventional SCADA measurements by the digital twin and HIL environment and will be able to coordinate the small/medium-scale FSP (virtual or actual flexible actuators) that are considered in the digital twin or a HIL environment. The platform will also be compatible with the OneNet system to facilitate standardized communication and data exchange with the different entities (i.e., DSO local energy market, small/medium-scale FSP, etc.).

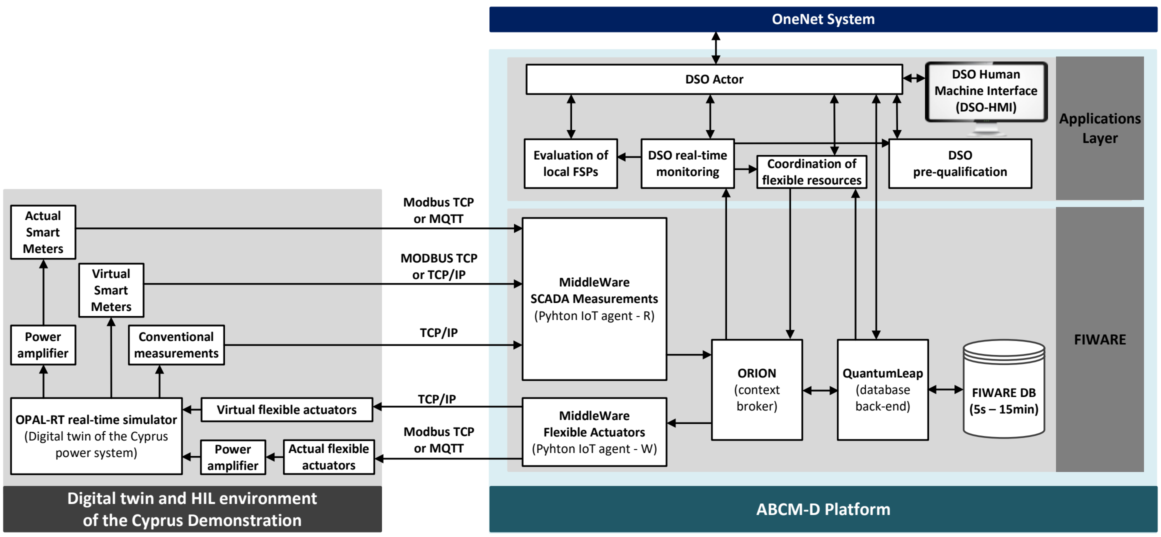

Figure 15. ABCM-D platform architecture

The exchange of information between the digital twin of the Cyprus power system and the ABCM-D platform will be facilitated through an open-source backend platform powered by FIWARE. In the FIWARE system, the middleware component will be developed as IoT agents to read the measurement from or write the coordination signals to the digital twin of the Cyprus grid. The middleware will be integrated with ORION context broker to manage the information while QuantumLeap will be used for storing, querying and retrieving data to/from a time-series database.

Adequate API will be developed to allow the interaction between the backend system (FIWARE) and the application layer, where all the applications/tools will be integrated to enable the DSO related system use cases in this demonstration. These applications will obtain smart meter or conventional measurements (last value or

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

historical measurements) to enable (a) the real-time monitoring of the distribution grid, (b) the DSO pre-qualification process, (c) the evaluation of the small/medium-scale FSP response, and (d) the coordination of the flexibility services in the distribution grid. The DSO actor will interact with these applications through a Human Machine Interface/GUI (DSO-HMI) either to monitor the operation of the distribution grid, procure services in the local market, define location-based pre-qualification limits, prepare a report for the adequate response of market participants, or coordinate online all the flexible resources awarded by the local market. The DSO will also communicate or exchange information with other entities (i.e., local market operators, small/medium-scale FSPs, etc.) in a harmonised manner through the OneNet system.

3.2.4 Cyprus Demo Scenarios

In the Cyprus demo, two main scenarios will be considered for demonstration purposes that are related mainly to the business use case that are going to be analyzed in the following Section 4. The first scenario will deal with the participation of FSPs to balance the frequency of the system after a disturbance, while the second scenario will have to do with the congestion management in the distribution grid including sub-scenarios for line overloading and voltage limit violation. In the following sections, the two scenarios are described.

3.2.4.1 Frequency balancing

The scenario for the frequency balancing of the grid deals with the loss of a generation after the occurrence of the grid fault. With the loss of generation, the balance between the generation and the demand is violated having, as a result, an intense frequency disturbance that can affect the frequency stability of the system. The flexible resources (FSP, aggregators, prosumers) which are awarded by the TSO market to participate in the frequency balancing are triggered automatically and provide automatic frequency support and synthetic inertia to balance the frequency. It should be noted that the flexible distributed resources participating in this scenario have already been awarded by the local DSO market (declaring their availability through bids) and their forwarded availability bids to the TSO market satisfy the prequalification criteria imposed by the DSO. In the case of the FSPs of the transmission level that participates in the TSO market, their awarded activation products should satisfy the prequalification criteria imposed by the TSO. After the provision of services by the FSPs participating to the frequency balancing, the TSO and DSO evaluates online the FSPs' response to verify the proper operation of the FSPs. An evaluation report is sent by the TSO and DSO to the energy market. The scenario for the frequency balancing is shown in Figure 16

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

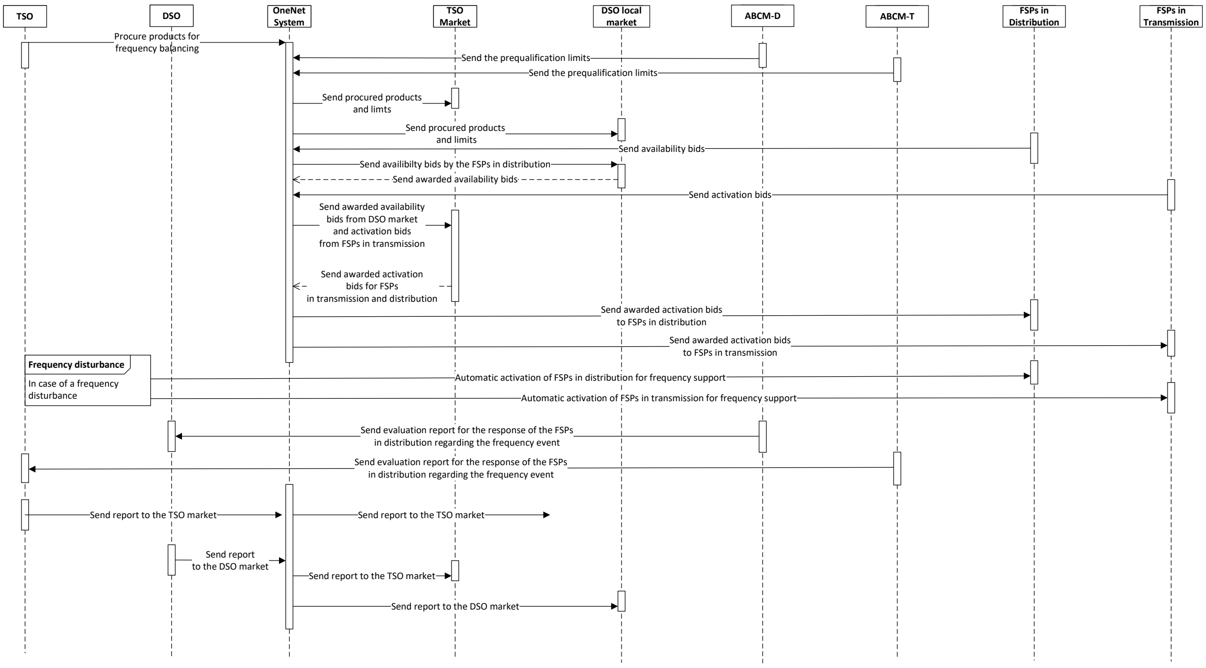

Figure 16: Sequence diagram for frequency balancing

3.2.4.2 Congestion management

The scenario for the congestion management of the distribution grid deals with the activation of flexibility services provided by the local distributed flexible resources for overcoming congestion problems (such as line overloading, low power quality, voltage limit violation, etc.) in a certain distribution feeder. In such a scenario, only the FSPs in the distribution feeder that are qualified through the DSO local market to provide congestion management services are activated. An important difference with the frequency balancing scenario is that the flexibility resources are activated through the ABCM-D platform when the congestion in the feeder occurs. For the sake of the scenario, the FSPs in the distribution system sends their availability bids in the local DSO market, while the DSO through the ABCM-D platform set prequalification limits for the provision of ancillary services by the distributed resources in order to ensure the operational limits of the grid. The local DSO market is cleared for the procured products (that were sent by the DSO), and the awarded bids are sent to the FSPs. In case of a congestion event, the ABCM-D platform detects the limit violation through the real-time monitoring system and coordinates the market qualified FSPs to provide services for mitigating the contingency. The response of the FSPs to the congestion event is evaluated through the ABCM-D platform and an evaluation report is sent by the DSO to the DSO local market. The sequence diagram for this scenario is illustrated in the Figure 17 below.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

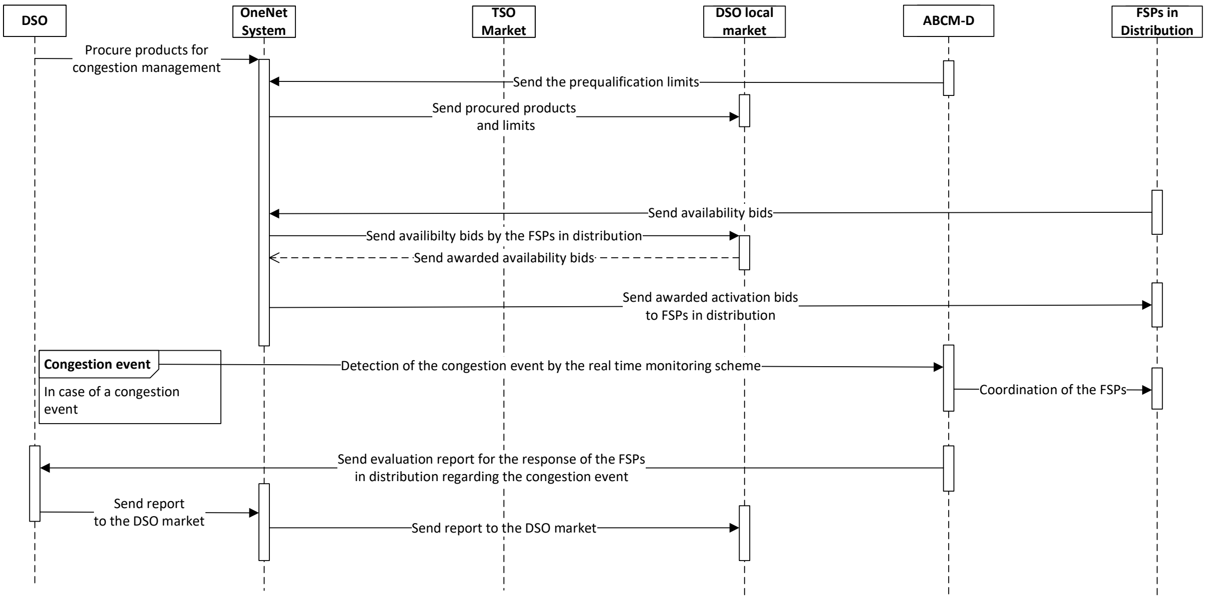

Figure 17 : Sequence diagram for congestion management

4 Business Use Cases, Products and KPIs of the Southern cluster

4.1 BUCs, Products KPIs for the F-channel demonstration in Greece

F- channel seeks to improve identification of the available flexibility resources, focused on a DSO voltage level, together with the improved identification of the power system flexibility needs, focused on a TSO voltage level grid, on a longer priod and wider geographical scope than the one being utilised today, through a simultaneous DSO and TSO and grid simulations backed up by AI based calculation engines.

4.1.1. Business Use Cases and KPIs for the F-channel demonstration in Greece

Two Business Use Cases (BUCs) have been identified for the F-channel platform that will be demonstrated though the Greek demonstration:

- BUC_1: Enhanced Active Power Management for TSO-DSO coordination
- BUC_2: Enhanced severe weather condition management and outage management for TSO, DSO and micro grid operator

These BUCs have been correlated with products and System Use Cases in collaboration with OneNet partners in WP2 and rest of partners in demo clusters (table A1 in the Appendix A).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

The details of each Business Use Case are the following.

Business Use Case 1: Enhanced Active/Reactive Power Management for TSO-DSO coordination

Description of the Business Use case

Scope: Improved identification of the available flexibility resources, focused on a DSO voltage level, together with the improved identification of the power system flexibility needs, focused on a TSO voltage level grid, on a longer time-span and wider geographical scope than the one being utilised today, through a simultaneous DSO and TSO and grid simulations backed up by AI based calculation engines.

Objectives:

- Frequency stability
- Load flow and contingency monitoring and predictions
- Predictive congestion management for maintaining secure and stable power system operation
- Cost-effective operation of the system
- Early warning on a hazardous power system regime,
- Better FSPs planning and managing flexibility resources.
- Better energy predictions and power system state predictions
- Improved identification of the available flexibility resources on all power system levels.
- Improved prediction of the system flexibility needs.

Short description:

Identification of the available flexibility resources, from residential prosumers to the centralised WPPs and SPPs connected to the distribution grid or any local micro-grid (local energy community), through improved predictions and forecasting efficiency from increased spatial resolution NWPs and AI integration and its presentation with the improved observability on a higher operational control and monitoring levels, including regional, RSC level. In parallel an improved power system state estimation will be developed in order to better predict system flexibility needs, with the wider geographical observability and longer "look into the future".

Complete description:

F-channel application, that will be developed under WP8 - southern cluster (Greece) will be capable of identifying flexibility resources more precisely and simultaneously for both DSO and TSO grid levels, mainly under OneNet focusing on the lover voltage levels prosumers, that are usually not being covered with that detailed energy predictions, as well as identifying the power system state (the need for the flexibility services) in a much more precise manner and longer time horizons than it is being done today, covering wider geographical scope than it is being covered today by national control centres, and/or RSCs... The aim is to

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

improve a production/consumption predictions for a different voltage level entities, from residential prosumers to the centralized WPPs and SPPs connected to the distribution grid or any local micro grid (local energy communities), through improved forecasting efficiency from increased spatial resolution NWPs and AI integration into the short to mid-term power system planning simulations.

- Improved identification of the available flexibility resources.
- Improved prediction of the system flexibility needs.

The application itself will not depend on the exact product being utilized within the market, or the market model itself (it will be possible to use it for different services and products, and different market models). It will focus on a predictive management of a products and need for those products. Possibility for products from a micro grid and DSO levels to be recognised and available for utilisation on higher voltage levels (TSOs, RSCs…) as well as on the administrative aggregator's level:

- improved system oriented predictions and forecasting efficiency ->limit the volume of flexibility needs,
- identification of the flexibility resources to procure grid services, and
- better FSPs planning and managing flexibility resources.

The main foreseen benefits/functionalities related to this particular business case (Enhanced Power Management for TSO-DSO coordination) are as follows:

- Identification of the available flexibility resources from DSO and microgrid voltage levels
- DSO, DG and micro grid POI management (Point of Interest updates, technical data, historic data, forecasted data…)
- Change View - different aggregation level simulations (Energy predictions and system state predictions for different aggregation levels of DSO grid and local micro grid: unit level (distributed gen. unit, OHL tower/section), plant level (solar park, wind park, OHL, substation), local micro grid level (part of the DSO grid), DSO/TSO grid level calculations.)
- Improved congestion management process on TSO and RSC side (Improved short term forecasts, contingency analysis and capacity calculations through utilisation of the information from DSO and/or local micro grid operators.)
- Improved frequency control on TSO side
- Improved Voltage control on DSO and TSO side
- Improved System adequacy on DSO and TSO side
- Improved Islanded operation on DSO and TSO side

In the table A2 of the Appendix A the key Performance Indicators are presented

The interactions of the Business Use Case 1 are presented in the following figure 18

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

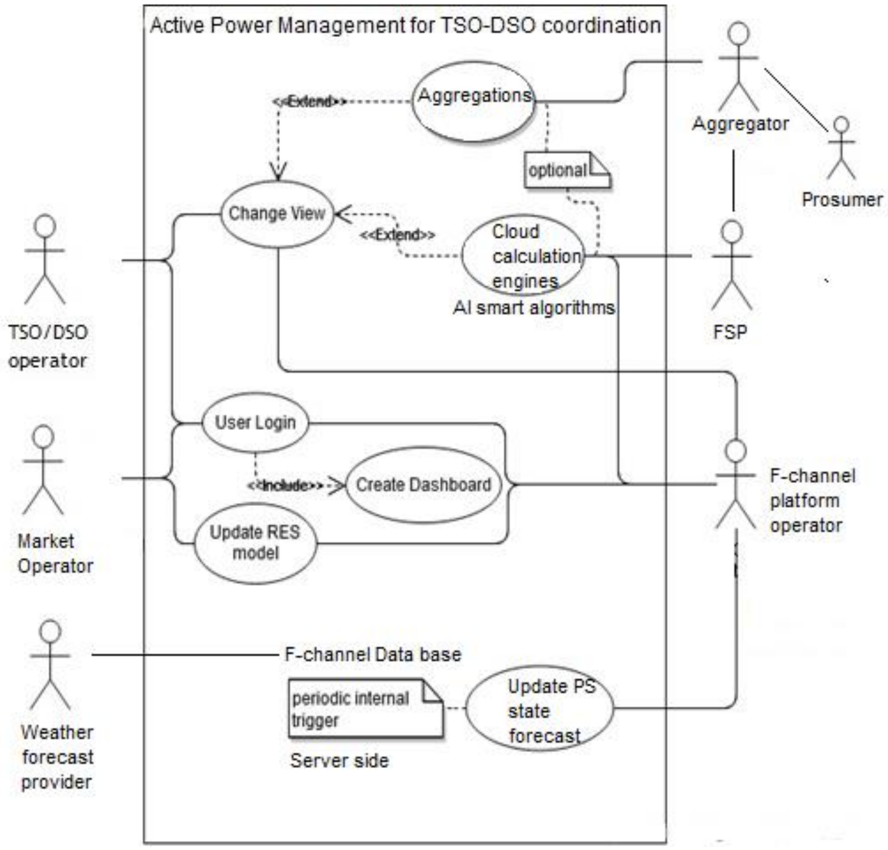

Figure 18. Diagram of the Business Use Case 1

The market process diagram is presented in the following figure 19:

