# A novel smart grid architecture that facilitates high RES penetration through innovative markets towards efficient interaction between advanced electricity grid management and intelligent stakeholders

H2020-GA-863876

# FLEXGRID use case scenarios, requirements' analysis and correlation with innovative models

## Deliverable D2.1

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# Glossary of Acronyms

**Project management terminology**

| Acronym | Definition |
|---|---|
| D | Deliverable |
| DoA | Description of Action |
| EC | European Commission |
| HLUC | High Level Use Case |
| MS | Milestone |
| RQT | Requirement |
| WP | Work Package |
| UCS | Use Case Scenario |

**Technical terminology**

| Acronym | Definition |
|---|---|
| AC-OPF | Alternating Current Optimal Power Flow |
| ADMo | Advanced Distribution Monitoring |
| AECC | Aggregated Energy Consumption Curve |
| AFAT | Automated Flexibility Aggregation Toolkit |
| AI/ML | Artificial Intelligence/ Machine Learning |
| API | Application Programming Interface |
| AS | Ancillary Service |
| ATP | Automated Trading Platform |
| AUW | Aggregated Users' Welfare |
| BMC | Business Model Canvas |
| BRP | Balance Responsible Party |
| BSP | Balancing Service Provider |
| BSU/ESU | Battery Storage Unit / Energy Storage Unit |
| B2B/B2C | Business to Business / Business to Consumer |
| CAPEX/OPEX | Capital Expenditures / Operational Expenditures |
| CACM | Capacity Allocation and Congestion Management |
| CEP | Clean Energy Package |
| DA/ID | Day-Ahead / Intra-Day |
| DB | Data Base |
| DC-OPF | Direct Current Optimal Power Flow |
| DER | Distributed Energy Resource |
| DFA | Distributed Flexibility Asset |
| DFMCT | Distribution Flexibility Market Clearing Toolkit |
| DG | Distributed Generator |
| DLFM | Distribution Level Flexibility Market |
| DMP | Data Management Plan |
| DR | Demand Response |
| DSM | Demand Side Management |

| | |
|---|---|
| DSO/TSO | Distribution/Transmission System Operator |
| ECC | Energy Consumption Curve |
| EIDaaS | Energy Information Distribution as a Service |
| ES | Energy Service |
| ESCO | Energy Services Company |
| ESP | Energy Service Provider; BSP stands for Balancing Service Provider |
| ESS | Energy Storage System |
| FFR | Fast Frequency Response |
| FST | FlexSupplier’s Toolkit |
| GL | Grid Location |
| GUI | Graphical User Interface |
| ICT | Information and Communication Technology |
| IoT | Internet of Things |
| KPI | Key Performance Indicator |
| LMP | Locational Marginal Price |
| MC | Market Clearing |
| mFRR | Manual Frequency Restoration Reserve |
| MFAL | Market Forecast Accuracy Level |
| MO | Market Operator; FMO stands for Flexibility MO |
| M&V | Measurement & Verification |
| NRA | National Regulatory Authority |
| OLTC | On-Load Tap Changer |
| OMP | Organized Market Place |
| OPF | Optimal Power Flow |
| PCC | Point of Common Coupling |
| P/F | Power Factor |
| PM | Pricing Model |
| QoS/QoE | Quality of Service/Quality of Experience |
| RES | Renewable Energy Sources |
| RESP | RES Producer |
| RPC | RES Production Curve |
| RFAL | Renewable Forecast Accuracy Level |
| RM | Reserve Market |
| RoCoF | Rate of Change of Frequency |
| RTP | Real Time Pricing |
| SGAM | Smart Grid Architecture Model |
| S/W | Software |
| SWOT | Strengths Weaknesses Opportunities Threats |
| ToE | Transfer of Energy |
| VPC | Value Proposition Canvas |
| VPP | Virtual Power Plant |
| WFIP | Weather Forecast Information Provider |

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# Document History

This deliverable includes the research outputs of Tasks 2.1-2.3. It includes the research methodology of FLEXGRID framework, the FLEXGRID use cases and operational scenarios as well as the requirements' analysis for all FLEXGRID services.

**Table 1: Document History Summary**

| Revision Date | File version | Summary of Changes |
|---|---|---|
| 23/10/2019 | v0.1 | Draft ToC circulated within the entire consortium. |
| 13/11/2019 | v0.2 | All partners commented on the draft ToC structure. |
| 21/11/2019 | v0.3 | Final ToC has been created by ICCS and has been circulated to all partners together with all writing task delegations. |
| 15/12/2019 | v0.6 | 1st round of contributions by all partners |
| 20/12/2019 | v0.7 | ICCS integrates text from all partners providing comments to all and NPC & ETRA start reviewing |
| 15/01/2020 | v0.8 | 2nd round of contributions by all partners addressing the comments made by NPC and ETRA. Draft final version discussed during 2nd plenary meeting (Valencia) and missing "bits and pieces" are agreed to be addressed. |
| 20/01/2020 | v0.9 | ICCS integrates text from all partners and NPC & ETRA review the pre-final version. |
| 27/01/2020 | v0.95 | The final D2.1 reviewed version is shared among all partners and the latter agree on final submission. |
| 31/01/2020 | v1.0 | ICCS (coordinator) makes final enhancements/changes based on all partners' final comments and submits in ECAS portal. |

# Executive Summary

This report is the first official deliverable of H2020-GA-863876 FLEXGRID project dealing with the detailed description of the FLEXGRID's use cases, system operation scenarios, and user/system requirements' analysis. Moreover, the deliverable includes details about FLEXGRID's research and business positioning in the current smart grid architecture landscape, which try to define in depth the interaction between the operation of the energy networks and the energy markets in Europe. This advanced interaction is expected to lead to more efficient operation of both electricity grid management systems and energy markets. FLEXGRID is a Research and Innovation (R&I) project and its implementation will be based on evolving previous efforts integrating a set of existing S/W platforms as well as doing high-quality research on advanced mathematical models and algorithms. FLEXGRID will develop a future smart grid architecture that will automate and optimize the composition and management of advanced Energy Services. FLEXGRID will target the development of (and the efficient interaction between): i) a B2B Automated Trading Platform (ATP), ii) an electricity grid management platform for DSOs/TSO, iii) an automatic Business Model (BM) composer and operator for Energy Service Providers (ESPs), and iv) a B2C automated flexibility aggregation advanced retail pricing tool for energy aggregators and retailers. In this process, FLEXGRID will conduct critical theoretical research and develop corresponding software tools on: i) Advanced flexibility market mechanisms, ii) Next-generation Optimal Power Flow (OPF) algorithms and iii) Artificial intelligence and data analytics towards intelligent energy service management. In particular, the structure of the deliverable is the following.

Chapter 1 describes the main FLEXGRID idea, research motivation, scope and purpose. The technical objectives are outlined and briefly described. The draft version of the system architecture is illustrated together with all major subsystems, while the multi-dimensional aspects of the expected impact are also stated together with the description of the proposed novel FLEXGRID marketplace and business ecosystem design.

Chapter 2 provides a list of the major stakeholders/users that will interact with FLEXGRID Automated Trading Platform (ATP). It presents their current role and their usual business models as well as the new roles and business models that they can develop within FLEXGRID framework. Additionally, the interaction that FLEXGRID envisages with them is analysed as well as the services that FLEXGRID offers to them. This work is very important in order to define the exact business positioning of FLEXGRID system before the architecture design and S/W implementation phases. Moreover, a summary of related flexibility market projects and initiatives around Europe are presented together with the proposed FLEXGRID advancements, innovative FLEXGRID services and intelligence.

In chapter 3, we present the research methodology of FLEXGRID's framework, which follows the standardized Smart Grid Architecture Model (SGAM) methodology in order to facilitate the architecture design, S/W development and lab experimentation work at later stages of the project's lifetime. We categorize the research problems into four main categories, which are mapped to the technical work packages 3-6. The first research thread deals with the design of future smart grid architectures that facilitate the efficient interaction between network operators (DSO/TSO) and all other market stakeholders focusing on Distribution Level Flexibility Markets (DLFMs) and the changes that are going to incur in current smart grid architecture landscape. The second research thread is related to advanced mathematical models and algorithms to minimize ESP's CAPEX and OPEX. The third one deals with the advanced distribution level flexibility market clearing models and algorithms as well as efficient coordination schemes for TSO-DSO collaboration. Finally, the fourth research thread is related with the automated aggregation and management of Distributed Flexibility Assets (DFAs).

In chapter 4, four (4) High-Level Use Cases (HLUCs) are described in detail. Each one of the HLUCs refers to a set of FLEXGRID ATP services offered to the Flexibility market Operator (cf. HLUC_01), the Energy Service Provider (cf. HLUC_02), the System Operators (cf. HLUC_03) and the energy aggregators (cf. HLUC_04). In chapter 5, we further elaborate on each HLUC in order to define more research-oriented Use Case Scenarios (UCS), which will be the basis of the high-quality research work to be conducted within WPs 3-5 context. Each HLUC is led by an industrial partner and each UCS is led by an academic partner.

Finally, in chapter 6, the user and system requirements are analysed. A total number of nine (9) different user categories are envisaged. Moreover, five (5) main subsystems have been identified, namely: i) the core FLEXGRID ATP, ii) the central FLEXGRID database, iii) the Automated Flexibility Aggregation Toolkit (AFAT), iv) the FlexSupplier's Toolkit (FST), and v) the Distribution Flexibility Market Clearing Toolkit (DFMCT). The requirements for all the technical Application Programming Interfaces (APIs) for the interaction among the various subsystems have also been specified as well as residual legal, regulatory and security requirements.

Conclusively, during the next months, FLEXGRID consortium will elaborate on the current work presented in this deliverable towards designing the final version of FLEXGRID system architecture and starting the research (WPs 3-5) and S/W implementation work (WP6).

# 1 Introduction

## 1.1 R&I motivation, scope and main FLEXGRID purpose

The high penetration of Renewable Energy Sources (RES) in smart grids delivers clean and low-cost energy as well as energy autonomous societies. On the other hand, in this very dynamic landscape, the current electricity grid architectures are facing severe efficiency and stability issues. This necessitates the exploitation of assets that are able to adapt consumption to production and guarantee the efficiency and stability of smart grids, such as: i) advanced Demand Side Management (DSM), ii) planning, siting and scheduling of modern Energy Storage Systems (ESS), and iii) new and enhanced energy markets and RES forecasters. In this context, there is an apparent and pressing need to redesign the architecture and the algorithms for the management of electricity grids so that they can adopt to the evolving environment and embed these assets.

At the same time, the ecosystem of energy sector stakeholders is changing from the traditional one, where the main interaction is between the monopolistic TSO/DSO pair and an electric utility company to a much more complex, challenging and liberalized environment with advanced Energy Services (ESs) where:

- DSOs/TSOs maintain the stability and efficiency of the electricity grid by buying services from distributed assets in flexibility markets. At the same time, they also design and dynamically upgrade their grid in a robust and fault tolerant way according to consumption and RES production patterns, while simultaneously mitigating market power abuse issues.
- Traditional utility companies are being transformed into Energy Service Providers (ESPs) that: a) buy energy from wholesale market, b) sell energy through retail markets, and c) participate, through the aggregation of flexibility assets and the use of ESS, in flexibility (real time) markets by offering flexibility services to DSOs/TSOs.
- RES Providers (RESPs) are new players and are competing to offer low cost energy with predictable RES Production Curves (RESPC), adapted (as much as possible) to the needs of the energy consumers.

Traditional markets (wholesale and retail market) and markets that operate closer to real time (e.g. balancing, flexibility) will soon constitute the main field of (B2B and B2C) interaction among the aforementioned stakeholders, under the coordination of Market Operators/MOs, towards the management of future electricity grids. Thus, the evolution of their architecture is a major issue and a major R&I motivation behind FLEXGRID.

In this landscape, recent efforts undertaken by the research community focus on achieving: i) flexible energy production/consumption solutions assisted by the use of data analytics and forecasting algorithms, ii) optimal design and management of the dynamic electricity grid through the use of modern optimization and control theory, and iii) efficient interaction between producers, network operators and consumers through the design of advanced market architectures.

By evolving previous efforts and integrating a set of existing S/W platforms, FLEXGRID will develop a future smart grid architecture that will automate and optimize the composition and management of advanced Energy Services. FLEXGRID will target the development of (and the efficient interaction between): i) a B2B and a B2C Automated Trading Platform (ATP), ii) an electricity grid management platform for DSOs/TSOs and iii) a BM composer and operator for ESPs and RESPs. In this process, FLEXGRID will conduct critical theoretical research and develop corresponding software tools on: i) Advanced Market Mechanisms, ii) Next-generation Optimal Power Flow Algorithms and iii) AI and data analytics towards intelligent energy service management. FLEXGRID will be based on its innovative data model that provides for easy and efficient interaction among the aforementioned systems and stakeholders. In this way, FLEXGRID aims to evolve the architecture of the Future Electricity Grid Models and the Future Energy Markets.

The purpose of FLEXGRID is to exploit recent theoretical advances in order to allow the easy and rich interaction between energy sector stakeholders, by proposing innovative and highly competitive Energy Services (ESs) for each of them. Through the FLEXGRID platform:

- <u>**DSOs/TSOs**</u> will be able to: i) **optimally plan/design** their distribution and transmission networks (CAPEX minimization), ii) **competitively operate** them at low cost (OPEX minimization), iii) efficiently use the energy markets in order to acquire flexibility services through their interaction with RESPs and ESPs.
- <u>**ESPs**</u> will be able to: i) **monitor, analyze and predict the existing and the envisioned real-time markets** towards more efficient energy trading, ii) **interact easily and effectively with their end users** in order to engage them in participating in the very dynamic, future, real time energy markets, iii) **plan and operate their assets optimally** (ESS, DSM) so that they can offer more competitive energy services and simultaneously increase their revenues.
- <u>**RESPs**</u> will be able to: i) **monitor, analyze and predict RES generation and markets** towards more efficient interaction with the latter, ii) **plan/compose and operate their assets optimally** towards more competitive energy services and increased revenues.
- <u>**End users (consumers)**</u> **will enjoy more robust energy services with lower cost, increasing thus EU's energy self-sufficiency and independency levels.**

## 1.2. FLEXGRID objectives

The goal of FLEXGRID is to facilitate energy sector stakeholders (DSOs, TSOs, ESPs and RESPs) to: i) easily and effectively create advanced Energy Services (ESs), ii) interact in a dynamic and efficient way with their environment (electricity grid) and the remaining of the stakeholders, and iii) automate and optimize the planning and the operation of their ESs. In this way, FLEXGRID envisages secure, sustainable, competitive, and affordable ESs. This section clarifies the objectives of FLEXGRID by: i) categorizing them as orthogonally as possible, ii) presenting them accurately, and iii) revealing the interactions among them. In particular, the objectives set by FLEXGRID are:

**Objective #1: An Automated Trading Platform (ATP) able to provide as a service the composition and the operation of energy markets**

The first objective of FLEXGRID is the development of an advanced ATP that is able to support the optimal and automated planning and operation of the markets, as required by modern stakeholders in order to interact with each other for offering competitive ESs through the advanced flexibility trading: i) in B2B form, between ESPs and DSOs/TSOs, and ii) in B2C form, between ESP and end users. Thus, FLEXGRID will develop:

1. **Innovative liberalized energy market architectures** that facilitate mitigation of market power and dispose the advanced features that modern Market Mechanisms are able to offer.
2. A **holistic trading data model and trading service composition** able to support advanced and easy flexibility trading, by acting as a language that models flexibility assets and composes flexibility services.
3. **Advanced B2B market mechanisms** that: i) allow DSOs/TSOs to exploit innovative services through a more efficient market clearing algorithm that FLEXGRID will develop in order to reduce the system cost and i) facilitate ESPs to analyse its data in order to improve their strategies and mitigate their risks.
4. **Advanced Retail Market Mechanisms (B2C)** able to harmonize very dynamically the end-user consumption patterns based on the dynamic prices in various markets, not only through the monitoring of the latter, but also through advanced learning algorithms.
5. A modular by design architecture that ensures **compatibility of the proposed ATP platform with the legacy technology** of current energy sector stakeholders (e.g., DSO/TSO SCADA systems).

**Objective #2: Automated planning of DSO's/TSO's Energy Services**

The second objective of FLEXGRID is to automate the planning process of the ESs offered by system operators through the use and evolvement of recent research advances in Optimal Power Flow (OPF) algorithms. In more detail, the objective here is to seek a trade-off between the minimization of CAPEX in the design of the electricity grid and the maximization of network robustness for obtaining competitive and secure electricity grids. The proposed FLEXGRID platform will provide services such as:

1. **Efficient, accurate and dynamic Advanced Distribution Monitoring (ADMo)** able to: i) inform DSOs/TSOs on the monitoring architecture that they have to develop and ii) intelligently exploit monitoring output towards OPF and market clearing algorithms.
2. **Optimal ESS sizing and siting** (which may be under the ownership/management of the DSO/TSO or of external stakeholders/ESPs that interact with DSO/TSO through FLEXGRID's ATP) through the use of advanced algorithms that take into account the history and prediction of: i) the RES Production Curves (RPCs) and their location, ii) the Aggregated ECCs (AECCs) and the flexibility levels of the participating consumers for a given network location, iii) the underlying network topology, and iv) the local flexibility market prices, and their predictions and accuracy levels.
3. **Algorithms able to determine market power mitigation-aware network upgrades** (e.g., capacity and/or security/fault tolerance upgrades) in electricity grid through the quantification of the relationship between CAPEX increase (investments for upgrades and changes) and OPEX reduction (expenses in the flexibility markets) that these

modifications and upgrades will cause. Thus, ESPs become more competitive and sustainable and ESs for end users will have lower cost.

4. **Fault tolerance services** through algorithms able to intelligently process the dynamic input from the ADMo and derive conclusions and actions to be taken to address network faults, problems and events. These types of services will be integrated with dynamic markets towards disaster management.

**Objective #3: Optimal operation of DSO's/TSO's Energy Services**

The third objective of FLEXGRID is the optimal operation of the electricity grids in terms of low cost and high stability (tolerance/robustness to the very dynamic and distributed RES production). In particular, electricity grid aware, dynamic management of ESPs' flexibility assets is targeted through FLEXGRID's ATP platform (cf. Objective 1). In order to achieve this, FLEXIGRID will develop:

1. **Innovative Market Clearing (MC)/OPF algorithms** that allow the operation of the electricity grid in a broader area (increase market freedom), thus reducing the cost of energy services.
2. **Scalable and Multi period MC/OPF algorithms with low computational overhead** that can make efficient use of flexibility assets (exploitable through ATP) whose management spans across multiple time periods regarding: i) DSM (load shifts) and ii) ESS for higher RES exploitation.
3. **Robust MC/OPF algorithms able to address the inaccuracy of market, RES and AECC forecasters that multi-period OPF introduces** based on recent advances in robust and stochastic optimization.
4. **Dynamic interaction with DSM and ESS systems,** directly or through ATP, by using advanced optimization algorithms that take into account the historical data as well as the predictions on: i) the RES Production Curves (RPCs) given their corresponding location, ii) the Aggregated ECCs (AECCs) and the flexibility levels of the participating consumers at a given network location, iii) the underlying network topology, and iv) the local (e.g. ATP) market prices.

**<u>Note:</u>** In FLEXGRID, the main focus will be placed in the design, development and performance evaluation of Distribution Level Flexibility Markets (DLFMs). However, not only DSOs but also TSOs will be affected by the proposed DLFMs.

**Objective #4: Automated Planning of ESP's Business Models (assets and policy)**

The fourth objective relates to the development of models for the automation of the planning of the services offered by ESPs. As described earlier, ESPs are private companies, energy cooperatives, or public organizations that: a) buy energy from the wholesale market, b) are DSM capable (having their own portfolio of end users/customers and selling energy through their participation in retail markets), c) dispose or manage ESS, d) participate in flexibility markets in order to deliver competitive and profitable energy services, e) possibly combine these services with other revenue sources. In more detail, FLEXGRID will offer to ESPs services such as:

1. **Exploitation in the BMs of ESPs of innovative FLEXGRID's Market Clearing algorithms and data model, which improve market freedom and reduce market power**. In this way, investments are incentivized and the cost of ESs becomes more competitive.
2. **Optimal ESS sizing and siting** according to: i) the estimated prices in energy markets, ii) the estimated ECCs and flexibility levels of their consumers, iii) the underlying topology of the electricity grids, and iv) the interaction with DSOs/TSOs.
3. **Planning of interaction policy with energy markets** and innovative MC (wholesale market, ancillary services market, retail market) towards the maximization of **stacked revenues** and the design of more competitive ESs.
4. **Design of dynamic ESP's retail market scheme (DSM scheme)** able to incentivize and treat consumers (distributed flexibility asset owners) in a **fair way,** according to the flexibility levels (changes in their ECC) they exhibit. Through these models, ESPs will provide competitive services (attractive to end users) and will dynamically maximize the stacked revenues derived from their participation in all energy markets.

**Objective #5: Optimal operation of ESP's Business Models**

The fifth objective is the mathematical modelling of the dynamic optimization process of the ESP's services. FLEXGRID will minimize the OPEX of the offered services by developing:

1. **AI technologies** in order to **deliver accurate and dynamic forecasters** to estimate: i) the RES production, ii) the behaviour (price trends) of modern electricity markets (day ahead and real time) and iii) the accuracy level of the forecasts to be exploited in **automated policy enforcers** (optimize interactions and plan/operate assets according to high-level rules, such as minimum/average profit maximization, etc.).
2. **Efficient and stable interaction with other stakeholders** (B2B interactions) and energy markets **by considering price makers** (participants of high enough size to have an impact on market prices) and not price takers (advanced MPEC/EPEC algorithms which enhance market equilibrium points with attributes that constitute energy markets more open and efficient).
3. **Models that provide the dynamic co-optimization of ESS and DSM systems** in order to reveal the added value of the interaction between these two flexibility asset types.
4. **Dynamic tuning of the parameters of the DSM scheme** according to: i) the forecasted prices in energy markets, ii) the energy available in the ESS systems, and iii) the dynamic flexibility levels of participating users.

**Objective #6: Services to RES Producers (RESPs)**

The sixth objective of FLEXGRID is the provision of services to RES producers. In this way, RESPs will be able to plan and operate efficiently their services according to the environment they operate. More specifically, FLEXGRID will develop:

1. **Advanced RES forecasting tools** that provide dynamic estimates of: i) the RES Production Curves (RPCs) based on historical and other data for a specific location and ii) the accuracy of the prediction. These forecasts will help hedge the risks and allow the sustainable commercial exploitation of the energy produced by RES.

2. **Planning services** that optimize the RES compositions (in terms of RES location, and quantity for each type in the mixture) and the ESS according to: i) RES forecasting algorithms, ii) available CAPEX and iii) the history and predictions of the prices in energy markets.
3. **Dynamic ESS and energy trading scheduling** services, which include: i) dynamic management of ESS systems (charge/discharge schedulers of the ESS managed by RESPs) and ii) schedulers that determine how RESPs will interact with the (day ahead and real-time) markets. The goal here is to increase RESP's assets "dispatchability rate" in order to efficiently participate in multiple energy markets in the future.

**Objective #7: A modular, configurable, customizable, open, and extendable S/W platform**

The proposed cloud based FLEXGRID S/W platform will be designed and developed so that it is:
1. **Modular**, meaning that there will be well-designed technical APIs allowing the low-level flexibility assets to be automatically transformed into trading assets (middle level) and ultimately give rise to novel flexibility services (upper level).
2. **Configurable**, in the sense that the data exchange modelling will be abstract enough to facilitate the easy integration of the proposed FLEXGRID platform with the existing legacy technology of energy sector stakeholders (e.g. DSO/TSO management systems) following the well-established standardization efforts.
3. **Customizable**, meaning that the individual S/W toolkits (cf. middle level) will provide a wide variety of options for each stakeholder to run various types of exhaustive "what-if" scenarios with respect to many differentiated business cases. This feature is expected to boost the FLEXGRID's exploitation activities (see more in section 2.2)
4. **Open,** in terms of being able to deliver Energy Information Distribution as a Service (EIDaaS) to 3rd parties, facilitate cross-border collaborations among stakeholders from different EU member states and generally disseminate the project's foreground knowledge via a clear data management plan (see more details in section 2.2).
5. **Extendable,** in terms of being able to facilitate the creation, composition and trading of many more advanced energy meta-services in the future. The APIs will be rich and flexible enough to allow future platforms to be integrated and avoid vendor lock in.

Last, but not least, the platform will respect the privacy and the anonymity of the participating users/stakeholders, while their unreserved consent will always be a prerequisite.

**Objective #8: Pilots with existing and prestigious stakeholders in Energy Sector**

FLEXGRID will conduct a wide range of pilots and lab experimentations exploiting AIT's research infrastructure in order to evaluate the aforementioned services and evolve its platform empirically through the feedback obtained from real stakeholders.

## 1.3. FLEXGRID concept, main idea and architecture

As analysed earlier, FLEXGRID envisages a service oriented smart grid architecture equipped with all the necessary mathematical models and algorithms required in order to offer to energy stakeholders all the background and corresponding software tools for: i) optimizing internally the planning and the operation of the ES that they offer, ii) participating in real time markets of future smart grids, and iii) interacting through markets with other stakeholders in order to meet the highly demanding objectives of future smart grids as analysed in the aforementioned objectives.

FLEXGRID lies on the idea that its S/W platform will be able to host a variety of actors, including: i) **DSOs/TSOs** that want to effectively plan and operate their electricity grid towards low-cost and high-quality ESs (distribution and transmission services), ii) **progressive ESPs (utilities)** that want to provide more advanced ESs and achieve an attractive trade-off between their risks, their profits and the quality of services they deliver, iii) **RES Providers,** that are eager to address their high volatility and uncertainty of RES, and offer more competitive ESs (i.e. enhancing the RES "dispatchability" and thus be able to participate in equal terms in the EU energy markets).

In this context, FLEXGRID will be based on recent research in the energy sector, including: i**) Optimal Power Flow (OPF) algorithms**, *in order to* a) analyse and optimize across a finite time horizon the dynamic state of electricity grids and b) cope with the uncertainties; ii**) Data Analytics** that act as input to **Optimization and AI algorithms** *towards* intelligent decision making for optimally planning and managing the internal assets of the participating energy sector stakeholders; iii) Novel **Pricing and Market Clearing algorithms**, based on recent advances in algorithmic game theory and auction theory, *in order to* offer B2B Automated Trading markets that harmonize the interaction between the energy sector stakeholders and increase the stability and efficiency of ESs.

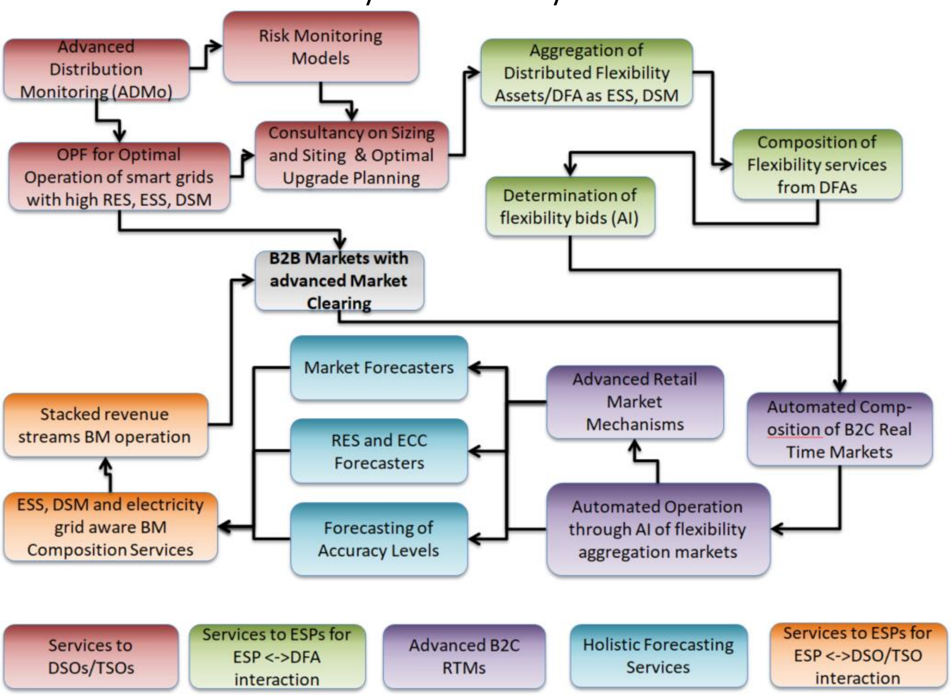


**Figure 1: FLEXGRID's Functional Architecture (modular-by-design development approach)**

In order to connect FLEXGRID's S/W architecture with its objectives, the figure below illustrates the hierarchical FLEXGRID framework. It consists of 3 main layers. At the lower layer, all FlexAssets and electricity grid assets are monitored at both FlexSupply and FlexDemand sides respectively. In the middle layer, each stakeholder makes use of FLEXGRID's models, algorithms and S/W tools in order to manage the operation and planning of the FlexAssets. In other words, FlexAssets are being automatically transformed into trading assets, thus composing FlexRequests (for FlexBuyers like DSO/TSO) and FlexOffers (for FlexProviders like ESP/RESP). Finally, in the upper layer, the various individual S/W tools from the middle layer interact towards the efficient trading of FlexAssets through FLEXGRID's Automated Trading Platform (ATP). Hence, FlexAssets are transformed into FlexServices and B2B partnerships are facilitated through the use of ATP. As also shown in the following figure, multiple well-designed APIs facilitate the efficient interaction among any combination of S/W components.

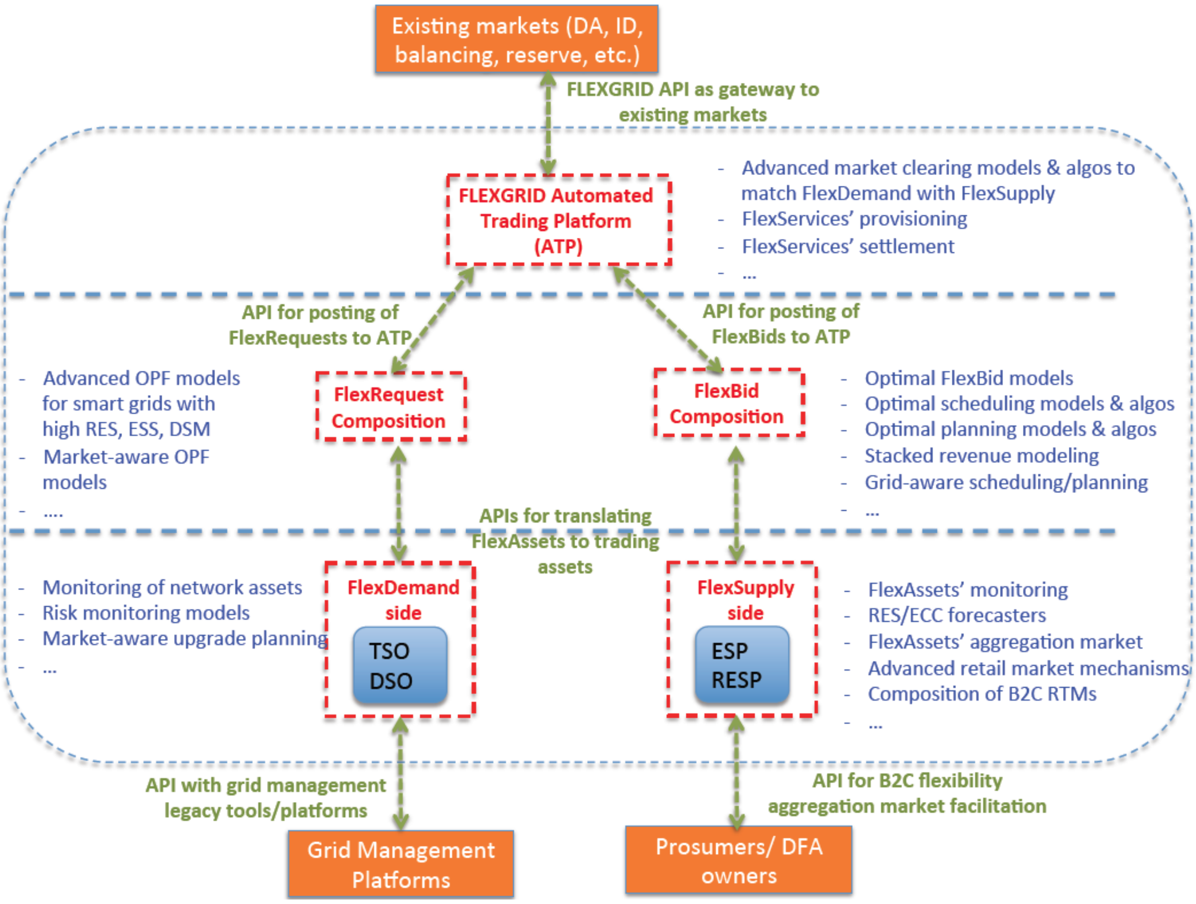


**Figure 2: Draft FLEXGRID architecture design**

## 1.4 Expected impact

Figure 3 illustrates a high-level description of FLEXGRID's market design, including the roles of each participating stakeholder. On the left side of the figure, those who buy flexibility are shown: TSOs and DSOs. In addition, Balance Responsible Parties (BRPs) might re-trade committed flexibility with other BRPs that offer cheaper flexibility. These buyers will have to define their willingness to pay for activation of flexibility at particular Geographical

Locations (GLs) and feed this information, in the form of FlexOffers/FlexRequests, continuously into FLEXGRID ATP via an API. The flexibility is made available by the flexibility providers on the FlexSupply side, who will act on behalf of the owners of the FlexAssets and feed these FlexOffers into FLEXGRID ATP via another API. The next step will be for the FLEXGRID Automated Trading Platform (ATP) to match FlexDemand with FlexSupply, thus clearing the flexibility market, and define the FlexPrice according to the FlexAssets to be traded. The FLEXGRID ATP will also be able to interact with the existing energy markets (day-ahead, intra-day, reserve, balancing, etc.), making platform's flexibility available to these markets, too. This means that flexibility sellers can also differentiate their FlexOffers depending on whether the FlexAssets are sold locally or centrally. Selling locally, at a specific location, can in many cases be riskier, as there are fewer alternatives in case the seller needs to rebalance due to unforeseen unavailability of some FlexAssets. In contrast, contractual positions in the intra-day market are much easier to rebalance, but the FlexPrice is expected to be much lower. The proposed FlexOffer structure will be complex/rich enough to define the FlexSupplier's (i.e. ESP, aggregator) portfolio within each GL and differentiate the price and other properties [ramping capability (max/min), source, production, consumption, max/min activation time, max/min activation duration etc]. DSOs might in some cases prefer increased consumption instead of ramping down RES. TSOs might have preferences to activation time and ramping when products are sold in their balancing markets. FLEXGRID ATP will have filters that flexibility buyers can use when they optimize their grid costs according to their actual need of flexibility quality. Thus, interaction with grid operation will be facilitated through an API, which will communicate in an intelligent manner all the network-related constraints.

Finally, the sellers of flexibility (ESPs, aggregators) will need to have a business model with the FlexAsset owners and/or their clients (energy prosumers) in the form of FlexContracts, while the required ICT technology that activates the flexibility should be available, too. FlexContracts will define the exact way that end prosumers will be compensated in exchange of offering their flexibility. Each end prosumer evaluates in a different way the trade-off between the electricity bill's reduction and the incurred inconvenience. This trade-off is mathematically represented by FlexAssets' cost function. Thus, advanced pricing algorithms will reside at the ESP's side in order to clear the internal market between the ESP and its end prosumers/FlexAsset owners.

FLEXGRID ATP facilitates the automated, real time and optimal trading of FlexAssets, realizing "win-win" business contexts for energy market stakeholders at both FlexSupply and FlexDemand sides. FLEXGRID ATP may be owned by an independent Flexibility Market Operator (FMO) legal entity, who will realize revenues in the form of license fees paid by all involved FLEXGRID actors. Moreover, through its innovative market architecture it also facilitates innovative Energy Services (ESs) that highly enhance the management efficiency of the various market stakeholders' internal business portfolios (cf. Objectives 2-6 mentioned in subsection 1.2).

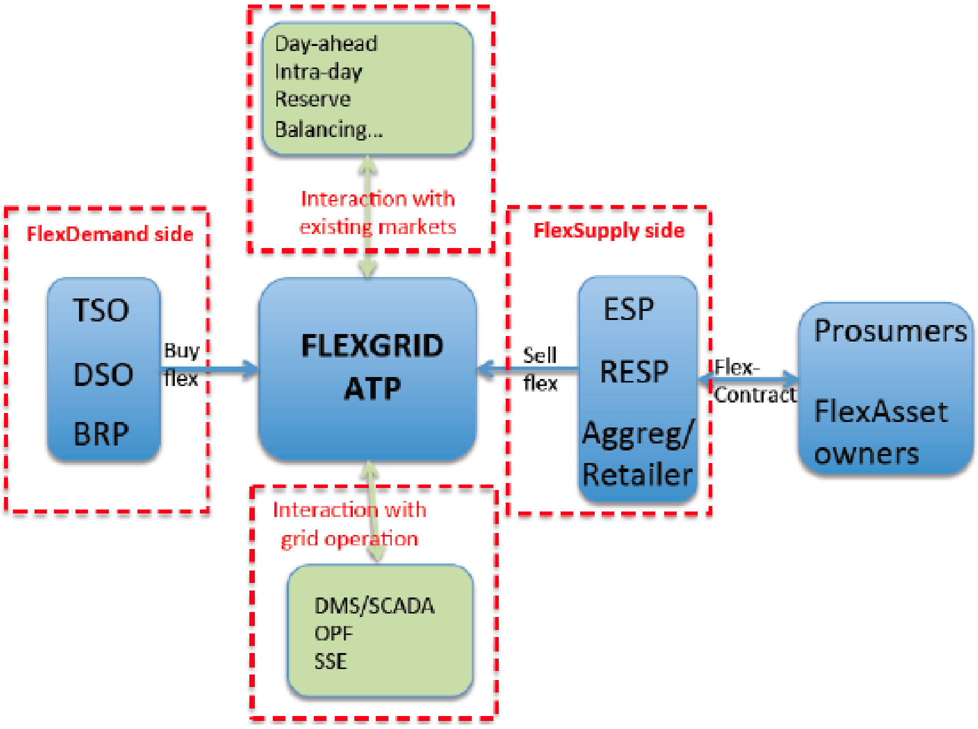


**Figure 3: FLEXGRID marketplace and intelligent business ecosystem design**

**Note**: The term "FlexBid" and "FlexOffer" are used interchangeably in this report and refer to the bid/offer made by the FlexSupply side of the proposed marketplace (i.e. by ESPs, RESPs and aggregators). The term "FlexRequest" refers to the bid made by the FlexDemand side of the proposed marketplace (i.e. by TSO, DSO, BRP).

# 2 FLEXGRID stakeholders, business ecosystem design and services

In this chapter, we describe all energy market and system stakeholders who participate in the FLEXGRID ecosystem. For each stakeholder, we describe: i) its current role and responsibilities based on the state-of-the-art EU regulation, ii) future challenges that it faces with respect to FLEXGRID project, and iii) how FLEXGRID project aims at dealing with the pre-mentioned challenges (or else how these actors will benefit from FLEXGRID services and context in comparison with their Business-As-Usual BAU process.

## 2.1. Stakeholders

### 2.1.1 (Independent) aggregator

An aggregator means a market participant that takes a role of combining (i.e. aggregating) flexibility from energy prosumers and/or consumers for selling it to different stakeholders like ESPs (i.e. suppliers), BRPs, DSOs or TSOs. The special case of an independent aggregator means a company that is not affiliated with an ESP (supplier) or a BRP.

### 2.1.2 Balancing Service Provider (BSP)

A market participant that provides balancing services to TSOs either in the form of capacity or energy or both. BSPs may need to meet certain pre-qualification criteria in order to offer their products to TSOs. An ESP can take the role of a BSP if it meets the relevant requirements.

### 2.1.3 Balance Responsible Party (BRP)

A BRP is a defined role in European wholesale electricity markets. BRPs are responsible for notifying the TSO of a relevant bidding zone of its intended feed-in or offtake of electricity into the grid. A BRP bears the financial responsibility for real-time deviations of its nominated position to the TSO. In many imbalance regimes, BRPs are being penalized for deviating from their nominated portfolio position. Apart from the (voluntary) participation in electricity markets, BRPs may also provide balancing services to TSOs if they meet their minimum quantity and quality criteria.

### 2.1.4 Distribution System Operator (DSO)

A DSO is responsible for the distribution of electricity to end customers like households and businesses. In order to achieve this goal, DSOs are entrusted, through their organization as regulated natural monopolies, with a number of different tasks. These include long-term planning regarding installation and maintenance as well as short-term operation of their grid infrastructure. DSOs usually operate at lower voltage levels than TSOs but can also be responsible for parts of the high voltage grid (varies with national regulation). For DSOs, increasing amounts of distributed energy resources generation are challenging the distribution network, e.g. causing local congestions and voltage support issues that need to be addressed. Traditionally, these local network problems are being handled through investments in new and/or upgraded distribution system components. These new investments and upgrades are expensive, and nowadays often unable to follow the fast uptake of DERs in the distribution network.

### 2.1.5 Energy Service Provider (ESP)

ESP is a general term that is used in the FLEXGRID project. In the most general case, it means a profit-oriented company, which may make contractual arrangements with various types of flexibility assets (e.g. DSM, RES, storage). An ESP: i) buys energy at wholesale market, b) sells energy through retail market, and c) participates in near-real time flexibility markets (if applicable). An ESP may offer various types of services to TSOs/DSOs and BRPs. In case that an ESP has a portfolio comprised of energy consumers only, its role is similar to the *"Supplier"* as described below.
In case that the ESP is a non-profit entity like a RES Cooperative (RESCOOP), the main difference is that a RESCOOP's primary goal is not to maximize profits, but other KPIs, which are more related to the welfare maximization of the RESCOOP members (i.e. end energy prosumers).

### 2.1.6 Market Operators (MO)

MOs are entities (usually commercially run companies), which are responsible for one or more of the functions regarding development, operation and maintenance of marketplaces designed for the exchange of a commodity (e.g. electricity). The distinctive role of MOs lies in the efficient and robust execution of matching, clearing and settlement of bids and offers from both sides of the market (i.e. supply and demand). MOs provide the market with an open, transparent and cost-effective means of handling multi-lateral commodity transactions as compared to alternative methods, e.g. bilateral *over-the-counter* (OTC) transactions. It must be noted that the MO role varies with regard to different market sequences. These are described below:

#### *2.1.6.1 Day-ahead/intraday Market Operator*

The main role of this type of MO is the operation of markets for the exchange of wholesale electricity products. In member states regulated by the *Capacity Allocation and Congestion Management* (CACM) guideline, this role is described in Article 7 of the regulation[1]. The CACM guideline introduces the role of Nominated Electricity Market Operators NEMOs, who shall act as MOs for national and regional markets in cooperation with TSOs to perform *Single day-ahead and intraday coupling.*

#### *2.1.6.2 Balancing Market Operator (BMO)*

A balancing market operator (BMO) is a company, which operates markets or marketplace solutions for ancillary services. The typical BMO is a TSO that acts as a single buyer for

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32015R1222

products with a variety of different characteristics regarding duration, response, quality of delivery, etc. Products are typically either capacity-based, energy-based or a combination of both.

#### *2.1.6.3 Flexibility Market Operator (FMO)*

This is a new market role proposed within FLEXGRID project. The FMO operates, maintains and develops products and services that encompass a broader range of products than the incumbent role of *Nominated Electricity Market* Operators (NEMOs). The FMO in FLEXGRID will not be restricted to offering electricity products but will include both long-term and short-term capacity products that can be utilized by TSOs, DSOs and market participants alike. FMO will be able to operate a novel flexibility marketplace, in which TSO/DSO/BRPs are potential buyers of flexibility services and ESPs/RESPs/aggregators are potential sellers of flexibility services. In FLEXGRID, we consider FMO’s interaction with the existing NEMO and BMO as well as interaction with the underlying physical network operation (see more details in sections 1.3 and 1.4 above).

### 2.1.7 Energy Prosumers/ FlexAsset owners

This role describes a customer purchasing electricity for either its own or third-party use and can include both households, and commercial activities. It covers also customers or a group of customers, who store and/or sell electricity produced on their location or participate in DR schemes, possibly through the use of aggregators.

### 2.1.8 Regulatory Authority (RA)

The role of a Regulatory Authority is a public authority designated by each Member State by e-Directive as laid out in Article 57(1) of the e-Directive.

### 2.1.9 Renewable Energy Service Provider (RESP)

RESP actors are a special case of ESPs. The distinction is made to emphasize the special case of ESPs, which contract RES (e.g. large wind/PV parks). RESPs are relatively new players in the market in the sense that they enable RES units to be fully dispatchable like traditional energy units in the markets (like the fully-controllable conventional non-RES units). We assume that a RESP acquires a cluster of non-dispatchable RES technologies configured in *Virtual Power Plants (VPPs)* using storage and advanced control technologies to create a dispatchable virtual plant connected to the grid at a Point of Common Coupling (PCC).

### 2.1.10 Supplier (retailer)

Suppliers are companies that represent the buying side of the wholesale electricity market. Typically, a supplier makes forecasts on the energy demand for a set of customers in each discrete spatial area, i.e. bidding zone. It then procures the energy and resells it to end prosumers. In a truly competitive retail market environment, suppliers are empowered to act independently of other stakeholders, e.g. generators or DSOs (i.e. no need to be vertically integrated). In addition, they are allowed to apply free pricing, meaning they are not restricted by upper price caps as practiced in some Member States. Suppliers add value for society by creating real competition on the demand side.

#### 2.1.11 Transmission System Operator (TSO)

TSOs are service companies, which are responsible for the transmission of electrical power on a national and/or cross-regional level. Since the role of a TSO is usually designed to be a natural monopoly, its activities and income is mostly subject to extensive regulation from National Regulatory Authorities. In addition to long-term planning regarding system adequacy, dimensioning and maintenance, TSOs also ensure the short-term continuous balance between supply and demand. For the latter, many TSOs make use of single-sided markets for procuring reserves that can be dispatched in real-time if capable and where necessary.

#### 2.1.12 FlexAsset units

These are RES, storage/battery and DSM units, which can be intelligently controlled by FLEXGRID platform (i.e. charge/discharge, turn on/off, decide about optimal setpoints of operation, etc.). These FlexAsset units are mostly controlled by an aggregator/ESP/RESP entity and belong to these actors' business portfolio, but in special cases could also participate in a flexibility market as standalone units (e.g. in case they are large enough to participate in a market or the flexibility market size is adequately small permitting thus their direct participation).

#### 2.1.13 Weather Forecast Information Provider (WFIP)

An entity that provides, upon request, weather forecast information (e.g. through web APIs).

### 2.2 FLEXGRID business ecosystem design

The FLEXGRID project proposes a new and innovative business ecosystem design that will highly evolve the structure of the existing energy market landscape by adding novel intelligent elements to it. The core of the design is the FLEXGRID Automated Trading Platform (ATP). The ATP will facilitate the automated, real time and optimal trading of assets by different flexibility providers that are registered on the platform. FLEXGRID ATP's innovative market architecture will provide many of the stakeholders described in section 2.1 with new business opportunities compared to the status-quo.

Most of the consumption assets (most notably on household level) connected to the grid today are non-intelligent in the sense that they exhibit an almost perfectly inelastic demand curve. Legacy technology coupled with aging business models in many member states create little incentives and opportunities for consumers to respond to price signals from wholesale markets other than sporadic supplier switches. Supplier switches are in many MSs impeded by a wide range of fees charged as a result of these. Although some consumers, mostly on industrial and commercial level, make some attempts to optimize their energy consumption behavior (e.g. through load-shifting away from peak-hours), most prosumers make implicit use of the guaranteed supply provided by their local DSO.

Today, new technologies like smart metering and IoT, rapidly change the landscape in which incumbent stakeholders in the energy markets operate. New companies, like ESPs provide tools and services which enable them, as well as prosumers directly, to interact and control assets remotely and on demand. This adds a whole new dimension of demand-side flexibility to the energy system, because it offers the possibility for asset owners, ESPs and independent aggregators to provide both *implicit (i.e. price-based) and explicit (i.e. incentive-based) flexibility* services to system operators. This can be achieved by aggregating a minimum critical amount of flexible assets as long as the resulting asset portfolio meets the quality and/or volume requirements set by the different system operators or NRAs.

In this changing framework, regulation on national and supra-national level plays a significant role, because it determines the boundaries under which the stakeholders identified in section 2.1 are permitted to operate. The Clean Energy for all Europeans package (CEP)[2] lays out the basic principles that member states have agreed upon and defines the roles and responsibilities of the different actors.

For **TSOs**, one of the main challenges under current market design will be to make sure to meet adequacy and security of supply requirements. Triggered by the phase-out of conventional thermal and nuclear power generation units in a number of member states, TSOs are forced to find new ways to secure adequacy (e.g. through capacity markets) and make alterations to existing procurement schemes, e.g. through reduced volume requirements in ancillary services markets.

Increasing amounts of flexibility will need to be provided by RESPs, ESPs and BSPs, whose assets are mainly connected to grid levels that fall within the responsibility domain of DSOs. Due to the localization of these assets, flexibility providers will be able to offer their services not only to TSOs, but also to DSOs, **leading to potential competition for flexibility and new needs for coordination between system operators**. In FLEXGRID, TSOs will constitute the demand side of flexibility services and thereby take the role of a buyer in the proposed ATP.

**DSOs**, like TSOs are facing new roles and responsibilities in a changing market environment. They are in the process of changing their portfolio of tasks, maintaining monopoly functions such as responsibility for local grid planning and operation, while being forced to sell off competitive functions like energy supplier businesses as a result of stricter unbundling rules.

Due to the increasing amount of iRES connected to DSO grid levels, the companies are faced with new operational challenges that need addressing on a local level. This means that DSOs are taking upon tasks that in parts resemble that of TSOs, albeit at lower voltage levels, constituting a shift towards becoming a true system operator. Unlike TSOs, DSOs

[2] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019L0944

currently have no market-based mechanisms they can use for the procurement of ancillary services at local grid level.

This has triggered the investment in new infrastructure (e.g. batteries) to address some of the issues DSOs are facing. Despite these initiatives, much larger efforts need to be made to ensure secure grid operations in the changing market environment. Most of all, an active demand side is essential for being able to address issues such as local congestion. Efficient operations require the establishing of markets for flexibility to provide flexibility on a local level. **According to the *e-Directive Article 32*, DSOs shall facilitate flexibility arrangements through establishing specifications for flexibility services they would like to procure**.

The alternative to market-based flexibility would be DSOs controlling hundreds or thousands of assets directly based on inflexible bilateral agreements without the use of prices signaling scarcity on local level. Like TSOs, DSOs will constitute the demand side on the proposed FLEXGRID ATP with the exception that DSOs will not run local markets for frequency control. The *Directive on common rules for the internal market*[3] recommends the procurement of non-frequency ancillary services in a transparent, non-discriminatory and marked-based manner.

**Suppliers** are operating in an increasingly competitive environment. Stricter unbundling rules lead to a decrease of DSO ownership at retail companies, many of which have traditionally benefited from cross-subsidization of their mother companies. This leads to increased competitive pressure on incumbents, since a larger number of actors are forced to run businesses based on market principles. New technology, especially smart metering, data hubs and new innovative forms of billing facilitate for the automation of large parts of the value chain.

Increased competition has led to the emergence of innovative products and services as well as a diversification into adjacent business areas, like telecommunications and broadband on the retail side. Some suppliers, partly encouraged by lower volume requirements and permittance of DSR, have also entered the aggregator business in order to offer their customers' demand flexibility to higher-valued markets, e.g. balancing markets. **The main difference from independent aggregators is that the supplier has balance responsibility for its portfolio, either directly with the relevant TSO or indirectly via a third-party BRP**. In FLEXGRID, suppliers are part of the supply side of flexibility to the ATP.

**ESPs** are benefiting from increased interest of (mostly commercial and industrial) consumers to optimize their energy consumption behavior in order to reduce energy and grid tariff related costs. This can be achieved through a variety of measures, e.g. flattening of the load profile to avoid consumption peaks or steering of energy consumption towards market time units with lower prices. ESPs are mostly engaged in offering services of *implicit flexibility (i.e. price-based)*, meaning a longer-term systematic change in consumption behavior.

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52016PC0864R%2801%29

Increasing competition on the supply side as well as flexibility favoring new regulation on EU level has led to the emergence of new business models that support the role of (independent) **aggregators**. There exist several business opportunities for independent aggregators (i.e. without balance responsibility for the prosumers) where a combined model can ensure optimal exploitation of their flexibility portfolios. Comprehensive load scheduling models are required to find an optimal allocation. In order to realize the whole potential of demand side flexibility, both contractual and market-based models may be required.

Most of the demand side flexibility, especially on LV level, is still unrealized potential. Future system challenges require more available distribution network level flexibility, however, current market studies[4] show that incentives for the demand side might still be too weak for consumers to change their prosumption behaviour. Hence, aggregators currently are still struggling to establish viable business cases. Furthermore, there is still a lack of functioning processes defining the contractual relationships between independent aggregators and the relevant BRPs. Art. 17(3) in the e-Directive of the CEP oblige aggregators to be financially responsible for the imbalances they cause in the electricity system. Compared to ESP business, (independent aggregators) also provide services for *explicit flexibility (i.e. incentive-based)*, where (controllable) flexibility can be activated on short notice and is therefore usable for offering ancillary services and/or congestion management.

FLEXGRID will address the challenges faced by aggregators within its proposed structure of high-level use cases (HLUC) and use case scenarios (UCS). In particular, HLUC_01 & 04 will enhance the opportunities for aggregators by using the research outcomes of WPs 3 & 6 to offer intelligent services for automated flexibility aggregation and advanced market clearing. Aggregators represent the supply side in the FLEXGRID ATP.

**Tech companies/asset manufacturers** are increasingly entering the ecosystem as new market opportunities arise from the possibilities of remote aggregation and steering of consumption assets. Companies that have traditionally offered electricity consuming assets (e.g. water boilers, heat panels, heat pumps, EV chargers, floor heating) are now adding functionalities to control these assets as well as adjacent services for data aggregation and analysis. FLEXGRID will promote these actors by developing services for the automatic aggregation of flexibility assets in WP3. The FLEXGRID ATP will enable these actors to offer the aggregated flexibilities to the FMO, either directly or indirectly via an aggregator or ESP.

The **FMO** is entering the ecosystem as a novel type of marketplace that endeavors to fill a gap in the current energy market landscape. As a result of the challenges outlined above, the incumbent ecosystem needs new and innovative models that provide for the simpler and cheaper participation of prosumers at organized marketplaces (OMPs). Currently, OMPs are designed as B2B venues with (often) complicated and lengthy admission routines

[4] https://www.ei.se/Documents/Publikationer/rapporter_och_pm/Rapporter%202019/Ei_R2019_04%20Tj%c3%a4nster%20f%c3%b6r%20efterfr%c3%a5geflexibilitet%202019.pdf

paired with high capital requirements. This makes the participation unattractive for most SMEs and prohibitive for small asset owners and households.

NODES, based on its experience as the industrial partner representing the FMO role, has already conducted a lot of work prototyping a marketplace for local flexibility. In its market concept, NODES is designed to be a marketplace for any flexibility supplier irrespective of size and/or capital endowment. In this way, it will provide a platform for the above stakeholders where the supply and demand side of flexibility are able to meet and trade.
Through its role in FLEXGRID, the FMO role will be enhanced compared to the status-quo of the market platform. It will benefit from the development of advanced matching and clearing models. NODES will be able to exploit the research results and ATP modules developed in the project through being able to offer new and improved products and services for a more automated marketplace that is necessary for the efficient handling of large amounts of FlexAssets.

## 2.3 Summary of flexibility market projects and proposed FLEXGRID advancements

Flexibility markets are recognized as a promising tool to make better use of existing distribution grids and thereby also reduce the need for grid investments. The newly adopted Clean Energy Package for all Europeans[5] states that distribution system operators shall procure services in a market-based manner from resources such as distributed generation, demand response or storage, when such services are cheaper than grid expansion. Four pioneering projects implementing flexibility markets are: Piclo Flex, Enera, GOPACS and NODES. The projects can be analyzed based on the following questions: (1) Is the flexibility market integrated in the existing sequence of EU electricity markets; (2) Is the flexibility market operator a third party; (3) Are there reservation payments; (4) Are the products standardized; (5) Is there TSO-DSO cooperation for the organisation of the flexibility market; (6) Is there DSO-DSO cooperation for the organisation of the flexibility market. **All the considered flexibility markets are operated by a third party**. All projects also engage with multiple DSOs in order to become the standardized platform provider. Important differences between the projects are the extent to which the flexibility markets are integrated into other markets, the use of reservation payments, the use of standardized products and the way TSO-DSO cooperation has been implemented.

**Table 2: Overview the answers of the four projects for the six design controversies[6]**

| | YES | NO |
|---|---|---|
| **1. Is the flexibility market integrated in the existing sequence of EU electricity markets?** | GOPACS and NODES | Piclo Flex and Enera |
| **2. Is the flexibility market** | All projects. GOPACS is not a | / |

[5] A. Nouicer, L. Meeus, The EU Clean Energy Package (CEP), Technical Report, October 2019.
[6] Schittekatte Tim; Meeus Leonardo "Flexibility markets: Q&A with project pioneers", Working Paper, EUI RSCAS, 2019/39, Florence School of Regulation, Energy.

| | | |
|---|---|---|
| **operator a third party?** | market platform operator but an intermediary. Currently, the market platform is ETPA. | |
| **3. Is there a reservation payment?** | Piclo Flex | Enera, GOPACS and NODES (all projects envision to integrate reservations) |
| **4. Are products standardized in the flexibility market?** | Piclo Flex, Enera and GOPACS (IDCONS product) | NODES |
| **5. Is there TSO-DSO cooperation for the organisation of the flexibility market?** | GOPACS (TSO and DSOs use the same intermediary). Enera and NODES (soon also the TSOs will be active). | Piclo Flex is solely a DSO platform |
| **6. Is there DSO-DSO cooperation for the organisation of the flexibility market?** | Piclo Flex (6 DSOs), GOPACS (4 DSOs), Enera and NODES (one DSO active per installation, soon more will join) | |

Geographic scope and state of implementation:

The table below provides an overview with each proposal's name, region, current state of implementation and key goals. A majority of proposals are German, reflecting the considerable academic, political, and industry interest in market-based congestion management during recent years. Furthermore, one proposal is in the UK, one in the Netherlands, and one multinational proposal. Most projects are in the process of piloting and have already facilitated first transactions between grid operators and flexibility providers. NODES is one of the two projects categorized as business cases, which are being implemented by private companies and have partially started commercial operation. Nevertheless, no large-scale flexibility market exists at this stage.

Key objectives:

All proposals seek to develop platform-based solutions to tap local flexibility to alleviate congestion and broaden the scope of congestion management tools for distribution grid operators. By setting up a market platform, they intend to create a mechanism that i) makes flexibility demand and supply visible to each other, ii) coordinates both sides, considering the increasing number of supply side participants, and thereby iii) creates incentives for previously unused resources to participate in congestion relief. Only few proposals additionally aim to incentivize large-scale investments into new flexible assets or at deferring grid reinforcement. Finally, none explicitly seeks to replace existing congestion management and voltage control mechanisms. Instead, flexibility markets are considered complementary tools. In the case of Germany, this would mean a hybrid system of regulatory and market-based congestion management.

**Table 3: Overview of flexibility market proposals and pilots in the EU area[7]**

| Proposal | Region | State of Impl. | Key Objectives |
|---|---|---|---|
| Bne Flexmarkt | DE | Proposal | Reform German grid fee regulation to tap existing |

[7] Radecke, Julia; Hefele, Joseph; Hirth, Lion (2019): Markets for Local Flexibility in Distribution Networks, ZBW – Leibniz Information Centre for Economics, Kiel, Hamburg.

| | | | |
|---|---|---|---|
| | | | and incentivize new resources for congestion management in the distribution grid and reduce concurrence |
| SINTEG C/sells: Comax | DE | Pilot | Develop a coordination platform to promote congestion management with small-scale flexibility on lower voltage levels and improve grid operator coordination |
| SINTEG WindNode: Flexibilitätsplatt-form | DE | Pilot | Expand congestion management options by tapping additional flexibility sources connected to the distribution grid |
| SINTEG Enera: Flexmarkt | DE | Pilot | Develop a platform to coordinate flexibility demand and supply, improve congestion management options for grid operators, and reduce renewable energy curtailment |
| SINTEG New 4.0: ENKO | DE | Pilot | Develop a coordination mechanism for grid operators to showcase the potential of local loads as an alternative to redispatch, and renewable energy curtailment |
| DA/RE | DE | Pilot | Develop IT platform to tap flexibility potential located on the distribution grid for congestion management and improve coordination between grid operators |
| Nodes Market | Europe | Business case | Create a marketplace to improve grid operation, tap additional flexibility potential and enhance congestion management options for grid operators |
| Grid Integration | DE | Proposal | Develop a flexibility market platform with largely automated processes to improve congestion management in the distribution grid |
| GOPACS/ IDCONS | NL | Pilot | Develop a mechanism to increase available flexibility volume, reduce costs, and standardize and harmonize grid operator products and processes to address congestion on lower voltage levels |
| Piclo Flexibility Marketplace | UK | Business case | Develop a marketplace to standardize and facilitate DNO flexibility procurement, make more efficient use of the existing grid, and reduce the need for grid reinforcement |

**Product and remuneration:** In all markets, flexibility providers sell the deviation from their assets' baseline, i.e. they sell the service to generate or consume more or less electricity than originally planned or scheduled. Typically, they do so for 15-minute or 60-minute intervals. In return, they either receive dispatch payments (€/kWh), i.e. flexibility providers are paid for each affected deviation from their assets' original dispatch, or availability payments (€/kW), i.e. flexibility providers are paid for reserving flexibility availability, or a combination of both. In all cases, flexibility providers are responsible for balancing their schedules, e.g. through trade on the zonal market. Most proposals employ dispatch payments. Five employ availability payments or a combination of the two.

**Product differentiation:** Half of the proposals offer more than one type of flexibility product. For instance, NODES market offers a spot market product as well as a so-called “availability contract” (or else capacity payment in euros/KW and can be long-term or short-term). For the former, flexibility providers receive dispatch payments. The latter allows them to commit a certain flexibility profile over a longer time horizon for which they receive an availability payment. In addition, most proposals offer largely standardized product specifications, such as interval length and remuneration schemes. NODES market and the Piclo Marketplace allow for a greater scope of individualizing product features. For instance, in flexibility procurement contracts that are auctioned off through the Piclo Marketplace, grid operators individually determine procurement periods that currently range from one season to several years, offer different combinations of dispatch and availability payments, and select different weekdays, hours of the day, and interval lengths for which they require flexibility.

# 3 Research methodology of FLEXGRID's framework

The integration of large amounts of Distributed Energy Resources (DERs) according to Clean Energy Package (CEP)[8], such as PV/Wind generation, electric vehicles, Energy Storage Systems (ESS) and Demand Side Management (DSM) tools, poses new challenges and opportunities for the power sector. Relying only on grid investments to cope up with this new regime in Power Systems will be very expensive and consequently inefficient. Moreover, current electricity markets do not take into account the physical constraints that the distribution grid introduces. In this context, the volatile and unpredictable distributed energy production that high RES penetration introduces, create additional challenges necessary to cope up with congestion, reactive power instability and voltage issues.

Flexibility Markets are considered as a promising alternative towards: i) the efficient utilization of the distribution grid, ii) the reduction of the need for grid investments, iii) the facilitation of the penetration of distributed renewable generation, and iv) the increase of investments sustainability' in Energy Storage Systems and Demand Response. A series of recent studies and research projects have dealt with the conceptualization of Flexibility Markets. However, there are several questions to be answered regarding the design of these markets' architecture:

1. Who runs the Flexibility Market?
2. Which is the cooperation framework through which TSOs and DSOs interact?
3. Which are the products of the Flexibility Market?
4. Who can participate in the Flexibility Market?
5. Which will be the market structure (market running times, market clearing algorithm, bidding structures, pricing method, etc.)?
6. Which interaction framework between DSO-DSO should be used?

More specifically the research threads of FLEXGRID are based around its it's proposed innovative smart grid architecture which is relevant which the development of flexibility markets which offer efficient and stable services in smart grids with distributed and high RES penetration.

In more detail in today's smart grids, the clearing process of the energy markets does not take into account the physical constraints that the transmission and distribution grid introduce. Consequently, TSOs modify the dispatch decision of the energy markets in order to secure the stable operation of the power grid. On the other hand, the existing smart grid architecture does take into account neither the efficiency of the distribution nor potential violations of the physical constraints from which the distribution network is limited. Distributed and dynamic energy production that high RES penetration introduces deteriorate the stability of the grid. Thus, distribution grids suffer from congestion problems and voltage stability issues.

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[8] https://ec.europa.eu/info/news/clean-energy-all-europeans-package-completed-good-consumers-good-growth-and-jobs-and-good-planet-2019-may-22_en

**In order to alleviate these issues, the main architectural proposition of FLEXGRID is the development of a sophisticated Distribution Level Flexibility Market (DLFM), whose operating area is correlated with the topology of a distribution network. For the realization of this market, the DSO should provide high-level information of its network topology together with specific Geographical Locations (GLs) within which the present FlexAssets could offer their flexibility at a given price. This price will be higher if the DSO's congestion/voltage problem is important and the price will be low in the opposite case.**

Consequently, a DSO (FlexDemand side) sends information relevant with its grid topology and constraints to a Flexibility Market Operator (FMO), which coordinates the operation of the proposed DLFM through an Automated Trading Platform (ATP), which is a software platform that FLEXGRID develops.

In more detail, the FMO is entering the proposed smart grid ecosystem as a novel type of stakeholder that appears in order to facilitate the operation of smart grid which model network constraints and have high RES penetration. FMO will use the proposed FLEXGRID ATP to host information on FlexAssets and FlexRequests (i.e. FlexDemand side) and will enable the trading as well as market clearing and settlement of contracts. Because of the challenges outlined above, the incumbent ecosystem needs new and innovative models that provide for the simpler and cheaper participation of prosumers at Organized MarketPlaces (OMPs).

In FLEXGRID, NODES (as an FMO) is the stakeholder that disposes the necessary experience in order to offer consulting services towards the design of flexibility market architecture and evaluate the proposed solutions. In its market concept, NODES is designed to operate a marketplace for any flexibility supplier irrespective of size and/or capital endowment. In this way, it will provide a platform for the above stakeholders, where the supply and demand side of flexibility are able to meet and trade.

More specifically, the FMO interacts with ESPs (e.g. energy storage owners, DR aggregators/providers, RESPs, etc.) that represent FlexSupply Side. ESPs bid their flexibility (time constraints, price and quantity). Finally, the FMO communicates with the traditional energy market operator in order to: i) acquire information relevant to the dispatch schedule (i.e. schedules are based on portfolio/bidding zone level), ii) affect the market clearing through information relevant to its operating area.

According to these, flexibility market clearing algorithms (that FMO executes) are able to minimize the cost of the flexibility that is required in order to: i) make the distribution network's operation efficient and ii) satisfy the constraints that the distribution network sets. In order to achieve this, the aforementioned flexibility market operations could take place in two phases.

The first phase is right after the Day Ahead Energy Market (DA-EM) and Reserve Market[9] (RM) clearing. In this stage, flexibility market addresses problems in the distribution

[9] Reserve is additional generation capacity above the expected load. Scheduling excess capacity protects the power system against the uncertain occurrence of future operating events, including the loss of energy or load forecasting errors. Reserve market that is designed to clear existing Day-Ahead Scheduling Reserve requirements as defined by reliability standards.

network that the production and demand forecasts reveal through the in advance scheduling of flexibility assets in distribution network.

The second phase is closer to real time. In this phase, flexibility market copes up with more dynamic issues in production (e.g. outages/damages, sudden weather change) and demand (e.g. real-life events that change demand patterns).

The two aforementioned stages enable an interaction between the dispatch of the existing energy markets and the Distribution Network's physical constraints. In this way, the proposed flexibility market efficiently mitigates congestion issues and facilitates appropriate voltage levels in the whole distribution grid.

The proposed architecture necessitates the development of four research threads. These are mapped in the four high-level use cases for FLEXGRID and described in detail in chapter 4.

Briefly, the first research thread focuses on the monitoring of the transmission and the distribution networks in smart grids and in resolving the problems that high RES penetration introduces such as congestion issues and voltage control. A major objective of this thread is the creation of the architecture of the flexibility market that FLEXGRID proposes. This thread is partially covered in WP4 and WP5 and hosts more S/W development effort towards this goal.

The second research thread is relevant with the optimal operation of assets that ESPs dispose and the advanced planning of their investments according to a careful examination of the market needs and the competition. This thread constitutes the research objectives of WP4 research work.

The third research thread examines in depth the operation of the existing energy markets and the innovative flexibility markets that FLEXGRID proposes. It unfolds around the development of advanced market clearing algorithms able to model adequately the underlying grid and ensure at the same time market power mitigation (strategic bidding avoidance). WP5 will mainly host research activities relevant to this thread.

Finally, the fourth research thread of FLEXGRID spans around the aggregation of flexibility assets and their optimal and parallel use in existing energy markets and in the flexibility markets that FLEXGRID proposes and develops. The core of this research thread unfolds in the context of WP3 research work.

The interaction among the aforementioned research threads and the requirement of each one of them composes the research methodology of FLEXGRID.

## 3.1. Research thread 1: Future smart grid architecture design

Nowadays, EU DSOs have started facing new operational challenges (i.e. local congestion management and voltage control), which is mainly due to the continuously increasing RES penetration and distributed FlexAssets' installation at the distribution grid level. The roles and responsibilities of the future DSOs will resemble much those of TSOs, but at lower voltage levels. Unlike TSOs, DSOs currently have no market-based mechanisms that they can use for the procurement of ancillary services at local grid level.

This has triggered the investment in new infrastructure to address some of the issues that DSOs are facing. Efficient operations require the establishing of markets for flexibility to provide flexibility on a local level. According to the EU e-Directive Article 32, DSOs shall facilitate flexibility arrangements through establishing specifications for flexibility services they would like to procure. The alternative to market-based flexibility would be DSOs controlling hundreds or thousands of small and distributed FlexAssets directly based on inflexible bilateral agreements without the use of prices signalling scarcity on local level.

Thus, the major objective of this thread is to derive the requirements of the proposed Distribution Level Flexibility Market (DLFM) and to analyse how various DLFM architectures are able to cope up with them. In the rest of this section, we briefly categorize various DLFM architectures and presents their advantages and disadvantages.

There are two possible types of DLFM architectures in terms of the TSO-DSO relationship in which they are based. The former one noted here as wholesale market dispatch centric DLFM (in which transmission level market clearing has priority) and the latter as Social Welfare (SW) centric DLFM (in which TSO-DSO relationship is much more interactive). In wholesale market dispatch centric DLFM, the flexibility dispatch that DLFM derives (through its market-clearing algorithm) does not affect the dispatch of the wholesale market, which is given as a priori input to the FMO in order to clear DLFM[10]. Thus, this type of architecture is compatible with the existing smart grid architecture. On the other hand, DLFM is not able to give its feedback to wholesale market and under this perspective dispatch centric DLFM is not as efficient as possible. The latter one (SW centric DLFM) is based on a more interactive (dialectic) relationship between wholesale market and DLFM in order to offer higher levels of Social Welfare (SW) than the former but it is not compatible with the existing smart grid architecture and concerns future smart grids.

As far as it concerns the former (wholesale market dispatch centric DLFM architecture), the FMO takes the wholesale market dispatch as a priori input which includes the production and the consumption of the distribution network in which DLFM operates and derives an optimal dispatch of the available flexibility at the distribution network. The optimality concerns the minimization of the flexibility cost the constraints of the distribution grid.

An alternative approach in this case could be calculation of the bidding curve in the wholesale market by taking into consideration: i) the cost of flexibility needed and ii) the feasibility of the bid in the wholesale market in terms of the constraints that distribution network introduces. The drawback of this alternative is the possible complexity and the level of efficiency of an algorithm able to execute this task.

The latter case, which is Social Welfare (SW) centric DLFM architecture, is more complex and is divided into two sub cases according to the relationship between the TSO (which is connected with the balancing market and indirectly connected with the operation of the wholesale energy market) and the DSO (which is closely connected with the operation of the flexibility market).

The first one is cooperative Social Welfare (SW) centric DLFM architecture. In this case, TSO and DSOs co-optimize the use of energy and flexibility in a way that maximizes SW and this is done through their efficient communication and collaboration. The advantage of this architecture is SW maximization and the disadvantage is the complexity and scalability of an algorithm able to clear a market of that large scale. **The use of scalable algorithms in order to solve in a distributed fashion large-scale optimization problems is of high importance here.**

[10] Please note that this DLFM architecture alternative will be used as a baseline scenario with which proposed FLEXGRID market architectures will be compared.

The second one is competitive Social Welfare (SW) centric FM architecture in which TSO and DSO (actors) interact through in a game theoretic perspective. In this architecture, market clearing requires several interactions between TSO and DSOs in order to reach equilibrium. This approach can possibly be formulated as a game theoretic model, where the actors are the TSO and DSOs. In every iteration of the game, TSO clears wholesale market and this output will be used by DSOs in order to clear their DLFM respectively. This clearing influences the bids in the wholesale market, which will be cleared again under the perspective of this information. This iterative process facilitates the wholesale market price discovery, which allows FMO to clear its market in a more efficient way and maximize social welfare. When this process converges (i.e. they reach an equilibrium), it derives the final clearing for both markets simultaneously. The clearing of the market is the dispatch of each actor at the last iteration.

In the rest of this document, there is a description of the possible phases of the DLFMs and it follows a categorization of DLFM architectures according to the relationship and interaction between TSO and DSO, which is respectively the interaction between the wholesale energy market and the DLFM.

FLEXGRID will investigate the necessity and the requirements of the following 4 potential Flexibility Market phases:

1. **Day-Ahead Flexibility Market (DAFM)**

In this phase, Flexibility Suppliers bid their flexibility and the FMO calculates the optimal flexibility dispatch schedule so as to tackle predicted flexibility needs (based on RES, load forecasts and TSO day-ahead dispatch) and operational challenges (voltage limit violations and thermal overloading of network assets).

2. **Flexibility Reserve Market (FRM)**

This phase is necessary in order to allow DSO to purchase reliability of resources from the market participants and be able in this way to guarantee network's stable operation in case that predictions are inaccurate or in case that there is no DAFM. When called, these flexibility reserves will deliver congestion avoidance or voltage support services. Thus, FlexSuppliers offer their capacity to adjust their operating point if needed.

3. **Two-Stage Stochastic Day-Ahead Flexibility Market (SDAFM)**

In this phase it is necessary to co-optimize Day-Ahead and Reserve Market based on multiple scenarios of the next day's consumption and RES production, which is actually an integrated version of DAFM and FRM.

4. **Real-Time Flexibility Market (RTFM)**

The fourth and final phase is necessary for the efficient and reliable continuous operation of the distribution grid which must be guaranteed even in case of inaccurate predictions and unexpected events. Therefore, FMO runs a Flexibility Real-Time Market and recalculates the flexibility dispatch based on the updated system state in order to keep the system within its operating limits. FMO uses FlexSuppliers' bids/offers to determine a cost-reflective flexibility spot price (Phase 4 can co-exist with 1/2 or 3).

FLEXGRID in the context of WP3-WP5 will develop algorithms to instantiate the aforementioned architectures according to the requirements that stakeholders set. The aforementioned categorization, in four (4) categories, of the research problems that will be examined from FLEXGRID are used as input to the definition of the four (4) high-level use cases and use case scenarios to be described in the next sections.

## 3.2. Research thread 2: Optimal ESP operation and planning

As explained earlier, modern ESPs are expected to face three major changes/challenges in the future. The first is that they are in an environment in which traditional energy markets (e.g. wholesale and balancing market) and “modern” (e.g. flexibility market at distribution network level) energy markets co-exist. The second is that competition is strong and they have to consider the features of their competitors in their short term (e.g. asset management) and in their long-term decisions (e.g. asset investments). The third is the necessity to co-optimize in parallel a set of services (e.g. Demand Side Management, optimization of parallel participation in multiple markets, retail market pricing, etc.) in order to be efficient and competitive.

In this context, FLEXGRID organizes its research towards Optimal ESP operation and planning according to the features of this environment.

**The first research objective** is the minimization of ESPs OPEX by optimally scheduling: i) the flexible consumption of its end users (e.g. home devices), ii) the possible production of its RES and iii) its aggregated flexibility assets (e.g. ESS, EVs, etc.) according to the conditions and the forecasts of the aforementioned markets.

More specifically, ESPs have to optimize the operation of their assets and derive the bidding strategy that maximizes their profits. Towards this goal, they exploit: market forecasters, consumption forecasters and information relevant with underlying network topology[11]. In this context they are able to possibly use MPEC models (Mathematical Program with Equilibrium Constraints), bi-level optimization, AI, etc. in order to model the market behaviour and act as price makers (consider the impact that their decisions have in the market equilibrium). In this way, ESPs maximize their profits and are able to defend to attempts that they competitors may execute in order to exercise market power.

**The second research objective** is the maximization of ESP’s profits by co-optimizing their participation in several energy markets (wholesale energy markets, ancillary services, local flexibility markets). In order to maximize its profits, ESP joins several energy markets. High RES penetration makes the behaviour of various energy markets much more dynamic and this concerns especially markets relevant with dynamic RES production (balance market, proposed flexibility market). Thus, ESPs are able to exploit their assets in an efficient way only if they co-optimize their use through market forecasts able to forecast all the aforementioned energy markets.

**The third research objective** is the minimization of ESP’s CAPEX by making optimal investments (i.e. optimal sitting and sizing) on end user portfolio, RES and flexibility assets.

More specifically, in addition to the optimal operation, competitive ESPs have to derive efficient investment plans by taking into account: i) the energy demand/ user portfolio and its location, ii) their competitors (other ESPs in the same markets and grid locations), iii) their existing flexibility assets. In this context, FLEXGRID will develop scalable algorithms able to minimize ESP’s CAPEX through intelligent investment planners and models that effectively model the competition from other rival ESPs.

[11] We assume that this type of information will be increasingly available by DSOs in the future based on the description of article 32 of CEP named “Incentives for the use of flexibility in distribution networks”. This article discusses about the need for DSOs to provide transparent network development plans, which will be publicly available for all interested stakeholders.

**The fourth research objective** is to enrich FLEXGRID's investment planners with intelligence that takes into account the expected/predicted investment plans of the competitor ESPs.
In this way, ESPs avoid to invest on assets non useful for their future profitability and at the same time they become financially sustainable even in cases of strong competition. Towards this goal FLEXGRID will indicatively exploit mathematical tools EPEC models (Equilibrium Program with Equilibrium Constraints) and AI algorithms in order to evaluate their performance and their ability to predict market equilibria in case that several competing ESPs conduct investments.
**The fifth objective** is market forecasting which is necessary in order to allow ESPs to be able to act intelligently to the proposed smart grid architecture. In addition, the development of DLFM constitutes to market forecasting which is useful for the optimal exploitation of the various flexibiltiy assets in order to have stable and low cost energy services.

## 3.3. Research thread 3: Advanced market clearing algorithms

In this thread, FLEXGRID will develop market clearing algorithms able to clear DLFM in a way that it is able to mitigate congestion problems, voltage stability issues and reactive power imbalances. According to the research community, these algorithms exploit optimization theory and have two major parts. The first is the distribution network model and the second is the arithmetical method that derives the optimal operating point.
In more detail market clearing algorithms exploit a set of optimization problems in electricity grids, known as Optimal Power Flow (OPF). OPF is a constrained nonlinear optimization problem that seeks to optimize the operation of an electric power system subject to the constraints imposed by: i) physical constraints: electrical laws (Kirchoff's laws, Ohm's Law, Power balance), ii) operational constraints: engineering limits, market constraints or other performance constraints (e.g., voltage limits, line ampacity limits, generator ramping constraints, power factors).
The cost parameters that formulate the objective function of the optimization problem vary depending on the specific use case or application of OPF. In particular, the major challenges that have to be modeled are:

- Flexibility cost – cost of ESS, DSM and other flexibility assets that are required in order to avoid the violation of the constraints that the distribution network set.
- Economic Dispatch (ED) - determination of the optimal short-term output of electricity generation facilities.
- Unit Commitment (UC) - optimal scheduling of generating units, usually performed for one day with hourly or 15-minute resolution.
- Line Losses - minimization of thermal losses on the lines of the grid.
- Distributed Energy Resources (DER) investment, operational costs and losses - DER usually refers to Renewable Energy Sources (RES) and Distributed Energy Storage Systems (D-ESS). D-ESS are often expensive to install, maintain and operate. RES are highly variable, but provide low-cost energy production, which is occasionally lost due to congestion/balance issues.
- Voltage Deviation - the difference of each bus voltage from the nominal value should be minimized and is an index of network stability and congestion.
- Network congestion – power threshold that network lines are able to transfer

The objective of FLEXGRID is to design a DLFM able to cope up with all these issues and derive an optimal trade off among the DLFM requirements, which are:

- Tractability/Scalability of the market clearing algorithm which can be expressed as the time that is required as a function of the distribution network size and parameters
- Efficiency/Accuracy, which is the level with which the dispatch that the market clearing algorithm approximates the optimal solution (i.e. flexibility cost minimization).

## 3.4. Research thread 4: Automated aggregation and management of distributed flexibility assets

As already, analysed, Demand Side Management (DSM) is the major small-scale flexibility asset. This research thread copes up with the way that Aggregator/ESP orchestrates these Distributed Flexibility Assets (DFAs) in order to optimally respond to FlexRequests and participate in various markets aiming at deriving an attractive trade-off between its profits and the welfare of its end users.

**The first research objective** in this area is the efficient correspondence of the ESP to FlexRequests by optimally orchestrating its aggregated flexibility portfolio. In more detail ESP/aggregator analyzes the behavior of various energy markets and optimally exploits the set of its already aggregated flexibility assets (from its end users) by centrally optimizing their use in a dynamic fashion in order to maximize the sum of the profits that it acquires from the various energy markets (wholesale, ancillary services, local flexibility markets).

**The second research objective is dedicated to analysing** how a flexibility aggregator (ESP) efficiently aggregates the flexibility of its end users by employing advanced pricing architectures for the retail market. In other words, this can be expressed as the way that an aggregator/retailer operates an end user centric ad hoc flexibility market by employing advanced retail pricing models. In more detail, the aggregation of small-scale flexibility assets (end user electric appliances with modifiable loads, EVs, etc.) requires the development of a retail flexibility market through which ESP trades dynamically with end users the value of the flexibility assets that the latter dispose. The development of dynamic pricing schemes and auctions has several requirements because these systems have to be: Real Time, Efficient, Strategy Proof, Competitive, Scalable, Fair and Privacy Protecting. In addition, the uncertainty in the constraints and preferences that end-user introduces is a critical requirement towards their development.

**The third research objective is to propose** advanced ways for ESP to dynamically interact with its end users towards optimal participation in several energy markets. Briefly, FLEXGRID exploits its forecasters and analyses how an ESP will maximize its profits by optimally orchestrating distributed FlexAssets from its end users in order to optimally and strategically participate in several energy markets.

In more detail, ESPs act as flexibility asset aggregators and interact with end users in order to trade their aggregated dynamic potential to shift or curtail consumption. In addition, ESPs participate in various energy markets. In this context, they develop user compensation mechanisms (dynamic retail pricing and/or auction algorithms), which allow them to trade in these markets more efficiently through this dynamic interaction. The major requirements from these mechanisms that will constitute the KPI of their success are: i) the efficient exploitation of the profit opportunities that the behaviour of flexibility markets sets, ii) the level of satisfaction of the end users (user welfare) from the compensation mechanisms, iii) the profits of the ESP (i.e. sum of profits from simultaneously participating in several markets).

## 3.5 SGAM methodology

The Smart Grids Architecture Model (SGAM) framework[12], is generally described as the architectural structure of a practical methodology where each particular UC can be modelled and analysed from different aspects, thus providing a structured approach for modelling smart grid use cases. The basis for SGAM is a three-dimensional framework consisting of domains, zones and layers as its three axes.

The domains represent the traditional layout of the electrical energy infrastructure:

- *Generation* (generation of electrical energy in bulk quantities).
- *Transmission* (infrastructure and organization that transports electricity over long distances).
- *Distribution* (infrastructure and organization that distributes electricity to customers).
- *DER* (small-scale distributed energy resources directly connected to the public distribution grid).
- *Customer Premises* (end-users and producers of electricity).