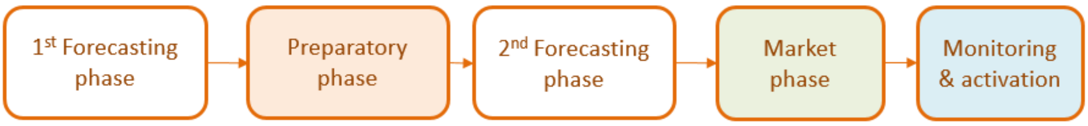

Figure 19. The market process diagram of the Business Use Case 1

The following steps reflect the actions in figure 19

Forecasting phase:

1. Makes a forecast of potential flexibility resources
2. Exchange information about potential flexibility resources
3. Informs potential flexibility resources
4. Optimize Portfolio

Preparatory phase:

1. Define the prequalification requirements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

2. Send the prequalification requirements
3. FSP notifies that he is interested in providing flexibility services.
4. Send the prequalification requirements
5. Forward the fulfilled prequalification requirements
6. Evaluation of the Product & Grid prequalification requirements
7. Request additional prequalification information
8. Send additional prequalification information
9. Accept / Reject registration on Market
10. Notify of prequalification result

2nd forecasting phase:

1. Makes a forecast of possible congestion areas
2. Exchange information about possible congestion areas
3. Informs possible congestion areas
4. Publish the possible congestion areas
5. Optimize Portfolio
6. Makes a forecast of the grid status
7. Check power flows
8. Detect possible congestions
9. System reconfiguration
10. Assesses the amount of flexibility required
11. Exchange information about the amount of flexibility required

Market phase:

1. Offer active power flexibility products
2. Informs the amount of flexibility required
3. Capacity Bids Selection
4. Selects the bids that may be a solution
5. Sends the capacity bids
6. Technical evaluation of the bids
7. Accept bids
8. Sorts the bids by a merit order list
9. Sends the accepted/rejected capacity bids
10. Notifies the result and if Accepted commits the FSP to make bid available on the ST Market
11. Selects the bids that may be a solution

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

12. Sends the bids
13. Technical evaluation of the bids
14. Accept bids
15. Sorts the bids by a merit order list
16. Send the accepted/rejected bids
17. Check the Location of the bids
18. Notifies the result and If Accepted commits the FSP to make bid available on the ST Market
19. Sends the information of the bid
20. Evaluates grid constraints
21. Accept/Reject bid
22. Notifies the result and if Accepted commits the FSP to make bid available on the ST Market

Monitoring & activation phase:

1. Sharing of accepted bids
2. Checks grid constrains
3. Informs what Bids can/cannot be activated
4. Allows/Not allow bid activation
5. Informs the result
6. Informs the activation of the bid

The actors involved are presented in the table A3 of the Appendix A

The scenarios to be tested in the Greek demo are presented in the table A4 of the Appendix A

In the following paragraphs we present some more details for the scenarios.

Scenario name #1: Contingency identification and mitigation

Potential contingencies are identified up front (predicted) in the distribution and transmission grids via improved power system state prediction tools. The flexible resources are coordinated by the DSO and TSO to provide active power regulation services in order to relieve the local contingency of the grid. The flexible resources participating in this scenario have already being awarded by the market (declaring their availability through bids) and their bids have been pre-qualified by the DSO or TSO in order to participate to the Predictive short-term local active product.

Provide/absorb of a certain amount MWh in specific timeframes in local distribution grid. This CM product will be automatically activated, and the flexibility resource will provide peak shaving services to the distribution

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

grid when needed. The resources could be connected to both transmission or distribution grid. The activation time could be from 15 minutes to 1 hour. The scenario 1 is presented in table A5 of the Appendix A

Scenario name #2: Coordinated voltage control

Potential overvoltage or under voltage severe states are identified, predicted upfront. These are the states that can endanger overall power system voltage stability. In case of voltage instability, the DSO will coordinate the flexible resources to provide reactive power flexibility. The flexible resources participating in this scenario have already been awarded by the market (declaring their availability through bids) and their bids have been pre-qualified by the DSO in order to participate in the reactive power compensation. It is also possible to use the reactive power from a TSO level through the interconnection transformers with the TAP change possibility.

In the occurrence of a predicted overvoltage or under voltage severe state that can endanger overall power system voltage stability. Provide/absorb a certain amount MVarh in specific timeframes in the local distribution grid through optimized coordinated tap change control on TSO-DSO interface, through an improved forecast of the power system state on both TSO and DSO voltage levels. It can be used to regulate voltage and reduce energy losses in the distribution grid and is linked with voltage control. The reactive support product will be automatically activated, and the flexibility resource will provide reactive compensation to the distribution grid when needed. The activation time could be from 15 minutes to 1 hour. The scenario 2 is presented in the table A6 of Appendix A

Scenario name #3: Improved power regulation through mFRR and RR

Provide identification of flexibility resources (primary, secondary and available tertiary reserve) more precisely, as well as identification of the flexibility needs in a more precise manner and longer time horizon than it is being done today. The activation time could be from 15 minutes to 1 hour.

Flexible resources will increase or decrease their active power output in order to support the frequency stability. The scenario 3 is presented in the table A7 of the Appendix A

The information exchanged is presented in table A8 of the Appendix A

Relation to other use cases

As already stated, the F-channel application itself will not depend on the exact product being utilized within the market, or the market model itself (it will be possible to use it for different services and products, and different market models) at the same time to demonstrate its usefulness and supremacy over existing similar tools and application with various Use Cases, that will be defined and implemented under OneNet project. The direct connection can be found with the following system use cases:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

SUC_8.2.1.1: Identification of the available flexibility resources from DSO and microgrid voltage levels

Scope:

Improved production and consumption prediction, focused on a DSO voltage level, on a longer time span and wider geographical scope than the one being utilised today, through a simultaneous DSO and TSO grid simulations backed up by AI based calculation engines.

Objectives:

- Frequency stability
- Cost-effective operation of the system
- Better FSPs planning and managing flexibility resources.
- Better energy predictions and power system state predictions
- Improved identification of the available flexibility resources on all power system levels.
- Improved prediction of the system flexibility needs.

Description:

Improved production and consumption prediction for DSO and micro-grid voltage levels that will allow for better identification of the available flexibility resources, from residential prosumers to the centralised WPPs and SPPs connected to the distribution grid or any local micro-grid (local energy community), through improved predictions and forecasting efficiency from increased spatial resolution NWPs and AI integration and its presentation with the improved observability on a higher operational control and monitoring levels, including regional, RSC level.

F-channel application, that will be developed under WP8 - southern cluster (Greece) will be capable of identifying flexibility resources more precisely and simultaneously for both DSO and TSO grid levels, mainly under OneNet focusing on the lover voltage levels prosumers, that are usually not being covered with that detailed energy predictions, in a much more precise manner and longer time horizons than it is being done today, covering wider geographical scope than it is being covered today by national control centres, and/or RSCs... The aim is to improve production/consumption predictions for different voltage level entities, from residential prosumers to the centralized WPPs and SPPs connected to the distribution grid or any local micro grid (local energy communities), through improved forecasting efficiency from increased spatial resolution NWPs and AI integration into the short to mid-term power system planning simulations.

The application itself will not depend on the exact product being utilized within the market, or the market model itself (it will be possible to use it for different services and products, and different market models). It will focus on a predictive management and need of a products. Possibility for products from a micro-grid and DSO levels to be recognised and available for utilisation on higher voltage levels (TSOs, RSCs…) as well as on the administrative aggregator’s level:

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 957739

- identification of the flexibility resources to procure grid services

The key performance indicators for this SUC 8.2.1.1 are presented in the table A9 of the Appendix A

The actors participating in this SUC 8.2.1.1 are presented in the table A10 of the Appendix A

SUC_8.2.1.2: DSO, DG and micro-grid POI management

Scope:

Register of POIs - Point of Interest with necessary regular periodic updates, technical data, historic data, forecasted data archiving and analysis for AI applications…

Objectives:

- Frequency stability
- Load flow and contingency monitoring and predictions
- Predictive congestion management for maintaining secure and stable power system operation
- Cost-effective operation of the system
- Early warning on a hazardous power system regime,
- Better FSPs planning and managing flexibility resources.
- Better energy predictions and power system state predictions
- Improved identification of the available flexibility resources on all power system levels.
- Improved prediction of the system flexibility needs.

Description:

Register of POIs - Point of Interest with necessary regular periodic updates, technical data, historic data, forecasted data archiving and analysis for AI applications…

The information for the actors in this SUC 8.2.1.2 are presented in the table A11 of the Appendix A

SUC_8.2.1.3: Change View - different aggregation level simulations

Scope:

User defined domain of DSO/Micro-grid and TSO voltage level area of interest for which simulation of a power production, consumption and load flow (contingency analysis) is being performed.

Objectives:

- Frequency stability
- Load flow and contingency monitoring and predictions
- Predictive congestion management for maintaining secure and stable power system operation
- Cost-effective operation of the system

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

– Early warning on a hazardous power system regime,
– Better FSPs planning and managing flexibility resources.
– Better energy predictions and power system state predictions
– Improved identification of the available flexibility resources on all power system levels.
– Improved prediction of the system flexibility needs.

Description:

Energy predictions and system state predictions for different aggregation levels of DSO grid and local micro-gid: unit level (distributed gen. unit, OHL tower/section), plant level (solar park, wind park, OHL, substation), local micro-grid level (part of the DSO grid), DSO/TSO grid level simulations/calculations depending on a selected area of interest by the end user.

The key performance indicators are presented in table A12 of the Appendix A:

The actors are presented in the following table A13 of the Appendix A.

SUC_8.2.1.4: Improved congestion management process on TSO and RSC side

Scope:

Improved short term forecasts, contingency analysis and capacity calculations through utilisation of the information from DSO and/or local micro grid operators.

Objectives:

– Frequency stability
– Load flow and contingency monitoring and predictions
– Predictive congestion management for maintaining secure and stable power system operation
– Cost-effective operation of the system
– Early warning on a hazardous power system regime,
– Better FSPs planning and managing flexibility resources.
– Better energy predictions and power system state predictions
– Improved identification of the available flexibility resources on all power system levels.
– Improved prediction of the system flexibility needs.
– Improved frequency control on TSO side
– Improved Voltage control on DSO and TSO side
– Improved System adequacy on DSO and TSO side
– Improved Islanded operation on DSO and TSO side

Description:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Improved power system state estimation in order to better predict system flexibility needs, with the wider geographical observability and longer "look into the future". through improved predictions and forecasting efficiency from increased spatial resolution NWPs and AI integration and its presentation with the improved observability on a higher operational control and monitoring levels, including regional, RSC level. KPIs for this SUC are presented in table A14 of the Appendix A. Information on the actors in SUC 8.2.1.4 is presented in table A15 of the Appendix A.

Business Use Case 2: Enhanced severe weather condition management and outage management for TSO, DSO and micro grid operator

Scope*:*

Enhanced severe weather condition management with predictive maintenance algorithms with the enhanced storm and icing predictions in order to preserve power system from running into dangerous topological or operational states.

Objectives:

- Predictive maintenance and outage management,
- Enhanced severe weather condition management,
- Outage management optimisation for increased system adequacy,
- Early warning on a potentially hazardous power system topology and regimes
- Avoidance of a damages caused by the severe weather conditions

Description of the Business Use case

Enhanced severe weather condition management will include the following elements: distributed generation units (WPPs and SPPs, as well as individual units), micro-grid OHLs, DSO OHLs and TSO OHLs of interest. Predictive maintenance algorithms with the enhanced storm and icing predictions will be developed in order to preserve system running into a dangerous topological or operational states. DSO grid, local micro-grid outage management that takes into account improved predictions and forecasting efficiency from increased spatial resolution NWPs and AI integration together with the Early warning on a potentially hazardous power system topology and regimes and avoidance of damage caused by the severe weather conditions.

The main foreseen benefits/functionalities related to this particular business case (Enhanced Power Management for TSO-DSO coordination) are as follows:

- Storm and Icing predictive maintenance process in TSO grid, DSO grid and local micro-grid
- Outage management process in TSO grid, DSO grid and local micro-grid

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

In the table A16 of the Appendix A, the KPIs for the BUC 2 are presented

The conditions / assumptions/prerequisites for the BUC 2 are presented in the table A17 of the Appendix A.

A diagram of interractions for the BUC 2 is presented in the following figure 20

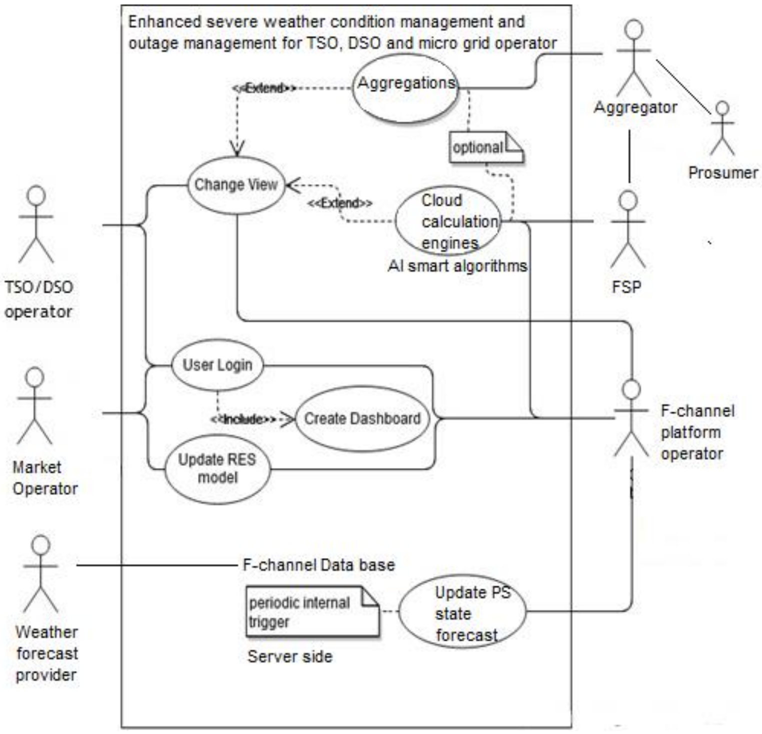

Figure 20. Interractions in BUC 2

It has to be mentioned that the only difference with the BUC- Enhanced Active Power Management for TSO-DSO coordination is in a set of data delivered by the Weather forecasting provider as well as with the smart calculation, AI based, engines that will be utilised.

The actors in this BUC 2 are presented in the table A18 of the Appendix A.

An overview of the scenarios in this BUC 2 is depicted in the table A19 of the Appendix A

Scenario name #1 Early severe state warning system / prevention and restoration

In order to avoid severe damages to the equipment and load losses, it is of outmost importance to prepare the power system elements for the incoming severe weather conditions as well as for the severe power system state conditions. Provide improved identification of severe system states and contingencies that can cause severe system states in a more precise manner and longer time horizon than it is being done today together

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

with the improved identification of flexibility resources, as well as improved identification of the flexibility needs. The activation time could be from 15 minutes to 1 hour.

A Scenario step by step analysis is presented in the table A20 of the Appendix A

The information exchanged for this scenario 1 is presented in the table A21 of the Appendix A

The connected SUC are the following

SUC_8.2.2.1: Storm and Icing predictive maintenance process in TSO grid, DSO grid and local micro-grid

Scope:

DGs, Micro-grid OHLs DSO grid OHLs predictive maintenance and protection with the enhanced storm and icing predictions.

Objectives:

- Predictive congestion management for maintaining secure and stable power system operation
- Cost-effective operation of the system
- Early warning on a hazardous power system regime,

Description:

Identification of the severe weather conditions that can cause tripping of the lines or DG outages and as a consequence partial or full blackouts in the region of interest.

The main foreseen benefits/functionalities related to this particular use case are as follows:

- Improved System adequacy on DSO and TSO side
- Improved Islanded operation on DSO and TSO side

The key performance indicators are presented in the table A22 of the Appendix A

The information for the actors in the SUC 8.2.2.1 are presented in the table A23 of the Appendix A

SUC_8.2.2.2: Outage management process in TSO grid, DSO grid and local micro-grid

Scope:

DSO/TSO grid, local micro grid outage management that takes into account improved predictions and forecasting efficiency from increased spatial resolution NWPs and AI integration.

Objectives:

- Predictive congestion management for maintaining secure and stable power system operation
- Cost-effective operation of the system
- Early warning on a hazardous power system regime,

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Description:

DSO/TSO grid, local micro grid outage management that takes into account improved predictions and forecasting efficiency from increased spatial resolution NWPs and AI integration.

The main foreseen benefits/functionalities related to this particular use case are as follows:

- Improved System adequacy on DSO and TSO side
- Improved Islanded operation on DSO and TSO side

The Key performance indicators and actors are the same like in the previous SUC 8.2.2.1.

4.1.2. Products

F-channel application will be capable of identifying flexibility resources, as well as identifying the power system state (the need for the flexibility services) in a much more precise manner and longer time horizons than it is being done today. Application such that will not depend on the exact product being utilized within the market, or the market model itself (it will be possible to use it for different services and products, and different market models). Nevertheless, to demonstrate capabilities of the application the following set of market products and services have been identified for the Southern cluster, Greek demo in the table A24 of the Appendix A.

4.2 BUCs, Products KPIs for the ABCM platform demonstration in Cyprus

The ABCM platforms for the TSO and DSO will demonstrate a seamless coordination between the TSO, the DSO and the flexible services providers to increase system flexibilities and improve the operating conditions, the stability and the power quality of the Cyprus power system. The main business use cases (BUCs) for this demonstration among with the corresponding system use case (SUCs) and products will be analyzed in this section. Furthermore, the assumptions and prerequisites for this demonstration are stated and the related key performance indicators (KPIs) that will be used in the evaluation framework are presented.