On the other hand, the zones depict a typical hierarchical power system management:

- *Process* (physical energy conversion and primary equipment of the power system).
- *Field* (protection, control and monitor equipment).
- *Station* (aggregation level for fields, e.g. for substation automation).
- *Operation* (power system control operation in the respective domain, e.g DMS/EMS).
- *Enterprise* (commercial and organizational processes, services and infrastructures for enterprises).
- *Market* (market operations possible along the energy conversion chain).

These two axes combine to form the *Component* layer, which represents the physical layer, including all system equipment, network infrastructure and protection devices. On top of the Component layer, four interoperability layers are placed.

With a completed UC analysis and the developed component layer, mapping UCs in SGAM and development of SGAM layers generally goes in the following order:

- *Business* layer (business view on the information exchange related to smart grids).
- *Function* layer (functions and services, including their relationships from an architectural viewpoint).
- *Information* layer (information that is being used and exchanged between functions, services and components).
- *Communication* layer (protocols and mechanisms for the interoperable exchange of information between components in the context of the underlying use case, function or service).

A graphical representation of the SGAM framework can be seen in the figure below:

[12] KTH, SGAM Template for EH2740

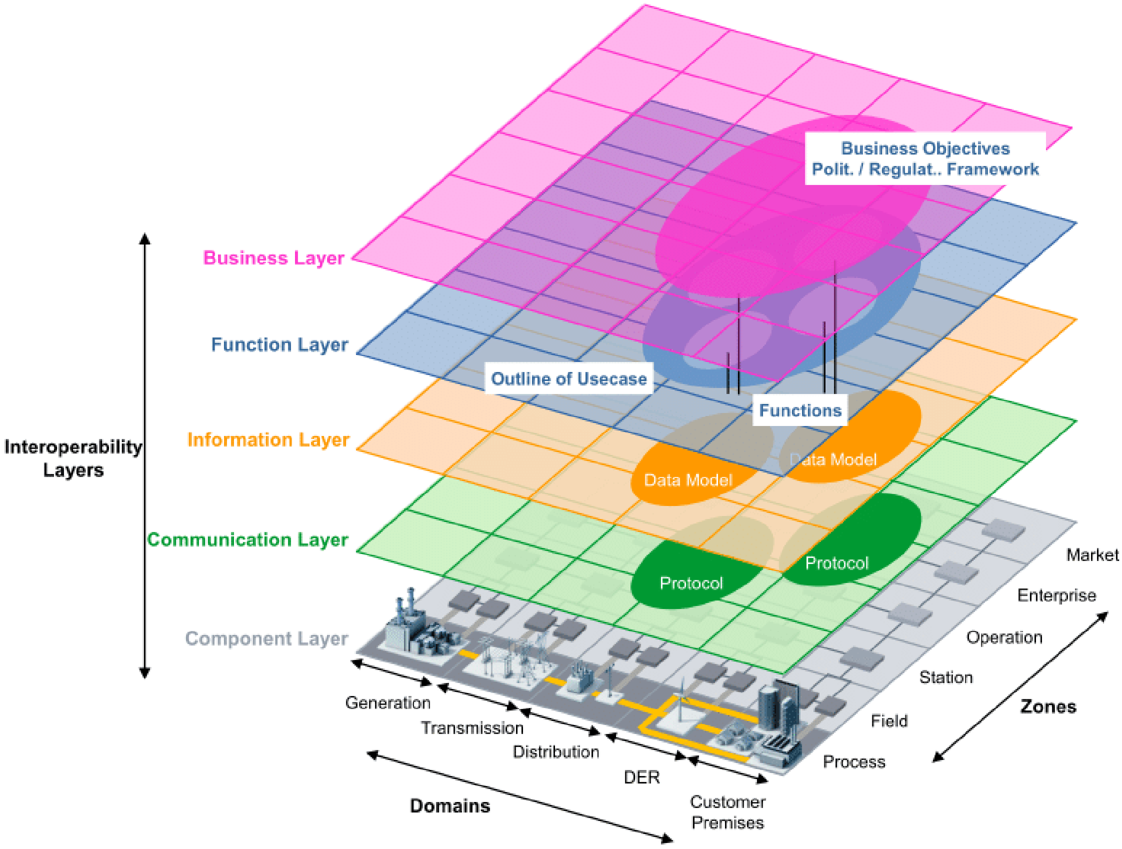


**Figure 4: SGAM framework[13]**

According to the aforementioned SGAM framework, FLEXGRID will exploit its research objectives in order to define its use cases and scenarios, requirements' analysis, definition of technical specifications as analysed in Section 4. In addition, in WP2, FLEXGRID will define its architecture according to SGAM model in the context of D2.2. Finally, FLEXGRID will follow SGAM model in its software integration process (WP6) and in the execution of its pilots and lab experimentations (WP7).

[13] CEN-CENELEC-ETSI Smart Grid Coordination Group, "Reference Architecture for the Smart Grid," 2012.

# 4. FLEXGRID high-level use cases

According to the four (4) research threads outlined and extensively described in the previous section (as part of Task 2.1 work), four (4) respective High-Level Use Cases (HLUCs) have been defined and are led by FLEXGRID's industrial partners. There is a close relationship and direct mapping between the research threads and the HLUCs. In other words, research thread #1 is closely inter-related with HLUC_01, research thread #2 is closely inter-related with HLUC_02, research thread #3 is closely inter-related with HLUC_03 and research thread 4 is closely inter-related with HLUC_04.

From a project management perspective, the Use Case (UC) creation process is vital for project success, given that UCs provide a structure for gathering research project's requirements and setting the project's scope. By deliberating the UCs, members of the consortium were able to describe and define key processes and functionalities of the intended research solutions aimed at achieving the project objectives. FLEXGRID's project structure is organized in a manner that applies the so-called top-down approach where, based on project objectives, the more general High-Level Use Cases (HLUCs) are created first (work led by industrial partners) and specialized Use Case Scenarios (UCS) are developed later (work led by academic partners) to explain a tangible elaboration of the technical or functional details.

The four (4) high-level use cases (HLUCs) that were created addressing project's objectives and following up the description of the four (4) research threads (cf. section 3) are:

- HLUC_01: FLEXGRID ATP offers advanced market clearing services to the Flexibility Market Operator (interaction between markets' and networks' operation) (Leader: NODES/NPC)
- HLUC_02: FLEXGRID ATP offers advanced flexibility supply management services to Energy Service Providers (Leader: BADENOVA)
- HLUC_03: FLEXGRID ATP offers advanced flexibility demand management services to system operators (Leader: HOPS)
- HLUC_04: FLEXGRID ATP offers automated flexibility aggregation management services to ESPs/Aggregators (interaction with end users) (Leader: UCY)

**Important note:** It should be noted that all HLUCs deal with the proposed FLEXGRID system operation as a whole. However, each one of them is focused on specific parts of the FLEXGRID S/W platform (i.e. ATP). For example, HLUC_01 is focused on the FLEXGRID services provided to the Flexibility Market Operator (FMO), who operates a Distribution Level Flexibility Market (DLFM), while also interacting with existing market platforms (i.e. day-ahead, intra-day, balancing, reserve markets). HLUC_02 focuses on FLEXGRID services provided to the Energy Service Provider (ESP), who operates at the FlexSupply side of the proposed business ecosystem. HLUC_03 focuses on FLEXGRID services provided to the system operators (emphasizing on DSO), who operate at the FlexDemand side of the proposed business ecosystem. Finally, HLUC_04 focuses on FLEXGRID services provided to the independent aggregators/suppliers, who act as intermediary entities between the end prosumers and the energy markets (i.e. B2C flexibility market).

## 4.1 FLEXGRID ATP offers advanced market clearing services to the Flexibility Market Operator (interaction between markets' and networks' operation)

<table>
<tr><th>HLUC_01</th><th>FLEXGRID ATP offers advanced market clearing services to the Flexibility Market Operator (interaction between markets' and networks' operation)</th></tr>
<tr><td>Description</td><td><u>Scope/Purpose:</u><br>This HLUC focuses on FLEXGRID ATP's operation and its interaction with incumbent markets and the underlying physical network operation. The initial idea is based on NODES business model[14] in collaboration with Nord Pool Consulting (NPC) aiming at defining and developing advanced mathematical models and research algorithms. The aim is to define and develop advanced clearing models for the FMO that go beyond the state-of-the-art as described further below.<br>HLUC_01 will be supported by the following Use Case Scenarios (UCS) which are designed to represent real-world challenges of grid operators (i.e. basically of the DSO but also the TSO) that the FMO aims to solve. A detailed description of each UCS can be found in section 5.1. The UCS of HLUC_01 are the following:<ul><li>UCS_01: Distribution network aware flexibility market clearing via FLEXGRID ATP (led by DTU)</li><li>UCS_02: Market-based local congestion management using FLEXGRID ATP in distribution networks using output from AC-OPF model calculation as dynamic input for ATP (led by DTU)</li><li>UCS_03: Market-based local voltage control using FLEXGRID ATP in distribution network operation (led by DTU)</li><li>UCS_04: FLEXGRID ATP operates as a gateway to redirect local active power flexibility to TSO platforms (interaction with existing TSO balancing markets) (led by ICCS)</li></ul><br><u>Detailed description:</u><br>The FMO is responsible for the operation of the proposed Distribution Level Flexibility Market (DLFM). The aim of the DLFM is to fill a gap in the current wholesale electricity market design. This gap results from the way that grid constraints are represented in the European target model for wholesale electricity markets as regulated by the guideline on capacity allocation and congestion management (CACM)[15]. This model assumes that grid constraints only exist between (mostly politically determined) bidding zones, while power flows within bidding zones are unrestricted (basically assuming a copper plate on bidding zone level).<br><br>This model increasingly leads to infeasible market outcomes (i.e. the higher the RES penetration levels are, the bigger the problem becomes), because it neglects the existence of grid constraints within bidding zones. FLEXGRID will develop services that address these issues and offer them, via its ATP, to the newly established role of FMO. The aim is to provide grid-aware services for use</td></tr>
</table>

[14] https://nodesmarket.com/2018/11/07/document-test/
[15] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32015R1222#d1e40-24-1

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| | case scenarios (UCS) that are currently not being addressed through market-based mechanisms. The ATP can thus be seen as an enabler for Art. 32 of the e-Directive[16]. The ultimate goal is to align market outcomes with technical restrictions of the electricity grid in the most efficient way.<br><br>One of the key requirements to the ATP for being able to solve grid-related problems is a **higher spatial resolution** than currently available at Organized MarketPlaces (OMPs) along with **parametrization** of offers to provide additional information to ATP users. Due to the potential large number of flexibility providers (i.e. ESPs) and grid locations, a high degree of **automation** is required for the efficient and robust operation of the DLFM. In addition, advanced automated market clearing algorithms that go beyond current pay-as-bid models is required for efficient matching of many small Distributed Flexibility Assets (DFAs).<br><br>The FMO, as a user of the FLEXGRID ATP, will define a set of requirements for the ATP that are described in more detail in section 6.1. At this point, it is important to distinguish between *market services* (which are covered by the UCSs and thus FLEXGRID ATP) and *adjacent services,* which are not covered by the ATP but nonetheless need to be considered by the FMO (e.g. financial settlement, common & support functions, risk management). The user requirements proposed later in the document will cover only market services, focusing on the development of easy-to-use APIs and GUIs for efficient market operation.<br><br>Being a user of the FLEXGRID ATP, the role of the FMO will to a large extent be defined by monitoring the platform and intervention in case of technical challenges acting thus as an administrative user of the platform.<br><br>**<u>Current Status:</u>**<br>- Currently no FMO is in commercial mode, all platforms are at some kind of pilot stage, either privately or publicly funded.<br>- Flexibility market concepts apply different strategies regarding the relationship between platform company and operating company (FMO).<br>- Some flexibility marketplaces are being built on top of existing trading systems (e.g. ENERA uses EPEX Spot's M7), while others are built from scratch (e.g. NODES platform).<br>- All flexibility marketplace concepts provide a higher spatial resolution than incumbent OMPs as an integral part of their architecture.<br>- Main use case focus of current marketplace pilots is on local congestion management, either horizontally (i.e. at DSO level) or vertically (i.e. at the interface between TSO/DSO levels.<br>- Different approaches on how to handle transfer of energy (ToE); some platforms offer energy products (i.e. MWh with ToE), while others offer capacity products (i.e. MW without ToE)<br>- Time horizons vary, some platforms offer long-term (i.e. weeks or months ahead) availability contracts (e.g. Piclo), while others offer both, long-term availability and short-term activation (e.g. NODES). |

[16] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L0944&from=EN

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| | - Varying pricing models ranging from auction-based with single market clearing price for long-term availability contracts to pay-as-bid continuous for short-term activation (e.g. NODES).<br><br>**Innovation:**<br>- FLEXGRID uses outputs of adjacent systems (i.e. FLEXGRID S/W toolkits) as input for the ATP to build more intelligent services based on different use cases.<br>- Propose and develop a distribution flexibility market clearing toolkit - DFMCT (i.e. integrating research algorithms from WP5) for the different UCSs (see section 5.1), e.g. local voltage control or local congestion management based on input from advanced AC-OPF models.<br>- API integration of Automated Flexibility Aggregation Toolkit – AFAT (input from WP3) and automatic FlexOffer generation.<br>- API integration of FlexSupplier's Toolkit - FST (input from WP4) and automatic FlexOffer generation.<br>- Enabling TSOs to deal with frequency-related issues through market-based mechanism in ATP.<br>- Propose sophisticated market power mitigation models to deal with strategic players.<br><br>**Challenges:**<br>Regulatory:<br>- Varying degrees at which DSOs in different member states are allowed to offset OPEX (i.e. market-based flexibility) through regulated income framework.<br>- Different time span and scope on implementing e-Directives into national legislation.<br>- Non-harmonized retail market models in the member states.<br>- Unresolved challenges in the proposed flexibility market design regarding inc/dec gaming issue[17] (i.e. need for sophisticated market power mitigation models).<br>- No commonly agreed baseline methods for delivery verification.<br><br>Legal:<br>- Unclear contractual relationship between independent aggregators and BRPs.<br>- Lack of standardized contracts for aggregator services to FlexAsset providers.<br><br>Economic:<br>- Little financial incentives for DR at the residential level.<br>- Unclear responsibility for imbalances incurred at BRP's portfolio.<br>- Uncertain revenue streams for aggregators, where willingness to pay is not revealed by system operators.<br>- High costs involved with installing controllable assets (especially at the household level). |

[17] file:///Users/prodromosmakris/Downloads/217_abstract_20190607_162443%20(2).pdf

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| | Technical:<br>- Widely differing dissemination of smart meters in the member states<br>- Availability of data hubs exchange of meter data<br>- Lack of controllable consumption assets in regions with a low level of electrification |
| **Actors involved** | - Flexibility Market Operator (FMO)<br>- FlexDemand stakeholders (TSO, DSO, BRP)<br>- FlexSupply stakeholders (ESP, aggregator, RESP) |
| **Triggering Event** | Various system actors from both the FlexDemand and FlexSupply sides can use the FLEXGRID ATP in order to trade FlexProducts and FlexServices via market-based mechanisms. |
| **Pre-condition** | System Operators submit their FlexRequests (at the FlexDemand side) of the proposed FLEXGRID ATP and ESPs respond with their FlexOffers (at the FlexSupply side). Alternatively, FlexSuppliers may submit their available flexibility independently. |
| **FLEXGRID services involved** | - Advanced market clearing models for DLFMs<br>- Market-based congestion and voltage management at DSO level<br>- Optimal FlexServices' provisioning<br>- API integration of toolkits with FLEXGRID ATP<br>- API for FLEXGRID ATP's interaction with existing markets |
| **Post-condition** | The Distribution Level Flexibility Market (DLFM) is cleared and the ESPs will offer FlexServices, based on their FlexUnit portfolios to the system operator or BRP, who requested the service. |

**Basic Path**

| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |
|---|---|---|---|---|---|
| 1 | TSOs/DSOs/BRPs calculate flexibility demand | TSOs/DSOs use power flow and system analysis to determine demand for active and reactive power flexibility. BRPs use portfolio optimization tools to gauge demand for energy flexibility. | Optimal Power Flow (OPF) algorithm is executed | TSO/DSO/ BRP | TSO/DSO/ BRP |
| 2 | TSO/DSO/BRP composes FlexRequest automatically | System operators use power flow calculations to assemble FlexRequest per grid location. | - Location<br>- Qty unit (MW, MWhs, MVar)<br>- Time unit | TSO/DSO/ BRP | TSO/DSO/ BRP |
| 3 | TSO/DSO/BRP posts FlexRequest in ATP | FlexRequests are posted on ATP, using either GUI or API | - Location<br>- Qty unit (MW, MWhs, MVar)<br>- Time unit | TSO/DSO/ BRP | FMO (ATP) |
| 4 | FlexSuppliers calculate/forecast the flexibility of their FlexAssets' | ESPs and other FlexSuppliers use optimization tools for determining flex availability | Optimal scheduling algorithm is executed | ESP/Aggr | ESP/Aggr |

| | | | | | |
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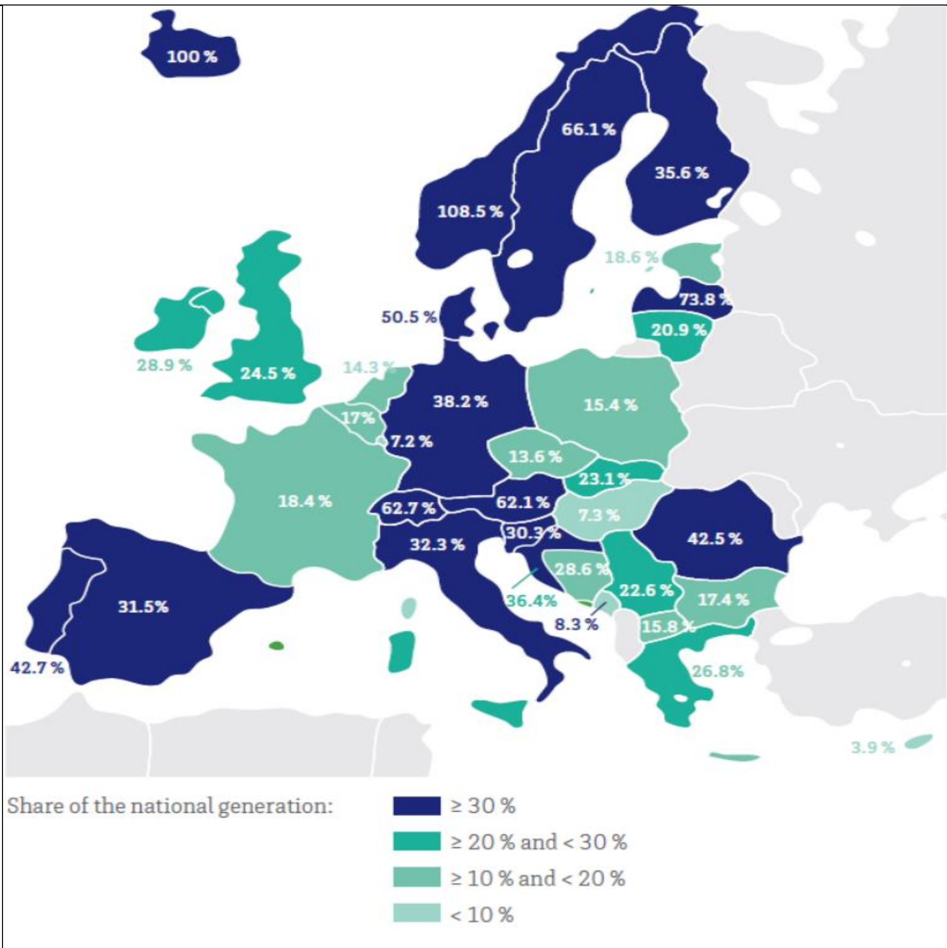
| | portfolio | | | | |
| 5 | FlexSuppliers compose FlexOffer automatically | FlexSupplier's toolkit (FST) auto-generates flexibility market offers/bids | - Location<br>- Qty unit (MW, MWhs, MVar)<br>- Time unit | ESP/Aggr | ESP/Aggr |
| 6 | FlexOffers are posted in ATP | FST posts FlexOffers on ATP | - Location<br>- Qty unit (MW, MWhs, MVar)<br>- Time unit | ESP/Aggr | FMO (ATP) |
| 7 | FMO matches FlexDemand with FlexSupply and clears the flexibility market | Automatic process involving ATP and market clearing toolkit (DFMCT) | - Matched volume<br>- Matched price<br>- Duration | FMO (ATP) | ESP/Aggr/ TSO/DSO |
| 8 | FlexSupplier schedules the control actions and sends the setpoints to all involved FlexAssets/ units | API message exchange with flex buyers/sellers including information from step 7 | - Matched volume<br>- Matched price<br>- Duration | ESPs | FlexAsset Owners |
| 9 | Real control actions take place for all involved FlexAssets/ units | FlexAsset owners activate FlexUnits according to specifications in step 8 | - Location<br>- Qty unit (MW, MWhs, MVar)<br>- Time unit | FlexAsset owner | FlexUnits |
| 10 | TSO/DSO/BRP verifies the control actions and sends an ack to FMO | Flex buyers verify delivery by comparing setpoints with baseline | - ACK message type confirming successful delivery | FMO (ATP) | TSO/DSO/ ESP/Aggr |
| 11 | FMO handles transactions between FlexSupplier & FlexBuyer | Financial settlement of transaction(s). | - ATP calculates amounts due and payable | FMO (ATP) | TSO/DSO/ ESP/Aggr |
| **Exception path #1: A FlexRequest is not matched with any FlexOffer** | | | | | |
| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |
| 1 | No matching in ATP due to lack of FlexSupplier offers | FlexSuppliers have no available flexibility and FST does not generate any flexibility market offers. | No FlexSupply to meet TSO/DSO/BRP FlexDemand | FMO/ESP/ Agg/DSO/ TSO | FMO/ESP/ Agg/DSO/ TSO |
| 2 | FlexRequest is changed with regards to price and/or technical specification | TSO/DSO can increase the price for their demand and/or change technical specifications in order to increase supply side | Changed FlexRequest with regard to Price, Volume, Unit, Location. | TSO/DSO (via FMO) | ESP/Aggr |

| Exception path #2: A FlexOffer made by a FlexSupplier cannot be matched with any FlexRequest in the FLEXGRID ATP and thus it is redirected to another existing energy market | | | | | |
|---|---|---|---|---|---|
| **Step No.** | **Event** | **Description of process/ Activity** | **Info exchanged** | **Actor producing the info** | **Actor receiving the info** |
| 1 | FlexOffer not matched in ATP | FlexOffers might be rejected based on different criteria (e.g. price, volume, wrong location, lack of demand etc.) | No matching information exchanged due to lack of trades in ATP. | FMO (ATP) | ESP/Aggr/ TSO/DSO |
| 2 | FlexDemand occurs (possibly from other actors TSO/MO/BRP) | FlexRequest entered in ATP based on market clearing toolkit | FlexRequest entered in ATP and submitted to FlexSuppliers via API | TSO/DSO/ BRP | ESP/Aggr (via ATP) |
| **Realization** | | | | | |
| **Main responsible partners** | **NODES, NPC (WP6/WP7 work)** | | | | |
| **Contributing partners** | **BADENOVA, HOPS, DTU, ICCS, UNIZG-FER (WP4-WP5 work)** | | | | |
| **Priority** | **High** | | | | |

## 4.2 FLEXGRID ATP offers advanced flexibility supply management services to Energy Service Providers

| **HLUC_02** | **FLEXGRID ATP offers advanced flexibility supply management services to Energy Service Providers (ESPs)** |
|---|---|
| **Description** | **<u>Scope/Purpose:</u>**<br>This HLUC focuses on FLEXGRID ATP's operation (in collaboration with the proposed FlexSupplier's Toolkit - FST) and its support to 'Energy Service Providers' (i.e. FlexSupply side of the proposed flexibility marketplace).<br><br>The increasing share of renewable energy in all European markets leads to more or less pronounced price fluctuations in the spot market. In 2017, 34.1 % of the overall consumption in the EU was already covered by renewable generation. Without hydraulic generation, renewable generation represented 19.1% of total consumption.<br><br>Operators of decentralized controllable devices can benefit from these price fluctuations by shifting the electricity generation or electricity consumption in times of economically advantageous market prices. Ideally, they use an external service provider for this – a so called 'Energy Service Provider' (ESP). ESP is a general term that is used in the FLEXGRID project. In the most general case, it means a profit-oriented company, which may make contractual arrangements with various types of flexibility assets (e.g. DSM, RES, storage). An ESP may offer various types of services to TSOs/DSOs and BRPs. |




**Share of consumption in the EU covered by renewable generation in 2017 (Source: ENTSO-E)**

HLUC_02 will be supported by the following use case scenarios (UCS), which are designed to represent real-world challenges that the ESP aims to solve. A detailed description of each UCS can be found in section 5.2.

- UCS_01: ESP minimizes its OPEX by optimally scheduling: i) the consumption of its end users, ii) the production of its RES and iii) its storage assets (led by UNIZG-FER)
- UCS_02: ESP minimizes CAPEX by making optimal investments (i.e. optimal siting and sizing) on RES and FlexAssets (led by UNIZG-FER)
- UCS_03: ESP maximizes its profits by co-optimizing its participation in several existing energy markets and distribution level flexibility markets (led by ICCS)
- UCS_04: An electric utility company/MG operator (like BADENOVA) applies network-aware optimal bidding policies to make optimal use of its FlexAssets taking into consideration the physical network constraints (led by ICCS)
- UCS_05: RESP optimizes the operation of its assets (combined RES & storage) in order to maximize the dispatchability rate of its RES-related assets (avoid imbalance penalties, participate in equal terms in the wholesale market) (led by UCY)
- UCS_06: Independent large-scale FlexAsset owner leases storage for

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| | different types of business purposes to several market stakeholders (led by UNIZG-FER)<br><br>**Detailed description:**<br>As the titles of the above-mentioned Use Case Scenarios (UCS) indicate, the optimization targets for an ESP can be diverse (i.e. a different KPI may be optimized at each time). Essentially, this type of flexibility marketing is focused on the determination of economically optimized operating schedules for distributed devices, which are based on the expected course of the residual load. Other aspects of flexibility marketing include the implementation of financially motivated quick schedule adjustments through intra-day transactions and the avoidance of balancing energy by smoothing out unexpected schedule deviations or forecast inaccuracies during balance group operation.<br><br>As a basic principle, an indicator of the need for flexibility in an energy system is the increasing volatility of the residual load. The level of the residual load determines how much electrical power actually needs to be provided by conventional power plants and other sources – mostly uncontrolled feed-in from fluctuating generators, such as wind power and photovoltaic systems - at a given time in order to ensure a balance between load and generation. It can be seen in all European markets facing a transition to more renewable energies that the volatility in residual load increased significantly. In times of weak wind and heavy cloud cover, the residual load can become very large, while in times of high wind supply and low load, it can fall to a very low level. Locally, there may even be situations that more electricity is supplied from RES than is required.<br><br>So, in addition to load forecasts, ESPs must take into account the feed-in forecasts of RES in order to ensure that the most precise positioning in the energy market in a sense of the required residual load coverage becomes possible. For this purpose, the so-called price-forward curves (PFCs) are in use, which take into account not only the predicted load, but also wind and PV feed-in forecasts as well as other seasonal price effects.<br><br>Conventional power plants in use today and in the future are required to provide flexible performance and, if necessary, to be able to reduce power as accurately as possible to cover the predicted residual load. Small decentralized RES plants such as biogas plants, heat-controlled CHP plants with heat storages, battery storage as well as controllable loads are suitable for this task. The increasing orientation towards the residual load will lead to more frequent start-up and shutdown of devices. The more precisely production can be approximated to the actual residual load response by predictive trade, the lower the ultimate need for frequency control and balance energy will be. This means cost savings for the whole economy in the long term, as these costs are paid by all customers via grid usage fees or taxes. So, from a superior economic point of view, higher expenses for active device control on one hand can be compensated on the other hand by savings in another area.<br><br>In order to ensure the balance between electricity generation and consumption in the future, despite the weather dependence of the electricity supply, the |

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| | increased use of systems will be necessary that allow residual load-oriented operation and whose operating schedules are adaptable during the day. Numerous biogas and CHP plants, battery storage systems and controllable loads located in the distribution networks have the potential to offer their flexibility as a system service. On one hand, the cost-effectiveness of such an optimization depends on the realizable additional revenues or cost savings. On the other hand, economic efficiency is significantly influenced by the system costs incurred for the construction of the necessary infrastructure. Thus, both models are present in the market today:<br>1. Controllable generation devices are possessed by the ESP<br>2. Controllable generation devices are owned by other legal entities and the ESP only acquires the right of control<br>Both cases are covered by the use case scenarios mentioned above.<br><br>Nevertheless, the setup and operation of the optimization software and data transfer infrastructure, the positioning of bids on the energy exchange and the clearing of balance group positions resulting from electricity marketing is taken over by the ESP and so do the costs.<br><br>In the second case, an additional question arises for the ESP as how to charge the customers for its services. Firstly, it has the opportunity to act as an integrated supplier and flexibility marketer and to take over customer investments in its own trading portfolio against payment of an agreed price. Secondly, within the framework of a service contract (i.e. FlexContract), it can offer the system-sharp optimization of customer devices as well as the handling of the realized electricity transactions.<br><br>This is exactly where FLEXGRID will comes into play. The aim of its software platform for forecasts and optimized operation of decentralized devices (i.e. FlexUnits) is to determine economically optimal schedules, which are on the one hand in line with the technical and contractual restrictions of the device and on the other hand can be flexibly adapted to the expected price developments. This will help bringing ESP services in the market in a larger scale.<br><br>**<u>Current Status:</u>**<br>- There are already companies working as ESP active in the market. Many of them are utilities marketing their own controllable generation devices or doing that as service providers for linked third parties as swimming bath operating companies, hospitals, libraries and schools providing own devices – mostly CHPs. In Germany, it is quite common, that public utilities are owned by municipalities even responsible for the public services mentioned above. So, it is kind of service for linked third parties.<br>- Independent companies are already operating in the market. Mostly, they don’t own assets. Rather, they gain control on assets of other companies by paying a fee. Most common market model is to let the owner participate by a share of the additional revenues generated due to flexibility marketing.<br>- All market players focus on controllable assets with at least 100 kW – better more. The reason is simple: The cost for hardware installations to realize a stable data transfer to a control platform is more or less the same for big and small devices; even the efforts for clearing and accounting afterwards. |

So, smaller devices especially households with PV storage devices, heat pumps and wall boxes for electrical vehicles are completely out of scope right now.

- Only one noteworthy company tries to sell flexibility originating from private households in one of the possible flexibility markets. It’s the company “Sonnen” successfully producing and selling PV-storage systems in the German market. They are market leaders. But it must be stated, that additional revenues by marketing flexibility (at present solely in the primary control market) are only a side effect and probably not really countable. The focus lays on selling devices in the market. So, flexibility marketing is more or less only an additional value and a differentiating characteristic compared to competitors.

**Innovation:**

- FLEXGRID uses outputs of adjacent systems (i.e. FLEXGRID S/W toolkits) as input for the ESP to create more profitable or even new services based on different use cases.
- API integration of automated flexibility aggregation toolkit (input from WP3) and automatic bid generation for several markets.
- API integration of FlexSupplier’s toolkit (input from WP4) and automatic bid generation for several markets.
- Optimal investment analysis for the integration of new FlexAssets in ESP’s business portfolio.

**Challenges:**

Regulatory:

- Different time span and scope on implementing e-Directives into national legislation.
- Non-harmonized market models in the member states.
- No special exchange for flexibility established.

Legal:

- Unclear contractual relationship between independent ESPs and BRPs.
- Lack of standardized contracts for independent ESPs and FlexAsset providers.

Economic:

- Uncertain revenue streams for ESPs as residual load fluctuations and price spreads are influenced by political decisions.
- Several energy exchanges in Europe with different market principles and pricing schemes.
- Different price spreads on the several energy exchanges.
- Non-harmonized markets and rules for participation in the frequency and voltage control markets.
- Financial participating model if controllable assets are not owned by ESP, but by other legal entities.
- Unclear responsibility for imbalances incurred at BRP’s portfolio.
- High costs involved with installing controllable assets (especially at the household level).

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| | Technical:<br>- Widely differing dissemination of smart meters in the member states.<br>- Availability of data hubs for collecting metering data.<br>- Alternatively establishing reliable communication links to controllable assets.<br>- Lack of international standards for data exchange and control from/to/of assets. Proprietary protocols are widely used. |
| **Actors involved** | • FlexSupply stakeholders (ESP, RESP, aggregator)<br>• Prosumers/ FlexAsset owners<br>• FlexUnits (i.e. a FlexAsset owner may have several FlexUnits)<br>• Flexibility Market Operator (FMO)<br>• Market Operator (interaction with existing energy markets)<br>• FlexDemand stakeholders (TSO, DSO, BRP) |
| **Triggering Event** | ESPs/RESPs/Aggregators can use the FLEXGRID ATP to participate in a flexibility market and sell their flexibility. |
| **Pre-condition** | • ESP (FlexSupplier) can monitor and control all its available FlexAssets and units.<br>• ESP (FlexSupplier) is registered in FLEXGRID ATP.<br>• ESP (FlexSupplier) can participate in multiple energy markets. |
| **FLEXGRID services involved** | • Optimal FlexOffer models<br>• Optimal FlexAsset planning models and algorithms<br>• Optimal FlexAsset scheduling models and algorithms<br>• Optimal FlexServices' provisioning to end users |
| **Post-condition** | ESP (FlexSupplier) sells its aggregated flexibility (own devices or gathered from its end users) to the flexibility market, control actions are realized and end prosumers are compensated based on their individual contribution. Regarding FlexAsset planning decisions, the ESP can now make the optimal investment to minimize CAPEX/OPEX in the long term. |

**Basic Path**

| Step No. | Event | Description of process/ Activity | Info. exchanged | Actor producing the info | Actor receiving the info |
|---|---|---|---|---|---|
| 1 | Techno-economic investments study | Techno-economic study to identify the best possible solution for RES/ESS/DSM investments quantify the cost of FlexServices' procurement | CAPEX and OPEX for available assets | FlexAsset owners | ESP (FlexSupplier) |
| 2 | Analysis of FlexMarkets | FlexSupplier defines in detail all the contexts under which its participation in a FlexMarket is beneficial. | Historical prices and price forward curves for power exchanges as well as frequency control / voltage control markets | special service providers, MO, FMO | ESP (FlexSupplier) |

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| 3 | Optimization FlexOffer policy | FlexSupplier defines its optimal FlexOffer policy according to each business case/ type of FlexRequest | All necessary data already available | FlexUnits | ESP |
| 4 | ATP Surveillance | Once the optimal FlexOffer policy is decided, the FlexSupplier monitors the ATP to identify any FlexRequests that match with FlexSupplier's business interests | FlexRequests | FLEXGRID ATP, FlexAsset owners | ESP (FlexSupplier) |
| 5 | Analysis of optimized asset operation | Once a suitable FlexRequest is identified, the FlexSupplier monitor its available FlexAssets and forecasts RES/ECC for the time interval of interest | Operational data | FlexAsset owners | ESP (FlexSupplier) |
| 6 | OPEX minimization | FlexSupplier forecasts market prices and schedules its FlexAssets optimally in order to minimize its OPEX | Price forward curves, operational data | ESP (FlexSupplier) | ESP (FlexSupplier) |
| 7 | FlexOffer generation | FlexSupplier composes its FlexOffer automatically and posts it to the FLEXGRID ATP | FlexOffer | ESP (FlexSupplier) | FLEXGRID ATP |
| 8 | Adapted asset control | When the FlexOffer is accepted, FlexSupplier sends the control actions (i.e. setpoints) to its end users | Control signals | ESP (FlexSupplier) | FlexAsset owners |
| 9 | Asset response surveillance | FlexAsset owners perform the real control actions and send the results back to the FlexSupplier | Operational data | FlexAsset owners | ESP (FlexSupplier) FlexDemand Stakeholders |
| 10 | Compensation of participating FlexAsset owners | FlexSupplier measures and verifies the results and compensates the FlexAsset owners/ end prosumers | Operational data, revenue data from FLEXGRID ATP | FlexAsset owners, FLEXGRID ATP | ESP (FlexSupplier) |
| **Exception path #1: FlexOffers are not matched with a given FlexRequest, so FlexSupplier sells its flexibility to existing energy markets** | | | | | |
| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the information** | **Actor receiving the information** |

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| 7 | FlexOffer generation | FlexSupplier composes its FlexOffer automatically and posts it to the relevant market platform | FlexOffer | ESP (FlexSupplier) | MO |
| 8 | Adapted asset control | When the FlexOffer is accepted, FlexSupplier sends the control actions (i.e. setpoints) to its end users | Control signals | ESP (FlexSupplier) | FlexAsset owners |
| 9 | Asset response surveillance | FlexAsset owners perform the real control actions and send the results back to the FlexSupplier | Operational data | FlexAsset owners | ESP (FlexSupplier) |
| 10 | Compensation of participating FlexAsset owners/ end prosumers | FlexSupplier measures and verifies the results and compensates the FlexAsset owners/ end prosumers | Operational data, revenue data from energy exchange / ancillary market | FlexAsset owners | ESP (FlexSupplier) |
| **Exception path #2: FlexSupplier's forecasts mismatch with real values and an internal portfolio rebalancing is required** | | | | | |
| **Step No.** | **Event** | **Description of process/ Activity** | **Info exchanged** | **Actor producing the info** | **Actor receiving the info** |
| 1 | Forecasts mismatch with real values | Assets have been sold on FLEXGRID ATP / energy exchange markets but operational data indicate, that assets don't response appropriate on control signals. | Operational data | FlexAsset owners | ESP (FlexSupplier) |
| 2 | Activation of other assets | Other assets must be activated within 15-min interval to close the energy gap | Control signals | ESP (FlexSupplier) | FlexAsset owners |

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| **Realization** | |
| **Main responsible partners** | **BADENOVA** |
| **Contributing partners** | **UNIZG-FER, ICCS, UCY, NODES** |
| **Priority** | **High** |

## 4.3 FLEXGRID ATP offers advanced flexibility demand management services to system operators

<table>
<tr><th>HLUC_03</th><th>FLEXGRID ATP offers advanced flexibility demand management services to system operators</th></tr>
<tr><td>Description</td><td><u>Scope/Purpose:</u><br>The purpose of HLUC_3 is to develop and test various ways of simultaneous use of FLEXGRID ATP together with existing market-based mechanisms. It should be beneficial for TSOs and DSOs to decide whether it is more cost-effective and efficient to purchase flexibility services from FLEXGRID ATP or the existing markets. HLUC_03 will also compare future investment scenarios for DSOs. There are two main alternatives for DSOs[18]: i) continue with their Business-As-Usual (BAU) scenario in which they invest on new CAPEX in order to reinforce their network, or ii) purchase flexibility from ESPs and aggregators. The second alternative is FLEXGRID project’s proposal and can be further divided in two sub-scenarios, namely: i) either purchase flexibility via long-term and bi-lateral contracts with local flexibility providers or ii) purchase flexibility through a Distribution Level Flexibility Market (DLFM) via continuous auction-based mechanisms. In order to run the system in a safe and the most economical way, TSO/DSO cooperation is also crucial. Hence, several TSO-DSO coordination schemes will be studied and compared.<br><br>List of Use Case Scenarios (UCS):<br>• UCS_01: Coordinated voltage/reactive power control either by aggregating flexibility from multiple FlexAssets or through a market-based mechanism (led by AIT)<br>• UCS_02: TSO-DSO collaboration for coordinated management of aggregated FlexAssets and interaction between networks’ and flexibility markets’ operation (led by AIT)<br>• UCS_03: TSO deals with a frequency control problem either by aggregating flexibility from multiple FlexAssets or through a market-based mechanism (led by AIT)<br>• UCS_04: Co-optimization of FlexAsset investments between a System Operator and profit-based ESPs to minimize network upgrade investments (led by UNIZG-FER)<br><br><u>Detailed description:</u><br>FLEXGRID ATP should offer a cheaper and more cost-effective alternative for procuring flexibility compared to today’s mechanisms. ESPs could offer their flexibility much easier on ATP (e.g. one contract) compared to traditional balancing markets (e.g. one contract for each service).<br><br>Future grids with high level of RES penetration require very good interaction between the markets and real time grid management. The platform should serve to TSOs and DSOs as a place to buy FlexServices, if it is more efficient and cost effective than what today’s markets offer. It should alleviate the level of risks for new FlexService providers such as wind, solar, battery storage, demand response, etc. and facilitate clearing and adjusting their positions closer to real-</td></tr>
</table>

[18] These are directly influenced by revenue models, which are decided by national regulators.