4.2.1. Business Use Cases

Two main BUCs have been identified for the ABCM platforms and the Cyprus demonstration. The first BUC focuses on enhancing the active power flexibility of the power system while the second BUC targets on reactive power and power quality flexibilities. Each BUC are described below.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Business Use Cases 1: Active power flexibility

Cyprus power system favors the massive installation of PV due to the climate conditions (abundant sun) in order to achieve the national environmental target. The high penetration of renewables in combination with the islanded nature of the system creates critical challenges related to frequency stability and balancing (due to the unpredicted nature of RES). In addition, several distribution feeders in the island experience a large concentrations of PVs and as a result, local congestion problems (voltage and thermal limit violations) appear. Therefore, the first BUC aims to enhance of active power flexibility of the system by enabling the provision of coordinated active power-related ancillary services (i.e., peak shaving, energy shifting, droop control and inertia, etc.) by distributed flexible resources (i.e., energy storage system, PV systems, etc.). The main objectives of this BUC are to:

- Enhance the frequency stability of the power system,
- Relieve the congestion management for maintaining capacity limits of the grid,
- Ensure the cost-effective operation of the system.

This business use case exploits the flexible resources located at the distribution grid level (i.e., large energy storage systems, PV parks, prosumers, etc.) to provide active power related services in real-time, in the framework of primary, secondary reserve such as:

- Droop control and synthetic inertia of flexible resources to support frequency,
- Ramping control to compensate large power fluctuations.

Furthermore, the business use case will enable the participation of the distributed resources in the day-ahead and intra-day market by providing active flexibility services, such as:

- Peak shaving service to relieve local congestion problems,
- Power regulation to track day-ahead profile.

All these services will be procured by both the transmission and distribution system operators (TSO and DSO) to the day-ahead, intra-day, and real-time market. The energy market will allocate the services to the different flexible actors (aggregators and prosumers) according to the market rules. The activation of these services will be coordinated by the operators and/or based on the grid operating conditions.

The provision of droop and ramping control are currently provided by the conventional generation plants at the transmission level of the system, while this business use case will enable the distributed resources to provide and remunerated for these services. In addition, peak shaving services can provide local congestion management capabilities to minimize PV curtailments and increase the penetration of photovoltaic energy.

Business Use Case 2: Reactive power flexibility and power quality

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

The national environmental targets of Cyprus will be achieved by the massive deployment of PVs due to the environmental conditions in the island (very high solar irradiation potential). The high penetration of photovoltaics plants in specific feeders causes local congestion problems (voltage and thermal limit violations) in the distribution grid. In addition, the majority of loads are single phase connected to the grid, creating intense phase imbalances and thus the power quality and the grid capacity are negatively affected.

The second business use case aims to enhance of reactive power flexibility and power quality of power grids by coordinating the provision of ancillary services (i.e., voltage support, congestion management, phase balancing) by the distributed flexible resources located in the distribution grids. The main objective of this BUC is to:

- Enhance the voltage stability of distribution grids,
- Reduce the energy losses and increase the efficiency of the distribution grid,
- Relieve the congestion management for maintaining capacity limits of the grid,
- Improve the power quality and symmetrize phase loading conditions at the distribution level.

This business use case exploits the flexible resources of the distribution grid (i.e., large energy storage systems, PV parks, prosumers, etc.) to provide reactive power and phase balancing services. These services will be procured by the transmission and distribution system operators (TSO and DSO) to the day-ahead, intra-day or real-time market. The energy market will allocate the services to the different flexible actors (flexible service provides, aggregators and prosumers) according to the market rules. The activation of these services will be coordinated by the operators considering the grid operating conditions.

Currently, the reactive/voltage support is performed by reactors/capacitors installed in the transmission level or by predefined support schemes (i.e. cosϕ(P)) provided by the PV inverters in the distribution grid according to the grid regulations [46]. In addition, phase balancing has recently introduced in the IEEE standards for micro-grids [47] but has not been used in distribution grids. In this business use, reactive support and phase balancing will be provided by flexible resources and will be online coordinated by DSO to increase efficiency, relieve congestion, reduce curtailments and increase PV penetration. The flexible resources will be remunerated for these services enhancing their competitiveness in the energy market.

4.2.2 System Use Cases

The following system use cases (SUCs) have been identified for the Cyprus Demonstration and will be included in ABCM-T and ABCM-D platforms. These four SUCs will be used to accomplish both BUCs for the specific demonstration. The SUCs consider the monitoring of the operating conditions at both the transmission and the distribution grid, the prequalification of the location-based limits for the market products, the evaluation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

of the FSPs response, and the online coordination of the flexibility services by the distributed resources. The SUCs are listed below:

- **SUC1 – Real-time monitoring of the grid:** The operating condition of the transmission and distribution grid will be monitored using real-time measurements. In the case of the transmission grid, PMU and SCADA measurements will be used in a real-time monitoring scheme, while in the case of the distribution grid smart meter and SCADA measurements will be used.
- **SUC2 – Prequalification of the location-based limit of each market product:** Use available monitoring information (from SCADA, PMUs, smart meters) and historical data to determine the location-based limits. In the case of the transmission grid the location-based limit will be determined at the primary substation (HV/MV interface) while in the distribution grid the limit will be calculated at the secondary substation (MV/LV interface). The prequalification of the limits will be done for a specific time interval ahead according to the market time frame.
- **SUC3 – Evaluation of the FSPs response:** Use available monitoring information (from SCADA, smart meters, PMUs) for evaluating the response of the FSPs located at the transmission and the distribution grid after the provision of grid services. This SUC will determine if their response corresponds to the awarded bids cleared by the TSO and local DSO market respectively.
- **SUC4 – Coordination of distributed flexible resources:** Use available monitoring information (from SCADA, smart meters) in order to automatically coordinate the operation of the distributed flexible resources to ensure the proper, efficient, and high power quality of the distribution grid.

It should be noted that the SUC 1-3 will be included in both the ABCM-T and ABCM-D platforms and each of this SUC will be tailored according to the specific characteristics of the transmission and distribution grid respectively. The SUC 4 will be developed for the case of the distribution grid and will only be included in the ABCM-D platform.

4.2.3. Actors and Sequence diagrams of BUCs

Both business use cases related to the Cyprus demonstration involves five main actors to ensure the proper coordination between the TSO, the DSO, and the flexible end users to improve the system flexibility and the power quality. The five actors, the description of each actor and the relation with the specific BUCs are presented in the table A25 of the Appendix A.

In both BUCs, a similar sequence of interaction and exchange of information between the main actors is identified considering the prior-mentioned SUCs. The common sequence diagrams for both BUCs with the corresponding SUCs and the related actors is demonstrated in Figure 21, while the main steps of the interaction between the actor are explained below:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

- The TSO and DSO monitor the system in real-time to ensure the proper operation of the system within the desired limits. The monitoring of the transmission system is facilitated by PMUs and SCADA measurements while the monitoring of the distribution grid is enabled by smart meter and SCADA.
- TSO and DSO procure orders in the market for maintaining the voltage stability and power quality of the system and overcoming any local contingencies
- The aggregators and the prosumers bid their location-based reactive power and power quality services into the market.
- Energy market allocates the flexibility services to distributed resources
- The aggregators and the prosumers provide the reactive power flexibility, and the power quality services by regulating the reactive support and phase balancing operation of their distributed resources.
- The operation of the whole grid is evaluated by the two operators based on real-time measurements

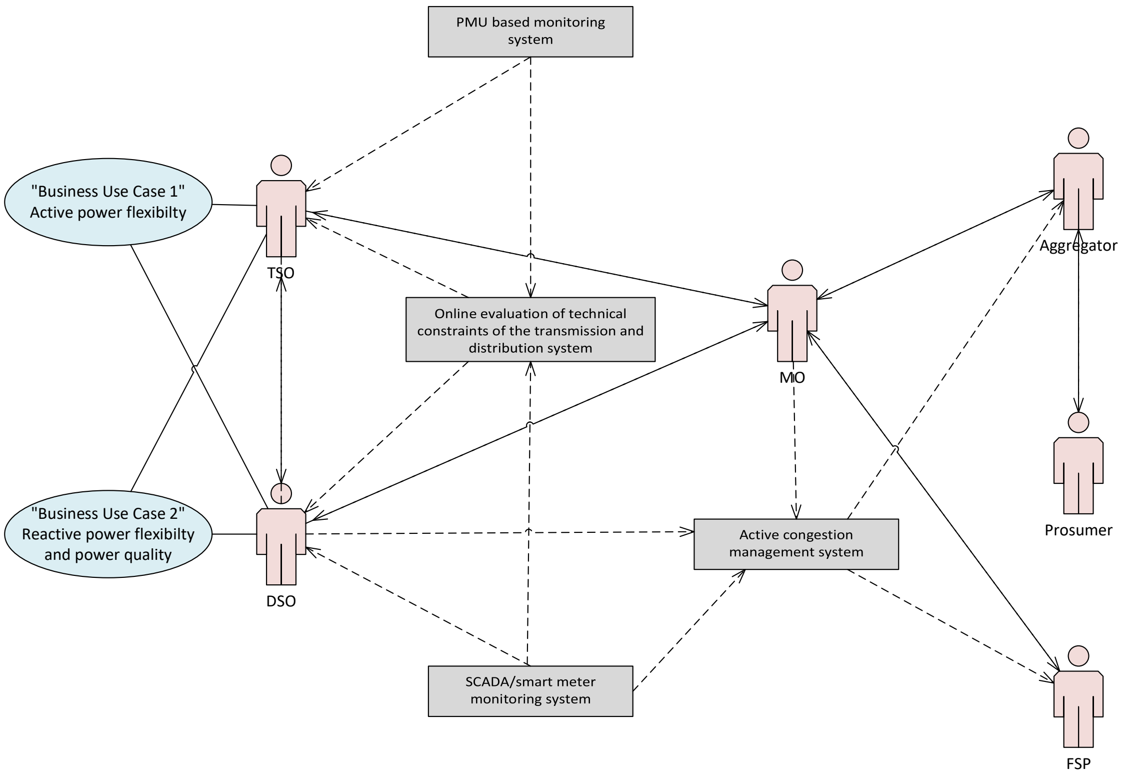

Figure 21. Sequence diagram of the two BUCs of the Cyprus demonstration.

4.2.4. Products and Services

The Cyprus demonstration through the ABCM platform will coordinate the provision of different services by the distributed flexible resources. These services are related to:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

- Congestion management
- Voltage control
- Day ahead active power management
- Frequency control

Six different products have been defined to enable the provision of the services mention above, these products are described below and the correlation with the corresponding services is explained:

- **Change of active power (i.e., load shifting, peak shaving)**

  This product will provide/absorb a certain amount of MWh in specific timeframes in the local distribution grid to provide load shifting or peak shaving flexibilities. It can be used for avoiding overloading conditions in the distribution grid and is linked with network congestion management. The peak shaving product will be automatically activated and the flexibility resource will provide peak shaving services to the distribution grid when needed. The activation time could be from 15 minutes to 1 hour.
- **Change of reactive power (i.e., voltage regulation, reactive power compensation)**

  This product will provide/absorb a certain amount MVh in specific timeframes in the local distribution grid. It can be used to regulate voltage in distribution grids and is linked with the voltage control service It can be also utilized to compensate the reactive power for reducing the energy losses and increasing the grid capacity which is linked with the congestion management service. The change of reactive power product will be automatically activated and the flexibility resource will be provided reactive power regulation to the distribution grid when is needed. The activation time could be from 30 seconds to 15 minutes.
- **Phase balancing (to symmetrize the loading conditions among the three phases)**

  Phase Balancing product will provide/absorb a certain amount of negative or zero sequence current in specific timeframes in the local distribution grid. It can be used for avoiding overloading conditions by symmetrizing the load conditions among the three phases (A,B,C of AC current)and is linked with the network congestion management and the power quality. The phase balancing product will be automatically activated and the flexibility resource will provide phase balancing services to the distribution grid when needed. This product can be paid through bilateral contracts. The activation time could be from 30 seconds to 15 minutes.
- **Power regulation (to meet the day-ahead system adequacy)**

  The power regulation product will provide/absorb a certain amount MWh in specific timeframes to meet the day-ahead awarded profile for each resource. This produce offers power generation scheduling control to meet the final nominated energy volume. The activation time could be from 15 minutes to 1 hour.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

- **Active power rate of change capability (i.e., ramping power per minute)**

  Provide a certain amount of MW per minute (MW/min) for a certain time interval. It can be linked with the automatic frequency restoration reserve for frequency control service. The product can be activated according to set points sent to the distributed flexibility resources. The activation time could be from 30 seconds to 15 minutes

- **Rapid active power change product according to system frequency (i.e., droop and inertia)**

  This product provides a certain amount of MW according to the change of frequency from its nominal value (MW/Hz) for a certain time interval. It can be linked with the automatic frequency restoration reserve products and can be automatically activated when the flexibility resource detects a certain amount of frequency change. This product will enable flexibility resources to provide droop control and synthetic inertia to the power system for enhancing the frequency stability of the power system. The product will be immediately activated when a frequency disturbance is observed.

4.2.5. Key Performance Indicators

An evaluation framework is needed to assess the overall performance of the Cyprus demonstration achieved by the developed BUCs. A holistic evaluation framework will consider different key performance indicators (KPIs), as shown in **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.** A26 of the Appendix A, to assess the performance improvement regarding the stability, power quality, and efficiency of the power system according to the coordinated provision of location-based flexibility by the distributed resources.

4.2.6. Assumption and prerequisites

Two main BUCs regarding the provision of active power flexibility, reactive power flexibility and power quality services by the distribution resources will be evaluated in the Cyprus demonstration. For both BUCs, the following assumption have been considered:

- The use case will be developed and demonstrated in a non-invasive environment using the real-time digital twin of the Cyprus power system.
- The TSO, DSO control center and the energy market will be emulated in the demo architecture.
- The energy market will be based on a generic market setup in the absence of an energy market in Cyprus
- Additional PVs and energy storage systems will be installed in the Cyprus power grid to represent near future conditions.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

- Aggregators and prosumers will be emulated in the demonstration considering online coordination capabilities by system operators.

It is also important to mention that for demonstrating the two BUC in a realistic environment, the following prerequisites have been considered in the Cyprus demonstration:

- Provision of PMU data from the transmission system
- Provision of SCADA data and/or smart meter data from the distribution grid
- Adoption of a generic energy market setup.

5 Implementation plan for the Southern cluster demos and connection with OneNet architecture

5.1 Implementation plan for the F-channel platform demonstration in the Hellenic TSO-DSO-consumer value chain

For the implementation of the Greek demo, a detailed implementation plan was developed early from the beginning of the project and has been followed precisely during this 12 month period. The plan is as follows

  - **Subtask 8.1.1 (M1-M3):** Data collection and identification of relevant Points of Interest:
    1. 1st data collection survey, (finalized)
    2. Identification of DSO, TSO, Micro Grid and DER Points of Interest in Greece (Peloponnese and Crete), (finalized)
  - **Subtask 8.1.2 (M3-M12): Technical specifications and architecture development** (**finalized**)
    1. 2nd data collection survey - Description of existing practice, standards, methodologies and software tools currently used,
    2. BUCs and SUCs mapping, preliminary list of actors, products and services covered,
    3. Requirements and system specifications,
    4. System Architecture, and
    5. Necessary resources.
- **Task 8.2 (M3-M30): Development and implementation of the platform in Greece:**
  - **Subtask 8.2.1 (M3-M4): Preparation of the overall development environment (finalised)**
    1. GIT repository,
    2. Python development environment,

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

3. Setting up the dedicated and allocated storage resources (Linux server, MySQL/Maria DB...)

- **Subtask 8.2.2 (M4-M22): Development and integration of the web based, client-server application (ongoing)**
  1. Data Base development, finalized
  2. App GUI development, ongoing
  3. AI algorithms and methods, ongoing
  4. Development of the cloud calculation engines
  5. Connection with the external clients

Subtask 8.2.3 (M22-M27) Testing and validation of the F-channel platform (future)

Subtask 8.2.4 (M24-M30): Demonstrations in Greece (future)

→ Phase 1: Analysis of the predefined POIs through predefined set of Scenarios and cases to be analyzed

→ Phase 2: Benchmark with the existing tools and practice in TSOs and DSOs.

→ Phase 3: Evaluation by Aggregators, Suppliers, Consumers, System operators.

The Points Of Interest identified for the preliminary analysis are

→ all the solar parks in Peloponnese with installed power greater than 2 MW,

→ all the 50 substations in Peloponnese (in a case of 28 substations both loads, and RES productions are connected, while in the rest 22 stations only RES productions are connected),

→ all the wind parks in Peloponnese,

→ from IPTO point of view there are two potentially critical lines in the region of Peloponnese. In particular, the first POI is the OHL that connects Korinthos and Megalopoli substations as it is a critical line concerning congestion issues. Undoubtedly, the interconnection line between Peloponnese and Crete is another POI. The aforementioned interconnection is between the regions of Sklavouna-Neapoli and Chania. This transmission line is already in operation will be fully utilised no later than the end of the year.

5.2 Implementation plan for the ABCM platform demonstration in the Cypriot TSO-DSO-consumer value chain

The main objective of the demonstration in Cyprus is to showcase the effective coordination of the TSO-DSO and prosumer. This will be done through the design and development of a collaboration framework that will be facilitated with the OneNet system and the two ABCM platforms (ABCM-T and ABCM-D). More specifically, the exchange of information of the TSO, DSO, Market Operator, and prosumers will be enabled through the OneNet

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

system, while the interaction of the TSO and DSO with the owners of distributed flexible resources will be done through the ABCM platforms.