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| | time.<br><br>**<u>Current Status:</u>**<br>In current state-of-the-art situation, there is an option for buying flexibility through a market, but market scope is usually limited to traditional flexibility service providers (e.g. hydro-power, conventional generators). This may become a problem considering EU goal to increase renewable energy production with which it is more challenging to balance the system. It could be expected that consumers will become active participants in service provision. In addition, current market design (e.g. minimum volume requirements from TSO, minimum technical requirements that should be respected, etc.) does not always give enough space for flexibility of some emerging technologies (e.g. provided by RESPs/aggregators), where they should be able to trade closer to real time.<br>When deciding on future investments in terms of network planning, intelligent methods should be used in order to make optimal decisions taking into account flexibility providers.<br><br>Under the EU Regulation (EU) 2019/943 on the internal market for electricity, there is a binding requirement on TSOs and DSOs to work together to ensure the most cost-efficient, secure and reliable development and operation of their network.<br><br>*Article 57* of EU Regulation 2019/943[19]<br>**Cooperation between distribution system operators and transmission system operators**<br>• Distribution system operators and transmission system operators shall cooperate with each other in planning and operating their networks. In particular, distribution system operators and transmission system operators shall exchange all necessary information and data regarding the performance of generation assets and demand side response, the daily operation of their networks and the long-term planning of network investments, with the view to ensure the cost-efficient, secure and reliable development and operation of their networks.<br>• Distribution system operators and transmission system operators shall cooperate with each other in order to achieve coordinated access to resources such as distributed generation, energy storage or demand response that may support particular needs of both the distribution system operators and the transmission system operators.<br><br>**<u>Innovation:</u>**<br>The main innovation lies in the fact that FLEXGRID will enable system operators to dynamically calculate the cost of flexibility procurement and purchase this flexibility through an innovative marketplace in a more cost-effective way. A techno-economic analysis will also take place in order for system operators to decide on the best mix of CAPEX (i.e. investing on network reinforcement) and |

[19] REGULATION 2019/943 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 on the internal market for electricity (recast), Official Journal of the European Union, 14.06.2019; Online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0943&from=EN

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| | OPEX (i.e. purchasing FlexServices from various flexibility markets) in order to guarantee the required KPIs related with security of supply and efficient network operation.<br><br>**Challenges:**<br>- How does the activation at the DSO level affect the TSO level?<br>- How does the TSO and DSO collaborate/communicate with each other to find a more efficient solution compared to the case that they act individually to deal with their own network problems?<br>- How will FlexGrid ATP be integrated with existing markets?<br>- What changes need to be made to existing grid and network codes to facilitate this?<br>- Making sure that all aspects of work are compliant with CEP |
| **Actors involved** | ● FlexDemand stakeholders (TSO, DSO, BRP)<br>● Flexibility Market Operator (FMO)<br>● FlexSupply stakeholders (ESP, RESP, aggregator)<br>● Prosumers/ FlexAsset owners<br>● FlexAsset units<br>● Market Operator (for interaction with existing energy markets) |
| **Triggering Event** | TSOs/DSOs/BRPs can use the FLEXGRID ATP to participate in a flexibility market and buy flexibility.<br>TSO predicts a frequency problem/congestion problem in its own grid.<br>DSO predicts a voltage problem/congestion problem in its own grid.<br>BRP predicts an imbalance context for its own portfolio. |
| **Pre-condition** | - Grid is continuously monitored.<br>- Grid topology is known and reflects the real topology.<br>- FlexAssets are connected to the grid and are controllable. |
| **FLEXGRID services involved** | - Market-aware upgrade planning<br>- Optimal investment planning (i.e. optimal trade-off between CAPEX and OPEX in the long-term)<br>- Advanced market clearing algorithms<br>- Frequency/voltage control services' provisioning via market mechanisms |
| **Post-condition** | - Frequency issue is solved, prevented or mitigated.<br>- Voltage issue is solved, prevented or mitigated.<br>- BRP's imbalances are settled. |

**Basic Path**

| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |
|---|---|---|---|---|---|
| 1 | Techno-economic study (e.g. 10-20 years ahead) to identify the best possible solution for network upgrade investments or FlexService provisioning (i.e. quantify the cost of FlexServices' purchase in a future flexibility market) | Long term optimisation to investigate if any of the network upgrade costs could be avoided by using | Recommendation for network upgrade investment with consideration of FlexServices | TSO/DSO | TSO and DSO internally, Regulatory Authorities |

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| | | FlexServices | | | |
| 2 | System Operator defines in detail all the future network operation contexts under which its participation in a FlexMarket is beneficial (cf. risk monitoring models). | System Operators notify participants in which segments they can benefit from FlexMarket | Benefits for FlexProviders | TSO | BRPs, FMO, FlexSupply stakeholders, prosumers |
| 3 | System Operator continuously monitors its network assets' operation in real time to identify a network problem | SO real time monitoring of network | Network problem | TSO/DSO | BRPs, FlexProviders |
| 4 | Once a network problem occurs, a FlexRequest is automatically composed (cf. NODES standardized FlexProducts and existing data models). | If there is a network problem, a request to provide service is issued through a platform | FlexRequest – volume and type of service to be provided | TSO/DSO | FMO (ATP) |
| 5 | The FlexRequest is posted in the FLEXGRID ATP and can be visualized by all eligible and interested FlexSuppliers | Request is posted in the ATP where all interested participants can access it | FlexRequest – volume and type of service to be provided | FMO (ATP) | FlexSuppliers |
| 6 | The FMO clears the market and the system operator is informed about the results (i.e. FlexSupplier, who is responsible to procure the FlexService) | SO finds out which set of providers are cleared in the market | Cleared providers who are expected to provide a reserve | FMO | TSO/DSO |
| 7 | The results of the FlexSupplier's scheduling process are sent to the system operator (i.e. setpoints for each involved FlexAsset/unit) | Service providers send a plan to the SO which should follow the profile that cleared in the FMO | Scheduling profile | FlexSuppliers | TSO/DSO |
| 8 | SO verifies the setpoints and acknowledges the technical feasibility from a network operation perspective | SO makes sure the plan is achievable and does not pose any risk to safe running of system. SO confirms the | Confirmation (Yes/No Status) from the SO the plan is achievable. Actions actually | TSO/DSO | FMO |

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| | | setpoints | happen. | | |
| 9 | FlexAsset owners perform the real control actions and send the results back to the FlexSupplier. The latter informs the SO. | FlexAssets send real time results to Suppliers who pass i tonto SOs | Real time service results – metered values | FlexAsset Owners | FlexSupplie rs/TSO/DS O |
| 10 | SO measures and verifies all the control actions and sends an acknowledgement to the ATP (FMO). | So perform validation of actions taken by FlexSuppliers | Comparison of data on FlexAsset and SO site – metered values | SO | FMO |
| 11 | FMO settles the market and FlexSupplier is compensated for its FlexServices (i.e. SO pays the FlexSupplier via ATP) | All suppliers are compensated for provision of FlexServices | Settlement results – volumes and prices | FMO | FlexSupplie r via SO |
| **Exception path #1: System Operator identifies a network problem, but decides to deal with it without the use of the FLEXGRID ATP or through a flexibility market mechanism** | | | | | |
| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |
| 1. | There is an urgent need to provide a quick service for system security and the SO deals with it through a regular balancing market | SO sends the setpoint to a provider outside of FLEXGRID platform | Setpoint | TSO/DSO | Service Provider |
| **Exception path #2: System Operator's FlexRequest is not matched with a FlexOffer, so the operator undertakes the responsibility to solve the network problem alone** | | | | | |
| **Step No.** | **Event** | **Description of process/ Activity** | **Info exchanged** | **Actor producing the info** | **Actor receiving the info** |
| 1 | Offers and requests are not matched on FMO and the SO takes actions outside of FLEXGRID ATP | SO takes actions outside of the platform | Setpoint given by the SO which has not come out of ATP | TSO/DSO | Service provider |
| **Exception path #3: System Operator identifies small discrepancies during the measurement and verification process.** | | | | | |
| **Step No.** | **Event** | **Description of process/ Activity** | **Info exchanged** | **Actor producing the info** | **Actor receiving the info** |
| 1 | SO notices discrepancies between FlexSupplier and SO measurements | FlexSupplier is not paid for the full amount or has to pay back if the discrepancy was | Measured values | TSO/DSO | FlexSuppli er |

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| | | on its side. | | | |

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| **Realization** | |
| **Main responsible partners** | **HOPS** |
| **Contributing partners** | **AIT, DTU, UNIZG-FER, ICCS** |
| **Priority** | **High** |

## 4.4 FLEXGRID ATP offers automated flexibility aggregation management services to ESPs/aggregators (interaction with end users)

| **HLUC_04** | **FLEXGRID ATP offers automated flexibility aggregation management services to ESPs/aggregators (interaction with end users)** |
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| **Description** | <u>Scope/Purpose:</u><br>This HLUC focuses on the operation of the automated flexibility aggregation, which is modeled as a novel ad-hoc energy market development and management as a service to be offered to independent aggregators and/or ESPs. It deals with the B2C interaction between an ESP/aggregator entity and its business portfolio, which comprises of a large amount of end energy prosumers together with their FlexUnits (i.e. DSM, RES and storage flexibility assets). In the context of FLEXGRID project, a S/W toolkit will be developed, which is called Automated Flexibility Aggregation Toolkit (AFAT) and its requirements are described in section 6.2.3. The AFAT will integrate several retail flexibility market pricing schemes, flexibility aggregation models and respective algorithms. There will also be an API in order for the AFAT to interact dynamically with the core FLEXGRID ATP. More specifically, the FLEXGRID ATP will send all available FlexRequests being made by TSO/DSO/BRP. Then, the AFAT will run a specific automated flexibility aggregation algorithm and the result will be an optimal FlexOffer that will be sent to back to the ATP[20]. In exercising this business approach, aggregators/ESPs can utilise advanced forecasting services to predict market prices and net load profiles of available end users' assets to facilitate optimal use of resource availability for maximising profits for all participants in the portfolio.<br><br>HLUC_04 will be supported by the following use case scenarios (UCS), which are designed to represent real-world challenges that aggregators/ESPs face, when they want to optimally manage their flexibility portfolio. A detailed description of each UCS can be found in section 5.4. The UCS of HLUC_04 are the following:<br>• UCS_01: ESP/aggregator efficiently responds to FlexRequests made by TSO/DSO/BRP by optimally orchestrating its aggregated flexibility portfolio of end energy prosumers (led by UCY)<br>• UCS_02: An aggregator/retailer operates an ad-hoc B2C flexibility market with its end energy prosumers by employing advanced pricing models and auction-based mechanisms (led by ICCS) |

[20] It should be noted that FlexSupplier's Toolkit (FST) will also generate optimal FlexOffers and post them in ATP. FST is targeted for ESP users, while AFAT is targeted for aggregator and retailer users.

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| | • UCS_03: ESP maximizes its profits by dynamically orchestrating distributed FlexAssets from its end users in order to optimally participate in several energy markets (led by ICCS)<br>• UCS_04: ESP exploits FLEXGRID's advanced forecasting services to predict market prices and FlexAssets' state and curves in the future (led by UCY)<br><br>**Detailed description:**<br>Automated aggregation of flexibilities is central in the objectives of FLEXGRID targeting the optimal use of available flexibilities from end users for providing a stack of services for maximising benefits. In principle, traders of flexibility can be private companies, energy cooperatives, or public organizations that buy energy from the wholesale market, but they also have their own end user portfolio, thus exploiting to the maximum the demand side flexibilities. The purpose of this HLUC is to create an ad-hoc flexibility market to aggregate Distributed Flexibility Assets (DFAs) in the most efficient way. Various trading options can be stacked offering the possibility for optimal use of resources responding to the needs of the integrated system. Internal optimisation between the portfolio members of the flexibility provider is central in the process, leaving tradeable the aggregated surplus capable of responding to open calls for flexibility from DSOs /TSOs (i.e. FlexBuyers).<br>Following this process, it will also evaluate real-time flexibility aggregation markets and algorithms to optimize DFAs efficiently and evaluate the accuracy of DFAs' curves. In addition, the ESP/aggregator will be able to optimally decide how to trade this DFA owners' aggregated flexibility in multiple energy markets such as day-ahead, intra-day, balancing, etc.<br>Through efficient exploitation of the above possibilities, the DFA owners will be able to achieve reduction in their electricity bill. So, the ESP/aggregator will optimally schedule the energy prosumption of all DFA owners trying to both maximize the ESP profits and end users' welfare (i.e. by finding an optimal trade-off between these two major KPIs).<br>In reality, the ATP will facilitate the automatic aggregation of provided flexibilities and utilise them sequentially as follows:<br>• Based on the published flexibility requests of the DSOs / TSOs, the market forecast and detailed demand profiles respond with the aggregated portfolio for the optimal benefit of flexibility providers.<br>• Maximise the interest of end users to provide their flexibilities through advanced pricing models and auction-based mechanisms that can reflect the forecasted market demand and demand profiles thus reflecting indirectly the targeted pricing that will maximise interest and response.<br>• Dynamically orchestrating distributed FlexAssets from its end users in order to optimally merge their divergence and their complementarity in energy use.<br>Optimally using the above stacked possibilities, the benefits can be maximised for the flexibility providers (i.e. ESPs). All these will be carefully selected not to violate the comfort of the end users, since this is a precondition for providing availability to the trading of flexibility and for the ESPs/Aggregators to be competitive enough in the liberalized retail flexibility market environment. |

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| | **Current Status:**<br>- DFAs cannot participate/do not have access in existing energy markets due to their small size and lack of market rules, appropriate regulation and policies.<br>- Some DR pilots are being operated by progressive electric utilities that either use simple dynamic pricing schemes or apply direct DR control.<br>- No use of advanced retail market mechanisms (i.e. pricing models), decentralized optimization models, aggregated flexibility markets.<br>- No use of sophisticated incentivization mechanisms to incentivize end energy prosumers to participate in retail flexibility markets by shaping their energy prosumption profile according to market price signals.<br><br>**Innovation:**<br>FLEXGRID WP3 proposes the following innovative solutions: i) aggregating and ii) efficiently operating Distributed FlexAssets (DFAs). These will include bidding protocols for market participants and market rules. In addition, intelligent market mechanism will have intelligence on the end user side. Decentralized optimization models will enable real-time market analysis and forecasting. Moreover, aggregators will be able to interact effectively with end users and apart from them, these models will enable aggregators to exploit their assets in order to provide better energy services. For the proposed retail flexibility market, a pricing mechanism will be designed that will combine many attractive benefits.<br><br>**Challenges:**<br>- ESP/Aggregator needs to develop a digitalized business experience to maximize profits and end user's welfare (or else Quality of Service/Experience).<br>- ESP/Aggregator has to deal with retail-level competition in order to derive economically sustainable business models.<br>- Create a unified approach for the local market design (i.e. design easily replicable solutions that may be applied in many EU locations with similar characteristics) since many countries use different regional conditions in terms of renewable, load density and flexibility potential that significantly affect the suitability for local markets as it requires large costs (both CAPEX & OPEX) to develop various market plans<br>- Aligning regulation needs to facilitate the operation of the market takes a very long time so system operators have no incentive to use the Local Flexibility Market concept<br>- Proposed business models should be financially sustainable for both ESPs/aggregators and end energy prosumers. |
| **Actors involved** | • ESP/aggregator<br>• Retailer<br>• End energy prosumers<br>• FlexUnits<br>• Flexibility Market Operator (FMO)<br>• Market Operator/BMO (interaction with existing energy/balancing markets) |

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| **Triggering Event** | An ESP/aggregator receives a FlexRequest from FLEXGRID ATP and should optimally manage its flexibility portfolio in order to deliver the agreed FlexService. |
| **Pre-condition** | - ESP/aggregator has a centralized S/W agent and infrastructure that can communicate with all FlexAsset owners and smart electric appliances (i.e. FlexUnits).<br>- A distributed S/W agent resides at each Distributed FlexAsset (DFA) that can monitor and control all FlexUnits and can also communicate with the centralized S/W agent.<br>- Price-based DR (i.e. real time pricing models) can be applied to incentivize energy prosumers to shift their energy prosumption curves in response to price signals. |
| **FLEXGRID services involved** | - Automated flexibility aggregation management services<br>- Advanced retail flexibility market services<br>- Automated composition of B2C real-time flexibility markets<br>- Forecasters of RES generation, consumption and battery state of charge<br>- Advanced Market Forecasting Algorithms able to exploit historical data from various markets. |
| **Post-condition** | The B2C flexibility aggregation market is cleared and ESP/aggregator optimally responds to a FlexRequest. |

**Basic Path**

| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |
|---|---|---|---|---|---|
| 1 | DFA owners register in the ESP's S/W platform, declare their flexibility availability preferences and constraints and agree on a specific FlexContract with the ESP | The ESP offers the S/W platform to be used for information exchange, flexibility exchange and flexible device programming. The ESP will act as local facilitator market. | - owner's flexibility preferences and constraints<br>- agree on a specific FlexContract | DFA owners | ESP/aggr |
| 2 | After FMO has cleared the FlexMarket, a selected FlexRequest is sent to the ESP/aggregator | FMO ensures that the market is cleared. Subsequently, FlexRequests are sent to the ESP/aggregator | FlexRequest | FMO (ATP) | ESP/aggr |
| 3 | ESP/aggregator optimally schedules its available DFAs and sends control actions' schedule to each one of them | The ESP/aggregator looks at the preferences and constraints of its end users and based on the increase in its profit chooses the optimal case and then informs them | Control actions to the end users (setpoints per end user) | ESP/aggr | FlexAsset owners |
| 4 | Each DFA receives its own schedule and stores it until the operation time | Each FlexAsset owner saves the schedule information for each FlexUnit until the operation time | DFA's schedule (setpoints per FlexUnit) | FlexAsset Owner | FlexUnits |

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| 5 | When the operation time comes, each DFA performs the real control actions according to the schedule and sends back this info to the ESP/aggr | The DFA checks that their requirements are met and there is no problem and then sends confirmation to the ESP/aggregator | Real Control Actions | FlexAsset Owner | ESP/aggr |
| 6 | ESP/aggr measures and verifies the whole process | The ESP/aggregator through the information sent by the DFA, sees that the whole process is running smoothly without any problems | Measurement and Verification (M&V) process | ESP/aggr | ESP/aggr |
| 7 | ESP/aggr settles the flexibility aggregation market and reimburses all involved DFAs based on each one's contribution | The ESP/aggr acts as a central body that monitors the market for electricity generation and consumption, settlement and contract fulfillment. | Reimbursement of end users | ESP | FlexAsset owners |
| 8 | ESP/aggr sends an acknowledgement message to FMO | The ESP/aggr sends a confirmation message that consumers serve no problem | Acknowledgement message | ESP/aggr | FMO |
| **Exception path #1: ESP follows a decentralized model (i.e. pricing scheme) to clear the B2C flexibility aggregation market** | | | | | |
| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the information** | **Actor receiving the information** |
| See more details about the entire concept and all the steps followed in UCS 4.2 in section 5.4.2 below. | | | | | |
| **Exception path #2: ESP dynamically re-schedules its DFA portfolio in order to optimize its participation in various energy markets** | | | | | |
| **Step No.** | **Event** | **Description of process/ Activity** | **Info exchanged** | **Actor producing the info** | **Actor receiving the info** |
| See more details about the entire concept and all the steps followed in UCS 4.3 in section 5.4.3 below. | | | | | |

| **Realization** | |
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| **Main responsible partners** | **UCY** |
| **Contributing partners** | **ICCS, UNIZG-FER, BADENOVA, NODES, NPC, ETRA** |
| **Priority** | **High** |

# 5. FLEXGRID Use Case Scenarios (UCS)

For each one of the four (4) high-level use cases (HLUCs) extensively described in section 4, this section goes in more technical detail to describe all FLEXGRID system operation scenarios or else use case scenarios (UCS). Each UCS includes high-quality research and is under the responsibility of an academic partner. Each leading academic partner is closely collaborating with the leading industrial partner (per HLUC) in order to ensure that all research efforts are focused on real business problems and challenges, which are already existing or expected to be "hot" issues within the next years in the smart grid industry.

The UCS template (like the HLUC template) contains all useful information that defines each UCS and it is aligned with the needs and the structure of the Smart Grid Architecture Model (SGAM) framework. The FLEXGRID architecture design work (cf. Task 2.4) that will be delivered via D2.2 will take as input the standardized SGAM templates in order for a consistent and high-quality outcome to be ensured throughout the whole FLEXGRID project's development lifecycle.

## 5.1 Use Case Scenarios for HLUC #1

### 5.1.1 Distribution network aware Flexibility Market Clearing via FLEXGRID ATP

| HLUC01_UCS01 | Distribution network aware Flexibility Market Clearing via FLEXGRID ATP |
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| Description | **Scope/purpose:**<br>The existing electricity markets do not consider the constraints of local distribution networks, leading to a sub-optimal use of these networks. Costly correction actions are needed to cope with line congestions and voltage deviations that are not overseen. On the other hand, the penetration of distributed energy resources connected to the distribution network is continuously increasing. It becomes necessary to consider the creation of a market, which takes into account the distribution networks, their constraints, and the location of the sources that could provide flexibility to decrease the occurrences of line congestions and voltage deviations. This could in turn drive down the costs for the whole system, and be an alternative to distribution network reinforcement/upgrade.<br><br>**Detailed Description:**<br>The Optimal Power Flow (OPF) algorithms included in FLEXGRID ATP will be essential to clear the Distribution Level Flexibility Market (DLFM). The idea is to take into account the distribution network topology and have an accurate description of it, the market clearing process, including reactive power and power losses in the modelling phase. This allows to take into account the needs for flexibility that can arise, both in terms of congestion and voltage control. With these models, the location is also included, to make sure that flexibility is provided where it is needed.<br><br>These models should be multi-periodic, in order to include the possibility |

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| | of FlexOffers in the form of block offers. They are essential to take into account the option for a flexibility provider to provide flexibility for a maximum of hours in a row.<br><br>The market clearing will first be implemented as an auction-based system: FlexOffers and FlexRequest are aggregated; the model runs and gives the schedule and a single price for each product traded. Pay-as-bid mechanism will also be considered as a second option for the market architecture: the market works in continuous mode and each flexibility scheduled gets its bid price. Pay-as-bid is already used by NODES platform and its basic advantage is that it is simple enough and thus can be used in near-real-time flexibility markets.<br><br>**Current Status:**<br>- The distribution network is not modelled in the electricity markets<br>- AC-OPF is not used for Market Clearing in Europe. Simplifications such as DC-OPF (simplified network) or Economic Dispatch (power lines ignored) are used. These simplifications do not consider ohmic losses, voltage, and reactive power.<br><br>**Innovation:**<br>- Account for the distribution network in market clearing processes<br>- Consider ohmic losses, reactive power and voltage for distribution networks<br>- Implement flexibility markets as an auction-based architecture and as a pay-as-bid architecture<br><br>**Challenges:**<br>- Provide Convexified AC-OPF models to be used as a substrate for the modelling of other complex problems<br>- Computational burden / scalability<br>- Extraction of Locational Marginal Prices (LMPs) that give correct and accurate market signals: extracting nodal prices in the same way as DC-OPF might not make sense in the case of AC-OPF. |
| **Actors involved** | • FMO<br>• DSO<br>• ESP |
| **Triggering Event** | The FMO wants to clear the Distribution Level Flexibility Market (DLFM) via the ATP, in order to determine the optimal schedule of flexibility providers and give the market price. |
| **Pre-condition** | The DSO has informed the ATP with its network data. Production and consumption schedules from markets with earlier clearing times are available, with the location included. |
| **FLEXGRID services involved** | - Advanced market clearing models<br>- FlexServices' provisioning |
| **Post-condition** | The Distribution Level Flexibility Market (DLFM) is cleared in an efficient, timely and accurate manner. |
| **Basic Path** | |

| Step No. | Event | Description of process/ Activity | Info. exchanged | Actor producing the info | Actor receiving the info |
|---|---|---|---|---|---|
| 1 | Distribution network data acquisition | DSO provides its network data as input in the ATP | Network data and topology | DSO | FMO (through ATP) |
| 2 | Production and consumption data | The platform is updated with the production and consumption schedules from existing markets | Production and consumption schedules with location | DSO | FMO (through ATP) |
| 3 | Acquisition of FlexRequests | FMO takes as input the details of flexibility requests by the DSO | FlexRequests including location and price. | DSO | FMO |
| 4 | Flexibility provider information acquisition | FMO takes as input the details from flexibility providers | FlexOffers including location, operating limits, costs | ESP | FMO |
| 5 | Calculation of the optimal power flow | FMO runs the OPF to determine the schedule and prices for the market participants | Schedule for flexibility and payments | FMO | DSO, ESP |
| **Realization** | | | | | |
| **Main responsible partners** | **DTU** | | | | |
| **Contributing partners** | **NODES, AIT, ICCS, UNIZG, NPC** | | | | |
| **Priority** | **Medium** | | | | |

### 5.1.2 Market-based local congestion management using FLEXGRID ATP in distribution networks using output from AC-OPF model calculation as dynamic input for ATP

| **HLUC01_UCS02** | **Market-based local congestion management using FLEXGRID ATP in distribution networks using output from AC-OPF model calculation as dynamic input for ATP** |
|---|---|
| **Description** | **<u>Scope/purpose:</u>**<br>As the existing electricity markets do not consider the constraints of local distribution networks, line congestions that were not overseen can arise. As a result, re-dispatches may be necessary, which imply that more expensive units will have to be running and renewable energy production could be spilled.<br><br>Using an AC-OPF model makes it possible to anticipate/estimate the flow in each line of the distribution network and thus to identify/forecast the line congestions. This information can be used to relieve line congestions through the FLEXGRID ATP. This is possible because the AC-OPF model |

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| | gives a good description of the distribution network, including line constraints and power which is lost in the lines.<br><br>**Detailed Description:**<br>The AC-OPF model developed as part of the FLEXGRID project can be used by the DSO to identify/forecast line congestions. The DSO must have completed the platform with its network topology and details. The DSO can input the production and consumption schedules from earlier stages of the market, with location, and run the OPF to determine the needs for flexibility to prevent line congestions.<br>This information, with associated bidding prices, constitutes the FlexRequests.<br>The ESPs on their side, give their FlexOffers on the ATP.<br>The FMO runs the AC-OPF (i.e. via the DMFCT[21]) to clear the market and determine the flexibility units scheduled and the prices for the trades. These prices are nodal prices, referred to as Distribution Locational Marginal Prices (D-LMPs).<br><br>**Current Status, Innovation and Challenges** are the ones stated for the general model in HLUC01_UCS01 in part 5.1.1. |
| **Actors involved** | • FMO<br>• DSO<br>• ESP |
| **Triggering Event** | The DSO wants to identify potential line congestions in the distribution network and prevent them. |
| **Pre-condition** | The DSO has informed the ATP with its network data. Production and consumption schedules from markets with earlier clearing times are available, with the location included. |
| **FLEXGRID services involved** | - Advanced market clearing models<br>- Market-based congestion management at the distribution network level |
| **Post-condition** | The Distribution Level Flexibility Market (DLFM) is cleared and local congestions are minimized. |

| **Basic Path** | | | | | |
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| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |
| 1 | Distribution network data acquisition | DSO provides its network data as input in the ATP | Network data and topology | DSO | FMO (through ATP) |
| 2 | Production and consumption data | The platform is updated with the production and consumption schedules from existing markets | Production and consumption schedules with location | DSO | FMO (through ATP) |

[21] It should be noted that the DSO user will run the AC-OPF given its network topology data. The results of the AC-OPF algorithms that run in DFMCT will be posted back to the FLEXGRID ATP and thus the D-LMPs and Q-LMPs will be available to the FMO user and FlexSupplier users (i.e. ESP, aggregator, RESP), too.

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| 3 | Acquisition of FlexRequests for line congestions | FMO takes as input the details of FlexRequests by the DSO | FlexRequests with location, active power value and price. | DSO | FMO |
| 4 | Flexibility provider information acquisition | FMO takes as input the details from flexibility providers | FlexOffers, location, active power offered, operating limits, costs | ESP | FMO |
| 5 | Calculation of the optimal power flow and D-LMPs | FMO runs the OPF to determine the schedule and prices for the market participants | Schedule for flexibility, d-LMPs, payments | FMO | DSO, ESP |
| **Realization** | | | | | |
| **Main responsible partners** | **DTU** | | | | |
| **Contributing partners** | **NODES, AIT, ICCS, UNIZG, NPC** | | | | |
| **Priority** | **High** | | | | |

### 5.1.3 Market-based local voltage control using FLEXGRID ATP in distribution network operation

| **HLUC01_UCS03** | **Market-based local voltage control using FLEXGRID ATP in distribution network operation** |
|---|---|
| **Description** | **<u>Scope/purpose:</u>**<br>As the existing electricity markets do not consider the constraints of local distribution networks, voltage deviations that were not foreseen can arise. In particular, the models used in the existing markets, do not take into account reactive power. As a result, re-dispatches may be necessary, which imply that more expensive units will have to be running to provide reactive power.<br><br>Using an AC-OPF model makes it possible to anticipate/estimate the voltage level at every node of the distribution network and thus to identify/forecast voltage deviations. This information can be used to relieve voltage deviations through the FLEXGRID ATP. This is possible because the AC-OPF includes voltage and reactive power in the network.<br><br>**<u>Detailed Description:</u>**<br>The AC-OPF model developed as part of the FLEXGRID project can be used by the DSO to identify voltage deviations. The DSO must fill in the platform with its network topology and details. The DSO can input the production and consumption schedules from earlier stages market, with location, and run the OPF to determine the needs for flexibility to prevent voltage deviations. |

<table>
<tr><td></td><td colspan="5">This information, with associated bidding prices, constitutes the FlexRequests.<br>The ESPs on their side, give their FlexOffers on the ATP.<br>The FMO runs the AC-OPF to clear the market and determine the flexibility units scheduled for the provision of reactive power and the prices for the trades. These prices are nodal prices, referred to as Locational Marginal Prices for Reactive Power (Q-LMPs).<br><br><u>Current Status, Innovation and Challenges</u> are the ones stated for the general model in HLUC01_UCS01 in part 5.1.1.</td></tr>
<tr><td>Actors involved</td><td colspan="5">• FMO<br>• DSO<br>• ESP</td></tr>
<tr><td>Triggering Event</td><td colspan="5">The DSO wants to identify potential voltage deviations in the distribution network and prevent them.</td></tr>
<tr><td>Pre-condition</td><td colspan="5">The DSO has informed the ATP with its network data. Production and consumption schedules from markets with earlier clearing times are available, with the location included.</td></tr>
<tr><td>FLEXGRID services involved</td><td colspan="5">- Advanced market clearing models<br>- Market-based voltage management</td></tr>
<tr><td>Post-condition</td><td colspan="5">The market is cleared and voltage deviations are minimized.</td></tr>
<tr><td colspan="6">Basic Path</td></tr>
<tr><td>Step No.</td><td>Event</td><td>Description of process/ Activity</td><td>Info. exchanged</td><td>Actor producing the info</td><td>Actor receiving the info</td></tr>
<tr><td>1</td><td>Distribution network data acquisition</td><td>DSO input its network data in the ATP</td><td>Network data and topology</td><td>DSO</td><td>FMO (through ATP)</td></tr>
<tr><td>2</td><td>Production and consumption data</td><td>The platform is updated with the production and consumption schedules from existing markets</td><td>Production and consumption schedules with location, voltage and reactive power limits</td><td>DSO</td><td>FMO (through ATP)</td></tr>
<tr><td>3</td><td>Acquisition of FlexRequests for voltage management</td><td>FMO takes as input the details of flexibility requests by the DSO</td><td>FlexRequests with location, reactive power value and price</td><td>DSO</td><td>FMO</td></tr>
<tr><td>4</td><td>Flexibility provider information acquisition</td><td>FMO takes as input the details from flexibility providers</td><td>FlexOffers, location, reactive power offered, operating limits, costs</td><td>ESP</td><td>FMO</td></tr>
<tr><td>5</td><td>Calculation of the</td><td>FMO runs the OPF to determine the</td><td>Schedule for flexibility, Q-LMPs, payments</td><td>FMO</td><td>DSO, ESP</td></tr>
</table>

| | | | | | |
|---|---|---|---|---|---|
| | optimal power flow and Q-LMPs | schedule and prices for the market participants | | | |
| **Realization** | | | | | |
| **Main responsible partners** | **DTU** | | | | |
| **Contributing partners** | **NODES, AIT, ICCS, UNIZG, NPC** | | | | |
| **Priority** | **High** | | | | |

### 5.1.4 FLEXGRID ATP operates as a gateway to redirect local active power flexibility to TSO platforms (interaction with existing TSO balancing markets)

| **HLUC01_UCS04** | **FLEXGRID ATP operates as a gateway to redirect local active power flexibility to TSO platforms (interaction with existing TSO balancing markets)** |
|---|---|
| **Description** | **<u>Scope/Purpose:</u>**<br>There are currently many initiatives from TSOs across Europe to access distributed flexibility. In fact, most of the new flexibility is at the distribution level and many of the existing conventional flexibility sources (i.e. reserves) at the transmission level are being phased out/closed down due to their high cost both in economical and environmental means. In the upcoming future of high RES penetration contexts, TSO and DSO are expected compete for the same flexibility in order to fulfil their mission. FLEXGRID project assertion is that to the extent possible this "competition" should be through the value given in a flexibility market within the grid location decided by the DSO and/or TSO. In more detail, in cases where distributed flexibility has the highest value for the DSO and the local congestion/voltage management, flexibility stays local. And vice versa, in cases where distributed flexibility has the highest value for the TSO, flexibility is traded in the balancing markets operated by the TSO. FLEXGRID ATP will provide transparency on how flexibility resources are contracted. Moreover, advanced market clearing algorithms will be developed and used (cf. UCS 1.1 above) in order to enable the collaboration between TSO and DSO towards achieving better solutions in terms of social welfare. FLEXGRID ATP design and operation will be based on the existing NODES platform and related expertise from HOPS (i.e. TSO partner) and BADENOVA (i.e. DSO partner).<br><br>**<u>Detailed description:</u>**<br>The key feature of the proposed FLEXGRID ATP is the possibility to identify (through a location tag) and give a value (by putting a price tag on flexibility) to FlexSuppliers (or else ESPs). This opens new opportunities for grid operators (i.e. both DSO and TSO) that can procure distributed flexibility that lies at the distribution network level. DSOs are enabled to contract local flexibility to solve grid issues, while TSOs get access to smaller flexibility units that are currently excluded from traditional TSO markets. This integrated approach ensures that flexibility can be purchased and activated where it has the highest value, for local congestion in the DSO grid or balancing market for the TSO. |

| | |
|---|---|
| | ESPs that provide flexibility nowadays are rewarded through existing day-ahead, intraday and balancing markets. There is no market where a local flexibility resource is remunerated or can offer flexibility for solving congestion and other challenges at the distribution grid[22]. FLEXGRID ATP aims to promote extra value to this distributed flexibility through an integrated marketplace, and has already proven this value and the solution through mature pilot projects done by NODES in several EU countries during the last few years. However, at the local level (i.e. DSO), flexibility has a high extra value in certain hours, and zero value in many other hours[23]. Therefore, FLEXGRID ATP will function as a gateway to the existing, TSO balancing markets when value is higher there than at the distribution level flexibility market (DLFM). For existing ESPs, FLEXGRID ATP offers additional value to their existing portfolio. FLEXGRID ATP will develop APIs to serve all platforms used by ESPs, and this work will be closely consulted by FLEXGRID's industrial partners (i.e. NODES, HOPS, BADENOVA, NPC).<br><br>**<u>Current status:</u>**<br>- DSOs cannot contract flexibility to solve local congestion and voltage control issues (mainly due to the fact that current incentive regulation does not reward them to do it).<br>- TSOs do not have access to smaller FlexUnits (operating at the distribution level) that are currently excluded from TSO balancing markets[24].<br>- ESPs are rewarded through existing day-ahead, intra-day and balancing markets. There is no market where a local flexibility resource can be remunerated.<br>- Existing concepts and pilot solutions for local energy/flexibility markets are not connected to the existing market mechanisms like Intraday (ID) and the balancing markets organized by TSOs.<br>- TSOs and DSOs act independently in order to solve their grid-related problems and do not exchange any type of information (or at the best case, they exchange limited amount of information).<br><br>**<u>Innovation:</u>**<br>- FLEXGRID proposes novel Distribution Level Flexibility Markets (DLFMs) together with their interaction with existing markets operated by a traditional market operator and TSO.<br>- TSOs get access to smaller flexibility units that are currently excluded from traditional TSO markets<br>- ESPs owning small distributed FlexUnits at the distribution level can participate in both TSO's balancing markets and Distribution Level Flexibility Markets (DLFMs)<br><br>**<u>Challenges:</u>**<br>- A clear and efficient TSO-DSO coordination model/scheme is needed. |

[22] In the Nordic balancing regime, pay-as-bid pricing is used within the balancing market to handle grid constraints. This is what exactly FLEXGRID research will build on and enhance to realize this UCS.

[23] For short-term flexibility provisioning, this is true. For long-term contexts, it has a certain value all the time, if it can reduce DSO's CAPEX. In FLEXGRID WP5, techno-economic analysis is conducted to define this value taking into consideration various future scenarios (see also HLUC_03).

[24] In some countries, FlexUnits connected at DSO level provide primary, secondary and/or tertiary reserve services, but this is done in aggregated manner.

| | |
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| | - Model TSO/DSO competition for the procurement of flexibility services from distributed FlexAssets<br>- Design of an advanced energy market architecture enabling TSO/DSO collaboration towards increasing the social welfare. |
| **Actors involved** | • FMO<br>• TSO<br>• DSO<br>• ESP<br>• FlexUnits |
| **Triggering Event** | TSO detects frequency deviation in its control area and wants to procure flexibility from distributed FlexAssets residing at the distribution network level. |
| **Pre-condition** | - FLEXGRID ATP can offer FlexServices that meet TSO's requirements.<br>- FLEXGRID ATP interacts with existing TSO's balancing market through a web API<br>- TSO/DSO have access to the ATP for their own control area.<br>- ESP (and all its distributed FlexUnits) is registered in the FLEXGRID ATP |
| **FLEXGRID services involved** | - Gateway between FLEXGRID ATP and TSO balancing market system<br>- Advanced market clearing algorithms for TSO/DSO coordination<br>- Optimal FlexServices' provisioning |
| **Post-condition** | TSO includes FLEXGRID ATP's FlexOffers in its merit order list and clears the balancing market. |

**Basic Path**

| Step No. | Event | Description of process/ Activity | Info. exchanged | Actor producing the info | Actor receiving the info |
|---|---|---|---|---|---|
| 1 | Optimal FlexOffers | ESP calculates its optimal bid curve and sends it to the FLEXGRID ATP (FMO) | Bid curve for energy market participation | ESP | FMO |
| 2 | Search for match at the DSO level | If no match with available FlexRequest exists, then go to step 3 | FMO looks for available FlexRequests from the DSO | FMO | FMO |
| 3 | Aggregation of FlexOffers for TSO markets | FLEXGRID G ATP aggregates volumes of ESP's FlexOffers per control area and forwards them to TSO market systems (MS) | Depends on TSO requirements, but at a minimum bid price, volume, bidding zone, duration, BRP | FMO | TSO |
| 4 | TSO MS merges FlexOffers into its MS | TSO runs its balancing market according to own procedures and evaluates forwarded FlexOffers | TSO ranks regular bids and FlexOffers in merit order list and activates on demand. | TSO | TSO |
| 5 | TSO activates FlexOffers | TSO activates FlexOffers from merit order list to solve frequency issue | Depends on TSO requirements, but at a minimum clearing price, activated volume, bidding zone, duration, BRP | TSO | FMO |

| | | | | | |
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| 6 | ESP is informed | FMO sends the balancing market clearing results to the ESP | Aggregated flexibility curve to be activated by ESP | FMO | ESP |
| 7 | FlexUnits receive the setpoints | ESP dispatches the updated operation schedules to all its distributed FlexUnits | Setpoints per FlexUnit | ESP | FlexUnits |
| **Realization** | | | | | |
| **Main responsible partners** | | **ICCS** | | | |
| **Contributing partners** | | **NODES, HOPS, DTU, UNIZG-FER, NPC** | | | |
| **Priority** | | **Medium** | | | |

## 5.2 Use Case Scenarios for HLUC #2

### 5.2.1 ESP minimizes its OPEX by optimally scheduling the consumption of its end users, the production of its RES and its storage assets

| **HLUC02_UCS01** | **ESP minimizes its OPEX by optimally scheduling the consumption of end users, production of RES and storage assets** |
|---|---|
| **Description** | **Scope/purpose:**<br>Energy Service Providers (ESPs), as profit-oriented companies combine various energy market aspects to maximize their profit. Through contractual arrangements with various potential providers of flexibility (e.g. demand response, storage assets, etc.) and services provided to the DSO/TSO and BRPs, they can be considered as a coupling point between the retail and the wholesale market. The heterogeneous mixture of services they can provide and acquire has resulted (in the past) in non-negligible operating costs (OPEX). Competitive market structure introduced through processes of liberalization and deregulation of energy markets enables ESPs an even broader aspect of services they can provide exploiting their portfolio. Such developments pose a risk of even higher OPEX, but also bring an opportunity to increase their income by optimally acting in energy markets taking advantage of complementarity between various services. In this manner, FLEXGRID develops an advanced optimization model that considers optimal scheduling of FlexAssets to yield higher profits by boosting the income and reducing the operating costs.<br><br>**Detailed Description:**<br>Generally speaking, an ESP operates flexible loads, inflexible loads, Energy Storage Systems (ESSs) and production of Renewable Energy Sources (RES). Each of these elements has its own and unique set of characteristics, resulting in different benefits and challenges to the ESP's business strategy. In order to exploit advantages and minimize negative impacts of certain technologies, all relevant aspects, including high-fidelity models, need to be considered as well as specific characteristics and opportunities that various |

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| | markets (e.g. day-ahead, intraday, reserve, etc.) present. Therefore, the developed tools will result in an operating schedule, which finds the minimum OPEX, while respecting all the technical and market constraints.<br><br>FlexSupplier's (FST) toolkit provides ESPs the needed mathematical models and algorithms to approach the problem in a holistic and novel way. One of the prerequisites for a valid model essential for optimal scheduling is the accurate topology (provided by the local DSO) of the observed distribution network. Precise topology combined with extensive technical data provides valuable insight in possible locations of network congestion. These technical constraints are included in the scheduling model of the ESP[25]. Another prerequisite is the newly developed high-end FlexForecast models. The forecasts observe the matter both from the supply and the demand side. They predict end-users' consumption on the demand side by gathering and observing the respective historical data and weather forecasts. Furthermore, RES production curve prediction and market prices predictions also play an important role for the optimal scheduling. These are predicted combining meteorological and historical data.<br><br>Once all of the required data is gathered and pre-processed, pre-conditions are met to run the algorithm and interpret the results. The algorithm on the FlexSupplier side aims at minimizing OPEX. By optimally scheduling market actions (buying/selling) and operation of its resources (e.g. energy storage charging/discharging, shifting the consumption of flexible loads), the optimal schedule is derived.<br><br>FLEXGRID ATP, as the base of the market players' interaction, provides the above-mentioned services that serve to improve ESPs' business strategy. ESP, as a player on the supply side, finds appropriate tools as a part of the FlexSupplier's toolkit within the FLEXGRID ATP toolkit package.<br><br>**<u>Current Status:</u>**<br>- ESP's optimization models do not consider complementarity between various heterogeneous FlexAssets (i.e. DSM, storage, RES)<br>- Distribution-level flexibility markets are not designed nor considered in the models<br>- Distribution network topology is not taken into consideration<br>- ESPs lack eagerness and opportunities to compete in different markets<br><br>**<u>Innovation:</u>**<br>- Scheduling based upon highly precise input data, including weather forecasts, consumption forecasts, market prices predictions, and possible congestions<br>- Observing various markets to decide how to plan market strategy as one |