The validation and testing environment that will be used for showcasing the different objectives of the Cyprus demo is illustrated in Figure 24. Since all the scenarios will be executed through dry run simulations, the Cyprus demonstration is separated in the digital twin and HIL demonstration environment and the Information and Communication (ICT) environment. In the Digital twin and HIL environment, the real-time simulator (OPAL RT OP5700) is very crucial since the digital twins of the Cyprus Transmission and Distribution systems will be developed and tested. The developed systems will be the replica of the real systems to emulate a realistic environment. To facilitate the real-time monitoring of these two systems, different metering equipment will be used at the transmission and distribution level. More specifically, the Cyprus transmission system is already observable by 18 PMUs, which will be either emulated in the real-time simulator or they will be connected to the real-time simulator through a HIL setup. In the case of the distribution system, the monitoring of the system will be facilitated either from smart meters or SCADA measurements. In the same way, as in the transmission level, some smart meters will be emulated to the real-time simulator while others will be connected to the real-time simulator through a HIL setup. Novel monitoring schemes will be developed and included in the ABCM-T and ABCM-D platforms for facilitating the real-time monitoring of the two grid levels. The measurements provided by the measurement equipment in the transmission and distribution grid will be transferred from the real-time simulators to the two platforms. The FSPs will also be emulated in the real-time simulator and will be controlled through the innovative control methods (i.e., droop and ramping control, voltage regulation, and phase balancing) that will be developed in the context of Task 8.3. As aforementioned, the FSPs will communicate with the TSO and DSO through the ABCM platforms and will be coordinated through the respective ABCM platforms.

The ICT environment deals with the communication and information exchanged between the different actors and systems in the Cyprus demonstration. In particular, the ICT environment includes the ABCM-T and ABCM-D platforms that exist in the TSO and DSO control center respectively, the energy market that includes both TSO market and local DSO market, and the OneNet system. The exchange of information between all the actors in the Cyprus demo, (i.e., TSO, DSO, Market, and FSPs) is handled by the OneNet system as it is shown in Figure 22. In addition, the two ABCM platforms receive measurements by the measuring equipment for performing the different functionalities that are included in each platform, while the TSO and DSO communicate with the FSPs located at their system using the platforms.

Several scenarios according to the BUCs of the Cyprus demo will be tested, validated, and demonstrated in the environment shown in Figure 22. Therefore, to achieve the overall goal of the Cyprus demonstration and to create the demo environment indicated in Figure 22, the demo implementation plan for the following 27 months of the OneNet project was divided in several phases (subtasks) for better coordination of the activities in Task

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

8.3. More specifically, seven subtasks are mainly outlined below and indicate the activities that were done in the first 12 months of the project and the planned activities for the next months of the project. Therefore, although this deliverable is prepared in M12 of the project, the implementation plan for the Cyprus demo is analyzed for the whole duration of Task 8.3 (until M30).

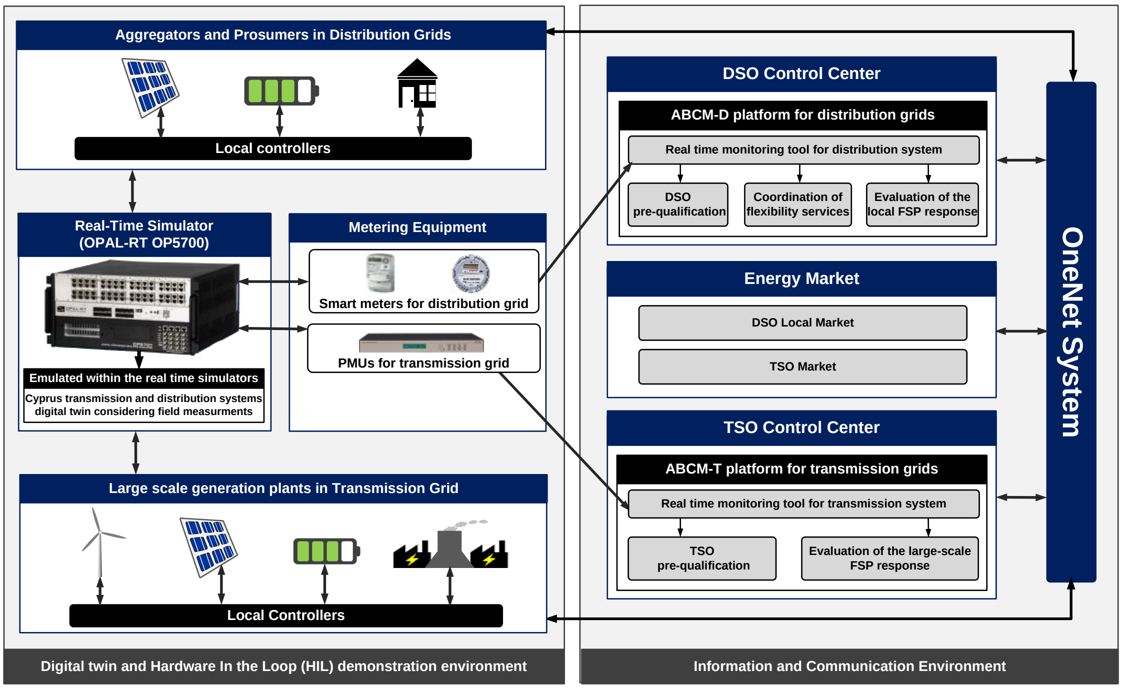

Figure 22: Validation and testing environment for the Cyprus demonstration

5.2.1 Implementation plan for the Cyprus demo

A detailed implementation plan for the Cyprus demo has been developed early form the beginning of the project, as follows:

- ✓ **Implementation of the testing environment (M3-M12)**

In this subtask, the Cypriot partners (UCY, TSOC, EAC) focused on the development of digital twin of the Cyprus transmission and distribution systems. Among the activities of this task were (1) the provision of data, such as topology, connectivity, and network parameters, of the Cyprus transmission and distribution system by the TSOC and DSO, (2) the electromechanical modelling of the two systems by the UCY team first in Matlab Simulink and then their upload in real time simulator, and (3) the validation and testing of the digital twin models in order to verify their proper operation in the simulation environment. The subtask was completed in M12, and the digital twins of the Cyprus transmission and distribution system were implemented successfully in the real time simulator.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

- ✓ **Development of the real time monitoring schemes for transmission and distribution systems (M3-M15)**

One of the system use cases described above in Section 4.2.2 is the real time monitoring of the transmission and distribution grid. The real time monitoring will provide a wide area visualization of the power system and will enable the timely activation of the flexible resources in order to mitigate grid disturbance and load balancing. This subtask deals with the development of two real time monitoring schemes that are applied to the transmission and distribution grid. In the case of the transmission grid, the scheme uses real PMU measurements derived by the different substations of the Cyprus power system, while in the case of the distribution grid the monitoring scheme is based on smart meter and SCADA measurements. This subtask is ongoing and is expected to finish by month 15. Until M12, the real time monitoring schemes for the transmission and distribution systems were developed and tested in testbed systems implemented in the real time simulator. Until M15 the application of the real time monitoring schemes to the digital twin of the Cyprus transmission and distribution system will be performed.

- ✓ **Development of tools for the active balancing congestion management of FSPs (M3-M21)**

One of the main objectives of the Cyprus demo is the management and control of the flexible resources exist in both the transmission and the distribution grid to provide support to the grid when needed. In order to achieve this, in this subtask the control methodologies for FSPs located at the transmission and distribution grid will be developed. More specifically, there will be common control methods for the FSPs located at the two grid levels regarding the frequency support. In this sense, droop and ramping control schemes will be developed and implemented in this subtask for the FSPs located in the transmission and distribution level. These schemes will be automatically triggered according to the local measurements of frequency. In addition, explicit congestion management schemes such as load shifting, reactive support, and phase balancing will be developed for the distributed flexible resources. These schemes will be coordinated by the ABCM-D platform as shown in Figure 22. Through this subtask different routines included in the ABCM platforms (for TSO and DSO) such as prequalification of FSP products, coordination of distributed flexible resources and online evaluation of FSPs' response will also be implemented. Until M12 the phase balancing, and the droop and ramping control were implemented and tested as stand-alone tools, while the reactive support schemes as well as the functionalities included in the ABCM-D and ABCM-T platform will be implemented in the next months.

- ✓ **Development and integration of the ABCM platforms (M6-M24)**

The ABCM platforms for the TSO and DSO control centre will the ABCM platforms. These platforms are intended to be a useful tool at the disposal of the DSO and TSO, since they will contribute to the effective management and coordination of the flexibility resources, ensuring at the same time the operation of the grid within proper limits. The integration of the functionalities that will be developed in the previous task (i.e., prequalification, coordination of flexibility resources, and online evaluation of the FSPs' response. Further to

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

that the two platforms will be integrated to the ICT environment of the Cyprus demo as illustrated in Figure 22 in order to be able to communicate both with the digital twin and HIL environment as well as with the OneNet System. The architectures of the two platforms as illustrated in Section 3.2 were designed and the backend interface under implementation. The development and integration of the ABCM platforms will finish in month 24.

- ✓ **Testing and validation of the ABCM-D and ABCM-T platforms (M21-M27)**

The testing and validation of the platforms in order to verify that the platforms fulfil all the functional requirements outlined in Section 3.2 will be performed in this task. The testing phase will begin at month 21 and will end at month 27 and will include the validation of the platforms interaction with the HIL environment as well as the proper communication with the OneNet system. In addition, any operational inconsistencies that will be revealed in the testing and validation phase will be fine-tuned in this task.

- ✓ **Integration of OneNet System and Energy Market to the Cyprus demo (M18-M27)**

The OneNet System will play a crucial role to the Cyprus demonstration as it is intended to facilitate the exchange of information with the TSO, DSO and the market operator. In this task the integration of the OneNet system to the ICT environment of the Cyprus demo will be performed. Further to that, the energy market platform that includes both the TSO market as well as the local DSO market will be will be integrated to the ICT environment of the demo. Several tests will be performed to ensure the proper integration of the OneNet system and the Energy Market platform to the Cyprus demonstration. It is expected that the activities will start by M18 of this task and will be ended by M27.

- ✓ **Demonstration (M24-M30)**

In this subtask the demonstration of the overall concept of the Cyprus demonstration will be performed. Several scenarios are expected to be demonstrated to showcase the importance of having a fully coordinated operation of the power system in all the levels. The demonstration will be done in a fully controlled environment using a Hardware in the Loop setup at the laboratory premises of UCY as indicated in Figure 24. The scenarios will be based on the two BUCs that were described above, and the KPIs that were outlined previously will be used for evaluating the performance of the proposed techniques that will be demonstrated as well as their potential impact to the grid.

5.3 Connection with OneNet architecture

5.3.1 Integration plan of F-channel with OneNet

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

OneNet system will provide the guideline in terms of specifying unique IT architecture which will fully support all services and exchange of data with other modules and other partners in the project. Currently, there are ongoing discussions with WP5 and WP6 partners to identify the integration plan of F-channel with OneNet.

The F-channel platform will be modular allowing for utilisation of a centralized register of FSPs, or centralized market clearing tool, provided by OneNet central system. F-channel will be based on a Geo Server technology [49]providing the rest of the OneNet partners/solutions with the state-of-the-art features related to the spatial-geo referenced presentation, simulations and analysis of the grid and all major power system elements.

The integration with ONENET 'platform of platforms' will be realised following the European data exchange reference architecture, as presented by BRIDGE [48], and is depicted in figures 23 and 24. A market clearing solution can potentially be connected with F0-channel platform as illustrated in Figure 25.

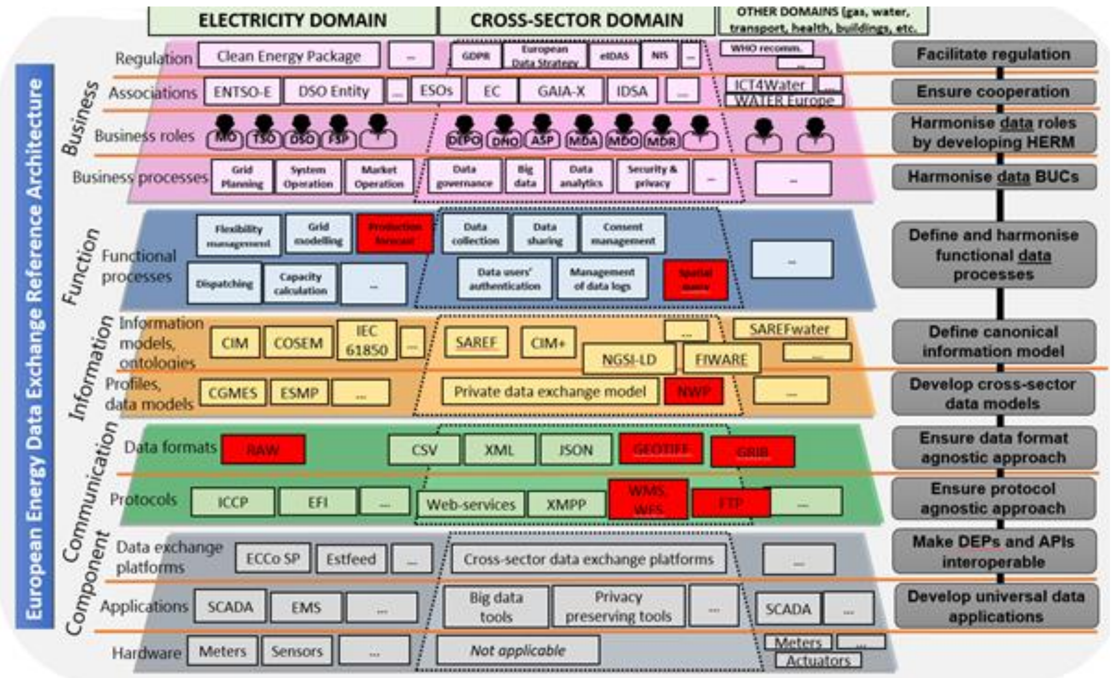

Figure 23. European Energy Data Exchange reference architecture [48]

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

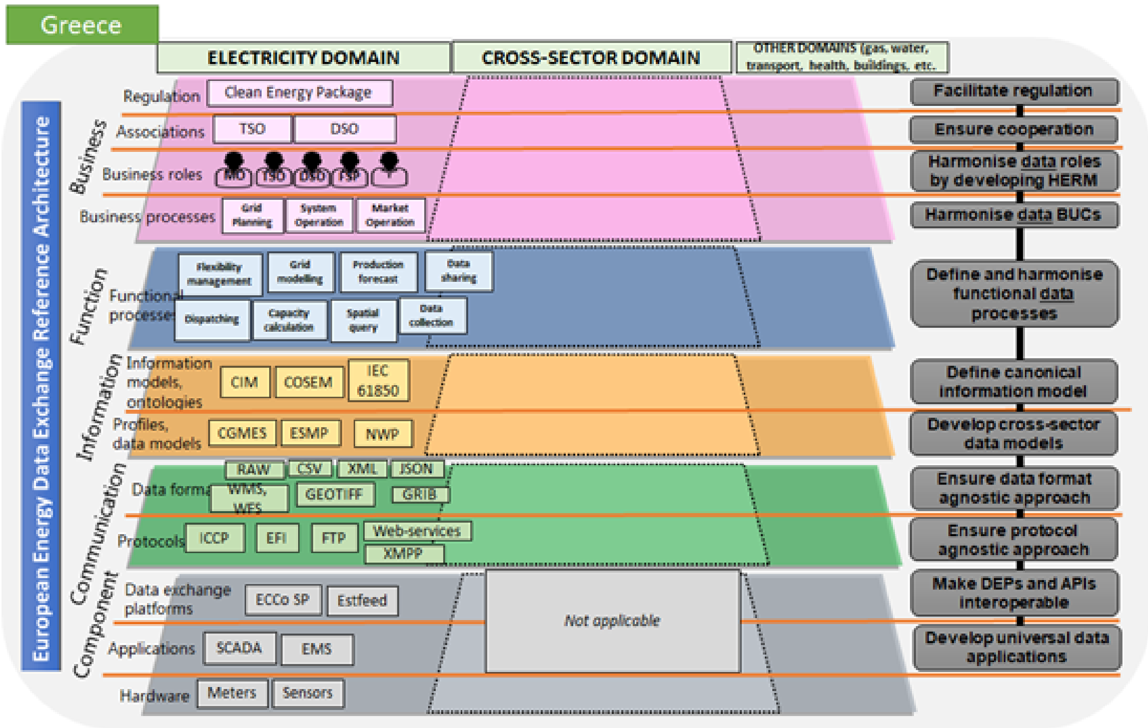

Figure 24. Identified domains for integration with F-channel

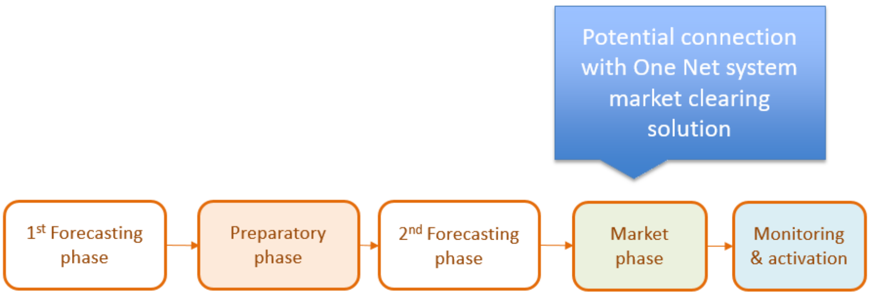

Figure 25. Onenet Market clearing solution in F-channel

5.3.2 Integration plan of ABCM platforms with OneNet system

The ABCM-T platform will be integrated into the Cyprus TSO control center to provide the adequate tools for the operator to monitor and manage the transmission grid considering the effective collaboration with other entities, such as the market, the DSO, the flexible services providers and the end-users. On the other hand, the

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

ABCM-D platform will be integrated in the control center of the Cyprus DSO to provide useful tools to the operators to monitor the operation of the distribution grid in real-time and automatically coordinate the flexible resources located at the distribution grid to ensure the effective, efficient and high power quality operation of the future distribution grids. However, to achieve the key objective of the OneNet project which is the cost-effective and environmentally-friendly operation of the entire electricity infrastructure, the effective collaboration between the TSO, the DSO, the market operator, and the flexible resources is needed. This collaboration will be facilitated through the OneNet system by enabling the exchange of data and information between the different entities, in a standardized manner. Therefore, all the individual platforms created for each different entity/actor need to be compatible for data exchange through the OneNet system.

In Cyprus demonstration, the two platforms (ACBM-T and ABCM-D) that will be developed for the Cyprus TSO and the Cyprus DSO respectively. The compatibility of both platforms with the OneNet system for standardized information exchange will enable the collaboration and coordination of action between the different entities (TSO, DSO, market operators, flexible resources) towards the adequate, efficient, stable and high-quality operation of the entire power grid. The standardized exchange of information between different entities will be realized by API developed for the communication of any platform with the OneNet system, while the OneNet system coordinate which information will be exchanged between specific entities. Figure 26 demonstrate the main information exchange between TSO, DSO, TSO market, FSPs participating in the TSO market, DSO local market, and FSPs participating in the local DSO market that will be done through the OneNet

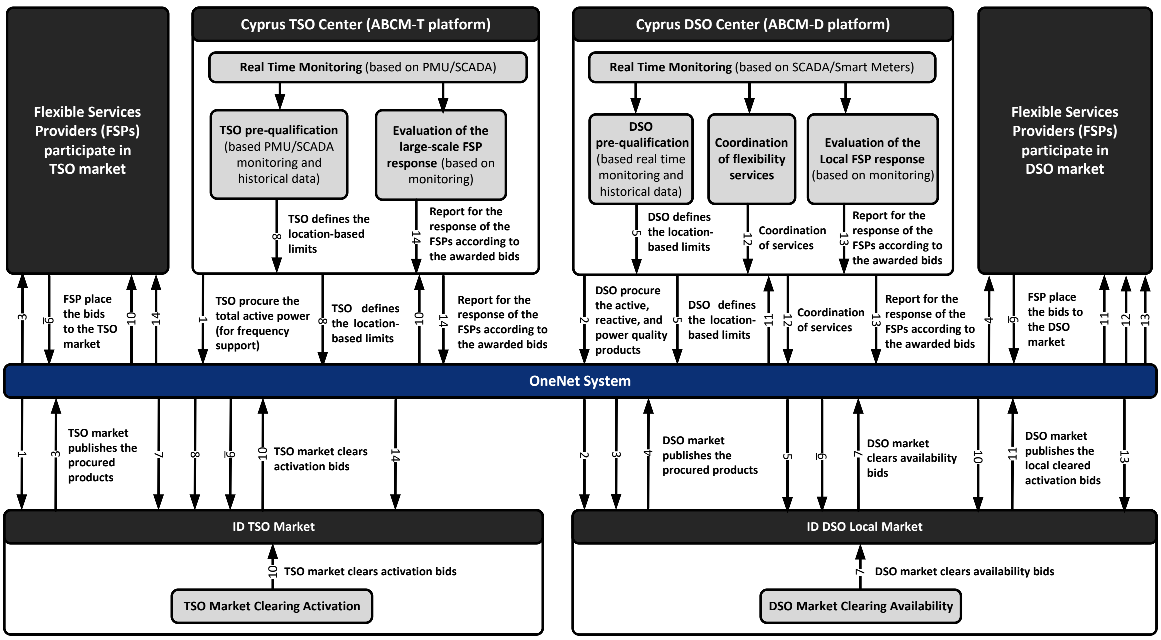

Figure ***Σφάλμα! Χρησιμοποιήστε την καρτέλα "Κεντρική σελίδα", για να εφαρμόσετε το 0 στο κείμενο που***

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

system. Examples of this information exchange through the OneNet system between the different platforms related to the Cyprus demo are listed below.

- TSO (ABCM-T platform) will inform the TSO market for the required products to be procured (i.e., total amount of active power required for frequency support).
- DSO (ABCM-D platform) will inform the local DSO market for the required products to be procured (i.e., total active, reactive power and power quality related products).
- The TSO market will publish the procured products to the large-scale FSPs participating in the TSO market and to the local DSO markets.
- The local DSO market will publish the procured products to the small/medium-scale FSPs participating in the local DSO market.
- DSO (ABCM-D platform) and TSO (ABCM-T platform) will define the location-based limits for each product according their foreseen operating conditions.
- Small/medium FSPs and large-scale FSP will place the bids in the local DSO and TSO market respectively.
- Local DSO market and TSO market will publish the cleared availability and activation bids.
- The DSO (ABCM-D platform) will send the coordination signal to the small/medium-scale FSPs through the OneNet system for coordinating the flexibility services provision.
- TSO (ABCM-T platform) and DSO (ABCM-D platform) will publish through the OneNet system evaluation report for the adequate response of the FSPs according to the awarded bids.

It should be noted that all the required information will be generated within the different platforms running in each entity, while the OneNet system will enable only the exchange of specific information between corresponding entities. Therefore, the integration of the ABCM-T and ABCM-D platforms will be achieved by ensuring compatibility with the standardized information exchange process defined by the OneNet system.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

6 References

[1] European Union, "Directive 2009/72/EC of the European Parliament and of the Council concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC", OJ L 211, 14.8.2009, pp. 55-93.

[2] European Union, "Directive (EU) 2019/944 of the European Parliament and of the Council on com- mon rules for the internal market for electricity and amending Directive 2012/27/EU", OJ L 158, 14.6.2019, pp. 125-199.

[3] European Union, "Regulation (EC) No 714/2009 of the European Parliament and of the Council on conditions for access to the network for cross-border exchanges in electricity and repealing Regulation (EC) No 1228/2003", OJ L 211, 14.8.2009, pp. 15-35.

[4] European Union, "Regulation (EC) No 713/2009 of the European Parliament and of the Council establishing an Agency for the Cooperation of Energy Regulators", OJ L 211, 14.8.2009, pp. 1-14.

[5] European Union, "Commission Regulation (EU) 2017/2195 establishing a guideline on electricity balancing", OJ L 312, 28.11.2017, pp. 6-53.

[6] European Union, "Commission Regulation (EU) 2017/1485 establishing a guideline on electricity transmission system operation", OJ L 220, 25.8.2017, pp. 1-120.

[7] European Union, "Commission Regulation (EU) 2015/1222 establishing a guideline on capacity allocation and congestion management", OJ L 197, 25.7.2015, pp. 24-72.

[8] European Union, "Commission Regulation (EU) 2016/1719 of 26 September 2016 establishing a guideline on forward capacity allocation", OJ L 259, 27.9.2016, pp. 42-68.

[9] KU Leuven Energy Institute. "EI Fact sheet: The current electricity market design in Europe". https://www.mech.kuleuven.be/en/tme/research/energy_environment/Pdf/ei-factsheet8-eng.pdf

[10] ACER, "European Electricity Forward Markets and Hedging Products – State of Play and Elements for Monitoring". https://www.acer.europa.eu/en/Electricity/Market%20monitoring/Documents_Public/ECA%20Report%20on%20European%20Electricity%20Forward%20Markets.pdf

[11] Florence school of regulation Electricity markets in the EU. https://fsr.eui.eu/electricity-markets-in-the-eu/

[12] EFET, "Towards an efficient intraday market design in electricity", 06.05.2020. https://data.efet.org//Files/Documents/Electricity%20Market/Spot%20and%20short-term%20markets/EFET_ID_MarketDesign_06052020.pdf

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

[13] K.-D. Borchardt, "Cross Border Intraday (XBID) Trading Solution Pre-launch Event", Brussels, Jan. 2018.

[14] M. Mathioulakis, and M. Lykidi, "Implementation of the Target Model: Regulatory reforms and obstacles for the regional market coupling", 2019.

[15] P.P. Popova, "A harmonized European electricity balancing market. Incorporation of congestion management into cross-border reserve procurement", Masterarbeit, 2017.

[16] ENTSO-E, "Balancing report". https://eepublicdownloads.azureedge.net/clean-documents/Publications/Market%20Committee%20publications/ENTSO-E_Balancing_Report_2020.pdf

[17] ACER, "Decision No 11/2020 on the Methodology for a list of standard products for balancing capacity for frequency restoration reserves and replacement reserves (SPBC), 17.06.2020.

[18] European Union, "Regulation (EU) 2019/943 of the European Parliament and of the Council on the internal market for electricity", OJ L 158, 14.6.2019, pp. 54-124.

[19] Single Electricity Market Committee, "System Services-Future Arrangement Scoping Paper", SEM-20-044, 08.07.2020. https://www.semcommittee.com/sites/semc/files/media-files/SEM-20-044%20System%20services%20future%20arrangements%20scoping%20paper.pdf

[20] IPTO, "The European Target Model". https://www.admie.gr/en/market/general/description

[21] ECCO International, "Detailed Level Market Design of the Hellenic Forward, Day-Ahead and Intraday Markets and respective Market Codes and high-level IT", Intra-Day Market Code: JR- C/PTT/2017/C.3/0017/OC, vol. 4, 2017. https://www.dapeep.gr/wp-content/uploads/diavouleuseis/2017/2017.12.18_INTRADAY_MARKET

CODE ENGLISH.pdf

[22] ENTSO-E, "All TSOs' proposal for the implementation framework for a European platform for the exchange of balancing energy from frequency restoration reserves with automatic activation in accordance with Article 21 of Commission Regulation (EU) 2017/2195 establishing a guideline on electricity balancing", 18.12.2018.

[23] ENTSO-E, "Automatic Frequency Restoration Reserve Process Implementation Guide", 2019. https://eepublicdownloads.entsoe.eu/clean-documents/EDI/Library/ERRP/Automatic_Frequency _Restoration_Reserve_Process_IG_v1.0.pdf

[24] ENTSO-E, PICASSO Platform. https://www.entsoe.eu/network_codes/eb/picasso/

[25] ENTSO-E, MARI Platform. https://www.entsoe.eu/network_codes/eb/mari/

[26] ENTSO-E, TERRE Platform. https://www.entsoe.eu/network_codes/eb/terre/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

[27] Hellenic Association for Energy Economics (HAEE), "Greek Energy Market Report", 2020. https://www.haee.gr/FileServer?file=ca430e84-31ec-4fa8-8153-ac3f6eb16b70

[28] Hellenic Association for Energy Economics (HAEE), "Greek Energy Market Report", 2019. https://www.haee.gr/media/4858/haees-greek-energy-market-report-2019-upload-version.pdf

[29] Y. Kambouris, "The balancing market", RAE conference on Target Model, Athens, 20.07.2018. http://www.rae.gr/site/file/system/docs/various/anartiseis/2207_1

[30] Hellenic Energy Exchange (HEnEx), "Towards the integration of Greek and EU Energy Markets - Policy briefs", 2019.

https://www.haee.gr/media/4859/policy-brief-henex_-final-244201.pdf

[31] F. Ioannidis, K. Kosmidou, G. Makridou, and K. Andriosopoulos, "Market design of an energy exchange: The case of Greece", Energy Policy, 2019.

[32] A. Metaxas, and M. Mathioulakis, "Implementation of the Target Model: Regulatory Reforms and Obstacles for the Regional Market Coupling", European Energy Journal (EEJ), pp. 24-39, 2019.

[33] IPTO, "Balancing Market Rulebook", 2020. https://www.admie.gr/en/market/regulatory-framework/balancing-market-rule-book

[34] IPTO, "System Balancing", 2020. https://www.admie.gr/en/market/general/capacity-calculation

[35] F. Ocker, and K.-M. Ehrhart, "The German Paradox in the Balancing Power Markets", Renewable and Sustainable Energy Reviews, no. 67, pp. 892-898, 2017.

[36] EU Monitor, "Explanatory Memorandum to COM(2016)861 - Internal market for electricity", 2016.

https://www.eumonitor.eu/9353000/1/j4nvhdfdk3hydzq_j9vvik7m1c3gyxp/vk9njvls0xzt

[37] EU Monitor, "Explanatory Memorandum to COM(2016)863 - EU Agency for the Cooperation of Energy Regulators", 2016. https://www.eumonitor.eu/9353000/1/j4nvhdfdk3hydzq_j9vvik7m1c3gyxp/vk9njvlon5zs

[38] A. Metaxas, "Target Model Implementation and the Role of New Investments in Market Coupling Infrastructure", Financing the Energy Transition: Status and Future Challenges, ch. 6, Eurasia Publications, Athens, pp. 105-135, 2020.

[39] Support Group for Cyprus (SGCY) and CERA, “The new electricity market arrangements in Cyprus”, May, 2015.

[40] Cyprus Transmission System Operator, Trading and Settlement Rules, version 2, May 2017.

[41] IRENA, Renewable Energy Roadmap for the Republic of Cyprus, January, 2015

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 957739

[42] Transmission System Operator, “Annual report of the TSO”, 2019

[43] “2019 Annual Report of Cyprus TSO,” Nicosia, 2019

[44] “An integrated approach to Active System Management”, ENTSO-E, EDSO, 2019

[45] https://climate.copernicus.eu/climate-reanalysis

[46] TSO Cyprus, "Transmission and distribution rules - Issue 4.0.0," Transmission System Operator - Cyprus, July 2013 (in Greek), http://www.dsm.org.cy/

[47] “IEEE standard for the specification of microgrid controllers,” IEEE Std 2030.7-2017, pp. 1–43, April 2016.

[48] “European energy data exchange reference architecture”, BRIDGE, Data Management Working Group April 2021

[49] http://geoserver.org/

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 957739

APPENDIX A

Table A1. Correlation of System Use Cases (SUCs) , Products, and Business Use Cases (BUCs)

SUC	Product/s involved	Connected BUC/s
Improved congestion management process on TSO and RSC side (Improved short term forecasts, contingency analysis and capacity calculations through utilisation of the information from DSO and/or local micro grid operators.)	Predictive congestion management for TSO/DSO product	Enhanced Active Power Management for TSO-DSO coordination
Improved frequency control on TSO side	Power regulation through mFRR and RR – active power product	Enhanced Active Power Management for TSO-DSO coordination
Improved Voltage control on DSO and TSO side	Reactive power support product	Enhanced Active Power Management for TSO-DSO coordination
Improved System adequacy on DSO and TSO side (Storm and Icing predictive maintenance process in DSO grid and local microgrid & Outage management process in DSO grid and local microgrid)	Severe state prevention/restoration product (Predictive long-term local active product)	Enhanced severe weather condition management and outage management
Identification of the available flexibility resources from DSO and microgrid voltage levels	Predictive congestion management for TSO/DSO product, Power regulation through mFRR and RR – active power product, Reactive power support product	Enhanced Active Power Management for TSO-DSO coordination
DSO, DG and micro grid POI management (Point of Interest updates, technical data, historic data, forecasted data…)	N/A	Enhanced Active Power Management for TSO-DSO coordination

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		Enhanced severe weather condition management and outage management
Change View - different aggregation level simulations (Energy predictions and system state predictions for different aggregation levels of DSO grid and local micro grid: unit level (distributed gen. unit, OHL tower/section), plant level (solar park, wind park, OHL, substation), local micro grid level (part of the DSO grid), DSO/TSO grid level calculations.)	NA	Enhanced Active Power Management for TSO-DSO coordination Enhanced severe weather condition management and outage management

Table A2. Key performance indicators for BUC 1

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
1	Energy production prediction error		– Frequency stability – Load flow and contingency monitoring and predictions – Predictive congestion management for maintaining secure and stable power system operation – Early warning on a hazardous power system regimes, – Better FSPs planning and managing flexibility resources. – Better energy predictions and power system state predictions – Improved identification of the available flexibility resources on all power system levels. – Improved prediction of the system flexibility needs.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

2	Load prediction error		– Frequency stability – Load flow and contingency monitoring and predictions – Predictive congestion management for maintaining secure and stable power system operation – Early warning on a hazardous power system regime, – Better FSPs planning and managing flexibility resources. – Better energy predictions and power system state predictions – Improved identification of the available flexibility resources on all power system levels. – Improved prediction of the system flexibility needs.
3	Load flow prediction error		– Frequency stability – Load flow and contingency monitoring and predictions – Predictive congestion management for maintaining secure and stable power system operation – Early warning on a hazardous power system regime, – Better FSPs planning and managing flexibility resources. – Better energy predictions and power system state predictions – Improved identification of the available flexibility resources on all power system levels. – Improved prediction of the system flexibility needs.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

4	Capacity prediction error		– Load flow and contingency monitoring and predictions – Predictive congestion management for maintaining secure and stable power system operation
5	Transmission losses prediction error		– Cost-effective operation of the system
6	Contingency identification rate		– Better energy predictions and power system state predictions – Predictive congestion management for maintaining secure and stable power system operation – Early warning on a hazardous power system regimes
7	Early warning on a hazardous power system regimes rate		– Better energy predictions and power system state predictions – Predictive congestion management for maintaining secure and stable power system operation – Early warning on a hazardous power system regimes

Table A3. Actors involved in BUC 1

Actors			
Grouping (e.g. domains, zones)		***Group description***	
Actor name	***Actor type***	***Actor description***	***Further information specific to this use case***
Weather forecast provider;	Information provider	Unit inside the TSO/DSO, or contracted outsourced weather	POI weather forecasts are used as an input data for energy

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		forecast provider company responsible for weather forecasts for selected weather parameters and selected locations in the grid.	predictions, as well as for AI base PS state forecast.
Load Forecasting operator (DSO/Micro-grid operator);	Information provider	DSO/Short term planning department load forecasting operator is responsible for consumption short term, mid-term and long term forecasts, later on used for TSO level modelling under f-channel platform coordination: IGM updates, DACF and 2DACF procedures, Contingency Analysis and Capacity Calculations.	Load forecasts are using weather forecasts as an input and as an output provide further inputs for various functionalities inside of the f-channel platform as and input for further simulations, calculations and analysis.
Production Forecasting operator (DSO/Micro-grid operator);	Information provider	DSO/Short term planning department production forecasting operator is responsible for wind, solar and hydro, short term, mid-term and long term production forecasts, later on used for TSO	Production forecasts (in the case of F-channel, wind and solar parks production forecasts) are using weather forecasts as an input and as an output provide further inputs for various functionalities inside of