[25] In FLEXGRID project, we assume that DSO are eager to share (to the extent that they want) details and data about their network topology to other stakeholders (e.g. ESPs). The more data that DSOs will share, the higher the performance of FLEXGRID's research algorithms will be. FLEXGRID will study various cases to make sure that results can be applied in today's networks, but also in beyond 2030 networks, where high RES penetration contexts are expected as well as a more open data management policy by the DSOs.

| | | | | | |
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| | of the ways to minimize OPEX<br>- Using different types of FlexAssets and taking advantage of their heterogeneity<br><br>**Challenges:**<br>- Acquiring accurate network topology and network conditions (due to lack of real-time measurements) in distribution networks<br>- Obtaining or producing accurate forecasts (weather, production, consumption)<br>- Behaviour of the rival ESPs (game theory) | | | | |
| **Actors involved** | • ESP<br>• Aggregator<br>• FlexAsset owners (prosumers)<br>• FMO<br>• MO<br>• DSO | | | | |
| **Triggering Event** | ESP wants to use FLEXGRID ATP services to minimize OPEX taking into account all of the present constraints and conditions. | | | | |
| **Pre-condition** | - ESP and all of the involved FlexUnits are registered in the FLEXGRID ATP<br>- ESP is able to trade energy in the existing energy market platforms<br>- ESP has access to distribution network data and measurements | | | | |
| **FLEXGRID services involved** | - Optimal FlexOffer services for ESPs<br>- Optimal FlexAsset scheduling algorithm for ESP<br>- Optimal FlexServices' provisioning to end energy prosumers<br>- FlexForecast services | | | | |
| **Post-condition** | - ESP constantly observes current situation and predicts future trends (considering historical data) in order to undertake such actions to minimize operative costs<br>- ESP pays an appropriate register/license fee to the FLEXGRID ATP according to the traded flexibility volume and respective ESP's revenues (e.g. X % fee based on actual revenues or a monthly fixed license fee). | | | | |
| **Basic Path** | | | | | |
| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |
| 1 | Market Price forecasts | ESP takes as input the forecasted market prices and anticipates the impact of its decisions on the markets | Historical energy/power prices from various markets | MO/FMO | ESP |

| | | | | | |
|---|---|---|---|---|---|
| 2 | Supply and Demand side (production/ consumption) forecasts | ESP takes as input the forecasted data to calculate its optimal scheduling policy | Consumption data, Production data, Weather data | MO, FMO | ESP |
| 3 | Distribution network data acquisition | ESP takes as input the network data | Network data and topology | DSO | ESP |
| 4 | Optimal scheduling | ESP runs the algorithm and calculates optimal scheduling and checks if its scheduling respects the network constraints | Bidding strategy, FlexAssets utilization strategy | ESP | MO/FMO/ Aggregator/Prosumers |
| 5 | Bidding in the markets according to the scheduling | ESP uses the scheduling results to bid in the markets | Bid curve for market participation | ESP | MO/FMO/ TSO |
| 6 | Gate closure and dispatch of energy market | MO/FMO/TSO clears the market and sends dispatch schedule to market participants | Dispatch schedule | MO/FMO/TSO | ESP |
| 7 | Dispatch schedule is sent to all FlexUnits | ESP receives dispatch schedule results and sends them to each FlexUnit | Schedule results (i.e. in the form of setpoints) | ESP | FlexUnits |
| 8 | Operation phase | During operation phase, FlexUnits execute the schedule and send feedback to the ESP | Setpoints followed during operation phase | FlexUnits | ESP |
| 9 | M&V process | ESP informs the market operators about the M&V process results | M&V results | ESP | MO/FMO/ TSO |

| | | | | | |
|---|---|---|---|---|---|
| 10 | Market settlement | Market operators verify the results and settle the market (reimburse the market participants) | Reimbursements/ payments | MO/FMO/TSO | ESP |
| **Exception paths #1: Re-dispatch scheduling scenario** | | | | | |
| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |
| 1 | Dispatch schedule is different from the calculated one | ESP received a dispatch schedule that differs from the optimal one due to unexecuted orders in the markets | Difference between ordered and executed transactions | MO/FMO | ESP |
| 2 | Optimal scheduling | ESP runs the algorithm and calculates optimal scheduling according to the newly formed situation | Bidding strategy, FlexAssets utilization strategy | ESP | MO/FMO/ Aggregator/Prosumers |
| **Realization** | | | | | |
| **Main responsible partners** | **UNIZG-FER** | | | | |
| **Contributing partners** | **ICCS, DTU, UCY, BADENOVA, NPC** | | | | |
| **Priority** | **High** | | | | |

### 5.2.2 ESP minimizes CAPEX by making optimal investments (i.e. optimal sitting and sizing) on RES and FlexAssets

| **HLUC02_UCS02** | **ESP minimizes CAPEX by making optimal investments (i.e. optimal siting and sizing) on RES and FlexAssets** |
|---|---|
| **Description** | **<u>Scope/purpose:</u>**<br>Energy Service Providers (ESPs), as profit-oriented companies combine various electricity market aspects in order to maximize their profit. Through contractual arrangements with various potential providers of flexibility (e.g. demand response, storage assets, etc.) and services provided to the DSO/TSO and BRPs, they can be considered as a coupling point between the retail and the wholesale market. Long-term business plans include investment in both Renewable Energy Sources (RES) and FlexAssets. Various market situations and business strategies result in different investment plans. Furthermore, active participation in specific markets (e.g. reserve market) requires compliance with given technical constraints, which can affect both the operational and capital expenditures (OPEX and CAPEX). In this UCS, FLEXGRID provides an advanced optimization model, which considers a variety of relevant input factors, e.g. consumption, production and energy trading datasets. Such a holistic approach to the |

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| | problem enables incorporating most efficient algorithms providing optimal investment plans to minimize CAPEX and increase the return on investment, i.e. ratio between net profit (over a period) and cost of investment.<br><br>**Detailed Description:**<br>ESPs' portfolio includes flexible loads, inflexible loads, RES and Energy Storage Systems (ESSs). The latter two present a massive capital expenditure for an investor. Thus, there is a strong incentive to minimize the CAPEX. As capital investments are long-term decisions, multi-stage planning is also a possibility to hedge against potential inaccuracies in predictions regarding the future market trends, demand curves, weather conditions and other variables that could influence ESP's earnings.<br><br>Firstly, it is highly important to acquire relevant historical data. Those datasets present solid ground to model the future trends. Data is pre-processed in a way to respect the format requirements and to contain all the information that is expected from the input data for the developed algorithms to perform well. Should some required input data be missing, models will be less precise. A possible solution is to acquire the data from similar areas/markets, which have comparable characteristics and consequently akin historical data. This method can be used only if there is a strong correlation between the acquired data and the missing data.<br><br>FlexSupply offers tools to perform forecasts with the given input data. It uses the latest artificial intelligence (AI) methods to provide the extremely accurate predictions. The whole optimal investment problem is observed from multiple angles, because investment success is dependent on a wide variety of uncertain parameters. Thus, FlexTools provide a deep techno-economic analysis of the current electricity market characteristics and future trends. From the technological perspective, some of the most important factors are: i) future demand curves, ii) current network topology and probable expansion plans (acquired from the local DSOs), iii) possible technology breakthroughs. Nothing less important is the economic side of the analysis. Size and type of the investment made at one point in time is directly related to the predicted profits and associated costs (e.g. bank loan) that such investment yields in the future. Different metrics, such as Return on Investment (ROI), are used to quantitatively represent predicted effects of the investment. In that manner, sophisticated and reliable AI algorithms for predicting future market trends (e.g. day-ahead prices, futures, forwards and other derivatives) are an essential decision-making tool. However, for the picture to be complete, the economic calculations should also include factors such as: i) political incentives, ii) technology price curve, iii) associated costs (e.g. interest rates).<br><br>In order to provide a realistic techno-economic investment analysis, competition also needs to be included in the models. Rival ESPs are developing business models to improve their competitive advantage. Therefore, investment optimization models should include the latest developments in game theory, taking into account possible actions of the |

| | |
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| | players acting in the same market.<br><br>FlexSupplier's Toolkit (FST) provides a comprehensive interpretation of the developed models and co-observes them with optimal bidding strategies in various markets. Such thorough analysis identifies the most attractive electricity markets to participate in, considering technical constraints and CAPEX-to-profit ratio. Furthermore, due to possible future techno-economic trends, it considers a multi-stage investment plan in order to intelligently acquire the assets with the lowest CAPEX possible while obeying all of the constraints and requirements on the optimal siting and sizing of the relevant assets.<br><br>In addition to the optimal operation of ESP's DERs and the optimal bidding strategy, MPEC models are able to derive the optimal investment plan for the ESPs according to the energy demand and the competition. In this context, FLEXGRID will develop scalable algorithms able to minimize ESP's CAPEX through intelligent investment planners.<br><br>**<u>Current Status:</u>**<br>- Distribution network topology is not included in the state-of-the-art pre-investment analysis.<br>- ESPs lack eagerness and opportunities to compete in different markets<br>- Pre-investment analysis does not consider competition<br><br>**<u>Innovation:</u>**<br>- High-end AI prediction algorithms (demand, prices, etc.)<br>- Observing various markets and their characteristics in order to compete at the most attractive ones in terms of profits<br>- Using different FlexAssets and taking advantage of their heterogeneity<br><br>**<u>Challenges:</u>**<br>- Acquiring accurate network topology and network conditions (due to lack of real-time measurements) in distribution networks<br>- Acquiring historical data<br>- Modelling behaviour of the rival ESPs (game theory)<br>- Possible unstable economic/political situation influences the market |
| **Actors involved** | • ESP<br>• Aggregator<br>• FlexAsset owners (prosumers)<br>• FlexAsset producers<br>• MO<br>• DSO |
| **Triggering Event** | ESP wants to use FLEXGRID ATP services to minimize CAPEX taking into account all of the present constraints and conditions. |
| **Pre-condition** | - ESP and all of the involved FlexUnits are registered in the FLEXGRID ATP<br>- ESP is able to trade energy and other services in the existing market platforms |

<table>
<tr><td colspan="2"></td><td colspan="4">- ESP has access to distribution network data and measurements<br>- Precise forecasting tools<br>- Ability to acquire required historical data</td></tr>
<tr><td colspan="2">FLEXGRID services involved</td><td colspan="4">Services provided by FlexSuppliers Toolkit (FST):<br>- Optimal FlexOffer algorithms for ESPs<br>- Optimal FlexAsset schedulin g algorithm for ESPs<br>- Network-aware scheduling of an ESP’s HetFlex assets portfolio</td></tr>
<tr><td colspan="2">Post-condition</td><td colspan="4">- ESPs minimize CAPEX by making optimal investments<br>- ESP pays an appropriate register/license fee to the FLEXGRID ATP according to the traded flexibility volume and respective ESP’s revenues (e.g. XX % fee based on actual revenues or a monthly fixed license fee).</td></tr>
<tr><td colspan="6">Basic Path</td></tr>
<tr><td>Step No.</td><td>Event</td><td>Description of process/ Activity</td><td>Info. exchanged</td><td>Actor producing the info</td><td>Actor receiving the info</td></tr>
<tr><td>1</td><td>Market Price forecasts</td><td>ESP takes as input the forecasted market prices and predicts future market trends using FlexForecast services.</td><td>Historical energy/power prices from various markets</td><td>MO/FMO</td><td>ESP</td></tr>
<tr><td>2</td><td>Supply and Demand side (production / consumption) forecasts</td><td>ESP takes as input the forecasted data and predicts future trends</td><td>Consumption data, Production data, Weather data</td><td>MO, FMO</td><td>ESP</td></tr>
<tr><td>3</td><td>Distribution network data acquisition</td><td>ESP takes as input the network data and checks current topology and possible expansions</td><td>Network data and topology</td><td>DSO</td><td>ESP</td></tr>
<tr><td>4</td><td>Required market prediction as input for the optimization model</td><td>Using AI, FST builds detailed models and conducts analysis and prediction of the future market trends.</td><td>Future market trends</td><td>FLEXGRID ATP</td><td>ESP</td></tr>
<tr><td>5</td><td>Optimal Multi-Stage Investment plan</td><td>Given all needed models and data, CAPEX minimization is calculated and performed with a multi-stage optimal investment plan</td><td>Optimal investment plan (siting and sizing)</td><td>FLEXGRID ATP</td><td>ESP</td></tr>
</table>

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|---|---|---|---|---|---|
| 6 | Investments | ESP uses optimal investment plan to invest in FlexAssets | Purchase orders of the planned FlexAssets | ESP | FlexAssets producers /owners |
| 7 | Market participation according to the plan | ESP uses optimal investment plan to bid in the markets | Bid curves for market participation | ESP | MO/FMO/ TSO |
| **Exception path #1: Investment plan should be conducted in multiple stages** | | | | | |
| **Realization** | | | | | |
| **Main responsible partners** | | **UNIZG-FER, BADENOVA** | | | |
| **Contributing partners** | | **ICCS, HOPS, NODES, NPC** | | | |
| **Priority** | | **High** | | | |

### 5.2.3 ESP maximizes its profits by co-optimizing its participation in several energy and local flexibility markets

| **HLUC02_UCS03** | **ESP maximizes its profits by co-optimizing its participation in several existing energy markets and distribution level flexibility markets** |
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| **Description** | **Scope/purpose:**<br>Congestion management and frequency/voltage control issues caused by high RES penetration increase the volatility of energy prices in various existing energy markets (e.g. day-ahead, intra-day, balancing, reserve markets) as well as in emerging local flexibility markets (e.g. Distribution Level Flexibility Markets - DLFMs proposed by FLEXGRID). This volatility offers the potential for energy arbitrage (buy power when the price is low and sell it during high-price time periods) and respective revenues for ESPs, who own and invest on Energy Storage Systems (ESS).<br>In this Use Case Scenario (UCS), we consider a profit seeker Energy Storage Provider (ESP), who owns a set of Energy Storage Units (ESUs) located in different transmission network buses and nodes of a radial distribution network. In order to maximize its profits, ESP joins several energy markets and dynamically optimizes its bidding strategy. In more detail, it exploits: market price forecasters, energy prosumption forecasters and information relevant with the underlying network topology in order to derive an optimal scheduling and bidding strategy to maximize its business profits. We assume price-maker bidding models and several combinations of business cases (i.e. simulateneous participation in two, three, four or more energy markets). FLEXGRID will research on stochastic and robust optimization mathematical models and respective algorithms to solve the above-mentioned problem.<br><br>**Detailed Description:**<br>In the market environment described above, we propose a bi-level model in order to formulate the ESP's problem to calculate its optimal bidding strategy and the charging/discharging schedule of the Battery Storage Units (BSUs). For simplicity reasons and without lack of generality, we assume ESP's participation |

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| | in three (3) markets, namely: 1) Day Ahead Energy Market (DA-EM), 2) (day-ahead) Reserve Market (RM), and 3) Day Ahead Distribution Level Flexibility Market (DA-DLFM). Within FLEXGRID, a couple of other market combinations of ESP's stacked revenues' maximization may also be considered (e.g. near-real-time DLFMs operated by the FMO, balancing market operated by the TSO, etc).<br><br>For the above-mentioned ESP's participation in three markets, in the upper level problem, the ESP decides on the BSUs' operating schedule and its bidding strategy, while taking as input the Day-Ahead Energy Market's (DA-EM) forecasted prices and anticipating the impact of its decisions on the Reserve Market (RM) and Day-Ahead Distribution Level Flexibility Market (DA-DLFM). The ESP's decisions include the power traded to the DA-EM, along with the price and quantity bids to RM and DA-DLFM. In the lower level problem, for given ESP's decisions (i.e. derived from the upper level), the Reserve Market Operator (RMO) and the FMO clear the RM and DA-DLFM respectively. It is worth mentioning that in the RM and DA-DLFM clearing processes, the bids of the other market participants are treated as parameters. Finally, since the DA-DLFM follows the clearing process of the DA-EM and RM, the decisions of those markets, concerning the demand and production of the Distribution Network in which the ESP's BSUs are located, are also treated as parameters.<br><br>The objective function of the UL problem maximizes the ESP's aggregated profits from the three aforementioned markets. As far as the day-ahead wholesale energy market is concerned, the ESP decides the BSUs' operation by taking as input the nodal price, which corresponds to the node of the transmission grid on which the distribution network connects with. Secondly, the ESP earns a profit by providing upward and downward reserves in the day ahead reserve market. The upward/downward reserve prices are obtained from the reserve market clearing process and are the same throughout the transmission grid. Thirdly, the ESP participates in the DSO's day-ahead flexibility market, in which it gets paid for its flexibility services relevant with active and reactive power (P-flexibility and Q-flexibility) based on nodal prices that are calculated in the DA-DLFM.<br><br>**<u>Current Status:</u>**<br>- ESPs do not participate in local flexibility markets (i.e. stacked revenues are used only at the transmission level and only for large ESS).<br>- Existing stacked revenue models found in the international research literature consider only large ESS and not small-sized ones, which are used to deal with congestion management and voltage control problems at the DSO level.<br>- Underlying network topology is not taken into account for modelling optimal bidding strategies.<br>- TSO-DSO coordination is not taken into account to cope with local flexibility activation, which incurs imbalance problems at the TSO level.<br><br>**<u>Innovation:</u>**<br>- FLEXGRID proposes novel distribution flexibility market architectures and their inter-relation with existing energy markets (e.g. how decisions in one market affect the performance of another market)<br>- Stacked revenue modelling for ESPs, who participate with relatively small |

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| | ESS in distribution flexibility markets, too.<br>- Network-aware and context-aware bidding strategies for ESPs<br>- Use of advanced mathematical tools like stochastic bi-level optimization, robust optimization and artificial intelligence algorithms that can produce better results compared to state-of-the-art international academic literature.<br><br>**Challenges:**<br>- Price-maker ESP should not be able to abuse its market power. Respective market power mitigation measures should be in place.<br>- Competition modelling among several ESPs should be studied (i.e. what happens if we consider multiple price-maker ESP entities?)<br>- How to hedge the risks of an ESP (both in technical and regulated means) in order to make the proposed stacked revenue business model economically sustainable?<br>- How can required network topology data be disclosed to profit seeking ESP entities?<br>- Cooperation is needed between the ESP and the system operators as well as between the involved TSO and DSOs.<br>- Regulatory framework should permit private ESS investments at distribution network level and the operation of a distribution flexibility market.<br>- Regulation should permit ESP's participation in multiple energy markets. |
| **Actors involved** | • ESP<br>• MO<br>• FMO<br>• TSO<br>• DSO<br>• FlexUnits |
| **Triggering Event** | ESP wants to use FLEXGRID ATP services to construct an optimal sophisticated FlexOffer and participate concurrently in several energy and local flexibility markets in order to maximize its business profits. |
| **Pre-condition** | - ESP (and all its FlexUnits) is registered in the FLEXGRID ATP (S/W platform).<br>- ESP is registered in the existing energy market platforms.<br>- ESP has access to historical energy datasets and weather forecast information.<br>- Regulatory framework allows stacked revenue business model for ESS<br>- FMO operates a distribution flexibility market in cooperation with the local DSO.<br>- TSO and DSO entities collaborate in order to avoid technical network problems incurred by flexibility activation.<br>- ESP acquires the ICT infrastructure required to automatically monitor and control its FlexUnits. |
| **FLEXGRID services involved** | - Optimal FlexOffer models and algorithms for ESPs (FlexSuppliers)<br>- Optimal FlexAsset scheduling models and algorithms for ESPs (FlexSuppliers)<br>- Stacked revenue modelling for ESPs (FlexSuppliers)<br>- Optimal FlexServices' provisioning to end energy prosumers (FlexAsset owners) |

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| **Post-condition** | - ESP dynamically and optimally schedules and operates its FlexUnits' portfolio (as a virtual storage plant) by participating concurrently in several energy markets.<br>- ESP pays an appropriate register/license fee to the FLEXGRID ATP according to the traded flexibility volume and respective ESP's revenues (e.g. % fee based on actual revenues or a monthly fixed licence fee). | | | | |
| **Basic Path** | | | | | |
| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |
| 1 | Market price forecasts in the markets, in which the ESP acts as price-taker | ESP takes as input the forecasted market prices and anticipates the impact of its decisions on the markets, in which the ESP acts as price-maker | Historical energy price datasets from various existing energy markets | MO | ESP |
| 2 | RES/energy consumption forecasts | ESP takes as input the forecasted RES and energy consumption curves to calculate the optimal bidding policy | Historical energy data and weather forecast information | MO & WFIP | ESP |
| 3 | Optimal bidding in wholesale markets | ESP calculates its optimal bid and submits the part of the bid related with the day-ahead/intra-day markets | Bid curve for day-ahead market participation | ESP | MO |
| 4 | Optimal bidding in TSO markets (balancing/reserve) | ESP calculates its optimal bid and submits the part of the bid related with TSO markets | Bid curve for day-ahead reserve and/or balancing market participation | ESP | TSO |
| 5 | Optimal bidding in distribution flexibility markets | ESP calculates its optimal bid and submits the part of the bid related with distribution (local) flexibility markets | Bid curve for day-ahead and/or real-time distribution flexibility market participation | ESP | FMO |
| 6 | Gate closure and dispatch of the wholesale markets | MO clears the wholesale markets and sends dispatch schedules to market participants | Dispatch schedule for wholesale energy markets | MO | ESP |
| 7 | Gate closure and dispatch of TSO markets | TSO clears the day-ahead reserve and balancing markets and sends dispatch schedules to market participants | Dispatch schedule for TSO markets | TSO | ESP |

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| 8 | Gate closure and dispatch of distribution flexibility markets | FMO clears the distribution (local) flexibility markets and sends dispatch schedules to market participants | Dispatch schedule for distribution (local) flexibility markets | FMO | ESP |
| 9 | All dispatch schedules are sent to all FlexUnits | ESP gathers all discpatch schedule results from all markets and sends them appropriately to each FlexUnit | All dispatch schedule results (i.e. in the form of setpoints) | ESP | FlexUnits |
| 10 | Operation phase | During operation phase, FlexUnits execute the schedule and send feedback to ESP | Setpoints followed during operation phase | FlexUnits | ESP |
| 11 | M&V process | ESP informs the market/system operators about the M&V process results | M&V results | ESP | MO/FMO/ TSO |
| 12 | Market settlement | System/market operators verify the results and settle the market (reimburse the market participants) | Reimbursements/ payments | MO/FMO/T SO | ESP |
| **Exception path #1: Local flexibility that has been activated at DSO level incurs imbalance problems to the TSO level (i.e. re-dispatch process is needed)** | | | | | |
| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |
| 1 | Imbalance problem detection at TSO level due to local flexibility activation | FMO detects an imbalance at TSO level and informs the TSO | New FlexOffer submitted to TSO balancing market | FMO | TSO |
| 2 | Gate closure for balancing market | TSO clears the balancing market aaccepting the new FlexOffer and sends feedback to ESP | Redispatch schedule | TSO | ESP |
| **Realization** | | | | | |
| **Main responsible partners** | **ICCS, UNIZG** | | | | |
| **Contributing partners** | **DTU, AIT, BADENOVA, NODES, NPC** | | | | |
| **Priority** | **High** | | | | |

### 5.2.4 An electric utility company/MG operator applies network-aware optimal bidding policies to make optimal use of its FlexAssets taking into consideration the physical network constraints

| HLUC02_UCS04 | An electric utility company[26]/MG operator applies network-aware optimal bidding policies to make optimal use of its FlexAssets taking into consideration the physical network constraints |
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| Description | **Scope/purpose:**<br>High RES penetration and exploitation of heterogeneous flexibility (HetFlex) assets require an effective interaction between efficient energy markets and electricity grid management systems. In this business environment, modern Energy Service Providers (ESPs) need to: i) adopt imperfect market context - aware bidding strategies to maximize their profits, ii) respect the underlying network constraints, and iii) make decisions about the optimal mix of their HetFlex assets as well as their optimal sizing, siting and operation. In this UCS, FLEXGRID develops advanced models and algorithms that factorize all the above. The main purpose is to schedule Energy Storage Systems (ESSs) and Demand Side Management (DSM) systems optimally and in an integrated way in order to maximize a price maker ESP's profits. This scenario perfectly fits BADENOVA's business and can also be applied in a MicroGrid (MG)/energy island concept.<br><br>**Detailed Description:**<br>We consider a transmission grid, which is characterized by a set of buses and a set of transmission lines. An ESP acts as an orchestrator/aggregator of HetFlex assets over multiple geographically dispersed Distribution Networks (DNs). These DNs are connected to a set of buses of the transmission grid. Renewable generators, ESSs, flexible (shiftable) and inflexible loads are located in each DN urning it into a Virtual Power Plant (VPP), which can supply/draw power to/from the rest of the grid. More specifically, the DN connected to a given bus is characterized by a set of nodes (DN buses), a set of edges (DN branches), a set of ESSs, a set of renewable generators, a set of shiftable loads and a set of inflexible loads. The ESP is responsible for controlling the ESSs and the deferrable loads in order to strategically participate in the given market (e.g. day-ahead, balancing, flexibility market) and maximize its profits. In addition, the ESP has to ensure the reliable and stable operation of DNs. The goal of this UCS is to calculate the ESP's optimal bidding strategy in for participation in a given market and the optimal schedule of the HetFlex assets, while simultaneously taking into account the distribution network constraints.<br><br>In order for the ESP/MG operator to be able to derive a strategic and network-aware bidding policy through the optimal orchestration of its virtual and heterogeneous FlexAssets' portfolio, the following datasets are required as input: i) market price forecasts based on historical energy price datasets taken from the market operator, ii) RES, ESS and energy consumption forecasts based |

[26] This actor is not explicitly short-listed in section 2.1. However, this UCS refers to the case of an ESP who also owns the distribution network like the case of BADENOVA (and many other similar companies) in Germany. This UCS can also be applicable for MicroGrid (MG) Operators (cf. emerging DC microgrid concept).

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| | on historical energy datasets as well as weather forecasts, and iii) distribution network data and topology taken from the local DSO. Based on these inputs, the ESP runs an algorithm to calculate its optimal bidding and then submits it to the appropriate market operator. Then, the latter clears the market and derives the dispatch schedule, which is sent to the ESP. Once the ESP is informed about the dispatch schedule results, it calculates and sends the appropriate commands to all its FlexUnits. The latter follow the defined setpoints. A M&V process follows together with the market settlement process.<br><br>It worths noting there may be two basic cases for recalculating an optimal bid curve (see 2 exception paths described below). The first case is when the initially calculated bid curve does not meet the network constraints. The second case is when the bid is rejected by the market operator due to competition with other price-maker rival ESPs. In both cases, the ESP should recalculate a new bid curve.<br><br>FLEXGRID ATP will provide the above mentioned innovative services to the ESP user via the use of the FlexSupplier's Toolkit, where WP4 intelligence will be integrated.<br><br>**<u>Current Status:</u>**<br>- Current ESP's profit maximization models do not adequately model the competition with rival ESPs.<br>- Current hybrid virtual power plant (VPP) scheduling and operation models do not take into consideration the heterogeneity of the various FlexAssets (i.e. optimal mix of DSM, ESS and RES assets).<br>- Underlying network topology is not taken into account for modelling optimal bidding strategies.<br><br>**<u>Innovation:</u>**<br>- Modern ESPs act strategically as price maker entities having the capability to optimally bid in liberalized electricity markets taking into account the outer environment in terms of the decisions of electricity market competitors.<br>- ESP plans a distribution network –aware bidding strategy that saves it from high societal and monetary costs.<br>- ESP's optimal bidding strategy allows the adjustment and the respect of operational limits of a physical distribution network, ensuring that they will not be violated at any time.<br>- ESP can orchestrate its virtual HetFlex portfolio that comprises of distributed RES, DSM and ESS units. The coordinated planning and scheduling of HetFlex assets[27] results in higher RES utilization and cost-effective network operation.<br><br>**<u>Challenges:</u>**<br>- Liberalized energy market operation is assumed permitting the bidding of |

[27] DSO has also a role in the coordinated planning and scheduling of HetFlex assets. In this UCS, we assume that ESP and DSO roles are integrated in one market stakeholder (cf. BADENOVA case in Germany).

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| | | price maker ESPs.<br>- The ESP should have some kind of access to the underlying DSO network data and topology.<br>- Detailed datasets of the underlying distribution network topology are needed as well as accurate mathematical modeling of the distribution network operation.<br>- How to model the competition with other rival ESPs in order to make sure that ESP's bidding policies are optimal (e.g. stochastic and/or robust optimization models)?<br>- Regulatory framework should permit private ESS investments at distribution network level. | | | |
| **Actors involved** | | • ESP<br>• MO<br>• FMO<br>• TSO<br>• DSO | | | |
| **Triggering Event** | | ESP wants to use FLEXGRID ATP services to construct an optimal sophisticated bidding policy acting as a price maker entity taking into consideration underlying network constraints, too. | | | |
| **Pre-condition** | | - ESP (and all its FlexUnits) is registered in the FLEXGRID ATP (S/W platform).<br>- ESP is registered in the existing energy market platforms.<br>- ESP has access to distribution network data and topology.<br>- ESP has the ICT infrastructure required to automatically monitor and control its FlexUnits. | | | |
| **FLEXGRID services involved** | | - Optimal FlexOffer models and algorithms for ESPs (FlexSuppliers) and MG operators<br>- Network-aware scheduling of an ESP's HetFlex assets portfolio<br>- Optimal FlexAsset scheduling models and algorithms for ESPs (FlexSuppliers) and MG operators<br>- Optimal FlexServices' provisioning to end energy prosumers (FlexAsset owners) | | | |
| **Post-condition** | | - ESP dynamically and optimally schedules and operates its FlexUnits' portfolio (as a virtual storage plant) by taking into consideration the physical network constraints.<br>- ESP pays an appropriate register/license fee to the FLEXGRID ATP according to the traded flexibility volume and respective ESP's revenues (e.g. XX % fee based on actual revenues or a monthly fixed licence fee). | | | |
| **Basic Path** | | | | | |
| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |

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| 1 | Market price forecasts | ESP takes as input the forecasted market prices and anticipates the impact of its decisions on the markets, in which the ESP acts as price-maker | Historical energy price datasets from various existing energy markets | MO/FMO | ESP |
| 2 | RES/ESS/ consumption forecasts | ESP takes as input the forecasted RES, ESS and energy consumption curves to calculate its optimal bidding policy | Historical energy data and weather forecast information | MO/FMO & WFIP | ESP |
| 3 | Distribution network data acquisition | ESP takes as input the network data and checks if its bidding respects the network constraints | Network data and topology | DSO | ESP |
| 4 | Optimal bidding in an energy market | ESP calculates its network-aware and optimal bid to the market | Bid curve for energy market participation | ESP | MO/FMO/ TSO |
| 5 | Gate closure and dispatch of energy market | MO/FMO/TSO clears the market and sends dispatch schedule to market particpants | Dispatch schedule | MO/FMO/T SO | ESP |
| 6 | Dispatch schedule is sent to all FlexUnit | ESP receives dispatch Schedule results and sends them appropriately to each FlexUnit | Schedule results (i.e. in the form of setpoints) | ESP | FlexUnits |
| 7 | Operation phase | During operation phase, FlexUnits execute the schedule and send feedback to ESP | Setpoints followed during operation phase | FlexUnits | ESP |
| 8 | M&V process | ESP informs the market operators about the M&V process results | M&V results | ESP | MO/FMO/ TSO |
| 9 | Market settlement | Market operators verify the results and settle the market (reimburse the market participants) | Reimbursements/ payments | MO/FMO/T SO | ESP |
| **Exception path #1: The ESP's optimal bid curve (calculated at step 4) violates at least one of the underlying physical network constraints** | | | | | |
| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |
| 1 | Physical network violation problem | DSO network constraints cannot be met | Bid rejected by DSO | DSO | ESP |

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| 2 | Re-calculation of the optimal bid curve | ESP re-calculates the optimal bidding policy given the network constraints | New bid curve | ESP | MO/FMO/TSO |
| **Exception path #2: The ESP's optimal bid curve (calculated at step 4) does not take into consideration the existence of other price-maker rival ESPs** | | | | | |
| 1 | Optimal bid curve is rejected by the market | ESP is kept out of merit due to competition with other price-maker rival ESPs | Bid rejected by market operator | MO/FMO | ESP |
| 2 | Re-calculation of the optimal bid curve[28] | ESP re-calculates the optimal bidding policy given the competition | New bid curve | ESP | MO/FMO/TSO |
| **Realization** | | | | | |
| **Main responsible partners** | **ICCS, UNIZG-FER** | | | | |
| **Contributing partners** | **BADENOVA, DTU, AIT, NODES** | | | | |
| **Priority** | **Medium/low** | | | | |

### 5.2.5 RESP optimizes the operation of its hybrid RES/storage assets in order to maximize their dispatchability rate and ensure their equal market participation

| **HLUC02_UCS05** | **RESP optimizes the operation of its hybrid RES/storage assets in order to maximize their dispatchability rate and ensure their equal market participation** |
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| **Description** | **Scope/purpose:**<br>The RESP actor is essentially an ESP of renewable energy (large photovoltaic parks or wind parks). RESPs are new players in the electricity market, and this UCS aims at optimizing combined renewable and storage systems in order to avoid the (stiff) imbalance penalties that are included in the optimization model. That is, the hybrid unit behaves like a conventional energy generator. Thus, dispatchability rate can be increased by combining renewables with a storage system (e.g. battery). Moreover, another purpose of this UCS is to enable RESPs to i) monitor, analyze and predict RES generation and market prices towards more efficient use of resources ii) plan and operate their hybrid assets optimally towards more competitive energy services' provisioning and increased revenues.<br><br>**Detailed description:**<br>RESPs sell the energy they generate from RES in the wholesale market. RESPs will be able to optimize the operation of RES/storage resources through forecasting tools that will provide dynamic estimates of RES profiles based on data from a specific geographical region. Forecasting tools will also |

[28] We assume that all other steps described in the basic path are followed. The two exception paths describe two different sub-scenarios for the same UCS.

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| | provide RESPs precision so they can exploit commercially available energy with controllable risk (i.e. models for risk hedging/minimization). In addition, they will be able to optimally design their RES compositions according to the market prices, their forecasts and CAPEX. At the same time, RESPs will be able to manage the storage systems needed to increase the rate through dynamic services and commercial planning. In addition to this, RESPs will also be able to cope with the fluctuations in energy provided by RES.<br>In the context of this UCS, we also consider a sub-scenario in which RESPs optimise the RES generation by combining the diverse nature of different RES types belonging to its portfolio aiming to balance out the intermittency through improved forecasting processes to mitigate differences and thus reduce the need for supportive sources like storage to achieve the adequate dispatchability rates. Where needed, available forecasting tools or data from from literature (i.e. wind forecasting or wind data) will be used to complement the provided solutions. Combining this mixture of RES with biomass and/or highly efficient CHP using green gas can offer alternative solutions at a premium that will be taken into consideration in the optimization model.<br><br>**<u>Current status:</u>**<br>- There is little integration of ESS to enable RESPs to have adequate dispatchability rate to participate in equal terms in the existing wholesale markets.<br>- Increased risk of commercial exploitation generated by RES due to the high uncertainty levels that they present.<br>- There are no automatic (ICT-based) services to help RESPs to optimize the RES composition.<br><br>**<u>Innovation:</u>**<br>- Optimize the sizing and the scheduling of RESP's ESS by utilizing the provided forecasting errors through the Renewable Forecast Accuracy Levels indices (RFAL-related metrics).<br>- Interact with FLEXGRID's RES production farm composers in order to maximize RESP's profits.<br>- Advanced PV forecasting tools for RESPs<br>- Dynamic ESS and energy trading scheduling to increase RESP assets' dispatchability rate.<br><br>**<u>Challenges:</u>**<br>- For the implementation of these markets, installation of ICT infrastructure is required (smart meters, communication systems on top of the electricity network and more).<br>- Storage facilities and green gas should be available in order to adequately cover the natural intermittency of RES.<br>- Accurate forecasting tools should be made available to reduce the error from daily generation plans to meet profile needs.<br>- Regulation should permit free price determination on a real-time base at the retail level.<br>- Business models for RESPs must be sustainable in order to incentivize |

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| | the undertaking of such a role. |
| **Actors involved** | • RESP<br>• MO<br>• FMO<br>• TSO |
| **Triggering Event** | RESPs can manage their FlexAssets and sign contracts with consumers so that they can sell flexibility through FLEXGRID ATP to maximize their profits. |
| **Pre-condition** | - RESPs can monitor and control their assets in order to maximize the dispatchability rate.<br>- RESPs are registered in FLEXGRID ATP.<br>- RESPs can participate in the wholesale market. |
| **FLEXGRID services involved** | - Advanced RES forecasting tools for RESPs<br>- Planning services that optimize RES compositions<br>- Dynamic ESS scheduling and energy trading services for RESPs |
| **Post-condition** | Provide novel FLEXGRID services to RESPs in order to maximize their profits. |

| **Basic Path** | | | | | |
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| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |
| 1 | Prosumers register in the RESP's S/W, declaring their flexibility availability and agree to a FlexContract with their RESP | Prosumers will sign up to the RESP's S/W stating their flexibility and RESP will choose the optimal schedule to maximize their profits | Prosumers' flexibility availability | Prosumer | RESP |
| 2 | FMO clears the FlexMarket and FlexRequests are sent to the RESPs | The FMO clears the market so the RESPs can sell flexibility in the market | FlexRequest | FMO | RESPs |
| 3 | FlexSupply (the response from RESP to FlexRequests) | The RESP, through the FLEXGRID ATP, will be able to increase the dispatchability and thus be able to provide better services to its prosumers | Schedule / dispatch level for each prosumer | RESPs | FMO |
| 4 | Penalties for possible imbalances are calculated by TSO | By increasing the dispatchability value, the RESPs will avoid the imbalance penalties and thus be able to play an active role in the wholesale market | Deviations between initial schedule and final operation | TSO | FMO |

| Realization | |
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| **Main responsible partners** | **UCY** |
| **Contributing partners** | **ICCS, BADENOVA, NPC, NODES** |
| **Priority** | **Medium** |

### 5.2.6 Independent large FlexAsset Owner leases storage for several purposes to several market stakeholders

| HLUC02_UCS06 | Independent large FlexAsset Owner leases storage for several purposes to several market stakeholders |
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| **Description** | **Scope/purpose:**<br>Numerous FlexAssets, providing non-neglectable volume, are one of the main prerequisites for the flexible market to function in its full capacity bringing innovation and new opportunities to the electricity sector. There are multiple business cases for managing and generating income using FlexAssets. As this use case demonstrates, one can make a profit by only using FlexAssets without explicitly owning them. Here, this is achieved through the model of leasing a storage unit and market products to various market participants. In that way, some players will make profit by using leased FlexAssets (without explicitly owning them) and the owner will generate income simply by leasing its storage. This UCS describes a storage-lease business model.<br><br>**Detailed Description:**<br>FlexAssets consist of Renewable Energy Sources (RES), storage and Demand-Side Management (DSM). Storage that provides services in the flexibility market can be physically achieved in various forms. Technologically, it can be a battery storage, a flywheel, a pumped-hydro unit, hydrogen storage, an ultracapacitor or a thermal storage. In geospatial sense, this storage can be centralized, i.e. a single unit, or distributed, e.g. electric vehicles (EV), devices providing demand response, etc. Distributed storage units often suffer from limited availability, e.g. EVs are available only while connected to the grid. Although contractual agreements between aggregators and EV owners also present a form of storage lease, this UCS observes aggregated storage with the main goal of providing its capacity for various purposes in the electricity markets. In the remainder of this text, the term “storage owner” does not necessarily imply physical ownership over a storage unit, e.g. batteries of all aggregated EVs, but indicates that this legal entity owns capacity of the storage, regardless if this is a single storage unit actually owned by this legal entity or an aggregation of distributed storage units, e.g. EV batteries, with a contract with each EV owner.<br><br>As an owner of large storage capacity, one has many possibilities for generating profit. Therefore, innovative business models need to be developed by the storage owner to attract potential users to exploit its |

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| | available storage capacity. Storage owner will seek to take advantage of leasing its storage to several market stakeholders, who may act in different markets in different ways. To develop offers that can attract various market players, a thorough market analysis is one of the key prerequisites. Offers are tailor-made for each specific purpose (various markets) according to various factors, such as technical constraints, capacity demand volumes, market liquidity, etc. to meet the specific needs and present an attractive solution. In that manner, both sides of the lease agreement will have an incentive to form this kind of partnership.<br><br>Reliability is one of the most important requirements that such storage solutions need to provide. For this reason, a detailed analysis will be conducted on how a specific storage (with its technical characteristics) will perform under different conditions (durability, maximum power output, etc.). According to the results, FlexSupplier's Toolkit (FSP) may propose to the FlexAsset's provider parameters and warnings about technical performance of the storage.<br><br>Having taken into consideration all economic and technical aspects, FLEXIGRID ATP performs a bidding/auction process in which storage capacity owner consequently enters into contractual agreements with interested parties (if all conditions are met from both sides).<br><br>**<u>Current Status:</u>**<br>- Non-existent wide-spread business models of such nature<br>- Lack of R&D in that aspect of capacity trading<br>- Poor incentives for realizing storage-lease business model.<br><br>**<u>Innovation:</u>**<br>- Novel way of FlexStorage units' management<br>- Method of capital expenditures (CAPEX) minimization for stakeholders<br>- Opportunity for new market players to take part in electricity markets<br><br>**<u>Challenges:</u>**<br>- Possible lack of interest for the proposed business model<br>- Technical constraints of various markets<br>- Responsibility/accountability during malfunctions |
| **Actors involved** | • ESP<br>• MO<br>• FMO<br>• TSO<br>• DSO |
| **Triggering Event** | A storage investor recognizes that flexibility service providers have different storage capacity requirements during the year, thus it make sense to lease the capacity (CAPEX avoidance). |

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| **Pre-condition** | - All of the involved FlexUnits are registered in the FLEXGRID ATP<br>- FLEXGRID ATP provides storage trading services | | | | |
| **FLEXGRID services involved** | - Optimal FlexOffer models and algorithms<br>- Optimal FlexAsset scheduling<br>- Optimal FlexServices' provisioning (FlexAsset owners)<br>- Optimal FlexAsset leasing models | | | | |
| **Post-condition** | Flexibility providers offer their services on various markets, while outsourcing the storage units. | | | | |
| **Basic Path** | | | | | |
| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |
| 1 | Market Price forecasts | ESP takes as input the forecasted market prices and anticipates the impact of its decisions on the markets | Historical energy/power prices from various markets | MO, FMO, FST | ESP |
| 2 | Supply and Demand side (production/ consumption) forecasts | ESP takes as input the forecasted data[29] to calculate its optimal scheduling policy | Consumption data, Production data, Weather data | MO, FMO, FST | ESP |
| 3 | Distribution network data acquisition | ESP takes as input the network data and checks if its scheduling respects the network constraints | Network data and topology | DSO | ESP |
| 4 | Flexibility service provider needs additional storage capacity | Flexibility service provider calculates current need for the flexibility services and tries to acquire the required capacity temporarily through a lease agreement. | Storage allocation proposals | FlexSupplier | FlexAsset owner |
| 5 | Storage trading | FlexAsset owner uses FLEXGRID ATP services to sign contractual agreements with the interested parties | Storage lease agreements | FLEXGRID ATP | FlexAsset owner |
| **Realization** | | | | | |
| **Main responsible partners** | **UNIZG-FER, ICCS** | | | | |
| **Contributing partners** | **NPC, NODES, BADENOVA, HOPS, UCY** | | | | |

[29] The forecasting engine of the FlexSupplier's Toolkit (FST) run by the ESP user provides forecasted data.

| Priority | Medium/low |
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## 5.3 Use Case Scenarios for HLUC #3

### 5.3.1 Coordinated voltage/reactive power control either by aggregating flexibility from multiple FlexAssets or through a market-based mechanism

| HLUC03_UCS01 | Coordinated voltage/reactive power control either by aggregating flexibility from multiple FlexAssets or through a market-based mechanism |
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| Description | **Scope/Purpose:**<br>The scope of this UCS is to utilize reactive power provision capabilities of renewable energy resources (RES) and distributed energy resources (DER) as well as emerging technologies in the distribution grids to increase the hosting capacity and to improve voltage profiles both in transmission and distribution grids. This UCS utilizes untapped reactive power provision capability of RES and DER resources in the distribution grid (DSO level) in addition to conventional resources controlled by TSOs, taking into consideration new control schemes utilizing all possible flexibilities, which could be introduced by DG, DER and emerging technologies. The overall purpose is to increase the collaboration between TSOs and DSOs for an improved reactive power/voltage management scheme at interface level as well as evaluating available reactive power resources to be used both in transmission grids for counteracting voltage violations caused by RES and in distribution grids increasing RES hosting capacity. The proposal is that the future DSO, who tries to solve over/under-voltage issues has two basic alternative solutions (i.e. advanced control mechanisms vs. flexibility market-based mechanism). In case it is cheaper and more effective, the DSO will use a flexibility market-based mechanism. DSO will have the intelligence to decide dynamically on what control policy to follow based on the type of event/problem.<br><br>**Detailed description:**<br>With increasing share of DG/RES and the changing framework in the energy market, the number of conventional synchronous generators decreases, thus major sources for voltage control are missing. Additionally, voltages are changing much faster, depending on the system load and intermittent RES infeed. In unexpected high load / low RES infeed cases, voltage levels drop significantly, especially in the absence of voltage control devices. Having this in mind, TSOs can no longer control the voltage profiles in their systems by just giving set points for the transmission grid connected generators voltage controllers. Therefore, it is vital to develop approaches/tools for the management and planning of voltage/reactive power control in the future control centres. Considering that reactive power is always a local challenge and state of the art DG and RES units, mainly connected at distribution system level, are technically capable of controlling voltage, capabilities of these generation units must be seen from the perspective of operational control as further flexibilities. Since reactive power must be transported to the TSO grid, intensive cooperation between DSO and TSO demanding simultaneous coordination is necessary. |

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| | Thus, **the optimal planning and operation of DG and RES located in distribution grids in order to contribute to local and regional reactive power management and reactive power provision to the transmission grid must be enabled**.<br><br>The procedure is composed of three sequential steps by utilizing an OPF tool at each step. The steps may be carried out as part of the grid operator's day-ahead or hours-ahead operational planning, or as part of a real-time control scheme.<br><br>In the **first step**, a reactive power flexibility assessment is performed by the DSO using its own OPF tool (i.e. AC-OPF models proposed by FLEXGRID). Flexibility margins at connection points are computed using control variables of OLTC transformers and controllable generation units in the DSO grid by respecting interrelation of connection points in terms of calculated flexibilities. In this step, the TSO grid is represented in terms of grid equivalent(s) including connection points to the distribution grid. As a result of the first step, the DSO announces available reactive power flexibilities at the TSO/DSO connection points to the TSO. In case of operational planning, these may be flexibility schedules based on market mechanism using FLEXGRID ATP; in case of real-time control, the flexibilities will relate to reactive power that can be delivered in an ad-hoc manner.<br><br>In the **second step**, the TSO uses the reactive flexibility that was communicated and the values declared for each TSO/DSO connection point to run the TSO-level OPF, where distribution grid transformers could be represented as virtual generators, and DSO grids may be represented by grid equivalents (e.g. in case a DSO grid connects to the TSO by two or more connection points). The TSO's OPF tool calculates the set points for the TSO/DSO connection points as well as generators connected to the TSO's control area prioritizing its own control objectives. The result of the second step are set points for the TSO reactive power assets and the flexibility usage. Again, in the operational planning case, there will be set point schedules based on market mechanism using FLEXGRID ATP, while in the real-time operation case, there will be single set points.<br><br>As **third and final step**, the DSO computes the set points for its individual assets through its OPF tool (cf. FLEXGRID's DFMCT) by respecting set points given by the TSO for its control area. The set points can be either in the form of reactive power exchange or optimal voltage values at the TSO/DSO connection points.<br><br>**<u>Current status:</u>**<br>With increasing share of DG/RES and the changing framework in the energy market, the number of conventional synchronous generators decreases, thus major sources for voltage control are missing. Additionally, voltages are changing much faster, depending on the system load and intermittent RES infeed. In unexpected high load/low RES infeed cases voltage levels |

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| | drop significantly, especially in the absence of voltage control devices. Having this in mind, TSOs can no longer control the voltage profiles in their systems by just giving set points for the transmission grid connected generators voltage controllers. Therefore, it is vital to develop approaches/tools for the management and planning of voltage/reactive power control in the future control centres. **Considering that reactive power is always a local challenge and state of the art DG and RES units, mainly connected at distribution system level, are technically capable of controlling voltage, capabilities of these generation units must be seen from the perspective of operational control as further flexibilities**.<br><br>**<u>Innovation:</u>**<br>Since reactive power must be transported to the TSO grid, intensive cooperation between DSO and TSO demanding simultaneous coordination is necessary. Thus, the optimal planning and operation of DG and RES located in distribution grids in order to contribute to local and regional reactive power management and reactive power provision to the transmission grid must be enabled.<br>Regarding the coordinated TSO-DSO optimization, the above-mentioned optimization chain, is proposed. Different objective functions may be conceived. Q or V set-points are followed by the DSO at the TSO/DSO connection points.<br><br>**<u>Challenges:</u>**<br>The objective functions, which could be weighted as desired based on priorities of operators, are chosen among others as: (i) smoothing of voltage profiles, (ii) minimization of grid losses, (iii) minimization of tap position changes, (iv) minimization of quadratic deviation from global reactive power exchange target, (v) minimization of sum of quadratic deviations from voltage and reactive power targets at each connection point between TSO and DSO grids. |
| **Actors involved** | • FlexDemand stakeholders (TSO, DSO, BRP)<br>• Flexibility Market Operator (FMO)<br>• FlexSupply stakeholders (ESP, RESP, Aggregator, BRP, BSP)<br>• Prosumers/ FlexAsset owners<br>• FlexAsset Units<br>• Market Operator (interaction with existing energy markets) |
| **Triggering Event** | Need for coordinated reactive power flows at the TSO/DSO interface. |
| **Pre-condition** | - Due to different voltage control mechanisms by TSOs in EU member countries, the practices adopted by the Italian TSO according to the regulations in CEI 0-16 and CEI 0-21 and by Swiss TSO operators are assumed as reference.<br>- Regulating plants are assumed to follow given voltage set points and to be equipped with remote control.<br>- Availability of controllable reactive power devices in the grid model.<br>- An established communication channel with DER units and other active elements which can provide reactive power. |

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| | - Regulations and network codes for the above listed assumptions have to be complied with, before the implementation of the proposed interface controller.<br>- Detailed models for TSO and DSO grids with a suitable number of nodes are available. There must be at least one balancing zone with one TSO and at least one DSO, and the number of nodes should be 100 or more. The grid model does not have to span all voltage levels down to the LV network, but needs to include at least the EHV level (TSO) and HV level (DSO) for the operation areas of the grid operators considered. There are no dynamic grid models needed.<br>- Suitable grid equivalents for TSO and DSO are available.<br>- Realistic reactive power capabilities, generation profiles and time series for each resource within the network model (storage, controllable loads, renewable generators, etc.) are available. | | | | |
| **FLEXGRID services involved** | - Advanced market clearing models and algorithms<br>- Frequency/voltage control services' provisioning via market-based mechanisms<br>- Market-aware upgrade planning<br>- Optimal investment models | | | | |
| **Post-condition** | Increased RES hosting capacity and improved voltage profiles both in transmission and distribution grids | | | | |
| **Basic Path** | | | | | |
| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |
| 1 | TSO reactive power requirements assessment | The TSO forecasts the required reactive power in its grid as well as at TSO/DSO connection points. For this, predicted line loads, busbar voltage levels, planned reactive load power, and also active power flows need to be considered. For DG and RES in the DSO network, cos ϕ = 1 is assumed. The forecasted reactive Exchange power at TSO/DSO connection points may be set constant. | TSO active power generation and load forecast, reactive load power forecast | FlexUnits (Load and Generation forecast units) | TSO |
| 2 | TSO set point calculation | TSO calculates set points for its OLTC transformers which hold voltage levels in permitted limits. The required reactive power from the external slack node is also calculated. | TSO OLTC set points | TSO (grid operation planning) | FLEXGRID ATP |

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| 3 | DSO OPF | During real-time operation, the DSO optimizes the set points for its OLTC transformers. This optimization may be replaced by OLTC local control. | TSO OLTC set points | FLEXGRID ATP | DSO (OLTC controller) |
| 4 | DSO flexibility assessment - DER level | The DSO assesses the flexibility of its own DER resources to provide reactive power within the time of consideration ad hoc or up to 24 hours in advance, using appropriate forecasts. | DG & RES forecast | Load and generation forecast unit | FLEXGRID ATP |
| | | | Generation unit and storage status | DG, RES, controllers, storage inverter controllers | |
| | | | Reactive power forecast data | Load and generation forecast unit | |
| 5 | DSO flexibility assessment DSO/ TSO connection point level | Knowing the individual DER's reactive power flexibilities, the DSO calculates the amount of reactive power flexibility that can be delivered to the DSO/TSO connection points. During this, line loads, busbar voltage levels, and (predicted) active power flows need to be considered in order to make sure that the reactive power can really be transported to the TSO without problems. | reactive power flexibility | DSO | DSO |
| 6 | DSO flexibility assessment - announcement | The DSO announces the resulting and verified reactive power flexibilities at the DSO/TSO connection points to the TSO. | Reactive power provision capability at DSO/TSO connection points | DSO | FLEXGRID ATP |
| 7 | TSO OPF - TSO reactive power resource and requirement assessment | The TSO assesses available resources for reactive power, part of which are the flexibilities announced by the DSO(s). The TSO also assesses the amount of required reactive power in its grid, which will depend on network configuration, and operation planning of generators and | TSO asset reactive power provision status and capability, TSO reactive power generation and load forecast, TSO grid status | FLEXGRID ATP | TSO (reactive power assessment and planning tool) |

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| | | loads. | | | |
| 8 | TSO OPF - optimization | Knowing the reactive power availabilities and requirements and also the active power operational planning or current status, the TSO uses an OPF to calculate optimal set points for reactive power assets, including utilization of the DSO flexibilities, and respecting its individual optimization objectives. The OPF uses a detailed model of the TSO grid, and DSO grid equivalents to represent the DSO network as far as needed for correct load flow calculation. | OPF algorithm is running | TSO | TSO |
| 9 | TSO OPF - set point announcement for DSO | The TSO announces the target set points for reactive power provision at the DSO/TSO connection points to the DSO | Reactive power set points at TSO/DSO connection points | TSO | FLEXGRID ATP |
| 10 | TSO OPF - set points for TSO assets | The TSO fixes and transmits set points for reactive power transmission by its own assets | Reactive power set points for TSO assets | TSO reactive power assessment and planning tool | TSO-level OLTC, generator, power compensation, Cos phi, FACTS controllers |
| 11 | DSO OPF | Using the TSO set points, the DSO utilizes an OPF to optimally distribute the requested reactive power provision amongst its assets. Distribution is done through market mechanism using the FLEXGRID ATP. Here, the DSO uses a detailed grid model of its own grid, and eventually uses grid equivalents to represent the TSO network, as far as needed for correct load flow calculations. Grid | Reactive power set points for DSO-level DG, RES and storage inverter controllers | DSO | FLEXGRID ATP |

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| | | equivalents may also be used for parts of the DSO's own network which don't need to be modelled in detail, or even for networks of neighboring DSOs. | | | |
| 12 | Activation | The FLEXGRID ATP sends activation commands to the FlexAsset(s) and continues monitoring the behavior of the FlexAsset(s). | Activation signal | FLEXGRID ATP | FlexAsset owners |
| **Main responsible partners** | | **AIT** | | | |
| **Contributing partners** | | **BADENOVA, HOPS, NODES, DTU, ICCS** | | | |
| **Priority** | | **High** | | | |

### 5.3.2 TSO-DSO collaboration for coordinated management of aggregated FlexAssets and interaction between networks' and flexibility markets' operation

| **HLUC03_UCS02** | **TSO-DSO collaboration for coordinated management of aggregated FlexAssets and interaction between networks' and flexibility markets' operation** |
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| **Description** | **<u>Scope/Purpose:</u>**<br>Nowadays, flexibility service provisioning is decoupled from energy supply, so aggregation is possible across many different market players and balance groups. The scope of this UCS is the aggregation of geographically distributed resources (e.g., distributed generation, energy storage, and consumers) and charging stations for electric vehicles. Flexibility is additionally characterized by its location. Flexibility can be explored by a market player (e.g. ESP, aggregator, retailer) and used for commercial (manual frequency restoration reserve - mFRR, provision to TSO) or technical purposes (services for DSO to solve voltage problem or local congestions). The primary actor is the Flexibility Market Operator (FMO) proposed in FLEXGRID exploring the potential resources from various FlexSuppliers.<br><br>**<u>Detailed description:</u>**<br>Customers and distributed third-party energy resources that have the ability of changing their consumption or generation (including energy storage systems/units) for short time could be aggregated and their flexibility could be offered as ancillary service to TSO or to be used for DSO grid purposes. For commercial purposes, the Flexibility Market Operator (FMO) offers ancillary services to the TSO (frequency control services and balancing services). The FMO pools flexibility of DER with the commercial FlexAssets' management system operated by the FlexSupplier stakeholder. On the other hand, the same DERs' flexibility could be used by the DSO for non-frequency DSO needs (i.e. solving local congestions and voltage problems).<br><br>**<u>Current status:</u>** |

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| | - TSO and DSO have a very high level of collaboration and need to cooperate in a much more detailed and advanced way.<br>- Existing flexibility market frameworks that are being proposed in the international literature do not take into consideration the physical networks' operation<br>- Current ancillary services' provisioning processes are not based on market-based mechanisms.<br>- Existing TSO-DSO collaboration schemes do not take into consideration the existence of an independent flexibility market operator and the role that this actor will have with the system operators.<br><br>**Innovation:**<br>The main innovation is to supply reliable and efficient (technically and competitively priced) flexibility to TSO or DSO from geographically distributed third-party energy resources through the use of FLEXGRID ATP (operated by a novel FMO entity).<br><br>**Challenges:**<br>- To have a proper business model, in which consumers have an interest to curtail their consumption or generation (flexibility) when requested. grid fee or special discount on energy (for the grid and not for supplier).<br>- How does the activation at the DSO level affect the TSO level? How do the market clearing results of the proposed Distribution Level Flexibility Market (DLFM) affect the transmission grid operation as well as existing energy and ancillary service markets?<br>- How does the TSO and DSO collaborate/communicate with each other to find a more efficient solution compared to the case that they act individually to deal with their own network's problems?<br>- Which is the optimal TSO-DSO coordination scheme and which are the pros-cons of each proposed scheme? |
| **Actors involved** | • TSO<br>• DSO<br>• FMO<br>• ESP/Aggregator<br>• FlexAsset owners |
| **Triggering Event** | - TSO publishes the auction schedule via the FLEXGRID ATP<br>- DSO activation request (i.e. FlexRequest) is advertised via the FLEXGRID ATP |
| **Pre-condition** | - Customers have an interest and the ability to curtail their consumption or generation when requested.<br>- Two-way communication between the TSO/DSO system and FlexAssets' management System (i.e. ESP's/aggregator's portfolio).<br>- A proper business model, ensuring that consumers have an interest to curtail their consumption or generation (flexibility) when requested. Reward for resources which participated could be lower grid fee or special discount on energy (for the grid and not for supplier).<br>- Regulatory rules allow aggregation across balance responsible parties<br>- TSO ancillary service market is accepting flexibility bids (i.e. FlexOffers) from ESPs/aggregators (e.g. geographically distributed small-scale DER). |

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| | - The DSO is allowed to purchase ancillary services for support of distribution grid operation.<br>- The FlexAssets' management system of the ESP/Aggregator is pre-qualified (by TSO and DSO) for ancillary services' provisioning.<br>- The FlexAsset owners associated to the ESP/Aggregators should be able to comply with reliability standards for ancillary services' provisioning. (e.g. country/system operator specific requirements)<br>- Resource must provide at least 90% of requested flexibility within 15 minutes (TSO requirement).<br>- Resource must provide at least 90% of requested flexibility within 25 minutes (DSO requirement)<br>- Coordination between TSO and DSO is required for flexibility activation from FlexAssets. This requirement is related with the technical validation of flexibility activation of FlexAssets connected to the distribution network<br>- Availability of calibrated meters or sub-meters with high precision and short communication interval (according to national requirements, e.g. error class 1% and 1-minute measurement interval). |
| **FLEXGRID services involved** | - Advanced market clearing models and algorithms<br>- Frequency/voltage control services' provisioning via market-based mechanisms |
| **Post-condition** | - All required flexibility services were settled effectively<br>- No congestions/voltage control problems appear in the networks |

**Basic Path**

| Step No. | Event | Description of process/ Activity | Info. exchanged | Actor producing the info | Actor receiving the info |
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| 1 | Monitoring | The ESP/Aggregator gets information about expected market prices | Market price | FLEXGRID ATP | ESP/ Aggregator |
| 2 | Monitoring | The ESP/Aggregator gets information about available flexible capacities inside the pool. If no information is received from external systems, the ESP performs an internal calculation. | Electrical measurements | Prosumers/ FlexAsset owners | ESP/Aggregator |
| 3 | Monitoring | The FLEXGRID ATP periodically calculates the outlook for congestions per distribution grid section using latest data from the DSO's SCADA. | OPF results | DSO/TSO | FLEXGRID ATP |
| 4 | Monitoring | The ESP/Aggregator gets information about restrictions from grid operation via the FLEXGRID ATP. | Technical restrictions | FLEXGRID ATP | ESP/Aggregator |

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| 5 | Request | The TSO/DSO publishes the Auction schedule via the FLEXGRID ATP | Price information | DSO/TSO | FLEXGRID ATP |
| 6 | Monitoring | The ESP/Aggregator calculates available capacity and optimal price of bids, considering grid restrictions and further rules for internal backup. | Available capacity, price, restrictions | Prosumers/ FlexAsset owners | ESP/aggregator |
| 7 | Bidding | The ESP/Aggregator submits bids to the FLEXGRID ATP | Price Bids | ESP/ aggregator | FLEXGRID ATP |
| 8 | Bidding | The ESP/Aggregator sends information about volume and location of submitted bids to FLEXGRID ATP | Technical details | ESP/ aggregator | FLEXGRID ATP |
| 9 | Activation | The FLEXGRID ATP informs the ESP/ aggregator about acceptance or non-acceptance of submitted bids. | Y/N signal | FLEXGRID ATP | ESP/aggregator |
| 10 | Monitoring | The ESP/aggregator internally assigns flexibilities (incl. backup) to accepted bids and reserves the capacities (of DER) to avoid double trading of flexibilities. | Technical details | ESP/aggregator | Prosumers / FlexAsset owners |
| 11 | Monitoring | The ESP/aggregator sends information about volume and location (in the grid) of accepted flexible reserves to the FLEXGRID ATP | Technical details | ESP/aggregator | FLEXGRID ATP |
| 12 | Monitoring | The FLEXGRID ATP gets the information of reserved flexibilities (DER) and recalculates the OPF. | Technical details | ESP/aggregator | FLEXGRID ATP |
| 13 | Monitoring | Optional: The ESP/ aggregator informs the FlexAsset owner about reservation of flexibilities, if this was agreed between the parties | Technical details | ESP/aggregator | Prosumers / FlexAsset owners |
| **Exception path #1: Reserve activation** | | | | | |
| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |
| 1 | Monitoring | The ESP/aggregator periodically receives measurement of each FlexAsset via the DSO's advanced metering infrastructure. | Measurement data | FlexAssets | ESP/Aggregator |

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| 2 | Monitoring | The ESP (Aggregator) periodically receives congestion information of each relevant grid section. | Congestion information | FLEXGRID ATP / DSO | ESP (Aggregator) |
| 3 | Monitoring | The ESP (Aggregator) periodically calculates the aggregated values of the pool (e.g. baseline, measurements, available capacities) and sends the information to the TSO's P/f controller. This is only done if there is an accepted bid, which is currently active, otherwise 0 MW will be sent. (TSO-specific requirements). | Aggregated data | ESP/Aggregator | TSO |
| 4 | Activation | In case of an enduring frequency deviation the P/f-controller initiates the activation of FlexAsset by sending an activation request to the ESP/Aggregator. | Activation signal | TSO | ESP/Aggregator |
| 5 | Monitoring | The ESP Aggregator reads the latest activation status of FlexAsset from the FLEXGRID ATP and corrects the available flexibility periodically. | Technical data | FLEXGRID ATP | ESP/Aggregator |
| 6 | Monitoring | The ESP/Aggregator calculates the optimized dispatch of FlexAsset. | Available capacity | FlexAsset owners | ESP/Aggregator |
| 7 | Activation | The ESP/Aggregator sends activation commands to the FlexAsset(s) and monitors the performance of the activation. | Activation signal | ESP/Aggregator | FlexAsset owners |
| 8 | Monitoring | The ESP/Aggregator sends information about activated FlexAsset to the FLEXGRID ATP. | Technical details | ESP/Aggregator | FLEXGRID ATP |
| 9 | Activation | If needed, the TSO's P/f controller can change the activation schedule (capacity, end time or both) by sending a new command to the ESP/ Aggregator. If an activation change was received (step 9) the ESP/Aggregator repeats the steps 6 to 8) to adjust provision of ancillary service to the new schedule. | Activation signal | TSO | ESP/Aggregator |

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| 10 | Deactivation | The TSO's P/f controller sends the "activation stop" message to the ESP/Aggregator | Deactivation signal | TSO | ESP/Aggregator |
| 11 | Deactivation | The ESP/Aggregator sends deactivation commands to the FlexAsset(s) and continues monitoring the behaviour of the FlexAsset(s). | Deactivation signal | ESP/Aggregator | FlexAsset owners |
| 12 | Monitoring | The ESP/Aggregator sends an updated list of activated FlexAsset to the FLEXGRID ATP, so other systems like the DSO's SCADA can get updated information of activated FlexAsset from the FLEXGRID ATP | Technical details | ESP/Aggregator | FLEXGRID ATP |
| 13 | Monitoring | The ESP/Aggregator periodically receives measurement of each FlexAsset via the DSO's advanced metering infrastructure. | Technical details | DSO | ESP/Aggregator |
| **Realization** | | | | | |
| **Main responsible partners** | **AIT** | | | | |
| **Contributing partners** | **BADENOVA, HOPS, NODES, DTU, ICCS** | | | | |
| **Priority** | **High** | | | | |

### 5.3.3 TSO deals with a frequency control problem either by aggregating flexibility from multiple FlexAssets or through a market-based mechanism

| **HLUC03_UCS02** | **TSO deals with a frequency control problem either by aggregating flexibility from multiple FlexAssets or through a market-based mechanism** |
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| **Description** | **Scope/Purpose:**<br>Inertia management in a power system where synthetic inertia and fast frequency response mechanisms are possible to utilize.<br><br>**Detailed description:**<br>With rising RES penetration, frequency stability issues appear and one of the main problems is decreasing system inertia. This use case scenario (UCS) addresses this issue and proposes a solution in the form of inertia management, where additional control (synthetic inertia and fast frequency response) is implemented. Introduction of new types of control to RES and storage systems as well as proper operation planning could minimize curtailments of converter interfaced units due to frequency stability issues and allow for maximizing share of this type of generation in power systems. Synthetic inertia allows converter connected generation to emulate inertial response of synchronous units through |

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| | utilizing kinetic energy of wind turbines rotating masses and thus no curtailment is needed to provide frequency support. Fast frequency response (FFR) on the other hand, can either react proportionally to the deviation of frequency or inject power according to a pre-determined schedule (FFR approach can be used also for PV farms and storage systems). In addition of synthetic inertia and fast frequency control along with demand and weather forecasts, current system inertia estimation could be used for optimal inertia allocation with an objective to use RES/ESS units' capabilities first.<br><br>**<u>Current status:</u>**<br>Inertia is an inherent power system feature that opposes frequency deviations caused by power balance disturbance in a grid and gives time for the primary control to start acting. In the past, inertia was not a concern, since rotating masses of synchronous generation were contributing to its high amount. However, as power systems evolve and synchronous units are being replaced by converter connected RES, the problem arises since minimum system inertia in the system must be ensured for its secure and stable operation.<br><br>**<u>Innovation:</u>**<br>Introduction of new types of control to RES and storage systems as well as proper operation planning could minimize curtailments of converter interfaced units due to frequency stability issues and allow for maximizing share of this type of generation in power systems. Synthetic inertia allows converter connected generation to emulate inertial response of synchronous units through utilizing kinetic energy of wind turbines rotating masses and thus no curtailment is needed to provide frequency support. Fast frequency response (FFR) on the other hand, can either react proportionally to the deviation of frequency or inject power according to a pre-determined schedule (FFR approach can be used also for PV farms and storage systems).<br><br>**<u>Challenges:</u>**<br>- In this UCS, synthetic inertia and fast frequency control are used for the same purpose, i.e. limiting of RoCoF and, in turn, contributing to higher nadir. However, since the principle of the two control modes is different, the results can also be dissimilar and therefore two sub-scenarios are proposed to investigate the difference. From the perspective of sub-scenario description, these two control modes are used interchangeably. |
| **Actors involved** | • Transmission System Operator (TSO)<br>• Distribution System Operator (DSO)<br>• Prosumers/ FlexAsset owners<br>• FlexSupply stakeholders (ESP, RESP, Aggregator, BRP, BSP) |
| **Triggering Event** | - Need for limiting the Rate of Change of Frequency (RoCoF) |
| **Pre-condition** | - Synthetic inertia and fast frequency control are available<br>- Necessary regulations and laws are enforced<br>- Part of active power range from storage units can be used as ancillary service for frequency support |

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| | - Appropriate amount of primary and secondary reserves are ensured.<br>- It is required (assumed) that the list of (Flex)Units that can provide synthetic or real inertia is available to the TSO and the selection methodology can be based on any of the following: bids for inertia service on ancillary services market, bilateral agreements, mandatory control mode enforced by the network codes to be optionally used by the TSO or other. | | | | |
| **FLEXGRID services involved** | - Advanced market clearing models and algorithms<br>- Frequency/voltage control services' provisioning via market-based mechanisms<br>- Market-aware upgrade planning | | | | |
| **Post-condition** | - Optimal inertia allocation with the objective to use RES/ESS units' capabilities first | | | | |
| **Basic Path** | | | | | |
| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |
| 1 | Demand forecast | Receiving demand forecast | Demand forecast | FLEXGRID ATP | TSO |
| 2 | Dispatch data | Receiving dispatch data including status and generation schedule of generating units, HVDC links and storage as well as their constraints regarding active power generation/transfer/consumption | Dispatch data | FLEXGRID ATP | TSO |
| 3 | Calculation of available & needed inertia | TSO calculates available and necessary system inertia using dispatch data and forecasted load. Based on the largest infeed or load and assumed criteria regarding RoCoF. Then, it is compared to the inertia available from the scheduled generation. If the necessary inertia is higher than the available one, then the process of identification of additional inertia resources is initiated. | Value of system inertia | TSO | FLEXGRID ATP |
| 4 | Selection of units which can provide additional inertia | FlexUnits which will be used to provide additional inertia for the system are selected from the list of units that can provide this service based on the market services. The TSO will optimise the process of selection of the units, so that no surplus inertia is in operation. | Signal for activation of inertia control mode (SI, FFR or both) and respective set points for this control mode if necessary | FLEXGRID ATP | FlexUnits |
| **Exception path #1: inertia only from spinning masses of generators** | | | | | |
| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |

| | | | | | |
|---|---|---|---|---|---|
| 1 | Demand forecast | Receiving demand forecast | Demand forecast | FLEXGRID ATP | TSO |
| 2 | Dispatch data | Receiving dispatch data including status and generation schedule of generating units, HVDC links and storage as well as their constraints regarding active power generation/transfer/consumption | Dispatch data | FLEXGRID ATP | TSO |
| 3 | Calculation of available & needed inertia | TSO calculates necessary system inertia based on the largest infeed or load and assumed criteria regarding RoCoF. Then, it is compared to the inertia available from the scheduled generation. | Value of system inertia (for information purposes only) | TSO | FLEXGRID ATP |
| 4 | Activation | In case of need, TSO initiates the activation of FlexAsset by sending an activation request to the FLEXGRID ATP which forwards the activation to the selected FlexAssets | Activation signal | TSO | FLEXGRID ATP |
| **Realization** | | | | | |
| **Main responsible partners** | **AIT** | | | | |
| **Contributing partners** | **HOPS, BADENOVA, NODES** | | | | |
| **Priority** | **Medium** | | | | |

### 5.3.4 Co-optimization of FlexAsset investments between a System Operator and profit-based ESPs to minimize network upgrade investments

| **HLUC03_UCS04** | **Co-optimization of FlexAsset investments between a System Operator and profit-based ESPs to minimize network upgrade investments** |
|---|---|
| **Description** | **Scope/purpose:**<br>TSOs and DSOs are service-oriented companies responsible for transmission and distribution of electricity, respectively. Both roles are highly regulated as they are natural monopolies. In order to secure constant stability and reliability of the whole system, long-term planning considers factors such as future demand curves when making the investment decisions. Traditionally, the most common choice for securing sufficient network capacity during the peak hours is expansion of the network using physical assets, i.e. new lines, transformers, circuit-breakers, etc. This method has two negative consequences: i) high capital expenditure (CAPEX), ii) transmission/distribution system is most of the time heavily under-capacitated. This UCS therefore introduces a different perspective on the problem. Smart utilization of distributed FlexAssets can postpone major network expansion investments and result in a more uniform loading of the transmission and distribution systems. This novel approach presents many opportunities, but also challenges which are carefully studied. |

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| | **Detailed Description:**<br>Transmission and distribution systems constantly evolve and adapt to the newly formed circumstances. It is fair to say that electricity demand at most locations has been constantly growing, and it tends to grow even more as electric vehicles (EV). Furthermore, the whole electric generation industry is evolving as distributed energy generation is taking larger share in the total generation of electricity. Such developments challenge distribution network by causing local congestions. These congestions can be either voltage congestions (due to too high or too low voltage levels) or thermal congestion (too high loading). Conventional methods of dealing with these problems include investments in new and/or upgraded network components. Obviously, this kind of strategy causes high CAPEX. However, the hypothesis of this UCS is that the vast amount of newly installed distributed energy generation, storage capacities and flexible demand presents an opportunity to reduce CAPEX to the system operator.<br><br>Both TSOs and DSOs have high CAPEX due to the factors such as increasing demand curve and interregional energy trading. Focus of this UCS is primary on the DSOs, as FlexAssets are usually connected to the lower voltage levels, thus under the jurisdiction of the respective DSO. FlexAssets with their flexibility services benefit the network in multiple ways. Among others, they postpone capital investments to expand the network capacities, they shave peaks and provide an additional tool in network reliability management.<br><br>Clearly, the main result of the co-optimization of FlexAsset investments between a System Operator and profit-based ESPs is the CAPEX minimization and an optimal plan for the respective network. To do so, a detailed techno-economic analysis is required. Such analysis observes current situation, possible future network requirements (technical constraints) and possible strategies to satisfy the future needs.<br><br>The developed investment tool will minimize the distribution network investments and promote DSO payments to the flexible assets within the distribution grid (based on transparent auctions). This way, high CAPEX is replaced by slightly increased OPEX. Obviously, when voltage or thermal congestion appears only a few hours per year this slightly increased OPEX is a better option than the bulky CAPEX. Beside the DSO as a natural monopoly, other important players for the purpose of this UCS are ESPs. Profit-oriented ESPs compete among each other to provide their services to the DSO. As each ESP has in its portfolio a different HetFlex mixture, it can compete with different offers at different times. Some ESPs will win the auctions and provide services, and some will lose and prepare for the coming auctions.<br><br>For the whole process to be precisely modeled[30], this UCS is considered as a form of Stackelberg competition, meaning that the bilevel optimization problem is observed. The leader is the DSO and the followers are ESPs. The lower-level problem is an investment game equilibrium among HetFlex ESP |

[30] Various future demand/supply/market scenarios will be considered in the mathematical model.

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| | companies that compete. The upper-level problem is the network investment minimization problem.<br><br>FLEXGRID Automated Trading Platform (ATP) provides all the required FlexToolkits to the DSOs and ESPs as the mediator in the whole process. As DSOs and ESPs deliver all of the required data, FlexTool performs the bilevel optimization problem and afterwards the ATP provides all needed services in order for the DSO and ESPs to conclude their contractual agreements.<br><br>**<u>Current Status:</u>**<br>- TSOs/DSOs (as a rule) neglect other possibilities aside from network expansion in order to satisfy technical requirements<br>- Bilevel optimization is not used in network investment planning in practice<br>- Constantly increasing distributed energy resources and storage are not utilized as flexibility providers at the distribution level<br><br>**<u>Innovation:</u>**<br>- Bilevel optimization to minimize network investments<br>- OPEX rather than CAPEX for satisfying network needs<br>- Flexibility services used to postpone network expansion<br>- Stackelberg competition (DSO and ESPs)<br><br>**<u>Challenges:</u>**<br>- Regulatory framework considering DSOs and TSOs should permit such actions as a valid strategy to satisfy the future network needs<br>- Detailed datasets of the underlying distribution network topology are needed as well as accurate mathematical modeling of the distribution network operation<br>- How to realistically model the competition among the rival ESPs in order to make sure that DSO's incentives have the best effect |
| **Actors involved** | ● TSO<br>● DSO<br>● ESPs<br>● FlexAsset owners<br>● FMO (FLEXGRID ATP) |
| **Triggering Event** | DSO (TSO) wants to use FLEXGRID ATP services to minimize network investment costs (i.e. run exhaustive list of scenario combinations via simulations). |
| **Pre-condition** | - ESP (and all its FlexUnits) is registered in the FLEXGRID ATP (S/W platform).<br>- ESP has access to distribution network data and topology.<br>- ESP has the ICT infrastructure required to automatically monitor and control its FlexUnits.<br>- DSO is registered in the FLEXGRID ATP (S/W platform). |

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| **FLEXGRID services involved** | - Optimal FlexNetwork investment minimization tool<br>- Network-aware scheduling of an ESP's HetFlex assets portfolio<br>- Optimal FlexAsset scheduling models and algorithms for ESPs (FlexSuppliers) and MG operators<br>- Optimal FlexServices' provisioning to end energy prosumers (FlexAsset owners) |
| **Post-condition** | DSO minimizes investment cost and postpones network expansion.<br>FlexAssets provide flexibility services to the respective DSO. |

**Basic Path**

| Step No. | Event | Description of process/ Activity | Info. exchanged | Actor producing the info | Actor receiving the info |
|---|---|---|---|---|---|
| 1 | RES/ESS/ consumption forecasts | DSO takes as input the forecasted RES, ESS and energy consumption curves to calculate the future network needs | Historical energy data and weather forecast information | MO/FMO & WFIP | DSO |
| 2 | Distribution network data acquisition | ESP takes as input the network data and checks if its bidding strategy/policy respects the network constraints | Network data and topology | DSO | ESP |
| 3 | DSO acquires optimal investment plan | DSO obtains the optimal investment plan and ESPs are nominated to provide flexibility services[31] | Optimal investment plan, ESPs awarded for providing flexibility services (ESPs) | FLEXGRID ATP | DSO, ESPs |
| 4 | Operation phase | During operation phase, FlexUnits execute the schedule and send feedback to ESP | Setpoints followed during operation phase | FlexUnits | ESP |
| 5 | M&V process | ESP informs the market operators about the M&V process results | M&V results | ESP | MO/FMO/TSO |
| 6 | Market settlement | Market operators verify the results and settle the market (reimburse the market participants) | Reimbursements/ payments | MO/FMO/TSO | ESP |

**Realization**

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| **Main responsible partners** | **UNIZG-FER, ICCS** |

[31] Here, we assume various scenario combinations (e.g. via stochastic optimization modelling) that may occur in short-term scheduling horizon.