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		level modelling under f-channel platform coordination: IGM updates, DACF and 2DACF procedures, Contingency Analysis and Capacity Calculations.	the f-channel platform as and input for further simulations, calculations and analysis.
Production Forecasting operator (TSO/Aggregator);	Information receiver/provider	TSO/Aggregator Short term planning department production forecasting operator is responsible for wind, solar and hydro, short term, mid-term and long term production forecasts, later on used for TSO level modelling under f-channel platform coordination: IGM updates, DACF and 2DACF procedures, Contingency Analysis and Capacity Calculations.	Production forecasts (in the case of F-channel, wind and solar parks production forecasts) are using weather forecasts as an input and as an output provide further inputs for various functionalities inside of the f-channel platform as and input for further simulations, calculations and analysis.
Load Forecasting operator (TSO/Aggregator);	Information receiver/provider	TSO/Aggregator Short term planning department load forecasting operator is responsible for consumption short term, mid-term and long term forecasts, later on used	Load forecasts are using weather forecasts as an input and as an output provide further inputs for various functionalities inside of the f-channel platform as and input for further

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		for TSO level modelling under f-channel platform coordination: IGM updates, DACF and 2DACF procedures, Contingency Analysis and Capacity Calculations.	simulations, calculations and analysis.
Flexibility Register Operator (FRO);	Information receiver		
Production scheduling operator (market operator);	Information receiver		
DACF operator (TSO and corresponding expert in DSO);	Information receiver/provider	An expert from TSO/Short term planning department, responsible for day ahead congestion forecast simulation and analysis which as an output gives the list of critical elements and critical outages with the list of possible mitigation measures…If the DACF is performed by a national TSO than targeted, analysed system is usually only a national power system and first neighbouring systems.	DACF operator uses production forecasts, load forecasts and capacity forecasts, all already modelled inside of the IGM - Individual Grid Model, and performed n-1 analysis, so called contingency analysis on CGM - Common Grid Model, which is previously merged from IGM and all surrounding system models.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

2DACF operator (TSO and corresponding expert in DSO);	Information receiver/provider	The same as previous	The same as previous
IGM manager (TSO and corresponding expert in DSO);	Information receiver/provider	TSO/Short term planning department Expert/s responsible for development, maintenance and regular updates of an Individual Grid Models containing: consumption nodes (active and reactive power), production nodes (active power and voltage set), overall voltage profile, assumed power exchanges with the neighbouring systems...IGM models are further used by DACF, 2DACF and ATC calculator for further simulations, calculations and analysis.	IGM is being produced using production forecasts, load forecasts and condition forecasts outputs..
ATC calculator (TSO and RSC);	Information receiver/provider	TSO/Short term planning department Expert in charge of short to long term available capacity calculations, flow based or ATC based (bilateral or composite values).	IGM is being processed under f-channel platform, being updated with the new production, load and capacity/rating values for selected POIs. IGM is than being transferred

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			back to TSO main server and processed by ATC calculator for further available capacity calculations or simulations are done in a virtual f-channel grid environment..
Power system control expert (TSO/DSO);	Information receiver	TSO Operational personnel working on intraday - real time power system control and operations in a dispatching room, using DACF, 2DACF, Outage schedules, production schedules and Contingency Analysis outputs that are prepared on a 2day-ahead, or day-ahead basis. Also, these experts are using SCADA/EMS in order to perform intraday 5-15 min simulations and contingency analysis in order to update of the same analysis in a real time....	IGM, with 2-4 per day updates, is being processed under f-channel platform, being updated with the new production, load and capacity/rating values for selected POIs, covered by F-CHANNEL forecasting tool. IGM is than being transferred back to TSO main server and processed by operational personnel.
Balancing mechanism operator (TSO)	Information receiver		

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

RES Scheduling operator (TSO based);	Information receiver		
Losses calculator (TSO)	Information receiver	Improved forecasting of grid losses and available future capacities	
Regional DACF operator (RSC)	Information receiver	An expert from RSC-Regional Security Center, responsible for day ahead congestion forecast simulation and analysis which as an output gives the list of critical elements and critical outages with the list of proposed mitigation measures…If the DACF is performed by a RSC than targeted, analysed system is usually regional, CCR based network model (CGM - Common Grid Model).	RSC's DACF operator uses production forecasts, load forecasts and capacity forecasts, all already modelled inside of the CGM - Common Grid Model, and performed n-1 analysis, so called contingency analysis on CGM - Common Grid Model, which is previously merged from IGM and all surrounding system models, in this case covering its CCR.
Regional 2DACF operator (RSC)	Information receiver	The same as previous	The same as previous
CGM manager (RSC)	Information receiver	TSO/Short term planning department or and RSC's Expert/s responsible for development,	CGM is being produced using production forecasts, load forecasts and condition forecasts

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		maintenance and regular updates of a Common Grid Models containing: consumption nodes (active and reactive power), production nodes (active power and voltage set), overall voltage profile, assumed power exchanges with the neighbouring systems...CGM models are further used by DACF, 2DACF and ATC calculator for further simulations, calculations and analysis.	submodule outputs. CGM in the case of the F-CHANNEL platform represents an interface between a simulation/calculation/analysis tools that already exist in the RSC and/or TSO Energy Management Systems.
ATC coordinated calculator (TSO or RSC)	Information receiver	RSC's Expert in charge of short to long term available capacity calculations, flow based or ATC based (bilateral or composite values), calculated in a coordinated manner for all regional borders simultaneously or at least during the same calculation process.	CGM is being processed under F-CHANNEL platform, being updated with the new production, load and capacity/rating values for selected POIs, covered by F-CHANNEL forecasting tool. CGM is than being transferred back to RSC main server and processed by ATC calculator for further available capacity calculations.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Production Forecasting/Scheduling operator (Regional RES coordinator)	Information receiver	Future regional RES production coordinators...Still does not exist, but is foreseen by CEP...It will have a coordination role for all RES units, not only national/system located but all regional RES production will be run from this body. The role and relationship with the F-CHANNEL will be similar to what is now being used by TSOs for this same functionality which covers production forecasts...	

Table A4. Scenarios to be tested in the Greek demo

Scenario conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***
1	Contingency identification and mitigation	Potential contingencies are identified up front (predicted) in the distribution and transmission grids via improved power system state prediction tools. The flexible resources are	-FSP (energy storage, PVs) - Aggregators - Prosumers -DSO	Predicted contingency in the DSO or TSO grid	- High Resolution Numerical Weather Predictions with the extended geographical coverage and look into	Flexible resources will increase or decrease their active power output to shift an amount of energy to

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		coordinated by the DSO and TSO to provide active power regulation services in order to relieve the local contingency of the grid. The flexible resources participating in this scenario have already being awarded by the market (declaring their availability through bids) and their bids have been pre-qualified by the DSO or TSO in order to participate to the Predictive short-term local active product.	-TSO		the future. Available DSO and TSO voltage level forecasted grid models.	resolve contingency in the distribution or transmission grid.
2	Coordinated voltage control	Potential overvoltage or under voltage severe states are identified, predicted up front. This are the states that can endanger overall power system voltage stability. In case of voltage instability, the DSO will coordinate the flexible resources to provide reactive	-FSP (energy storage, PVs) -Aggregators -Prosumers -DSO -TSO	Predicted overvoltage or under voltage severe states in the DSO or TSO grid		In the occurrence of a predicted overvoltage or under voltage severe state that can endanger overall power system voltage

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		power flexibility. The flexible resources participating in this scenario have already being awarded by the market (declaring their availability through bids) and their bids have been pre-qualified by the DSO in order to participate to the reactive power compensation. It is also possible to use the reactive power from a TSO level through the interconnection transformers with the TAP change possibility.				stability. Provide/absorb of a certain amount MVarh in specific timeframes in local distribution grid through optimized coordinated tap change control on TSO-DSO interface, through an improved forecasts of the power system state on both TSO and DSO voltage levels. It can be used to regulate voltage and reduce energy losses in distribution grid and is

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

						linked with the voltage control. The reactive support product will be automatically activated, and the flexibility resource will provide reactive compensation to the distribution grid when needed. The activation time could be from 15 minutes to 1 hour.
3	Improved power regulation through mFRR and RR	Provide identification of flexibility resources (primary, secondary and available tertiary reserve) more precisely, as well as identification of the flexibility needs in a	-FSP (energy storage, PVs) - Aggregators - Prosumers	Predicted available reserves in the DSO or TSO grid	- High resolution Numerical Weather Predictions with the extended geographical coverage	Flexible resources will increase or decrease their active power output in order to support the

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		more precise manner and longer time horizon than it is being done today. The activation time could be from 15 minutes to 1 hour.	-TSO		and look into the future. Available DSO and TSO voltage level forecasted grid models.	frequency stability.

Table A5. Step- by-step analysis of the scenario 1

Scenario								
Scenario name		Contingency identification and mitigation						
Step No	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information exchanged (IDs)***	***Requirement, R-IDs***
1.1	Weather predictions	Trigger of the scenario	Unit inside the TSO/DSO, or contracted outsourced weather forecast provider company responsible for weather forecasts	CREATE	Weather forecast provider;	TSO, DSO short term planning departments	I1-01	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			for selected weather parameters and selected locations in the grid is providing us with the high resolution NWP.					
1.2	Energy predictions	Calculation of energy production and consumption	DSO/ TSO Short term planning department production forecasting operator is responsible for wind, solar and hydro, short	CREATE	Production and Load forecasting operator in DSO and TSO	IGM model operators	I1-02	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			term, mid-term and long term production forecasts, later on used for TSO level modelling under f-channel platform coordination: IGM updates, DACF and 2DACF procedures, Contingency Analysis and Capacity Calculations.					
1.3	IGM updates	Updating the INDIVIDUAL Grid Models	TSO/ DSO Short term planning departm	CREATE	IGM model operators	DACF and 2DACF operators in TSO and DSO	I1-03	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			ent Expert/s responsible for development, maintenance and regular updates of an Individual Grid Models containing: consumption nodes (active and reactive power), production nodes (active power and voltage set), overall voltage profile, assumed					

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			power exchanges with the neighbouring systems...IGM models are further used by DACF, 2DACF and ATC calculator for further simulations, calculations and analysis.					
1.4	Contingency predictions	Contingency analysis and identification of the problems in the system	An expert from TSO/DSO Short term planning department, responsible for day	REPORT	DACF and 2DACF operators in TSO and DSO	Power system control expert (TSO/DSO);	I1-04	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			ahead congestion forecast simulation and analysis which as an output gives the list of critical elements and critical outages with the list of possible mitigation measures …If the DACF is performed by a national TSO than targeted, analysed system is usually only a					

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			national power system and first neighbouring systems. Based on energy production and consumption predictions, grid simulation models are formed in order to be able to perform contingency analysis and identify potential contingencies in the grid.					
1.5	Mitigation	Identification	An expert	REPORT	DACF and	Power system	I1-05	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

	measure identification	of the list of potential mitigation measures	from TSO/DSO Short term planning department, responsible for day ahead congestion forecast simulation and analysis which as an output gives the list of possible mitigation measures …		2DACF operators in TSO and DSO	control expert (TSO/DSO);		
1.6	FSP response	Evaluation of the available responsiveness of the	Monitoring of the responsiveness of the flexible	EXECUTE	TSO and DSO, FSPs	Market operator	I1-06	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		flexible resources	resources by the TSO and DSO in order to evaluate whether the flexible resources have the proper response to the event. The evaluation report is provided to the market operator.					

Table A6. Step- by-step analysis of the scenario 2

Scenario								
Scenario name		Coordinated voltage control						
Step No	***Event***	***Name of process/ activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information exchanged (IDs)***	***Requirement, R-IDs***

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

2.1	Weather predictions	Trigger of the scenario	Unit inside the TSO/DSO, or contracted outsourced weather forecast provider company responsible for weather forecasts for selected weather parameters and selected locations in the grid is providing us with the high resolution NWP.	CREATE	Weather forecast provider;	TSO, DSO short term planning departments	I2-01	
2.2	Energy predictions	Calculation of energy production and consumption	DSO/TSO Short term planning department production forecasting operator is responsible for wind, solar and hydro, short term, mid-term and long term production	CREATE	Production and Load forecasting operator in DSO and TSO	IGM model operators	I2-02	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			forecasts, later on used for TSO level modelling under f-channel platform coordination: IGM updates, DACF and 2DACF procedures, Contingency Analysis and Capacity Calculations.					
2.3	IGM updates	Updating the INDIVIDUAL Grid Models	TSO/DSO Short term planning department Expert/s responsible for development, maintenance and regular updates of an Individual Grid Models containing: consumption nodes (active and reactive power), production nodes (active	CREATE	IGM model operators	DACF and 2DACF operators in TSO and DSO	I2-03	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			power and voltage set), overall voltage profile, assumed power exchanges with the neighbouring systems...IGM models are further used by DACF, 2DACF and ATC calculator for further simulations, calculations and analysis.					
2.4	Voltage condition prediction	Load flow and voltage profile calculation	Voltage profile for all power system substations that are in operation.	REPORT	DACF and 2DACF operators in TSO and DSO	Power system control expert (TSO/DSO);	I2-04	
2.5	Mitigation measure identification	Identification of the list of potential mitigation measures	Identification of a FSPs that can contribute to the resolution of the identified over or under	REPORT	DACF and 2DACF operators in TSO and DSO	Power system control expert (TSO/DSO);	I2-05	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			voltage in the system.					
2.6	Provision of reactive power flexibility services	Maintain proper and efficient grid operation	The flexible resources regulate their reactive power injection to the grid to relieve congestion, improve voltage stability and power factor, and symmetrize the grid loading condition. These services are provided according to the DSO coordination set points. The provision of the services is reported back to the DSO.	EXECUTE	FSP, Aggregator, Prosumer	DSO	I2-06	

Table A7. Step- by-step analysis of the scenario 3

Scenario	
Scenario name	Improved power regulation through mFRR and RR

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Step No	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information exchanged (IDs)***	***Requirement, R-IDs***
3.1	Weather predictions	Trigger of the scenario	Unit inside the TSO/DSO, or contracted outsourced weather forecast provider company responsible for weather forecasts for selected weather parameters and selected locations in the grid is providing us with the high resolution NWP.	CREATE	Weather forecast provider;	TSO, DSO short term planning departments	I3-01	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

3.2	Energy predictions	Calculation of energy production and consumption	DSO/ TSO Short term planning department production forecasting operator is responsible for wind, solar and hydro, short term, mid term and long term production forecasts, later on used for TSO level modelling under f-channel platform	CREATE	Production and Load forecasting operator in DSO and TSO	TSO (transmission monitoring system)	I3-02	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			coordination: IGM updates, DACF and 2DACF procedures, Contingency Analysis and Capacity Calculations.					
3.3	mFRR and RR activation necessary	Trigger of the scenario	TSO needs to activate secondary or tertiary reserve in order to maintain the frequency in the system and maintain the active power exchange	CREATE	TSO (transmission monitoring system)	TSO, FSP, Aggregator, Prosumer	I3-03	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			on its borders like scheduled.					
3.4	Active power support	Provision of active power support	The flexible resources (FSP, aggregators, prosumers) provide active power support to the system. The flexible resources report to the TSO and DSO their activation.	EXECUTE	FSP, Aggregator, Prosumer	TSO and DSO	I3-04	
3.5	Supervision of the active power	Evaluation of the proper responsiv	Monitoring of the responsiveness of	REPORT	TSO and DSO	Market operator	I3-05	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

	support product	eness of the flexible resources	the flexible resources by the TSO and DSO in order to evaluate whether the flexible resources have the proper response to the event. The evaluation report is provided to the market operator.					

Table A8. The information exchanged for the scenario 3

Information exchanged			
Information exchanged, ID	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

I1-01	Weather forecast REPORT	Weather forecast vendor provides json files with the high resolution weather forecast for the predefined Points of Interest.	File exchange or special API developed. Communication between weather forecasting vendor and TSO, DSO short term planning departments.
I1-02	Energy production and load forecast REPORT	DSO and TSO operator is performing energy production and load forecast using f-channel in built AI calculation engines.	Results are stored in a Data Base.
I1-03	Updating the INDIVIDUAL Grid Models	IGM is being updated with the current energy and production forecast.	IGM is kept in CIM xml files or stored in Data Base.
I1-04	Contingency analysis REPORT	Contingencies are identified and registered	Report is stored in the data base in TSO/DSO
I1-05	List of potential mitigation measures REPORT	Mitigation measures identified.	Report is stored in the data base in TSO/DSO
I1-06	Report	List of available FSPs.	Communication between TSO, DSO and the Market Operator
I2-01	Weather forecast REPORT	Weather forecast vendor provides json files with the high resolution weather forecast for the predefined Points of Interest.	File exchange or special API developed. Communication between weather forecasting vendor and TSO, DSO short term planning departments.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

I2-02	Energy production and load forecast REPORT	DSO and TSO operator is performing energy production and load forecast using f-channel in built AI calculation engines.	Results are stored in a Data Base.
I2-03	Updating the INDIVIDUAL Grid Models	IGM is being updated with the current energy and production forecast.	IGM is kept in CIM xml files or stored in Data Base.
I2-04	Load flow and voltage profile REPORT	Over and under voltages are identified and registered	Report is stored in the data base in TSO/DSO
I2-05	List of potential mitigation measures REPORT	Mitigation measures identified.	Report is stored in the data base in TSO/DSO
I2-06	Report	DSO/TSO report to the market operator the evaluation report for the reactive power flexibility services provided by the flexible resources.	Communication between DSO/TSO and the Market Operator
I3-01	Weather forecast REPORT	Weather forecast vendor provides json files with the high resolution weather forecast for the predefined Points of Interest.	File exchange or special API developed. Communication between weather forecasting vendor and TSO, DSO short term planning departments.
I3-02	Energy production and load forecast REPORT	DSO and TSO operator is performing energy production and load forecast using f-	Results are stored in a Data Base.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		channel in built AI calculation engines.	
I3-03			Communication between the flexible resources and the power system operators
I3-04			Communication between the flexible resources and the power system operators
I3-05			Communication between TSO, DSO and the Market Operator

Table A9. Key Performance Indicators for the SUC 8.2.1.1

Key performance indicators			
ID	***Name***	***Description***	***Reference to mentioned use case objectives***
1	Energy production prediction error		– Frequency stability – Better FSPs planning and managing flexibility resources. – Better energy predictions and power system state predictions – Improved identification of the available flexibility resources on all power system levels. – Improved prediction of the system flexibility needs.
2	Load prediction error		– Frequency stability – Early warning on a hazardous power system regime, – Better FSPs planning and managing flexibility resources.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			– Better energy predictions and power system state predictions – Improved identification of the available flexibility resources on all power system levels. – Improved prediction of the system flexibility needs.