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| **Contributing partners** | **BADENOVA, HOPS, NPC** |
| **Priority** | **Low/medium** |

## 5.4 Use Case scenarios for HLUC #4

### 5.4.1 ESP/aggregator efficiently responds to FlexRequests made by TSO/DSO/BRPs by optimally orchestrating its aggregated flexibility portfolio of end energy prosumers

| **HLUC04_UCS01** | **ESP/aggregator efficiently responds to FlexRequests made by TSO/DSO/BRPs by optimally orchestrating its aggregated flexibility portfolio of end energy prosumers** |
|---|---|
| **Description** | **Scope-Purpose:**<br>In this scenario, the interaction between the ESP/aggregator and the end-user will be studied. More specifically, there are FlexContracts between end users and ESP/aggregator, where the end users state their preferences. Then, the ESP/aggregator considers the available flexibility and selects the most appropriate mix of end users to satisfy the FlexRequest by choosing the most profitable solution, but at the same time considering the technical constraints (i.e. end-user's utility function and welfare[32]). Optimisation in this case is carried out centrally in contrast with the UCS 4.2 and 4.3 described below, where decentralized modelling and approaches are assumed. Interaction between ESP/aggregator and end users will be easy and effective, so that they can participate in future dynamic energy markets thereby increasing their profits.<br><br>**Detailed description:**<br>To enable the ESP/aggregator to manage optimally its aggregated flexibility portfolio of end energy prosumers, novel ad-hoc flexibility market mechanisms need to be designed. These new market mechanisms will include the bidding protocols for the market participants and the rules of market operation, namely an allocation rule and a pricing rule. This will create an interaction between ESP/aggregator and end energy prosumers.<br>In particular, end energy prosumers will state their preferences to ESP/aggregator. The ESPs/aggregators will then make the best choice (which maximizes their profits) and sign a contract with end energy prosumers. Subsequently, if TSO/DSO/BRP want to buy flexibility, they will turn to the ESPS/aggregators and they in turn, if interested in the purchase price (this will be done through the new market mechanisms), will sell their aggregated flexibility to the TSO/DSO/BRP and at the same time serve the end energy prosumers who are incentivized to participate in this process through a sophisticated reward-based mechanism.<br><br>**Current status:** |

[32] For the modelling of the end user's utility function, we will use state-of-the-art modelling solutions for the international literature as well as pilot testing results from previous related H2020 and national projects.

| | |
|---|---|
| | - End user engagement is yet to catch up<br>- Lack of intelligent S/W agents that negotiate with ESP/aggregator<br>- Academic research on designing optimization and control methods for extracting sustainable business value out of FlexRequests is relatively small.<br><br>**Innovation:**<br>- Advanced AI-based modelling tools for retail flexibility market<br>- Novel energy service provisioning to enhance the end prosumer's quality of service and experience (QoS/QoE)<br>- New revenue streams for ESPs/aggregators<br>- Novel market mechanisms, which will increase the profits of ESP/aggregator<br><br>**Challenges:**<br>- For the implementation of the proposed ad-hoc retail flexibility market, installation of ICT infrastructure is required (smart meters, smart plugs, communication systems on top of the electricity network, etc.).<br>- Intelligent controllers that manage the response of the distributed flexibility assets must be available and cost-effective as a commercial product (e.g. smart appliances).<br>- Regulation should permit free price determination on a real-time base at the retail level.<br>- Business models and value propositions for ESP/aggregator must be sustainable in order to incentivize the undertaking of such a role. |
| **Actors involved** | ● TSO<br>● DSO<br>● BRP<br>● ESP/aggregator<br>● End prosumers<br>● FlexUnits |
| **Triggering Event** | After a flexibility market clearing process has taken place, ESP/aggregator receives a FlexRequest from TSO/DSO/BRP (through FLEXGRID ATP). |
| **Pre-condition** | - ESP/aggregator has a S/W tool, where the end energy prosumer can register.<br>- A FlexContract is signed between the ESP/aggregator and the end energy prosumer.<br>- ESP/aggregator selects optimal case and sells flexibility in the market to maximize its profit. |
| **FLEXGRID services involved** | - Automated flexibility aggregation management services<br>- Advanced retail flexibility market services<br>- Automated composition of B2C real-time flexibility markets |
| **Post-condition** | - ESP/aggregator optimally manages its flexibility portfolio of end energy prosumers (in a centralized manner) through a multi-objective optimization process in order to find the optimal trade-off between maximizing its profits and the aggregated users' welfare (AUW). |

| Basic Path | | | | | |
|---|---|---|---|---|---|
| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |
| 1 | TSO/DSO/BRP wants to buy flexibility from market sending signals to ESP/Aggregator | In order for TSO/DSO/BRP to meet demand, they send signals to ESP/Aggregator to sell them flexibility | Signals relating to the flexibility need | TSO/DSO/ BRP | ESP/Aggr |
| 2 | ESP/Aggregator receives signals from TSO/DSO/BRP | ESP/Aggregator receive signals from TSO/DSO/BRP and evaluates the requested flexibility | Flexibility needs of TSO/DSO/BRP | TSO/DSO/ BRP | ESP/Aggr |
| 3 | ESP/Aggregator analyses the market and optimally uses available flexibility resources for responding | If the market price ensures an increase in profits, the ESP/Aggregator optimally organizes the flexibility assets and responds to the flexibility request | Price for requested flexibility | ESP/Aggr | TSO/DSO/ BRP |
| 4 | TSO/DSO/ BRP collects offers for flexibility | TSO/DSO/BRP analyses received offers for flexibility and decides on offers | Accepted offers for meeting flexibility needs | TSO/DSO/BRP | ESP/Aggr |
| 5 | ESP/Aggregator receives accepted offer for flexibility | ESP/Aggregator analyses the content of the offered flexibilities with related prices identifying assets that will meet the required flexibilities | Offered flexibilities | TSO/DSO/BRP | ESP/Aggr |
| 6 | ESP/Aggregator implements the required flexibility | The ESP / Aggregator implements required flexibility on identified assets of end users | Flexibilities on specific assets | ESP/Aggr | FlexAsset owner/ prosumer |
| 7 | ESP/Aggregator settles accounts of end users | The ESP/ Aggregator concludes financial credit to owners of provided flexibilities | Financial credits to owners of flexibilities | ESP / Aggregator | FlexAsset owner/ prosumer |

| | | | | | |
|---|---|---|---|---|---|
| 8 | TSO/DSO/BRP settles accounts of ESP / Aggregators | The DSO/TSO/BRP settles the accounts of the ESP / Aggregators that their offers have been implemented | Financial credits to authorised ESP/ Aggregators | TSO/DSO/BRP | ESP/Aggr |
| **Realization** | | | | | |
| **Main responsible partners** | **UCY** | | | | |
| **Contributing partners** | **ICCS, BADENOVA, NPC** | | | | |
| **Priority** | **High** | | | | |

### 5.4.2 An aggregator operates an ad-hoc B2C flexibility market with its end energy prosumers by employing advanced pricing models and auction-based mechanisms

| **HLUC04_UCS02** | **An aggregator operates an ad-hoc B2C flexibility market with its end energy prosumers by employing advanced pricing models and auction-based mechanisms** |
|---|---|
| **Description** | **Scope/purpose:**<br>The aggregation of small-scale distributed flexibility assets (end user electric appliances with modifiable loads, EVs, batteries, etc.) requires the development of a retail flexibility market through which ESP/aggregator trades dynamically with end users the value of the flexibility assets (FlexAssets) that the latter dispose. The development of dynamic pricing schemes and auctions has several requirements, because these systems have to be: Real Time, Efficient, Strategy Proof, Competitive, Scalable, Fair and Privacy Protecting. Moreover, the uncertainty in the constraints and preferences that the end user introduces is a critical research thread towards their development.<br><br>In this UCS, we consider the case of an aggregator that is responsible for coordinating the energy prosumption of end users within its portfolio, while facing costs and constraints on the aggregate energy prosumption. The aggregator takes on the task of satisfying the system constraints in the most efficient way (i.e. its objective is to maximize social welfare).<br><br>**Detailed Description:**<br>An aggregator is responsible for operating a market, where the market participants are the small scale FlexAssets. Through a market procedure, the aggregator aims at discovering a welfare-maximizing allocation of available resources (i.e. energy). In this UCS, we consider two sub-scenarios:<br>Sub-scenario 1: There is a constraint on the aggregated energy prosumption. This case refers to a number of situations in modern smart grids, including but not limited to:<br>• Enhancing the self-sufficiency of the community (cf. RESCOOP concept) |

| | |
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| | • Keeping islanded microgrids/energy islands economically viable<br>• Mitigate suppliers'/retailers' exercise of market power by taking coordinated action to reduce the demand in the face of such situations[33]<br>• Meeting the physical network's constraints by implementing the DSO's orders<br>• Enhancing the community's participation in flexibility markets<br>• Enhancing RES penetration by adapting demand to the intermittent generation.<br>• Meet the aggregator's market schedule (i.e. the quantity cleared in the wholesale market).<br>The constraint can be expressed either as an upper limit on aggregated prosumption or, equivalently, as a requested amount of aggregated prosumption reduction, depending on the market architecture. From a technical point of view, satisfying a system-wide constraint can be a challenge. In particular, constraint satisfaction typically depends on the aggregated prosumption profile of end users. This couples the system's decision variables that are controlled by different end users, which brings a fair amount of complications in the underlying n-person game. Another consideration refers to whether the constraint is known ahead of time (e.g. day-ahead) or it is imposed online, in a real-time fashion.<br><br>Sub-scenario 2: The aggregator's cost is defined over the aggregated energy presumption. This case refers to situations where the aggregated prosumption is not necessarily bounded by a constraint, but it is increasingly expensive to serve it. In other words, the system cost is an increasing convex function of the aggregated prosumption. This case models various situations in smart grids, including, but not limited to:<br>• Microgrids, where the aggregator is also responsible for dispatching local generators. The less expensive generators are dispatched first and as the load increases, more expensive generators are committed and more expensive offers are dispatched.<br>• The aggregator is a price-maker in the wholesale market. Thus, similarly to the first bullet, the aggregated prosumption of the aggregator affects the marginal generator cost.<br>• Meeting local RES generation. More specifically, local consumption is desired to be as close as possible to local RES production.<br>**Current Status:**<br>- Aggregators do not incorporate system constraints in their decisions and the operator takes proactive or corrective measures to ensure reliable operation.<br>- Loads/batteries do not bid for their prosumption and do not face dynamic prices. Thus, load/storage representatives face imbalance payment risks on which they do not have control over.<br>- Loads/batteries typically do not actively participate in the system optimization.<br><br>**Innovation:** |

[33] This can be achieved by developing novel mathematical models based on mechanism design theory.

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| | - FLEXGRID proposes dynamic mechanisms that balance supply and demand on the basis of value, while including distributed resources in the process of system reliability procurement.<br>- Auction-theoretic mechanisms for resource allocation achieve a number of desired requirements (efficiency, incentive compatibility, individual rationality, budget-balance)<br>- By leveraging the decentralized nature of auction-theoretic mechanisms, computational time is dramatically reduced (compared to centralized optimization), thus constituting the framework applicable to short timeframes.<br><br>**Challenges:**<br>- In order for the implementation of these markets, installation of infrastructure is required (smart meters, communication systems on top of the electricity network and more).<br>- Intelligent controllers that manage the response of the distributed flexibility assets must be available and cost-effective as a commercial product (e.g. smart appliances)<br>- Decentralized optimization modelling should ensure efficient outcomes for all involved stakeholders.<br>- Regulation should permit free price determination on a real-time base at the retail level.<br>- Business models for aggregators must be sustainable in order to incentivize the undertaking of such a role. |
| **Actors involved** | • Aggregator<br>• End energy prosumers<br>• FlexUnits |
| **Triggering Event** | The aggregator needs to acquire some service from the distributed flexibility assets (DFAs). |
| **Pre-condition** | - Aggregator (and all its prosumers and DFAs) are registered in the FLEXGRID ATP (S/W platform).<br>- There is a FlexContract that defines the services and terms between the end prosumer and the Aggregator<br>- Regulatory framework allows for the above-mentioned FlexContract and service.<br>- There is a reliable communication network infrastructure between the Aggregator and the end prosumers. |
| **FLEXGRID services involved** | - Automated flexibility aggregation management services<br>- Advanced retail flexibility market services<br>- Automated composition of B2C real-time flexibility markets |
| **Post-condition** | - Distributed flexibility assets (DFAs) offer services to the system, via a market architecture, while optimizing local objectives.<br>- Aggregator dynamically and optimally operates a market to draw services from DFAs. |

| **Basic Path** | | | | | |
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| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |

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|---|---|---|---|---|---|
| 1 | System condition is communicated to the aggregator | The aggregator is informed about relevant system conditions | Wholesale market prices, RES output, system constraints | Forecasting agent or DSO | Aggregator |
| 2 | Retail Flexibility Market initialization | Aggregator initializes the market procedure | Gate opening | Aggregator | End prosumers |
| 3 | Iterative Market Procedure | Aggregator and prosumers exchange messages | Messages include (dynamic) retail prices and prosumption schedules | Aggregator/ prosumer | Prosumer/ Aggregator |
| 4 | Convergence [34] | The market mechanism reaches equilibrium | Final schedules and prices per prosumer | Aggregator | End prosumers |
| 5 | Schedule per FlexUnit | Prosumer's HEMS decides about local energy management schedule | Final schedules and prices per FlexUnit | End prosumer (HEMS) | FlexUnits |
| 6 | Operation phase | FlexUnits execute the schedule and send feedback to aggregator | Setpoints followed during operation phase | FlexUnits | Aggregator |
| 7 | M&V process and market settlement | Aggregator verifies the results and settles the market | Reimbursements/payments | Aggregator | FlexUnits |
| **Realization** | | | | | |
| **Main responsible partners** | **ICCS, UCY** | | | | |
| **Contributing partners** | **BADENOVA, NODES, ETRA** | | | | |
| **Priority** | **High** | | | | |

### 5.4.3 ESP maximizes its profits by dynamically orchestrating distributed FlexAssets from its end users in order to optimally participate in several energy markets

| **HLUC04_UCS03** | **ESP maximizes its profits by dynamically orchestrating distributed FlexAssets from its end users in order to optimally participate in several energy markets[35]** |
|---|---|
| **Description** | **Scope/purpose:**<br>ESPs may act as flexibility asset (FlexAsset) aggregators and interact with end users in order to trade their dynamically aggregated capability to shift or curtail their energy prosumption. At the same time, ESPs may participate in various energy markets. This UCS envisages the development and the evaluation of end |

[34] Algorithm's convergence is not an easy task. If the algorithm does not converge, then the model should be better designed.

[35] This UCS has several similarities with UCS 2.3 described in subsection 5.2.3 above. The main difference is that this UCS considers a 3-level (hierarchical) problem formulation in which advanced pricing schemes are applied for the interaction between the ESP/aggregator and the end users (instead of direct FlexAssets' control assumed in UCS 2.3).

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| | user compensation mechanisms (dynamic retail flexibility pricing and/or action algorithms) able to cope up with this dynamic interaction. The major requirements from these mechanisms that will constitute the KPI of their success are: i) the efficient exploitation of the profit opportunities that the behaviour of these markets sets, ii) the level of satisfaction of the end users (i.e. end users' welfare) from the compensation mechanisms, iii) the profits of the ESP.<br><br>In this UCS, we consider the case of an ESP that is responsible for aggregating/coordinating the profiles of the FlexAssets within its portfolio, in order to offer services to the wholesale market or to a specific party (e.g. the DSO). The main difference with UCS 2.3 is that here we assume an ad-hoc B2C flexibility market like the one described in UCS 4.2. On the contrary, in UCS 2.3, we assume that the ESP can directly control all the FlexUnits that belong to its portfolio.<br><br>**Detailed Description:**<br>This UCS opens the way for the small distributed flexibility assets (DFAs) to offer services to the electricity system. Direct participation of the prosumers in the wholesale market is not a viable option since they do not have the risk tolerance that the volatile prices bear and also the dispatch problem becomes particularly complex. An alternative is for the prosumers to participate via ESPs and/or offer specific services upon request. Such an example is a Demand Response (DR) event, where the operator (e.g., the DSO) asks for a reduction of the prosumers' net aggregated consumption and offers monetary incentives to the ESP towards its realization.<br><br>An ESP is responsible for operating a market, where the market participants are the small-scale FlexAssets (or else DFAs). The signal for the service is envisioned as a function that maps different net load profiles to different rewards.<br>Upon receiving the signal that defines the requested service (e.g. modification of the aggregated net load profile) and the reward offered, the ESP initiates an ad-hoc flexibility market. Via a market mechanism, the aggregated net load profile of the ESP's portfolio is shaped such that the requested service is fulfilled. In order to achieve the profile modification, the ESP shares part of the reward with the prosumers as an incentive.<br><br>Through the ESP's market procedure, it is decided which prosumers are going to offer the requested service to the asking party. Thus, efficient service provision from small-scale DFAs to the system is achieved via a hierarchical framework.<br><br>**Current Status:**<br>- Small FlexAssets cannot offer services to the large-scale electricity system<br>- System operators have to acquire flexibility services only from conventional large generators<br>- RES generation that cannot be consumed locally is spilled and thus wasted.<br><br>**Innovation:**<br>- FLEXGRID proposes dynamic mechanisms that balance supply and demand on the basis of value, while including distributed resources in the process of |

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| | system reliability procurement.<br>- Efficient, reliable and scalable framework for drawing services from small-scale FlexAssets (DFAs).<br>- Auction-theoretic mechanisms for resource allocation achieve a number of desired requirements (efficiency, incentive compatibility, individual rationality, budget-balance)<br>- By leveraging the decentralized nature of auction-theoretic mechanisms, computational time is dramatically reduced (compared to centralized optimization), thus constituting the framework applicable to short timeframes (i.e. near-real-time market contexts).<br><br>**Challenges:**<br>- In order for the implementation of these markets, installation of infrastructure is required (smart meters, communication systems on top of the electricity network and more).<br>- Intelligent controllers that manage the response of the distributed flexibility assets must be available and cost-effective as a commercial product (e.g. smart appliances).<br>- Decentralized optimization modelling should ensure efficient outcomes for all involved stakeholders.<br>- Regulation should consider and permit the ESP role as a service provision entity.<br>- Business models for ESPs must be sustainable in order to incentivize the undertaking of such a role. |
| **Actors involved** | • ESP<br>• End energy prosumers<br>• MO<br>• FlexUnits |
| **Triggering Event** | A BRP or a DSO requests a specific service from an ESP and offers a reward structure to accommodate its realization. |
| **Pre-condition** | - The ESP is registered in the existing energy market platforms.<br>- ESP operates a distribution flexibility market in cooperation with the local DSO (via the use of FLEXGRID ATP).<br>- ESP (and all its prosumers and DFAs) are registered in the FLEXGRID ATP (S/W platform).<br>- There is a FlexContract that defines the services and terms between the end prosumer and the ESP.<br>- The market architecture defines the roles and communication protocols of the actors involved. |
| **FLEXGRID services involved** | - Automated flexibility aggregation management services<br>- Advanced retail flexibility market services<br>- Automated composition of B2C real-time flexibility markets |
| **Post-condition** | - DFAs offer services to the system, via a market architecture, while optimizing local objectives.<br>- ESP dynamically and optimally operates a market to draw services from DFAs and then sell novel services to various energy markets. |
| **Basic Path** | |

| Step No. | Event | Description of process/ Activity | Info. Exchanged | Actor producing the info | Actor receiving the info |
|---|---|---|---|---|---|
| 1 | Service Request | BRP or DSO sends a signal to the ESP | The requested service and the reward structure are defined | BRP/DSO | ESP |
| 2 | Ad-hoc Flexibility Market initialization | ESP monitors the current state of each FlexAsset and regards it as its baseline (initial condition) | ESP receives schedule and prosumption state from each FlexUnit | FlexUnit | ESP |
| 3 | Iterative Market Procedure | A market clearing algorithm matches the requested service with the flexibility capabilities of the FlexAssets | Rewards / net-load profiles | FlexUnits/ ESP | ESP / FlexUnits |
| 4 | Convergence [36] | The market mechanism reaches equilibrium | Final schedules and prices per prosumer | ESP | End prosumers |
| 5 | Schedule per FlexUnit | Prosumer's HEMS decides about local energy management schedule | Final schedules and prices per FlexUnit | End prosumer (HEMS) | FlexUnits |
| 6 | Operation phase | FlexUnits execute the schedule and send feedback to ESP | Setpoints followed during operation phase | FlexUnits | ESP |
| 7 | Service provision | ESP offers the acquired service to the actor who asked for it | Aggregated net load schedule | ESP | BRP/DSO |
| 8 | M&V process and market settlement | Market actor verifies the results and settles the market | Reimbursements/payments | BRP/DSO | ESP (all FlexUnits) |
| **Realization** | | | | | |
| **Main responsible partners** | | **ICCS** | | | |
| **Contributing partners** | | **UCY, BADEDOVA, NODES, NPC, ETRA** | | | |
| **Priority** | | **Medium/low** | | | |

[36] Algorithm's convergence is not a straight-forward task. If the algorithm does not converge, then the model should be better designed.

### 5.4.4 ESP exploits FLEXGRID's advanced forecasting services to predict market prices and FlexAssets' state and curves in the future

| HLUC04_UCS04 | ESP exploits FLEXGRID's advanced forecasting services to predict market prices and FlexAssets' state and curves in the future |
|---|---|
| **Description** | **Scope/purpose:**<br>This scenario concerns forecasting services' provisioning for ESP and aggregator actors. These services will include forecasting the ESP's/aggregator's generation by aggregating its end-users' generation (both day ahead and intra-day – predominantly from PV systems), and also considering the other available assets such as battery storage. Market price forecasting will also be considered in order to facilitate the optimal FlexOffer process towards efficient ESP's/aggregator's participation in all types of distribution level flexibility markets and wholesale/balancing markets (i.e. transmission system level). It should noted that available wind forecasting data and models from the literature will be considered and the main research efforts will be placed on PV forecasting.<br><br>**Detailed description:**<br>FLEXGRID project will develop mathematical models and forecast tools that will facilitate ESP to predict market prices in order to be able to efficiently participate in various distribution-level flexibility markets (DLFMs) as well as existing wholesale markets (i.e. day-ahead, intra-day, balancing, reserve markets operated at the transmission level). Moreover, advanced forecasting tools will help integrate more RES from producers as they will be able to increase their profits. FLEXGRID's forecasting engine will reside in the Automated Flexibility Aggregation Toolkit (AFAT) and FlexSupplier's Toolkit (FST) to be used by both aggregator and ESP market stakeholders. Following up the modular-by-design FLEXGRID architecture, the various forecasting algorithms will be run in the forecasting engine and well designed web APIs will provide: i) the input parameters and data for the running of the algorithms, and ii) the output parameters (algorithmic results), which will be sent to FLEXGRID ATP and then visualized by the ESP/aggregator user.<br><br>In addition, these services will exploit historical data from various markets and then obtain market price forecasts and market forecast accuracy levels (MFAL). Still, through Advanced Forecasting Services the operators will be able to manage their assets flexibly. Simultaneously with these models that will be created they will provide accuracy for the predictions in this service. ESP utilises historical data and published market data to plan the day ahead portfolio by employing simple expert systems that can build an improvement cycle thus minimizing deviations and hence reducing penalties. The correction cycle includes full load and generation profiles that reflect more accurately the required load and provided generation portfolio. RESPs utilise historical and market data as well as energy forecasting based on artificial neural networks in order to make optimum decisions. |

| | |
|---|---|
| | **Current status:**<br>- Today's forecasting services can't help ESP predict market prices so they can efficiently participate in them. This problem will be continuously becoming bigger in the future mainly due to expected high RES penetration contexts.<br>- No complete solution currently exists that can utilise accurate energy forecasting with market and load forecasting that will provide significant input for the optimisation of aggregation and dispatch of RES.<br><br>**Innovation:**<br>- Forecasting accuracy enhancement in order to mitigate the effects of forecast uncertainty introduced by high RES penetration.<br>- S/W tools needed to develop services that will help ESP to compile RES with high levels of accuracy.<br>- Advanced market forecasting algorithm able to exploit historical data from various markets.<br>- A complete solution that takes into consideration market, energy as well as load forecasting that will allow optimum decisions to be made.<br><br>**Challenges:**<br>- A well-structured database for useful data profiles for both generation and load should be made available with high security on stored data meeting all GDPR requirements.<br>- A well-structure database for market data will be made available for managing all published market data.<br>- Regulation should permit free price determination on a real-time basis at the retail level. Business models for aggregators must be sustainable in order to incentivize the undertaking of such a role. |
| **Actors involved** | ● ESP/RESP/aggregator<br>● DSO<br>● MO/FMO<br>● End prosumers<br>● FlexUnits |
| **Triggering Event** | - The ESP wants to use forecasting services to increase its profit by making informed market decisions and minimizing errors and deviation from declared position.<br>- The RESP wants to receive accurate energy and market forecasts that will allow him to plan accurately the next steps in an optimal way (both day-ahead and intra-day). |
| **Pre-condition** | - The ESP exploits its entire HetFlex portfolio (DSM, RES, Storage)<br>- The ESP uses forecasting tools to be able to provide better services to maximize profit<br>- If the buyer is interested in the market price, then the ESP sells his services in the market |

| | | | | | |
|---|---|---|---|---|---|
| **FLEXGRID services involved** | - Forecasters of RES generation, consumption and battery state of charge<br>- Market behaviour through the exploitation of Artificial Intelligence technologies and scalable forecasting.<br>- Advanced market forecasting algorithms able to exploit historical data from various markets.<br>- Forecasting of accuracy levels | | | | |
| **Post-condition** | Forecasting tools enable the ESP to offer better services by increasing its profits. | | | | |
| **Basic Path** | | | | | |
| **Step No.** | **Event** | **Description of process/ Activity** | **Info. exchanged** | **Actor producing the info** | **Actor receiving the info** |
| 1 | ESP optimally manages flexibility resources (RES, loads, storage, conventional sources) | ESP through forecasting tools will be able to optimally optimize its flexibility resources. Energy as well as load forecasting will provide the necessary information in order to have all the important information about the available flexibility. | Weather and load data will be exchanged and the output will be energy and load forecasts | WFIP ESP/RESP | ESP/RESP |
| 2 | The ESP uses market forecasting tools to forecast the day ahead market | ESPs will be able to predict the market price one day before trading. In this way, they will be able to organize their optimal bidding strategies. | Information about market prices | MO/FMO | ESP/RESP |
| 3 | ESPs based on the forecast results will submit their bids before the deadline | ESPs will submit their bids based on correct and accurate forecasting to maximize profits. This step will combine energy as well as load and market forecasting | Information about ESPs' bids | ESP/RESP | FMO/MO |
| 4 | The FMO/MO will collect the bids and set the market clearance price | Bids will be collected by the FMO who will calculate the market clearance price. | ESP bids and information about market clearance price | FMO/MO | ESP/RESP |
| 5 | The ESPs will be able to sell their optimum services in the Flexibility | The forecast engine will enable ESPs to optimize the services they can offer | ESP's services | FMO/MO | ESP/RESP |

| | | | | | |
|---|---|---|---|---|---|
| | Market | | | | |
| **Realization** | | | | | |
| **Main responsible partners** | | **UCY** | | | |
| **Contributing partners** | | **ICCS, UNIZG, NPC, BADENOVA, NODES** | | | |
| **Priority** | | **High** | | | |

# 6. User and system requirements' analysis

This section analyses the major functional requirements based on the aforementioned high-level use cases (HLUC) and use case scenarios (UCS) **from both users' and system's perspectives**. According to these requirements, the technical objectives and specifications of FLEXGRID will be derived and they will drive the technologies that are able to fulfil them. All these will be the foundation towards the development of the architecture of FLEXGRID that will be presented in D2.2 (Month 6).

## 6.1. Definition of FLEXGRID ATP User Requirements

There are various types of users that can use the FLEXGRID S/W platform (i.e. parts of it or the platform as a whole) according to the side-specific flexibility market structure. FLEXGRID S/W platform users are therefore categorized into core users and supplementary users. Core users are considered market participants that actively participate in the flexibility market and ensure the grid stability and market liquidity through their interaction and communication.

**Core users** are:

- Flexibility Market Operator (e.g. NODES)
- TSO (Flexibility demand side)
- DSO (Flexibility demand side)
- Flexibility Supplier/ESP company (Flexibility supply side)

**Supplementary users** are considered market participants that due to their function either facilitate the provision of flexibility of various assets, perform balance management actions or research activities like:

- Retailer company
- Aggregator company
- Balance Responsible Parties
- Market Operator (e.g. Nord Pool user)
- Other external users (e.g. 3rd party entities, researchers, policy makers, regulator, etc.)

Below, there is a concise description of the requirements per user category:

<u>**Core FLEXGRID ATP users:**</u>

| Flexibility Market Operator (FMO) | |
|---|---|
| **User Requirement description** | The Flexibility Market Operator (FMO) overviews all market activity across DSO regions. The FMO thus has a central role that requires all rights to ensure the correct functioning of the S/W platform and associated processes. |

| | |
|---|---|
| | The FMO must have the right to register/accept new platform users and to assign them their role according to their function/business activities on the market and within their company (e.g. assign administrator rights).<br><br>The FMO must be able to act on behalf of other participants to support their daily operational business activities such as updating orders and/or technical problem solving.<br><br>The FMO will manage the validation and settlement process in the market place, monitor the correct and prompt functioning of automated processes and correct delivery of the flexibility service through meter data and may re-run processes to include new information from data updates .<br><br>The FMO must be able to invoice the customers (e.g. DSO/FSPs) through the validation/settlement process once the correct delivery of flexibility for regulation purposes has been confirmed.<br><br>The FMO user should be able to execute advanced market clearing algorithms through the use of the Distribution Flexibility Market Clearing Toolkit (DFMCT) and visualize the results (nodal prices) in the FLEXGRID ATP frontend. |

| **Distribution System Operator (DSO)** | |
|---|---|
| **User Requirement description** | The Distribution System Operator (DSO) user should be able to register congested regions (grid locations) in the market platform by means of displaying a polygon of the geographical area, where relevant flexible resources can be identified in a congested area.<br><br>The DSO user should be able to approve FlexAssets as belonging to its grid and under a particular Grid Location (GL).<br><br>The DSO user should be able to view baselines, which are submitted and updated by FlexSuppliers/ESPs.<br><br>The DSO user should be able to enter Buy orders (i.e. FlexRequests) to either:<br>- Directly match a FlexOffer (aggressor order)<br>- Signal a buy interest by a passive order (initiator order)<br>This can be done similarly to the shortFlex concept (as for instance designed in NODES) with Pay-as-Bid as clearing price.<br><br>The DSO should be able to register and manage long term availability agreements, implemented in the platform to automate generation of |

| | |
|---|---|
| | Shortflex offers that can be cleared during the Intra-day phase.<br><br>The DSO will also be charged through the FMO validation/settlement process upon confirmation that the flexibility regulation service has been conducted correctly.<br><br>Depending on the markets/country, the DSO-TSO interaction must be clearly depicted on the platform to determine priorities of the use of flexibilities in case of congestion management and resulting congestions in connected DSO grids.<br><br>Finally, the DSO user should be able to use FLEXGRID services like the ones extensively described in UCS 5.3.1, 5.3.2 and 5.3.4 via the use of the Distribution Flexibility Market Clearing Toolkit (DFMCT). |

| **Transmission System Operator (TSO)** | |
|---|---|
| **User Requirement description** | The Transmission System Operator (TSO) user should be able to login to the system and view/manage flexibility offers aggregated from the connected DSOs.<br><br>TSO should have access to load/view forecasts/baselines entered in the DSO locations.<br><br>The Market platform should support 2 integration models (active/passive role) for TSOs.<br><br>- TSOs enters buy orders (i.e. FlexRequests) directly on the aggregated market (for congestion management)<br>- FMO aggregates FlexOffers and forwards them for the purpose of mFRR.<br><br>The TSO should be informed by ATP by « traffic light » models, which flexibility assets cannot be aggregated to TSO level.<br><br>FlexRequets by TSOs should be marked to stick out in case of congestion managment.<br><br>Depending on the markets/country, the DSO-TSO interaction must be clearly depicted on the platform to determine priorities of the use of flexibilities in case of congestion management and resulting congestion in connected DSO grids. |

| **Energy Service Provider - ESP (FlexSupplier) company** | |
|---|---|
| **User** | The ESP can be an industrial company, an individual unit or incorporate the |

| | |
|---|---|
| **Requirement description** | functions of an independent aggregator or an integrated aggregator with balance responsibility. If the ESP is an industrial or individual unit, an aggregator (independent/integrated) must be interconnected prior to Login to the FLEXGRID ATP.<br>ESP incorporating the role of an aggregator must be able to register assets in every DSO region on the platform.<br><br>After approval by the FMO, the ESPs should be able to group them in portfolios to offer aggregated flexibility. This gives the ESP the option to decide which asset(s) in the portfolio to dispatch when necessary; the validation/settlement will be performed on portfolio level.<br><br>As counterparty of the DSO, the ESP must be able to sell flexibility:<br>1. to directly match a FlexRequest from a DSO (aggressor order)<br>2. to signal a sell interest by a passive order (initiator order)<br>This can be done similar to the ShortFlex concept (as designed in NODES) with a pay-as-bid matching logic.<br><br>The ESP may decide if offers should be made available also for TSO aggregation; or only at a local level with the DSO.<br><br>The ESP will also be paid through the FMO validation/settlement process upon confirmation that the flexibility regulation service has been conducted correctly.<br><br>ESP users should be able to use FLEXGRID services like the ones extensively described in UCS 5.2.1 - 5.2.4 via the use of the FlexSupplier's Toolkit (FST). In more detail, the ESP user should be able to login in the FLEXGRID ATP and through a single sign-on process to be able to run several algorithms inside the FST in order to minimize its CAPEX and OPEX. |

**Supplementary FLEXGRID ATP users:**

| **Retailer company** | |
|---|---|
| **User Requirement description** | The Retailer user should be able to login the FLEXGRID ATP and through a single sign-on process to be redirected in the Automated Flexibility Aggregation Toolkit (AFAT).<br>In AFAT, the Retailer user should be able to run retail pricing algorithms, to achieve the optimal retail flexibility prices/tariffs to be given to each one of the FlexAsset owners. This process is extensively described in UCS 4.2 (cf. section 5.4.2).<br>In case that the retailer does not incorporate the function of an aggregator and/or BRP, the submission of FlexOffers has to be done through an |

| | |
|---|---|
| | aggregator company and/or BRP depending on their roles in the market. |

| **Independent Aggregator company** | |
|---|---|
| **User Requirement description** | An independent aggregator is a flexibility service provider without balance responsibility. A restriction in the ATP will be that each offer only contains flexibility from end customers that have the same BRP.<br><br>Moreover, the aggregator user should be able to operate an ad-hoc B2C flexibility market, in which the end users belonging to the aggregator's portfolio may compete in providing their flexibility to the aggregator. This UCS is extensively described in UCS 4.2 and 4.3.<br><br>The aggregator user should be able to login the Automated Flexibility Aggregation Toolkit (AFAT) and run an efficient automated flexibility aggregation algorithm. The results will be posted back and shown in the FLEXGRID ATP frontend. |

| **Balance Responsible Party (BRP)** | |
|---|---|
| **User Requirement description** | The BRP user should be able to login the FLEXGRID ATP to actively balance the supply and demand for its portfolio. |

| **Market Operator** | |
|---|---|
| **User Requirement description** | In the case that the Market Operator (MO, e.g. Nord Pool) fulfills the role of a BRP, the MO should have a login to submit FlexOffers. If the MO does not have BRP responsibilities, no login to the FLEXGRID ATP is required for operational purposes. |

| **Other external users** | |
|---|---|
| **User Requirement description** | FLEXGRID platform will be able to offer various open APIs for data access (i.e. read-only access) from third parties (e.g. EC, policy makers, companies, etc.) based on the Open Data approach. Data privacy and anonymity will be preserved according to EU Data Privacy directives and Ethical Laws. As a result, various types of external users should be able to have access to the Energy Information Distribution as a Service (EIDaaS) offered by FLEXGRID S/W platform. The external user should also be able to use FLEXGRID toolkits in order to set his/her own simulation scenario and run a specific FLEXGRID research algorithm. Then, s/he will be able to visualize the performance evaluation results and possibly extract them in a single file in case of further need for editing. In other words, users will be able to set their own input parameters and experiment with the results. An individual researcher should be able to exploit FLEXGRID S/W toolkits as an e-infrastructure for algorithm experimentation for academic purposes. |

## 6.2 Definition of FLEXGRID System Requirements

In this subsection, the functional requirements per S/W component, subsystem and system as a whole are defined by using a specific template. In more detail, the requirements for: ATP, AFAT (i.e. WP3 toolkit), FST (i.e. WP4 toolkit) and DFMCT (i.e. WP5 toolkit) as well as requirements for peripheral functionalities of FLEXGRID S/W platform are presented. In addition, the requirements for the interactions among the aforementioned subsystems are depicted. The next step (after the requirements analysis) will be the definition of the technical specifications in D2.2 (Month 6).

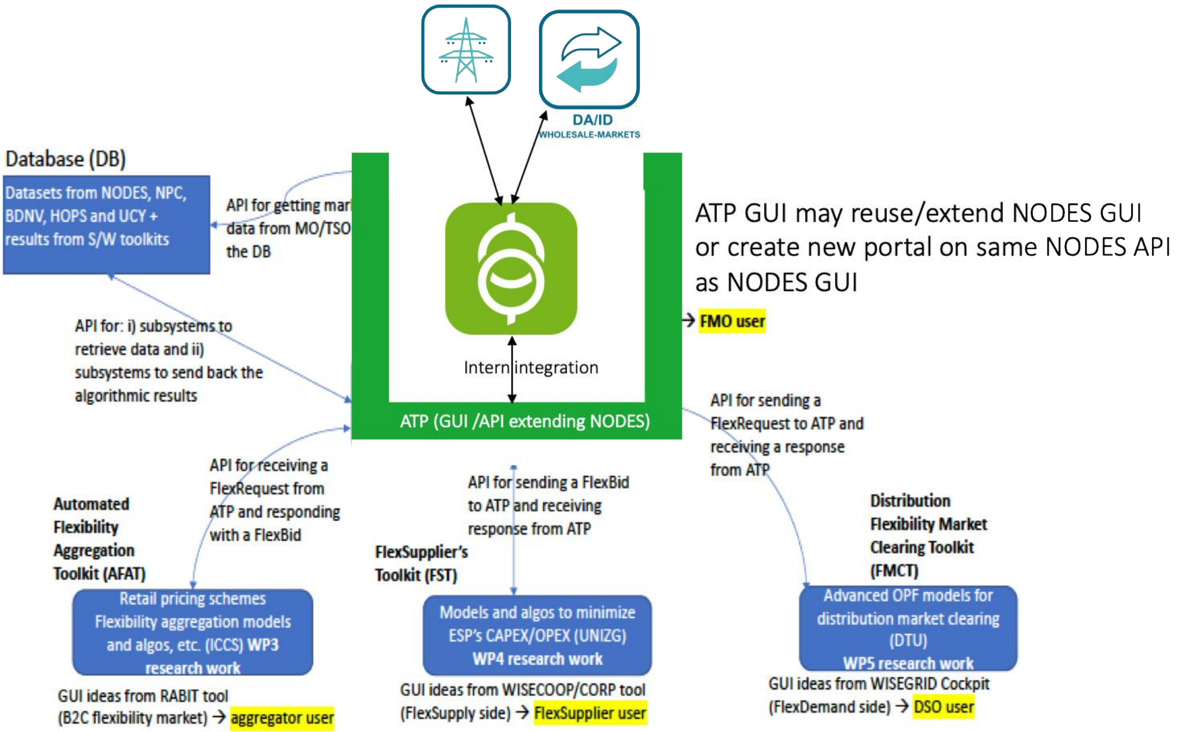


**Figure 5: Draft FLEXGRID S/W architecture design (Month 3)**

As shown in the figure above, a draft version of the FLEXGRID S/W architecture design has been agreed at a consortium level and will be finalized in Month 6 via the delivery of D2.2 (cf. MS 3). At the center of the architecture lies the FLEXGRID Automated Trading Platform (ATP), the "frontend" system, in which the various user types will login and be navigated through various Graphical User Interfaces (GUIs). There are several web APIs for the integration of the core ATP with the various subsystems. In this way, a modular-by-design architecture is realized as a strategic consortium decision to support guidance during the S/W implementation phase (i.e. WP6 work), and during the exploitation phase after the end of the project's lifetime. The S/W development of FLEXGRID ATP will be done by ETRA, who will also lead the S/W integration work with the different subsystems.

There are three major subsystems in the FLEXGRID S/W architecture, namely:

1) Automated Flexibility Aggregation Toolkit (AFAT):
2) FlexSupplier's Toolkit (FST)
3) Distribution Flexibility Market Clearing Toolkit (DFMCT)

AFAT is the S/W tool that integrates the WP3 research algorithms and will be implemented by ICCS. AFAT will receive a FlexRequest from the ATP, will then run a retail flexibility pricing or flexibility aggregation algorithm and will respond with a FlexOffer to the ATP. The retailer and independent aggregator user will use this toolkit.

FST is the S/W tool that integrates the various WP4 research algorithms and will be implemented by UNIZG-FER. FST will run a specific algorithm to minimize ESP's OPEX and will then send an optimal FlexOffer to the ATP. Based on the market clearing results and the response sent by the ATP, the FST will be able to re-calculate a better FlexOffer or schedule its FlexAssets in the optimal way. The ESP user will use this toolkit and two main algorithms are expected to be integrated, namely: i) optimal scheduling algorithm to minimize ESP's OPEX (cf. UCS 2.1), and ii) optimal investment algorithm to minimize ESP's CAPEX (cf. UCS 2.2).

DFMCT is the S/W tool that integrates the WP5 research algorithms and will be implemented by DTU. DFMCT will run advanced market clearing algorithms (e.g. AC-OPF for distribution networks). It will be used by the DSO user in order to calculate the nodal prices and thus send a FlexRequest to the ATP. Moreover, it will be used by the FMO user in order to automatically match FlexSupply and FlexDemand at the distribution network level.

All the algorithmic results will be stored in the central database (DB) together will all real-life/realistic datasets from NODES, NPC, BDNV, HOPS and UCY business partners. These datasets will be used for validation of the research algorithms. Finally, FLEXGRID ATP will be able to automatically generate and redirect FlexOffers to existing TSO markets. This process will be realized through a web API as shown in the figure above.

### 6.2.1. Requirements for the core FLEXGRID Automated Trading Platform (ATP)

It should be noted that the S/W development of FLEXGRID ATP will be based on already existing expertise and know-how provided by NODES. This will ensure that the proposed architecture design will meet the business requirements of the various market stakeholders, who will form the envisioned FLEXGRID business ecosystem.

The ATP platform should provide a real time and scalable clearing platform for buyers and sellers of flexibility.  There are different domains in this platform (currently supported by NODES as the inner platform). The figure below depicts the NODES model and architecture that FLEXGRID ATP will follow. The separation of domains supports the difference in scalability and other requirements.

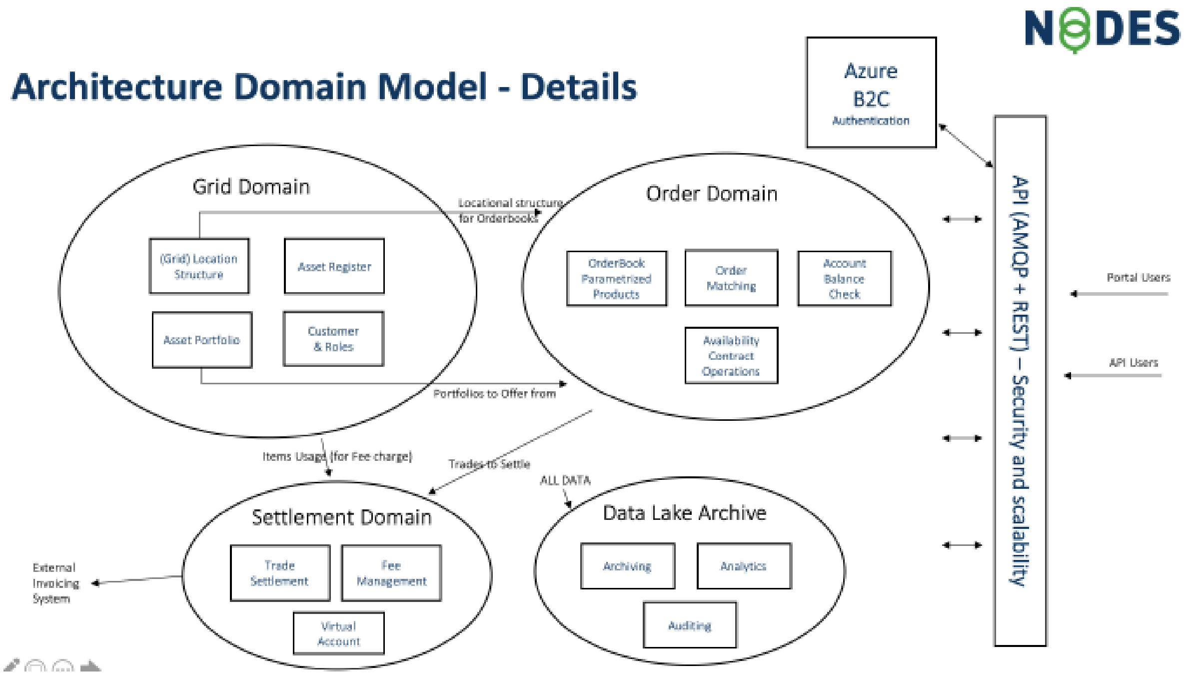


**Figure 6: NODES model and architecture that FLEXGRID ATP will follow**

## The Grid Domain

Core data model and structure for DSOs and ESPs, wherein the DSOs publish Grid Locations and connections between them, and ESPs publish FlexAssets and portfolios, connected to the Grid Locations. Technologically, this domain does not have real time requirements but with scaling capabilities in Kubernetes/Cloud cluster.

## The Order Domain

The actual clearing platform, built for horizontal scaling with microservices, Kafka queuing and low latency data store inside Kubernetes cluster.

## The Settlement Domain

Independent domain for supporting various Settlement providers in the different countries, where NODES operates.