Table A10. Information for the Actors for SUC 8.2.1.1

Actors			
Grouping (e.g. domains, zones)		***Group description***	
Actor name	***Actor type***	***Actor description***	***Further information specific to this use case***
Weather forecast provider;	Information provider	Unit inside the TSO/DSO, or contracted outsourced weather forecast provider company responsible for weather forecasts for selected weather parameters and selected locations in the grid.	POI weather forecasts are used as an input data for energy predictions, as well as for AI base PS state forecast.
Load Forecasting operator (DSO/Micro-grid operator);	Information provider	DSO/Short term planning department load forecasting operator is responsible for consumption short term, mid-term and long term forecasts, later on	Load forecasts are using weather forecasts as an input and as an output provide further inputs for various functionalities inside of the f-channel platform as

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		used for TSO level modelling under f-channel platform coordination: IGM updates, DACF and 2DACF procedures, Contingency Analysis and Capacity Calculations.	and input for further simulations, calculations and analysis.
Production Forecasting operator (DSO/Micro-grid operator);	Information provider	DSO/Short term planning department production forecasting operator is responsible for wind, solar and hydro, short term, mid-term and long term production forecasts, later on used for TSO level modelling under f-channel platform coordination: IGM updates, DACF and 2DACF procedures, Contingency Analysis and Capacity Calculations.	Production forecasts (in the case of F-channel, wind and solar parks production forecasts) are using weather forecasts as an input and as an output provide further inputs for various functionalities inside of the f-channel platform as and input for further simulations, calculations and analysis.
Production Forecasting operator (TSO/Aggregator);	Information receiver/provider	TSO/Aggregator Short term planning department production forecasting operator is responsible for wind, solar and hydro, short term, mid-term and long	Production forecasts (in the case of F-channel, wind and solar parks production forecasts) are using weather forecasts as an input and as an output provide further

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		term production forecasts, later on used for TSO level modelling under f-channel platform coordination: IGM updates, DACF and 2DACF procedures, Contingency Analysis and Capacity Calculations.	inputs for various functionalities inside of the f-channel platform as and input for further simulations, calculations and analysis.
Load Forecasting operator (TSO/Aggregator);	Information receiver/provider	TSO/Aggregator Short term planning department load forecasting operator is responsible for consumption short term, mid-term and long term forecasts, later on used for TSO level modelling under f-channel platform coordination: IGM updates, DACF and 2DACF procedures, Contingency Analysis and Capacity Calculations.	Load forecasts are using weather forecasts as an input and as an output provide further inputs for various functionalities inside of the f-channel platform as and input for further simulations, calculations and analysis.
Flexibility Register Operator (FRO);	Information receiver		
Production scheduling operator (market operator);	Information receiver		

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Table A11. Information for the Actors for SUC 8.2.1.2

Actors			
Grouping (e.g. domains, zones)		**Group description**	
Actor name	**Actor type**	**Actor description**	**Further information specific to this use case**
Load Forecasting operator (DSO/Micro-grid operator);	Information provider	DSO/Short term planning department load forecasting operator is responsible for consumption short term, mid-term and long term forecasts, later on used for TSO level modelling under f-channel platform coordination: IGM updates, DACF and 2DACF procedures, Contingency Analysis and Capacity Calculations.	Load forecasts are using weather forecasts as an input and as an output provide further inputs for various functionalities inside of the f-channel platform as and input for further simulations, calculations and analysis.
Production Forecasting operator (DSO/Micro-grid operator);	Information provider	DSO/Short term planning department production forecasting operator is responsible for wind, solar and hydro, short term, mid-term and long term production forecasts, later on used for TSO	Production forecasts (in the case of F-channel, wind and solar parks production forecasts) are using weather forecasts as an input and as an output provide further inputs for various functionalities inside of

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		level modelling under f-channel platform coordination: IGM updates, DACF and 2DACF procedures, Contingency Analysis and Capacity Calculations.	the f-channel platform as and input for further simulations, calculations and analysis.
Production Forecasting operator (TSO/Aggregator);	Information receiver/provider	TSO/Aggregator Short term planning department production forecasting operator is responsible for wind, solar and hydro, short term, mid-term and long term production forecasts, later on used for TSO level modelling under f-channel platform coordination: IGM updates, DACF and 2DACF procedures, Contingency Analysis and Capacity Calculations.	Production forecasts (in the case of F-channel, wind and solar parks production forecasts) are using weather forecasts as an input and as an output provide further inputs for various functionalities inside of the f-channel platform as and input for further simulations, calculations and analysis.
Load Forecasting operator (TSO/Aggregator);	Information receiver/provider	TSO/Aggregator Short term planning department load forecasting operator is responsible for consumption short term, mid-term and long term forecasts, later on used	Load forecasts are using weather forecasts as an input and as an output provide further inputs for various functionalities inside of the f-channel platform as and input for further

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		for TSO level modelling under f-channel platform coordination: IGM updates, DACF and 2DACF procedures, Contingency Analysis and Capacity Calculations.	simulations, calculations and analysis.
Flexibility Register Operator (FRO);	Information receiver		
Production scheduling operator (market operator);	Information receiver		
DACF operator (TSO and corresponding expert in DSO);	Information receiver/provider	An expert from TSO/Short term planning department, responsible for day ahead congestion forecast simulation and analysis which as an output gives the list of critical elements and critical outages with the list of possible mitigation measures...If the DACF is performed by a national TSO than targeted, analysed system is usually only a national power system and first neighbouring systems.	DACF operator uses production forecasts, load forecasts and capacity forecasts, all already modelled inside of the IGM - Individual Grid Model, and performed n-1 analysis, so called contingency analysis on CGM - Common Grid Model, which is previously merged from IGM and all surrounding system models.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

2DACF operator (TSO and corresponding expert in DSO);	Information receiver/provider	The same as previous	The same as previous
IGM manager (TSO and corresponding expert in DSO);	Information receiver/provider	TSO/Short term planning department Expert/s responsible for development, maintenance and regular updates of a Individual Grid Models containing: consumption nodes (active and reactive power), production nodes (active power and voltage set), overall voltage profile, assumed power exchanges with the neighbouring systems...IGM models are further used by DACF, 2DACF and ATC calculator for further simulations, calculations and analysis.	IGM is being produced using production forecasts, load forecasts and condition forecasts outputs..
ATC calculator (TSO and RSC);	Information receiver/provider	TSO/Short term planning department Expert in charge of short to long term available capacity calculations, flow based or ATC based (bilateral or composite values).	IGM is being processed under f-channel platform, being updated with the new production, load and capacity/rating values for selected POIs. IGM is than being transferred

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			back to TSO main server and processed by ATC calculator for further available capacity calculations or simulations are done in a virtual f-channel grid environment..
Power system control expert (TSO/DSO);	Information receiver	TSO Operational personnel working on intraday - real time power system control and operations in a dispatching room, using DACF, 2DACF, Outage schedules, production schedules and Contingency Analysis outputs that are prepared on a 2day-ahead, or day-ahead basis. Also, these experts are using SCADA/EMS in order to perform intraday 5-15 min simulations and contingency analysis in order to update of the same analysis in a real time....	IGM, with 2-4 per day updates, is being processed under f-channel platform, being updated with the new production, load and capacity/rating values for selected POIs, covered by F-CHANNEL forecasting tool. IGM is than being transferred back to TSO main server and processed by operational personnel.
Balancing mechanism operator (TSO)	Information receiver		

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

RES Scheduling operator (TSO based);	Information receiver		
Losses calculator (TSO)	Information receiver	Improved forecasting of grid losses and available future capacities	
Regional DACF operator (RSC)	Information receiver	An expert from RSC-Regional Security Center, responsible for day ahead congestion forecast simulation and analysis which as an output gives the list of critical elements and critical outages with the list of proposed mitigation measures...If the DACF is performed by a RSC than targeted, analysed system is usually regional, CCR based network model (CGM - Common Grid Model).	RSC's DACF operator uses production forecasts, load forecasts and capacity forecasts, all already modelled inside of the CGM - Common Grid Model, and performed n-1 analysis, so called contingency analysis on CGM - Common Grid Model, which is previously merged from IGM and all surrounding system models, in this case covering its CCR.
Regional 2DACF operator (RSC)	Information receiver	The same as previous	The same as previous
CGM manager (RSC)	Information receiver	TSO/Short term planning department or and RSC's Expert/s	CGM is being produced using production forecasts,

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		responsible for development, maintenance and regular updates of a Common Grid Models containing: consumption nodes (active and reactive power), production nodes (active power and voltage set), overall voltage profile, assumed power exchanges with the neighbouring systems...CGM models are further used by DACF, 2DACF and ATC calculator for further simulations, calculations and analysis.	load forecasts and condition forecasts submodule outputs. CGM in the case of the F-CHANNEL platform represents an interface between a simulation/calculation/analysis tools that already exist in the RSC and/or TSO Energy Management Systems.
ATC coordinated calculator (TSO or RSC)	Information receiver	RSC's Expert in charge of short to long term available capacity calculations, flow based or ATC based (bilateral or composite values), calculated in a coordinated manner for all regional borders simultaneously or at least during the same calculation process.	CGM is being processed under F-CHANNEL platform, being updated with the new production, load and capacity/rating values for selected POIs, covered by F-CHANNEL forecasting tool. CGM is than being transferred back to RSC main server and processed by ATC calculator for further available capacity calculations.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Production Forecasting/Scheduling operator (Regional RES coordinator)	Information receiver	Future regional RES production coordinators…Still does not exist, but is foreseen by CEP…It will have a coordination role for all RES units, not only national/system located but all regional RES production will be run from this body. The role and relationship with the F-CHANNEL will be similar to what is now being used by TSOs for this same functionality which covers production forecasts...	

Table A12. Information for the Actors for SUC 8.2.1.3

Key performance indicators			
ID	***Name***	***Description***	***Reference to mentioned use case objectives***
1	Energy production prediction error for the selected domain		– Frequency stability – Load flow and contingency monitoring and predictions – Predictive congestion

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			management for maintaining secure and stable power system operation – Early warning on a hazardous power system regime, – Better FSPs planning and managing flexibility resources. – Better energy predictions and power system state predictions – Improved identification of the available flexibility resources on all power system levels. – Improved prediction of the system flexibility needs.
2	Load prediction error for the selected domain		– Frequency stability

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			– Load flow and contingency monitoring and predictions – Predictive congestion management for maintaining secure and stable power system operation – Early warning on a hazardous power system regime, – Better FSPs planning and managing flexibility resources. – Better energy predictions and power system state predictions – Improved identification of the available flexibility resources on all power system levels.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			– Improved prediction of the system flexibility needs.
3	Load flow prediction error for the selected domain		– Frequency stability – Load flow and contingency monitoring and predictions – Predictive congestion management for maintaining secure and stable power system operation – Early warning on a hazardous power system regimes, – Better FSPs planning and managing flexibility resources. – Better energy predictions and power system state predictions – Improved identification of

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			the available flexibility resources on all power system levels. – Improved prediction of the system flexibility needs.
4	Capacity prediction error for the selected domain		– Load flow and contingency monitoring and predictions – Predictive congestion management for maintaining secure and stable power system operation
5	Transmission losses prediction error for the selected domain		– Cost-effective operation of the system
6	Contingency identification rate for the selected domain		– Better energy predictions and power system state predictions – Predictive congestion management

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			for maintaining secure and stable power system operation – Early warning on a hazardous power system regimes
7	Early warning on a hazardous power system regimes rate for the selected domain		– Better energy predictions and power system state predictions – Predictive congestion management for maintaining secure and stable power system operation – Early warning on a hazardous power system regimes

Table A13 Information for the actors in SUC_8.2.1.3

Actors	
Grouping (e.g. domains, zones)	***Group description***

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Actor name	*Actor type*	*Actor description*	*Further information specific to this use case*
DACF operator (TSO and corresponding expert in DSO);	Information receiver/provider	An expert from TSO/Short term planning department, responsible for day ahead congestion forecast simulation and analysis which as an output gives the list of critical elements and critical outages with the list of possible mitigation measures...If the DACF is performed by a national TSO than targeted, analysed system is usually only a national power system and first neighbouring systems.	DACF operator uses production forecasts, load forecasts and capacity forecasts, all already modelled inside of the IGM - Individual Grid Model, and performed n-1 analysis, so called contingency analysis on CGM - Common Grid Model, which is previously merged from IGM and all surrounding system models.
2DACF operator (TSO and corresponding expert in DSO);	Information receiver/provider	The same as previous	The same as previous
IGM manager (TSO and corresponding expert in DSO);	Information receiver/provider	TSO/Short term planning department Expert/s responsible for development, maintenance and regular updates of n Individual Grid Models containing: consumption nodes (active and reactive power), production	IGM is being produced using production forecasts, load forecasts and condition forecasts outputs..

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		nodes (active power and voltage set), overall voltage profile, assumed power exchanges with the neighbouring systems...IGM models are further used by DACF, 2DACF and ATC calculator for further simulations, calculations and analysis.	
ATC calculator (TSO and RSC);	Information receiver/provider	TSO/Short term planning department Expert in charge of short to long term available capacity calculations, flow based or ATC based (bilateral or composite values).	IGM is being processed under f-channel platform, being updated with the new production, load and capacity/rating values for selected POIs. IGM is than being transferred back to TSO main server and processed by ATC calculator for further available capacity calculations or simulations are done in a virtual f-channel grid environment..
Power system control expert (TSO/DSO);	Information receiver	TSO Operational personnel working on intraday - real time power system control and operations in a dispatching room, using	IGM, with 2-4 per day updates, is being processed under f-channel platform, being updated with the new production, load and

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		DACF, 2DACF, Outage schedules, production schedules and Contingency Analysis outputs that are prepared on a 2day-ahead, or day-ahead basis. Also, these experts are using SCADA/EMS in order to perform intraday 5-15 min simulations and contingency analysis in order to update of the same analysis in a real time....	capacity/rating values for selected POIs, covered by F-CHANNEL forecasting tool. IGM is than being transferred back to TSO main server and processed by operational personnel.
Regional DACF operator (RSC)	Information receiver	An expert from RSC-Regional Security Center, responsible for day ahead congestion forecast simulation and analysis which as an output gives the list of critical elements and critical outages with the list of proposed mitigation measures...If the DACF is performed by a RSC than targeted, analysed system is usually regional, CCR based network model (CGM - Common Grid Model).	RSC's DACF operator uses production forecasts, load forecasts and capacity forecasts, all already modelled inside of the CGM - Common Grid Model, and performed n-1 analysis, so called contingency analysis on CGM - Common Grid Model, which is previously merged from IGM and all surrounding system models, in this case covering its CCR.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Regional 2DACF operator (RSC)	Information receiver	The same as previous	The same as previous
CGM manager (RSC)	Information receiver	TSO/Short term planning department or and RSC's Expert/s responsible for development, maintenance and regular updates of a Common Grid Models containing: consumption nodes (active and reactive power), production nodes (active power and voltage set), overall voltage profile, assumed power exchanges with the neighbouring systems...CGM models are further used by DACF, 2DACF and ATC calculator for further simulations, calculations and analysis.	CGM is being produced using production forecasts, load forecasts and condition forecasts submodule outputs. CGM in the case of the F-CHANNEL platform represents an interface between a simulation/calculation/analysis tools that already exist in the RSC and/or TSO Energy Management Systems.
Production Forecasting/Scheduling operator (Regional RES coordinator)	Information receiver	Future regional RES production coordinators...Still does not exist, but is foreseen by CEP...It will have a coordination role for all RES units, not only national/system located	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		but all regional RES production will be run from this body. The role and relationship with the F-CHANNEL will be similar to what is now being used by TSOs for this same functionality which covers production forecasts...	

Table A14: The KPIs for the SUC_8.2.1.4

Key performance indicators			
ID	***Name***	***Description***	***Reference to mentioned use case objectives***
3	Load flow prediction error		– Frequency stability – Load flow and contingency monitoring and predictions – Predictive congestion management for maintaining secure and stable power system operation – Early warning on a hazardous

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			power system regime, – Better FSPs planning and managing flexibility resources. – Better energy predictions and power system state predictions – Improved identification of the available flexibility resources on all power system levels. – Improved prediction of the system flexibility needs.
4	Capacity prediction error		– Load flow and contingency monitoring and predictions – Predictive congestion management for maintaining secure and stable power

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			system operation
5	Transmission losses prediction error		– Cost-effective operation of the system
6	Contingency identification rate		– Better energy predictions and power system state predictions – Predictive congestion management for maintaining secure and stable power system operation – Early warning on a hazardous power system regimes
7	Early warning on a hazardous power system regimes rate		– Better energy predictions and power system state predictions – Predictive congestion management for maintaining secure and

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			stable power system operation – Early warning on a hazardous power system regimes

Table A15 Information on the actors in SUC 8.2.1.4:

Actors			
Grouping (e.g. domains, zones)		***Group description***	
Actor name	***Actor type***	***Actor description***	***Further information specific to this use case***
DACF operator (TSO and corresponding expert in DSO);	Information receiver/provider	An expert from TSO/Short term planning department, responsible for day ahead congestion forecast simulation and analysis which as an output gives the list of critical elements and critical outages with the list of possible mitigation measures…If the DACF is performed by a national TSO than targeted, analysed system is usually only a national power system and first neighbouring systems.	DACF operator uses production forecasts, load forecasts and capacity forecasts, all already modelled inside of the IGM - Individual Grid Model, and perform n-1 analysis, so called contingency analysis on CGM - Common Grid Model, which is previously merged from IGM and all surrounding system models.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

2DACF operator (TSO and corresponding expert in DSO);	Information receiver/provider	The same as previous	The same as previous
IGM manager (TSO and corresponding expert in DSO);	Information receiver/provider	TSO/Short term planning department Expert/s responsible for development, maintenance and regular updates of a Individual Grid Models containing: consumption nodes (active and reactive power), production nodes (active power and voltage set), overall voltage profile, assumed power exchanges with the neighbouring systems...IGM models are further used by DACF, 2DACF and ATC calculator for further simulations, calculations and analysis.	IGM is being produced using production forecasts, load forecasts and condition forecasts outputs..
ATC calculator (TSO and RSC);	Information receiver/provider	TSO/Short term planning department Expert in charge of short to long term available capacity calculations, flow based or ATC based (bilateral or composite values).	IGM is being processed under f-channel platform, being updated with the new production, load and capacity/rating values for selected POIs. IGM is than being transferred

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			back to TSO main server and processed by ATC calculator for further available capacity calculations or simulations are done in a virtual f-channel grid environment..
Power system control expert (TSO/DSO);	Information receiver	TSO Operational personnel working on intraday - real time power system control and operations in a dispatching room, using DACF, 2DACF, Outage schedules, production schedules and Contingency Analysis outputs that are prepared on a 2day-ahead, or day-ahead basis. Also, these experts are using SCADA/EMS in order to perform intraday 5-15 min simulations and contingency analysis in order to update of the same analysis in a real time....	IGM, with 2-4 per day updates, is being processed under f-channel platform, being updated with the new production, load and capacity/rating values for selected POIs, covered by F-CHANNEL forecasting tool. IGM is than being transferred back to TSO main server and processed by operational personnel.
Losses calculator (TSO)	Information receiver	Improved forecasting of grid losses and	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		available future capacities	
Regional DACF operator (RSC)	Information receiver	An expert from RSC-Regional Security Center, responsible for day ahead congestion forecast simulation and analysis which as an output gives the list of critical elements and critical outages with the list of proposed mitigation measures…If the DACF is performed by a RSC than targeted, analysed system is usually regional, CCR based network model (CGM - Common Grid Model).	RSC's DACF operator uses production forecasts, load forecasts and capacity forecasts, all already modelled inside of the CGM - Common Grid Model, and performed n-1 analysis, so called contingency analysis on CGM - Common Grid Model, which is previously merged from IGM and all surrounding system models, in this case covering its CCR.
Regional 2DACF operator (RSC)	Information receiver	The same as previous	The same as previous
CGM manager (RSC)	Information receiver	TSO/Short term planning department or and RSC's Expert/s responsible for development, maintenance and regular updates of a Common Grid Models containing: consumption nodes (active and reactive	CGM is being produced using production forecasts, load forecasts and condition forecasts submodule outputs. CGM in the case of the F-CHANNEL platform represents an interface between a

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		power), production nodes (active power and voltage set), overall voltage profile, assumed power exchanges with the neighbouring systems...CGM models are further used by DACF, 2DACF and ATC calculator for further simulations, calculations and analysis.	simulation/calculation/analysis tools that already exist in the RSC and/or TSO Energy Management Systems.
ATC coordinated calculator (TSO or RSC)	Information receiver	RSC's Expert in charge of short to long term available capacity calculations, flow based or ATC based (bilateral or composite values), calculated in a coordinated manner for all regional borders simultaneously or at least during the same calculation process.	CGM is being processed under F-CHANNEL platform, being updated with the new production, load and capacity/rating values for selected POIs, covered by F-CHANNEL forecasting tool. CGM is than being transferred back to RSC main server and processed by ATC calculator for further available capacity calculations.
Production Forecasting/Scheduling operator (Regional RES coordinator)	Information receiver	Future regional RES production coordinators...Still does not exist, but is foreseen by CEP...It will have a coordination role for all	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		RES units, not only national/system located but all regional RES production will be run from this body. The role and relationship with the F-CHANNEL will be similar to what is now being used by TSOs for this same functionality which covers production forecasts...	

Table A16. Key performance indicators for BUC 2.

Key performance indicators			
ID	***Name***	***Description***	***Reference to mentioned use case objectives***
1	Ice appearance prediction error		– Predictive congestion management for maintaining secure and stable power system operation – Early warning on a hazardous power system regimes
2	Storm appearance prediction error		– Predictive congestion

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			management for maintaining secure and stable power system operation – Early warning on a hazardous power system regimes
3	Optimal PS operation due to optimisation of the planned outages		– Predictive congestion management for maintaining secure and stable power system operation – Early warning on a hazardous power system regimes
4	Early warning on a hazardous power system regimes		– Predictive congestion management for maintaining secure and stable power system operation – Early warning on a hazardous

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			power system regimes

Table A17. Conditions / assumptions/prerequisites for the BUC 2

<table>
<tr><th colspan="3">Use case conditions</th></tr>
<tr><th colspan="3">Assumptions</th></tr>
<tr><td colspan="3">– The use case will be developed and demonstrated in a non-invasive, offline environment using the power system simulation models,
– Aggregators and prosumers will be simulated in the demonstration.
– Additional DERs will be simulated if necessary in order to represent the near future conditions</td></tr>
<tr><th colspan="3">Prerequisites</th></tr>
<tr><td></td><td>Availability of the network and market data</td><td>• Network models (in raw or uct file exchange format) data: IPTO and HEDNO network models (400 kV, 220 kV, 150 kV, 110 kV, 35 kV and 20 kV) voltage levels),
• Geospatial data: GPS coordinates, locations of considered RES production POIs and other power system elements of interest, including detailed routing and positions of each tower for the analysed WPPs and OHLs.
• Technical data: Technical data on wind turbines, solar parks, OHLs
• Historic weather and energy data: historic measured and forecasted data related to the weather and energy production/consumption of the analysed points of interest in Greece (Crete and Peloponnese).
• Information on the current practice and state of the art with the tools used for the forecasting, congestion management and balancing in TSO, DSO and producer/aggregator.
• Energy policy information: Information on applicable EU Directives and Regulations that are of interest for TSO DSO coordination.</td></tr>
</table>

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

	Active participation of the primary users (TSO, DSO, aggregator)	TSO, DSO and aggregator's departments for short term planning as well as departments for system operations and control should be deeply involved in the simulations and testing of the platform.

Table A18 Actors for BUC 2

Actors			
Grouping (e.g. domains, zones)		***Group description***	
Actor name	***Actor type***	***Actor description***	***Further information specific to this use case***
Weather forecast provider;	Information provider	Unit inside the TSO/DSO, or contracted outsourced weather forecast provider company responsible for weather forecasts for selected weather parameters and selected locations in the grid.	POI weather forecasts are used as an input data for energy predictions, as well as for AI base PS state forecast.
DSO/Micro grid operator	Information provider	DSO/Micro grid operator responsible for the overall O&M activates in a certain geographical area.	Load forecasts are using weather forecasts as an input and as an output provide further inputs for various functionalities inside of the f-channel platform as and input for further

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			simulations, calculations and analysis.
Maintenance and asset management operator (TSO/DSO)	Information receiver/provider	TSO/DSO asset department expert in charge of grid maintenance planning which uses grid condition forecasts to foresee potential risks and prepare a proper mitigation or preventive measures for it.	Condition forecasts module and its alarm system presented on a GIS based Grid map is utilised by maintenance and asset management operator for the above described purpose.
Outage scheduler (TSO/DSO)	Information receiver/provider	Expert in charge of outage planning. Outage schedules are further on used for IGM and CGM development and regular updates of a grid topology inside models. This person is an interface between TSO transmission department and TSO short term planning department, making sure that all maintenance activities are well covered and foreseen by IGM topology updates and simulations as well.	Outage scheduler has important role in IGM regular updates and its valuable inputs are further being used by all above listed simulations, calculations and analysis.
DACF operator (TSO and corresponding expert in DSO);	Information receiver/provider	An expert from TSO/DSO Short term planning department,	DACF operator uses production forecasts, load forecasts and

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		responsible for day ahead congestion forecast simulation and analysis which as an output gives the list of critical elements and critical outages with the list of possible mitigation measures...If the DACF is performed by a national TSO than targeted, analysed system is usually only a national power system and first neighbouring systems.	capacity forecasts, all already modelled inside of the IGM - Individual Grid Model, and performed n-1 analysis, so called contingency analysis on CGM - Common Grid Model, which is previously merged from IGM and all surrounding system models.
2DACF operator (TSO and corresponding expert in DSO);	Information receiver/provider	The same as previous	The same as previous
IGM manager (TSO and corresponding expert in DSO);	Information receiver/provider	TSO/DSO Short term planning department Expert/s responsible for development, maintenance and regular updates of an Individual Grid Models containing: consumption nodes (active and reactive power), production nodes (active power and voltage set), overall voltage profile, assumed power exchanges with	IGM is being produced using production forecasts, load forecasts and condition forecasts outputs..

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		the neighbouring systems...IGM models are further used by DACF, 2DACF and ATC calculator for further simulations, calculations and analysis.	
ATC calculator (TSO and RSC);	Information receiver/provider	TSO/Short term planning department Expert in charge of short to long term available capacity calculations, flow based or ATC based (bilateral or composite values).	IGM is being processed under f-channel platform, being updated with the new production, load and capacity/rating values for selected POIs. IGM is than being transferred back to TSO main server and processed by ATC calculator for further available capacity calculations or simulations are done in a virtual f-channel grid environment..
Flexibility Register Operator (FRO);	Information receiver		
Production scheduling operator (market operator);	Information receiver		

Table A19. Information on the scenarios for BUC 2

Scenario conditions

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Early severe state warning system / prevention and restoration	In order to avoid severe damages of the equipment and load losses it is of outmost importance to prepare the power system elements for the incoming severe weather conditions as well as for the severe power system state conditions. Provide improved identification of a severe system states and contingencies that can cause severe	TSO, DSO, Wind production units	Predicted contingency in the DSO or TSO grid	- High Resolution Numerical Weather Predictions with the extended geographical coverage and look into the future. Available DSO and TSO voltage level forecasted grid models.	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		system states in a more precise manner and longer time horizon than it is being done today together with the improved identification of flexibility resources, as well as improved identification of the flexibility needs. The activation time could be from 15 minutes to 1 hour.				

Table A20. Step-by-step analysis for scenario 1

Scenario	
Scenario name	Contingency identification and mitigation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Step No	Event	Name of process/ activity	Description of process/ activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1.1	Weather predictions	Trigger of the scenario	Unit inside the TSO/DSO, or contracted outsourced weather forecast provider company responsible for weather forecasts for selected weather parameters and selected locations in the grid is providing us with the high resolution NWP.	CREATE	Weather forecast provider;	TSO, DSO short term planning departments	I1-01	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

1.2	Energy predictions	Calculation of energy production and consumption	DSO/ TSO Short term planning department production forecasting operator is responsible for wind, solar and hydro, short term, mid-term and long term production forecasts, later on used for TSO level modelling under f-channel platform	CREATE	Production and Load forecasting operator in DSO and TSO	IGM model operators	I1-02	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			coordination: IGM updates, DACF and 2DACF procedures, Contingency Analysis and Capacity Calculations.					
1.3	IGM updates	Updating the INDIVIDUAL Grid Models	TSO/ DSO Short term planning department Expert/s responsible for development, maintenance and regular updates of an Individual Grid Models	CREATE	IGM model operators	DACF and 2DACF operators in TSO and DSO	I1-03	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			containing: consumption nodes (active and reactive power), production nodes (active power and voltage set), overall voltage profile, assumed power exchanges with the neighbouring systems...IGM models are further used by DACF, 2DACF and ATC					

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			calculator for further simulations, calculations and analysis.					
1.4	Severe power system state identification	Contingency analysis and identification of the problems in the system focusing on the severe power system state conditions	An expert from TSO/DSO Short term planning department, responsible for day ahead congestion forecast simulation and analysis which as an output gives the list of critical elements	REPORT	DACF and 2DACF operators in TSO and DSO	Power system control expert (TSO/DSO);	I1-04	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			and critical outages with the list of possible mitigatiom measures …If the DACF is performed by a national TSO than targeted, analysed system is usualy only a national power system and first neighbouring systems. Based on energy production and consumption predictio					

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			ns, grid simulation models are formed in order to be able to perform contingency analysis and identify potential contingencies in the grid.					
1.5	Mitigation measure identification	Identification of the list of potential mitigation measures	An expert from TSO/DSO Short term planning department, responsible for day ahead congestion forecast	REPORT	DACF and 2DACF operators in TSO and DSO	Power system control expert (TSO/DSO);	I1-05	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			simulation and analysis which as an output gives the list of possible mitigation measures …					

Table A21. Information exchange for scenario 1

Information exchanged			
Information exchanged, ID	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
I1-01	Weather forecast REPORT	Weather forecast vendor provides json files with the high resolution weather forecast for the predefined Points of Interest.	File exchange or special API developed. Communication between weather forecasting vendor and TSO, DSO short term planning departments.
I1-02	Energy production and load forecast REPORT	DSO and TSO operator is performing energy production and load forecast using f-channel in built AI calculation engines.	Results are stored in a Data Base.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

I1-03	Updating the INDIVIDUAL Grid Models	IGM is being updated with the current energy and production forecast.	IGM is kept in CIM xml files or stored in Data Base.
I1-04	Contingency analysis and severe state REPORT	Contingencies that can lead to the severe power system state are identified and registered	Report is stored in the data base in TSO/DSO
I1-05	List of potential mitigation measures REPORT	Mitigation measures identified.	Report is stored in the data base in TSO/DSO

Table A22. Key performance indicators for SUC 8.2.2.1

Key performance indicators			
ID	***Name***	***Description***	***Reference to mentioned use case objectives***
1	Contingency identification rate		– Better energy predictions and power system state predictions – Predictive congestion management for maintaining secure and stable power system operation – Early warning on a hazardous

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

			power system regimes
2	Early warning on a hazardous power system regimes rate		– Better energy predictions and power system state predictions – Predictive congestion management for maintaining secure and stable power system operation – Early warning on a hazardous power system regimes

Table A23: Information on the actors for the SUC 8.2.2.1

Actors			
Grouping (e.g. domains, zones)		***Group description***	
Actor name	***Actor type***	***Actor description***	***Further information specific to this use case***
Weather forecast provider;	Information provider	Unit inside the TSO/DSO, or contracted outsourced weather forecast provider company responsible for	POI weather forecasts are used as an input data for energy predictions, as well as for AI base PS state forecast.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		weather forecasts for selected weather parameters and selected locations in the grid.	
Maintenance and asset management operator (TSO/DSO)	Information receiver		
Outage scheduler (TSO/DSO)	Information receiver		

Table A24 Harmonisation of the products identified by Greek Demo

Products proposed by Greek Demo	**Description**	**Harmonised Products**
Reactive support	Provide/absorb a certain amount MVarh in specific timeframes in the local distribution grid through optimized coordinated tap change control on the TSO-DSO interface. It can be used to regulate voltage and reduce energy losses in the distribution grid and is linked with voltage control. The reactive support product will be automatically activated and the flexibility resource will provide reactive compensation to the distribution grid when needed.	Corrective local reactive
Predictive congestion management for TSO/DSO product	For a situation where forecasted or realized power flows violate the thermal limits of the elements of the grid and voltage stability or the angle stability limits of the power system. [Predictive] For congestions that are forecastable (e.g. redispatch, countertrading as well as the use of active power flexibility) grid- or market-related measures can be procured.	Predictive short-term local active

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Power regulation mFRR	Provide identification of flexibility resources (secondary and available tertiary reserve) more precisely, as well as identification of the flexibility needs in a more precise manner and longer time horizon than it is being done today.	mFRR
Power regulation RR	Provide identification of flexibility resources (secondary and available tertiary reserve) more precisely, as well as identification of the flexibility needs in a more precise manner and longer time horizon than it is being done today.	RR
Severe state prevention/restoration product	Provide improved identification of severe system states and contingencies that can cause severe system states in a more precise manner and longer time horizon than it is being done today together with the improved identification of flexibility resources, as well as improved identification of the flexibility needs.	Predictive long-term local active

Table A25. Actors related to the BUCs of Cyprus demonstration

Actor name	***Actor description***	***Further information specific to this use case***
Transmission system Operator	A party responsible for operating, ensuring the maintenance of and, if necessary, developing the system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the transmission grid to meet reasonable demands for the transmission of electricity.	Transmission system Operator will procure products related to frequency and congestion management services. In addition, TSO will procure products related to day-ahead active power management services.
Distribution system operator	A party responsible for operating, ensuring the maintenance of and, if necessary, developing the system in a given area and, for ensuring the long-term ability of the distribution grid to meet reasonable demands for the distribution of electricity.	Distribution system operator will procure products related to the congestion management services and will coordinate the provision of services.
Aggregator	A party that aggregates resources for usage by a service provider for energy market services.	Aggregator will provide congestion and frequency management services,

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

		as well as day-ahead active power management services.
Prosumer	A party that produces and consumes electricity.	Prosumer will provide congestion and frequency management services
Market operator	A market operator is a party that provides a service whereby the offers to sell electricity or electricity flexibility are matched with bids to buy electricity or electricity flexibility.	The market operator will award market products related to frequency and congestion management services, while MO will also handle products related to the day ahead active power management services.
Flexibility Service Provider (FSP)	A party providing flexibility services to energy stakeholders via bilateral agreements or flexibility markets.	FSP will provide frequency and congestion management services

TableA26. Key performance indicators for evaluating the performance improvement by the Cyprus demonstration

Key performance indicators			
ID	***Name***	***Description***	***Relation to use case objectives***
1	Rate of Change of Frequency (ROCOF)	This indicator considers the maximum rate of change of frequency (in Hz/s) after an intense disturbance on system balancing	Frequency Stability
2	Frequency Nadir	This indicator considers the minimum frequency (in Hz) observed after an intense disturbance on system balancing	Frequency Stability
3	Overloading	This indicator will provide information for the duration and the intensity of the overloading conditions occurs at the distribution grid	Congestion management
4	System operating cost	The overall operational cost for the system to serve the demand considering forecasting uncertainties.	Cost-effective operation of the system
5	Voltage limits violations	This indicator will provide information for the duration and the intensity of the over/under-voltage conditions occurs at the distribution grid	Congestion management, Voltage stability

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

6	Energy losses	Energy losses dissipated to the distribution grid	Congestion management
7	Loading asymmetries	This indicator will provide information about the loading asymmetry of the three phases, before and after the power quality enhancement	Power quality enhancement

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739