Whilst all domains have their own internal non-functional requirements that may vary, they can all be extended from the API level by adding additional functional requirements outside the core NODES platform. The FLEXGRID ATP will extend the model by integrating and reusing the storage and real time capabilities with a wrapper outside it. The external ATP will contain additional elements and store these in the central Database (cf. subsection 6.2.2) that also collects all data from internal and external sources.

| **Title** | | |
|---|---|---|
| **FLEXGRID ATP should allow the FMO to store additional data elements to support WP4 and WP5 modules.** | | |
| **Code id** | **Component** | **Priority** |
| ATP-RQT_01 | ATP | Essential |
| **Description** | | |

| |
|---|
| Define a Data Model that is based on the NODES data model, with additional objects extending the underlying model in NODES. For example: given the core FlexAsset properties in NODES, the ATP may create additional properties in the ATP database, with a foreign reference to the asset ID as it is stored in NODES; so when receiving the registration of a FlexAsset, first store the core elements in NODES, and next create the extension objects in the ATP with a reference to the NODES object. The core clearing model in NODES would run on the main FlexAsset object, whilst additional clearing algorithms for auctions (or other purpose) may take the additional properties into account. |
| **Notes** |
| Source code for the extensions will be available in public source code repository. |

| **Title** | | |
|---|---|---|
| **FLEXGRID ATP may support flexibility algorithms in other time frames than Intraday/Continuous market. e.g. Day-ahead flexibility auction** | | |
| **Code id** | **Component** | **Priority** |
| ATP-RQT_02 | ATP | Essential |
| **Description** | | |
| By referencing the data model in NODES, additional services could implement auction clearing algorithms, and evaluate when the liquidity is sufficient for this model vs the continuous trading model currently supplied by NODES. | | |
| **Notes** | | |
| Source code will be available in public source code repository. | | |

| **Title** | | |
|---|---|---|
| **FLEXGRID ATP should support several types of users (e.g. FMO, DSO, TSO, ESP, retailer, etc.)** | | |
| **Code id** | **Component** | **Priority** |
| ATP-RQT_03 | ATP | Essential |
| **Description** | | |
| Each type of user should be able to login the FLEXGRID ATP and through a single sign-on process to be able to navigate in all other subsystems as well as to visualize the algorithms results in the respective ATP GUI. | | |
| **Notes** | | |
| Each FLEXGRID ATP user will visualize different sets of datasets and inform in the platform's frontend. | | |

| **Title** | | |
|---|---|---|
| **FLEXGRID ATP should support interaction with other subsystems through well-designed web APIs** | | |
| **Code id** | **Component** | **Priority** |
| ATP-RQT_04 | ATP | Essential |
| **Description** | | |
| See more details about web APIs in subsection 6.2.6 below. | | |
| **Notes** | | |
| | | |

### 6.2.2. Requirements for the central FLEXGRID database

There will be a central database for FLEXGRID system, where all real-life datasets provided mainly by industrial partners will be gathered. These datasets will be used for FLEXGRID's research purposes (i.e. the evaluation and validation of the various research models and algorithms that are developed within WPs 3-5 context). This database will also include the most important results based on the execution of the various research algorithms. Finally, the database should also communicate via well-designed web Application Programming Interfaces (APIs) with the 3 main S/W toolkits (i.e. AFAT, FST and DFMCT) as well as with the core FLEXGRID ATP.

| Title | | |
|---|---|---|
| **FLEXGRID database should include real-life/realistic datasets from existing energy markets' operation** | | |
| **Code id** | **Component** | **Priority** |
| DB-RQT_01 | Database | Essential |
| **Description** | | |
| Real-life (or else realistic) data from day-ahead, intra-day, balancing and reserve markets' operation should be stored and be easily accessed and retrieved by FLEXGRID's research toolkits. Datasets should include historical bids (i.e. quantity and price curves) and market prices in a well-structured format. | | |
| **Notes** | | |
| The exact structured format will be agreed between research partners and NPC during the first months of WPs 3-5 duration, when the research algorithms' input/output requirements will be clearly defined. | | |

| Title | | |
|---|---|---|
| **FLEXGRID database should include real-life/realistic datasets from energy flexibility markets' operation** | | |
| **Code id** | **Component** | **Priority** |
| DB-RQT_02 | Database | Essential |
| **Description** | | |
| Real-life (or else realistic) data from recent real-life flexibility market pilots' operation in various EU countries should be stored and be easily accessed and retrieved by FLEXGRID's research toolkits. Datasets should include bids from the flexibility supply side as well as requests from the flexibility demand side. Results from flexibility market clearing process should also be stored in a well-structured and comprehensive format. | | |
| **Notes** | | |
| The exact structured format will be agreed between research partners and NODES during the first months of WPs 3-5 duration, when the research algorithms' input/output requirements will be clearly defined. | | |

| Title | | |
|---|---|---|
| **FLEXGRID database should include real-life/realistic datasets about transmission/distribution network topology together with respective technical specifications and constraints** | | |
| **Code id** | **Component** | **Priority** |
| DB-RQT_03 | Database | Essential |
| **Description** | | |

| | | |
|---|---|---|
| Real-life (or else realistic) network topology data should be stored and be easily accessed and retrieved by FLEXGRID's research toolkits. Datasets should include nodes', buses', lines', substations' etc. specifications. Results from optimal power flow (OPF) processes and respective economic dispatch should also be stored in a well-structured and comprehensive format. | | |
| **Notes** | | |
| The exact structured format will be agreed between research partners and HOPS/BADENOVA during the first months of WPs 3-5 duration, when the research algorithms' input/output requirements will be clearly defined. | | |

| **Title** | | |
|---|---|---|
| **FLEXGRID database should include real-life/realistic smart energy meter datasets about small-scale energy consumption profiles, battery storage profiles and RES production profiles** | | |
| **Code id** | **Component** | **Priority** |
| DB-RQT_04 | Database | Essential |
| **Description** | | |
| Real-life (or else realistic) smart energy meter data should be stored and be easily accessed and retrieved by FLEXGRID's research toolkits. Datasets should include renewable energy production, storage and consumption at a residential/commercial energy prosumer level at short time granularities (e.g. 15-minute interval). Per smart electric device consumption data should also be included. | | |
| **Notes** | | |
| The exact structured format will be agreed between research partners and BADENOVA/UCY during the first months of WPs 3-5 duration, when the research algorithms' input/output requirements will be clearly defined. | | |

| **Title** | | |
|---|---|---|
| **Results from the research algorithms' execution should be easily stored, accessed, retrieved in order to be possibly further exploited in the future** | | |
| **Code id** | **Component** | **Priority** |
| DB-RQT_05 | Database | Essential |
| **Description** | | |
| The proposed research algorithms (i.e. the most important variants) regarding the automated flexibility aggregation (WP3), minimization of ESP's CAPEX/OPEX (WP4) and advanced OPF models (WP5) should be integrated in each one of the 3 proposed S/W toolkits. Results should then be stored in FLEXGRID database and should be easily accessed and retrieved by a (certain type of) user in order to make any further data process. | | |
| **Notes** | | |
| The exact structured format of the research algorithms' outcomes will be defined within the context of WPs 3-5 work and will be documented in a specific user manual (e.g. comprehensive readme.txt file). | | |

| **Title** | | |
|---|---|---|
| **FLEXGRID database should communicate bi-directionally with the research S/W toolkits via web Application Programming Interfaces (APIs)** | | |
| **Code id** | **Component** | **Priority** |
| DB-RQT_06 | Database | Essential |
| **Description** | | |

| | | |
|---|---|---|
| FLEXGRID database should store the results of the various algorithms' execution that will take place in the 3 research S/W toolkits. Moreover, the latter should be able to easily access and retrieve data from FLEXGRID database, which will be served as input to the research algorithms' execution. | | |
| **Notes** | | |
| Each S/W toolkit will have its own local database, which will communicate with the central database. The exact structured format of the web APIs will be defined during WPs 3-5 work and will be documented in respective D3.1, D4.1 and D5.1 deliverables to be submitted in Month 12. | | |

| **Title** | | |
|---|---|---|
| **FLEXGRID database should communicate bi-directionally with the core FLEXGRID ATP via web Application Programming Interface (API)** | | |
| **Code id** | **Component** | **Priority** |
| DB-RQT_07 | Database | Desirable |
| **Description** | | |
| FLEXGRID database should store the data analytics results from FLEXGRID marketplace testbed evaluation tests in the context of WP7. This data analytics results will be made publicly available at the end of project and could be useful for project's communication activities. | | |
| **Notes** | | |
| The design structure of this web API will be defined in the context of WP6 work. | | |

### 6.2.3 Requirements for the Automated Flexibility Aggregation Toolkit (AFAT)

The "Automated Flexibility Aggregation Toolkit" (AFAT) is one of the major FLEXGRID subsystems and communicates with technical APIs (i.e. RESTful APIs and/or Message-Oriented Middleware – MOM) with the other FLEXGRID subsystems such as the core FLEXGRID ATP and the central database. AFAT is the S/W toolkit that integrates the most important WP3 algorithms. AFAT's operation is closely inter-related with HLUC_04 described in detail in section 4.4. The AFAT requirements' analysis is provided below:

| **Title** | | |
|---|---|---|
| **Automated Flexibility Aggregation Toolkit (AFAT) should be an open-source S/W offering a user-friendly web interface** | | |
| **Code** | **Component** | **Priority** |
| AFAT-RQT_01 | AFAT | Essential |
| **Description** | | |
| The S/W implementation will be based on open-source code in order for the toolkit to be further exploited beyond project's lifetime by other EU projects, individual researchers and even commercial stakeholders. The web interface will be user-friendly so that the user can be easily and efficiently navigated through all of its features and functionalities. | | |
| **Notes** | | |
| A DEMO version of AFAT S/W will be uploaded at a public repository (e.g. GitHub) and be publicly accessible. The exact exploitation and IPR strategy will be defined during project's lifetime (WP8). | | |

| **Title** |
|---|
| **Automated Flexibility Aggregation Toolkit (AFAT) should have a fine-grained API with the central database in order to receive all energy prosumption and end user flexibility related datasets** |

| Code | Component | Priority |
|---|---|---|
| AFAT-RQT_02 | AFAT | Essential |
| **Description** | | |
| AFAT will receive all energy prosumption curves, battery storage SoC curves, end user flexibility curves etc. from the central database. The API will be designed in a way that any combination of individual and/or set of energy prosumers will be retrieved upon request by AFAT. These datasets will then be stored in AFAT's local database, too. | | |
| **Notes** | | |
| More technical details about the structure of this API will be provided in D2.2. | | |

| Title | | |
|---|---|---|
| **Automated Flexibility Aggregation Toolkit (AFAT) should offer efficient visualization capabilities regarding the energy prosumption curves (ECC) and other user energy profiling data** | | |
| **Code** | **Component** | **Priority** |
| AFAT-RQT_03 | AFAT | Desirable |
| **Description** | | |
| AFAT will have a visualization interface in order for the user to be able to visualize any possible individual prosumption profile for any given timeframe and for any given time granularity (e.g. 15-min, 1-hour, 1-day, etc). Any combination of aggregated datasets from multiple energy prosumers can also be visualized via graphical representations. | | |
| **Notes** | | |
| | | |

| Title | | |
|---|---|---|
| **Automated Flexibility Aggregation Toolkit (AFAT) should allow multiple user categories** | | |
| **Code** | **Component** | **Priority** |
| AFAT-RQT_04 | AFAT | Optional |
| **Description** | | |
| AFAT should allow for access to the system, through differentiated access levels. End energy prosumer users will be able to access only their own data/profiles, whereas administrative users will be able to execute flexibility aggregation algorithms under different scenarios, visualise the results, and send actuation commands to the other modules, as well as recommendations to the end prosumers. There will optionally be another user account, where an energy community user (or else facility manager) may have access to multiple energy prosumer profiles that belong in its portfolio. | | |
| **Notes** | | |
| This functionality will be implemented only if enough resources are available. | | |

| Title | | |
|---|---|---|
| **A well-designed web GUI should be available for the AFAT user to run the various research algorithms and visualize the performance evaluation results** | | |
| **Code** | **Component** | **Priority** |
| AFAT-RQT_05 | AFAT | Essential |
| **Description** | | |
| The user of AFAT will be able to set his own simulation scenario and run a specific FLEXGRID WP3 research algorithm. Then, s/she will be able to visualize the performance evaluation results and | | |

| |
|---|
| possibly extract them in a single file in case of further need for editing. In other words, the user (experimenter) will be able to set his/her own input parameters and experiment with the results. |
| **Notes** |
| The user should be able to exploit AFAT as an e-infrastructure for algorithms' experimentation for academic purposes. This toolkit can be also be used for communication purposes targeting commercial stakeholders (i.e. aggregators, ESPs, facility managers, energy communities, etc). |

| **Title** | | |
|---|---|---|
| **Results from the AFAT research algorithms' execution should be easily stored, accessed, retrieved and possibly further exploited in the future** | | |
| **Code** | **Component** | **Priority** |
| AFAT-RQT_06 | AFAT | Essential |
| **Description** | | |
| The proposed WP3 research algorithms (i.e. the most important variants) should be integrated in AFAT. The user should be able to provide his/her input parameters via a web GUI, then see the execution of the algorithm and visualize the results. Results should then be stored in local AFAT database and should be easily accessed and retrieved by the user in order to make any further data process. | | |
| **Notes** | | |
| A selected subset of AFAT algorithms' results should also be stored in the central database. | | |

| **Title** | | |
|---|---|---|
| **User profiling, searching and recommendation functionalities should be supported** | | |
| **Code** | **Component** | **Priority** |
| AFAT-RQT_07 | AFAT | Desirable |
| **Description** | | |
| AFAT may optionally support user profiling, searching and recommendation functionalities. For example, results of a certain WP3 algorithm may be used as input for the creation of an automatic recommendation message that can be sent to the end prosumer. An advanced search functionality may help the AFAT user, when there are too many end prosumers registered in the platform and too many simulation scenarios and respective results. | | |
| **Notes** | | |
| | | |

| **Title** | | |
|---|---|---|
| **Automated Flexibility Aggregation Toolkit (AFAT) should host the operation of an ad-hoc flexibility market run by an aggregator company** | | |
| **Code** | **Component** | **Priority** |
| AFAT-RQT_08 | AFAT | Essential |
| **Description** | | |
| In the context of FLEXGRID WP3, an aggregator operates an ad-hoc B2C flexibility market with its end energy prosumers by employing advanced pricing models and auction-based mechanisms. This market operation should be simulated within AFAT and respective results should be visualized by the AFAT's admin user. | | |
| **Notes** | | |
| More technical details about the design of the proposed ad-hoc flexibility market operation will be provided in D3.1. | | |

| Title | | |
|---|---|---|
| **Automated Flexibility Aggregation Toolkit (AFAT) should host algorithms for the optimal orchestration of distributed FlexAssets (DFAs)** | | |
| **Code** | **Component** | **Priority** |
| AFAT-RQT_09 | AFAT | Essential |
| **Description** | | |
| In the context of FLEXGRID WP3, an ESP/aggregator dynamically orchestrates distributed FlexAssets from its end users in order to optimally participate in several energy markets and/or to optimally respond to a specific FlexRequest sent by a system operator via the FLEXGRID ATP. This operation should be simulated within AFAT and respective results should be visualized by the AFAT's admin user. | | |
| **Notes** | | |
| More technical details about the design of the proposed resource management and orchestration models and algorithms will be provided in D3.1. | | |

| Title | | |
|---|---|---|
| **Automated Flexibility Aggregation Toolkit (AFAT) should host a forecasting engine for the on-demand prediction of future market prices and energy prosumption profiles** | | |
| **Code** | **Component** | **Priority** |
| AFAT-RQT_10 | AFAT | Essential |
| **Description** | | |
| The forecasting engine will take as input historical energy prosumption profiles of a given set of end users. It will then run forecasting algorithms and the output will be the future energy prosumption profiles according to the scenario (e.g. day-ahead, intra-day, next hour, etc.). The same process will be followed for the market price forecasting. | | |
| **Notes** | | |
| This forecasting engine will be the same with the one required for FST's WP4 algorithms (see subsection 6.2.4 below). | | |

| Title | | |
|---|---|---|
| **Automated Flexibility Aggregation Toolkit (AFAT) should have a fine-grained API with the core FLEXGRID ATP to receive a FlexRequest and respond with a FlexOffer** | | |
| **Code** | **Component** | **Priority** |
| AFAT-RQT_11 | AFAT | Essential |
| **Description** | | |
| A web API will facilitate the communication between AFAT and the core FLEXGRID ATP. Once a system operator or BRP creates a FlexRequest, the ATP is informed and it sends the request to the AFAT. Then, the ESP/aggregator should run an optimal flexibility aggregation algorithm. After the algorithm's execution, an optimal FlexOffer is created and is then sent back to the FLEXGRID ATP. | | |
| **Notes** | | |
| More technical details about the structure of this API will be provided in D2.2. | | |

### 6.2.4 Requirements for the FlexSuppliers' Toolkit (FST)

FST mostly covers models and algorithms from the WP4 and the use case scenarios (UCS) under the HLUC_02.

| Title | | |
|---|---|---|
| **FlexSuppliers' toolkit (FST) should be an open-source S/W offering a user-friendly web interface** | | |
| **Code** | **Component** | **Priority** |
| FST-RQT_01 | FST | Essential |
| **Description** | | |
| The software developed within the needs of FST will be based on open-source code so the other EU projects, academic communities or even commercial sector could also exploit it. Furthermore, the whole interface should be well-designed in a user-friendly manner. In that way, the user could easily explore and use all of the Toolkit's features and functionalities. | | |
| **Notes** | | |
| Source code, or at least a demo version, will be available in public source code repository such as GitHub. | | |

| Title | | |
|---|---|---|
| **FlexSuppliers' toolkit (FST) should have a fine-grained API with the central database in order to receive all related datasets** | | |
| **Code** | **Component** | **Priority** |
| FST-RQT_02 | FST | Essential |
| **Description** | | |
| For the FST to perform well, appropriate dataset presents critical value. As all of the data is stored in the central database, API should enable easy and efficient fetching of the required data. Historical (and real-time) market prices, distribution network topology, historical (and real-time) weather data are all regarded as essential inputs for the FST. | | |
| **Notes** | | |
| More technical details about the structure of this API will be provided in D2.2. | | |

| Title | | |
|---|---|---|
| **FlexSuppliers' toolkit (FST) should be able to export the results in an easy to save form** | | |
| **Code** | **Component** | **Priority** |
| FST-RQT_03 | FST | Essential |
| **Description** | | |
| Once the developed toolkit executes the demanded task with the given input data and specific user preferences, results should be easily exported to multiple popular formats. In that way, the user could use the results in other programs and/or implement it in their reports, calculations etc. | | |
| **Notes** | | |
| Depending on the type of the exported results they could be in CSV, PDF or any other widely used format. Some results could also be sent to the central database to enable features such as user recommendation. | | |

| Title | | |
|---|---|---|
| **FlexSuppliers' toolkit (FST) should be able to provide meaningful visualizations and comparisons** | | |
| **Code** | **Component** | **Priority** |

| | | |
|---|---|---|
| FST-RQT_04 | FST | Essential |
| **Description** | | |
| FST offers to the user various business scenarios depending on the user preferences (smaller CAPEX, smaller OPEX, etc.). The toolkit should enable the user to compare different approaches and graphically present their outcomes (e.g. bar chart of the CAPEX dependent on the scenario). So, the visualizations should not only help the user to compare different scenarios, but also to deeply explore specific scenario (e.g. projected cashflow during a decade). User should be able to modify time scale, adjust colours and adjust other relevant features to understand the reports as good as possible. | | |
| **Notes** | | |
| | | |

| **Title** | | |
|---|---|---|
| **FlexSuppliers' toolkit (FST) should enable user profiling, searching and recommendations** | | |
| **Code** | **Component** | **Priority** |
| FST-RQT_05 | FST | Desirable |
| **Description** | | |
| As various users use the FST with various preferences, the toolkit could save specific results in the central database. Over the course of time, the AI algorithms could profile the users and suggest solutions to them. Furthermore, intelligent search algorithm could help the user choose the settings, which suit him the best. | | |
| **Notes** | | |
| | | |

| **Title** | | |
|---|---|---|
| **FlexSuppliers' toolkit (FST) should allow multiple user categories** | | |
| **Code** | **Component** | **Priority** |
| FST-RQT_06 | FST | Optional |
| **Description** | | |
| Different employees in an ESP have different responsibilities and authorization levels. FST will enable differentiated access levels. In that way, every user will be able to see/execute exactly as much as he is authorized to. | | |
| **Notes** | | |
| | | |

| **Title** | | |
|---|---|---|
| **FlexSuppliers' toolkit (FST) should run the algorithms in the cloud** | | |
| **Code** | **Component** | **Priority** |
| FST-RQT_07 | FST | Desirable |
| **Description** | | |
| Although the software will be based on open-source, for the purpose of the optimization commercial software (e.g. Gurobi) will be used. In order to enable all interested parties all benefits of the FST, the most elegant solution is to run the toolkit in the cloud with enabled access to Gurobi. | | |
| **Notes** | | |
| | | |

| Title | | |
|---|---|---|
| **FlexSuppliers' Toolkit (FST) should have a fine-grained API with the core FLEXGRID ATP for sending a FlexOffer and receiving a response** | | |
| **Code** | **Component** | **Priority** |
| FST-RQT_08 | FST | Essential |
| **Description** | | |
| Once the optimization is done, FST sends FlexOffers to the FLEXGRID ATP. FLEXGRID ATP then sends back the information that the FlexOffer has been accepted or (partially) rejected so that the ESP can act accordingly. That is why efficient web API for communication between the FST and FLEXGRID ATP is essential. | | |
| **Notes** | | |
| More technical details about the structure of this API will be provided in D2.2. | | |

### 6.2.5 Requirements for the Distribution Flexibility Market Clearing Toolkit (DFMCT)

| Title | | |
|---|---|---|
| **DFMCT should be an open-source S/W** | | |
| **Code** | **Component** | **Priority** |
| DFMCT-RQT_01 | FMCT | Essential |
| **Description** | | |
| The S/W implementation will be based on open-source code in order for the toolkit to be further exploited beyond project's lifetime by other EU projects, individual researchers and even commercial stakeholders. | | |
| **Notes** | | |
| Source code will be available in public source code repository. | | |

| Title | | |
|---|---|---|
| **Results from the DFMCT research algorithms' execution should be easily stored, accessed, retrieved and possibly further exploited in the future** | | |
| **Code** | **Component** | **Priority** |
| DFMCT-RQT_02 | FMCT | Essential |
| **Description** | | |
| The proposed WP5 research algorithms should be integrated in FMCT. Results should be stored in a database and should be easily accessed and retrieved in order to make any further data process. | | |
| **Notes** | | |
| | | |

| Title | | |
|---|---|---|
| **DFMCT should have an API with the core FLEXGRID ATP to send a FlexRequest and receive the schedule of FlexAssets** | | |
| **Code** | **Component** | **Priority** |
| DFMCT-RQT_03 | FMCT | Essential |
| **Description** | | |
| The results of the advanced market clearing algorithm contained in FMCT are generated in the form of FlexRequest, which is sent to FLEXGRID ATP via the API. The ATP then clears the flexibility market and sends back to FMCT the schedule of FlexAssets. | | |
| **Notes** | | |

| |
|---|
| More technical details about the structure of this API will be provided in D2.2. |

| Title | | |
|---|---|---|
| **DFMCT should have an API with the FlexSupplier's Toolkit (FST) for a network-aware operation of FlexAssets** | | |
| **Code** | **Component** | **Priority** |
| DFMCT-RQT_04 | FMCT | Essential |
| **Description** | | |
| This API between FMCT, which contains the advanced models for market clearing, and FST will facilitate the network-aware operation of FlexAssets. | | |
| **Notes** | | |
| More technical details about the structure of this API will be provided in D2.2. | | |

### 6.2.6 Requirements for the interaction between the subsystems

We will describe two different kinds of requirements: Technical and Functional. The Functional ones are those from FLEXGRID architecture figure, identified by API-FRQT_XX, and the Technical ones are more general ones and describe common requirements for the Functional APIs implementation; these are identified by API-TRQT_XX.

**APIs' Technical requirements (TRQT):**

| Title | | |
|---|---|---|
| **Authenticated APIs** | | |
| **Code** | **Component** | **Priority** |
| API-TRQT_01 | API | Essential |
| **Description** | | |
| All API uses shall be authenticated using API Keys method, having one different Key set for each API. | | |
| **Notes** | | |
| Minimum security level required for APIs' operation achieved through secret API Keys for backend usage. | | |

| Title | | |
|---|---|---|
| **RESTful Web Services** | | |
| **Code** | **Component** | **Priority** |
| API-TRQT_02 | API | Essential |
| **Description** | | |
| All APIs shall follow RESTful architectural style. | | |
| **Notes** | | |
| REST API is a well-known standard to exchange information between S/W modules/subsystems. A RESTful web service defines a uniform and predefined set of stateless operations that accept requests through a URI. | | |

| Title | | |
|---|---|---|
| **OpenAPI Specification (OAS)** | | |
| **Code** | **Component** | **Priority** |

| | | |
|---|---|---|
| API-TRQT_03 | API | Essential |
| **Description** | | |
| All APIs shall follow OpenAPI 3.0 (previously Swagger) specification. | | |
| **Notes** | | |
| Open standard for describing REST APIs. | | |

| **Title** | | |
|---|---|---|
| **Secure endpoints** | | |
| **Code** | **Component** | **Priority** |
| API-TRQT_04 | API | Essential |
| **Description** | | |
| All API endpoints shall encrypt point to point transmission via TSL/SSL, enabling HTTPS protocol usage. | | |
| **Notes** | | |
| API webservers must implement HTTPS support in order to increment information exchange security. | | |

| **Title** | | |
|---|---|---|
| **Comply performing specs** | | |
| **Code** | **Component** | **Priority** |
| API-TRQT_05 | API | Essential |
| **Description** | | |
| All APIs shall be implemented guaranteeing a minimum performance level, avoiding bottlenecks. | | |
| **Notes** | | |
| FLEXGRID operation must be fluent, so its APIs should perform associated operations within a proper timelapse, implementing their functionalities efficiently. | | |

| **Title** | | |
|---|---|---|
| **Wiki driven development** | | |
| **Code** | **Component** | **Priority** |
| API-TRQT_06 | API | Essential |
| **Description** | | |
| All API specifications development shall be assisted with a collaborative wiki tool. | | |
| **Notes** | | |
| In order to provide a coherent view of information across APIs, we recommend the use of Wiki based tool. These tools allow a collaborative approach to build the specifications and also allow the information to be presented in different formats. | | |

**APIs' Functional requirements (FRQT):**

| **Title** | | |
|---|---|---|
| **AFAT–ATP API** | | |
| **Code** | **Component** | **Priority** |
| API-FRQT_01 | API | Essential |
| **Description** | | |
| When ATP sends a FlexRequest to AFAT, AFAT shall send back an optimal FlexOffer to ATP. | | |
| **Notes** | | |

| |
|---|
| AFAT receives a FlexRequest from ATP. Then, AFAT runs an algorithm and sends back to ATP an optimal FlexOffer. |

| **Title** | | |
|---|---|---|
| **FST-ATP API** | | |
| **Code** | **Component** | **Priority** |
| API-FRQT_02 | API | Essential |
| **Description** | | |
| When FST sends an optimal FlexOffer to ATP, the latter shall reply with the result of the flexibility market clearing to FST. | | |
| **Notes** | | |
| FST runs an optimal scheduling algorithm and then sends an optimal FlexOffer to ATP. Then, ATP clears the flexibility market and FST receives a response from ATP about the result (i.e. schedule in setpoints). | | |

| **Title** | | |
|---|---|---|
| **FMCT-ATP API** | | |
| **Code** | **Component** | **Priority** |
| API-FRQT_03 | API | Essential |
| **Description** | | |
| When FMCT sends a FlexRequest to ATP, the latter shall respond with the result of the flexibility market clearing to FMCT. | | |
| **Notes** | | |
| FMCT runs an advanced market clearing algorithm and the result is that a FlexRequest is generated by the DSO and then it is sent to ATP. Then, ATP clears the flexibility market and FMCT receives a response from ATP about the result (i.e. schedule of all FlexAssets in setpoints that will provide their flexibility to DSO). | | |

| **Title** | | |
|---|---|---|
| **ATP–DB API** | | |
| **Code** | **Component** | **Priority** |
| API-FRQT_04 | API | Essential |
| **Description** | | |
| When any module stores results or retrieves data, it shall return the operation result on the DB. | | |
| **Notes** | | |
| API for subsystems to retrieve data and to send back their algorithmic results. | | |

| **Title** | | |
|---|---|---|
| **MKT–DB API** | | |
| **Code** | **Component** | **Priority** |
| API-FRQT_05 | API | Essential |
| **Description** | | |
| **#1:** If wholesale/TSO markets are not subscriptible, then a market agent shall poll for new data available from wholesale/TSO markets that has not already be stored on the DB.<br>**#2:** If wholesale/TSO markets are subscriptible, then the market agent shall subscribe for being noticed and able to accept new data available at wholesale/TSO markets that has not already be stored on the DB. | | |

| |
|---|
| **#3:** When new data is available on wholesale/TSO markets while running the market agent, the agent shall retrieve as a client this new information through external wholesale/TSO markets API and process it to be stored on the DB. |
| **Notes** |
| A wholesale/TSO market agent running is necessary, and it will use external MO/TSO Markets API for expecting and retrieving its data and then process it into the DB. |

| **Title** | | |
|---|---|---|
| **MKT–ATP API** | | |
| **Code** | **Component** | **Priority** |
| API-FRQT_06 | API | Essential |
| **Description** | | |
| When ATP sends a FlexOffer to the existing markets (i.e. wholesale/TSO-operated ones), the latter shall send back market clearing results. | | |
| **Notes** | | |
| API for redirecting FlexOffers from ATP and getting results from market's clearing process. | | |

### 6.2.7 Legal/regulatory/security requirements

This subsection describes all residual requirements for FLEXGRID system as a whole. In particular, we state the legal, regulatory and security requirements (cf. notation "RQT-LRS" below). Finally, privacy- and ethics-related requirements are stated.

| **Title** | | |
|---|---|---|
| **FLEXGRID ATP should adopt latest standards for handling distribution grid data** | | |
| **Code id** | **Component** | **Priority** |
| ATP-RQT_LRS_01 | ATP | Essential |
| **Description** | | |
| Where the ATP will consider distribution network data for market clearing, it will need to comply with EU regulatory standards for cybersecurity in distribution grids. | | |
| **Notes** | | |
| Relevant standardisation bodies include CEN-CENELEC Focus group on Cybersecurity, British Standards Institution (BSI), International Electrotechnical Commission standards, Center for Internet Security critical security controls. | | |

| **Title** | | |
|---|---|---|
| **FLEXGRID ATP has to be in line with DE Transmission and Distribution code** | | |
| **Code id** | **Component** | **Priority** |
| ATP-RQT_LRS_02 | ATP | Essential |
| **Description** | | |
| The FLEXGRID consortium must verify that the utilization of the ATP is in line with the standards of sources for the procurement of voltage control/balancing power (Verband der Netzbetreiber (2007a) & Verband der Netzbetreiber (2007b).) | | |
| **Notes** | | |
| The German Association of the Electricity and Water Industry (BDEW) should be able to provide English translations of the aforementioned documents. | | |

| Title | | |
|---|---|---|
| **FLEXGRID ATP should be able to provide datasets that are in line with reporting requirements** | | |
| **Code id** | **Component** | **Priority** |
| ATP-RQT_LRS_03 | ATP | Essential |
| **Description** | | |
| Annexes I & II of the regulation 2016/1952 describe in detail methodologies for collection and compilation of data on electricity prices for household and non-household consumers. It has to be analysed how the ATP-related expenses fit into this scheme. The FLEXGRID consortium must assess whether user-friendly methods to automatically meet reporting obligations under EU regulation 543/2013 should be integrated into the ATP. Furthermore, it has to be guaranteed that reporting data from the ATP is compliant with existing statistical data set requirements. | | |
| **Notes** | | |
| | | |

| Title | | |
|---|---|---|
| **FLEXGRID ATP has to comply with market surveillance requirements** | | |
| **Code id** | **Component** | **Priority** |
| ATP-RQT_LRS_04 | ATP | Essential |
| **Description** | | |
| The FLEXGRID consortium will have to analyse in cooperation with the National market surveillance bodies to which extent their authorization of the ATP is required due to the requirement to guarantee only appropriate usage of the consumer data. | | |
| **Notes** | | |
| | | |

| Title | | |
|---|---|---|
| **FLEXGRID ATP should protect the privacy of final customer data** | | |
| **Code id** | **Component** | **Priority** |
| ATP-RQT_LRS_05 | ATP | Essential |
| **Description** | | |
| FLEXGRID subsystems should comply with relevant EU law when processing personal data in accordance with Regulation (EU) 2016/679 (General Data Protection Regulation). | | |
| **Notes** | | |
| Data should be anonymized where possible. | | |

| Title | | |
|---|---|---|
| **FLEXGRID ATP should meet metering point operation and intelligent energy network requirements** | | |
| **Code id** | **Component** | **Priority** |
| ATP-RQT_LRS_06 | ATP | Essential |
| **Description** | | |
| In order to enable smart grids and end-customer participation through digitalization, the operation of measuring points has been regulated (Gesetz über den Messstellenbetrieb und die Datenkommunikation in intelligenten Energienetzen, 2016). This law describes, among other things, the minimum requirements for intelligent metering systems and the data communication with smart meters. The interoperability of the ATP with the legal requirements must be met. | | |
| **Notes** | | |

| Title | | |
|---|---|---|
| **FLEXGRID ATP should meet Network Codes Regulation 2016/631 & 2016/1388** | | |
| **Code id** | **Component** | **Priority** |
| ATP-RQT_LRS_07 | ATP | Essential |
| **Description** | | |
| The FLEXGRID consortium has to provide sufficient measures to allow for the interoperability of the ATP with the appliances that are covered by these regulations. | | |
| **Notes** | | |
| | | |

| Title | | |
|---|---|---|
| **FLEXGRID ATP should adopt latest standards for communication with DER assets** | | |
| **Code id** | **Component** | **Priority** |
| ATP-RQT_LRS_08 | ATP | Essential |
| **Description** | | |
| Where communicating with DER assets, FLEXGRID subsystems should comply with relevant Union security rules, ensuring the highest level of cybersecurity protection. Recommendations are made in IEC TR 62351-12. | | |
| **Notes** | | |
| Relevant standardisation bodies include CEN-CENELEC Focus group on Cybersecurity, British Standards Institution (BSI), International Electrotechnical Commission standards, Center for Internet Security critical security controls. | | |

| Title | | |
|---|---|---|
| **FLEXGRID ATP should adopt latest standards for communication of smart metering data** | | |
| **Code id** | **Component** | **Priority** |
| ATP-RQT_LRS_09 | ATP | Essential |
| **Description** | | |
| Where communicating with smart metering systems, FLEXGRID subsystems should comply with relevant Union security rules, ensuring the highest level of cybersecurity protection, as stated in directive (EU) 2019/944. | | |
| **Notes** | | |
| Relevant standardisation bodies include CEN-CENELEC Focus group on Cybersecurity, British Standards Institution (BSI), International Electrotechnical Commission standards, Center for Internet Security critical security controls. | | |

| Title | | |
|---|---|---|
| **FLEXGRID ATP should adopt latest ethical standards for human beings** | | |
| **Code id** | **Component** | **Priority** |
| ATP-RQT_LRS_10 | ATP | Essential |
| **Description** | | |
| During developing ATP, especially communicating with different actors in the flexibility market, the EU ethical standards about human beings should be applied. | | |
| **Notes** | | |
| | | |

| Title | | |
|---|---|---|
| **FLEXGRID ATP should adopt latest ethical standards for personal data** | | |
| **Code id** | **Component** | **Priority** |
| ATP-RQT_LRS_11 | ATP | Essential |
| **Description** | | |
| Contractual agreements are needed among different actors for the system to operate the flexibility market. | | |
| **Notes** | | |
| This should be in accordance with Regulation (EC) No 45/2001 of the European Parliament and of the Council (5). | | |

| Title | | |
|---|---|---|
| **FLEXGRID ATP should adopt latest ethical standards for end user assets' data management** | | |
| **Code id** | **Component** | **Priority** |
| ATP-RQT_LRS_12 | ATP | Essential |
| **Description** | | |
| The agreement about the permission of final users' needs to exist in order to make use of their data; anonymization of energy prosumer data | | |
| **Notes** | | |
| The purpose of this agreement aims to identify the necessary infrastructure (including secure communication channels) available to access the required data, as well as monitoring and data processing of aggregated units. | | |

| Title | | |
|---|---|---|
| **FLEXGRID ATP should adopt latest ethical standards for digitalization** | | |
| **Code id** | **Component** | **Priority** |
| ATP-RQT_LRS_13 | ATP | Essential |
| **Description** | | |
| AI issues is the latest issue that has been recently added to the ethics part. Therefore, the implementation of digitalization methodology should follow the relevant guideline and policy. | | |
| **Notes** | | |
| Relevant standards: The High-Level Expert Group on Artificial Intelligence from the European Commission (AI HLEG): Ethics Guidelines on Artificial Intelligence and Policy and Investment Recommendations | | |

| Title | | |
|---|---|---|
| **FLEXGRID ATP should adopt latest ethical standards for Non-EU country** | | |
| **Code id** | **Component** | **Priority** |
| ATP-RQT_LRS_14 | ATP | Essential |
| **Description** | | |
| Norway is a Non-EU country. The flexibility market regulation should in line with relevant requirements | | |
| **Notes** | | |
| Legal entities from Associated Countries have a similar status and can participate under the same conditions as entities from Member States. Article 7 within H2020 Programme Multi-Beneficiary General Model Grant Agreement sets out the conditions for association of non-EU countries to | | |

Horizon 2020.

**IMPORTANT NOTE:** Due to the recent political and regulatory developments on EU level, there is a number of relevant developments and regulations, which do not yet have an impact on FLEXGRID. However, these developments should be monitored during the project to adjust the project's focus, if required, in the context of WP8 work. Therefore, there are some requirements with the recommendation that the project management and Innovation Exploitation Committee (InEC) periodically reviews for new developments (especially national implementation) of these regulation areas. These requirements can be summarized as follows:

- Monitor National Implementation Plans of CEP[37] (Art. 32 about DSO tasks for using flexibility)
- Monitor further specification of EU regulation 2019/943[38]
- Declare FLEXGRID as market-based flexibility mechanism (i.e. FLEXGRID pilots as an experimental implementation of market-based flexibility mechanisms as described in Art. 32 of the e-Directive)
- Follow-up regulatory discussions and specifications on "demand aggregation" (cf. EU Regulation 2016/1388 defines in Article 19)[39]
- Integrate Energy Efficiency Directive EU 2012/27[40] into the external FLEXGRID's communication activities.
- Analyse state aid opportunities for FLEXGRID large-scale roll-out as part of the project's exploitation activities.
- Monitor Electricity Grid Access Ordinance & Regulatory Storage Integration Developments.

More details about these requirements and related legislation will be provided in D8.1 in Month 6.

[37] DIRECTIVE (EU) 2019/944 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast), June 2019.

[38] REGULATION 2019/943 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 on the internal market for electricity (recast), Official Journal of the European Union, 14.06.2019.

[39] Commission Regulation 2016/1388 of 17 August 2016 establishing a Network Code on Demand Connection; Online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R1388&from=EN

[40] EU (2012): DIRECTIVE 2012/27/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

# 7. Conclusions

Conclusively, during the next months, FLEXGRID consortium will elaborate on the current work presented in this deliverable towards designing the final version of FLEXGRID system architecture and starting the respective research and S/W implementation work. Step-wise, the actual work schedule plan is the following:

- Tasks 2.1-2.3 dealing with the: a) research methodology of FLEXGRID's framework (Task 2.1), b) definition of use cases, system operation scenarios and correlation wikth novel models (Task 2.2), c) requirements' analysis for all FLEXGRID services (Task 2.3) have been successfully accomplished and the results are incorporated in the current report.
- Until Month 6 (M6), the consortium will elaborate on D2.1 results to design the final version of FLEXGRID system architecture and provide the technical specifications for all FLEXGRID subsystems as well as the technical APIs for the interaction among the various subsystems (D2.2).
- Meanwhile, all academic partners have started the initial research work in WPs 3-5. Each academic partner works on its own research threads, as these have been explicitly and clearly defined in the description of the Use Cases Scenarios (see section 5 of this report). Collaboration with specific industrial partners (who lead respective High Level Use Cases - HLUCs) is also taking place.
- From M13 onwards, all partners will start collaborating towards integrating each individual subsystem into the single modular-by-design FLEXGRID S/W platform.

The figure below shows the current project's timeline schedule. Milestone #1 has been achieved, while there are two more milestones to be achieved in Month 6.

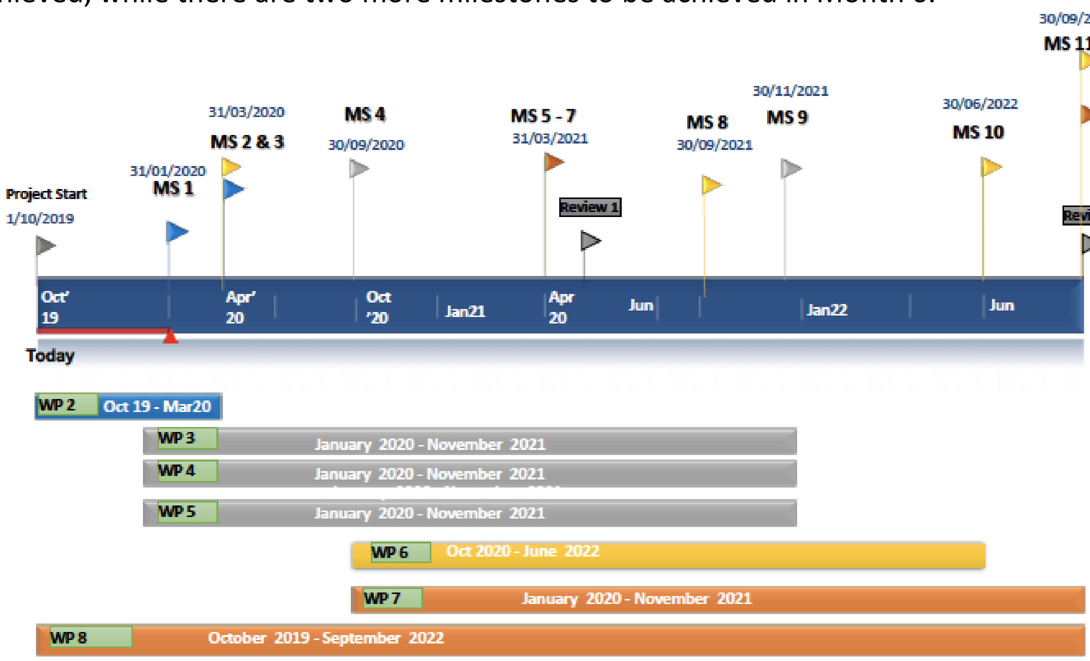


**Figure 7: Current FLEXGRID project's timeline schedule (MS 1 has been accomplished)**