Ref. Ares(2019)7933217 - 31/12/2019

Deliverable D2.2

REQUIREMENTS

Geographical Islands FlexibiliTy

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Date 19/12/2019

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 824410.

DELIVERABLE 2.2 – VERSION 1.2

WORK PACKAGE N° 2

Nature of the deliverable		
R	Document, report (excluding the periodic and final reports)	✓
DEM	Demonstrator, pilot, prototype, plan designs	
DEC	Websites, patents filing, press & media actions, videos, etc.	
OTHER	Software, technical diagram, etc.	

Dissemination Level		
PU	Public, fully open, e.g. web	✓
CO	Confidential, restricted under conditions set out in Model Grant Agreement	
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Quality procedure			
Date	Version	Reviewers	Comments
02/09/2019	0	Olivier GENEST (Trialog), Lizhen HUANG (NTNU)	Creation of the document structure
18/11/2019	1	Inputs from all consortium partners	Inclusion of the contributions from different partners: see section 3
19/12/2019	2	Reviews from all consortium partners. Formal review from Lizhen HUANG (NTNU)	Final version reviewed by consortium partners, with a formal review from WP3 (Lizhen HUANG, NTNU)

ACKNOWLEDGEMENTS

This report is part of the deliverables from the project "GIFT" which has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 824410.

More information on the project can be found at http://www.gift-h2020.eu/

EXECUTIVE SUMMARY

This document details the Requirements for the GIFT project: it contains a description of the transversal requirements that need to be fulfilled by all solution providers. This includes technical requirements as well as more generic and functional requirements. The different requirements have been written by consortium partners, according to their expertise and interests.

These requirements are meant to be updated during the lifetime of the project to reflect any change that may arise: a final version will be delivered at the end of the project.

This document is organized in seven main sub-sections, corresponding to the different requirements: Interoperability, Response time, Communication security, Privacy and data protection, Accuracy, Equity and Visualisation of flexibility incentives.

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1. INTRODUCTION

1.1. SCOPE OF THE DOCUMENT

The goal of this deliverable is to define the main requirements that are to be fulfilled by the solution providers. It explains what is to be implemented, and which of the GIFT solutions are concerned.

The seven requirements are technology-neutral, and each of them is defined by five questions:

- What does this requirement consist in, and why is it necessary?
- Are there any constraints from the fact that GIFT is situated within the energy sector?
- To which of the GIFT solutions does this requirement apply?
- What measures are requested to be implemented by the solutions?
- Which standards are being used to describe the requirement?

In order to be relevant through the duration of the project, the requirements will be updated during its lifetime:

- If new standards/regulations are published;
- If significant changes occur within the project affecting the relevance of one requirement or making the definition of a new requirement necessary.

The measures to apply for each requirement are regrouped in a table at the end of the description to enable future controls of the compliance.

The different requirements have been written by consortium partners, according to their expertise and interests. This document is public, and will be used for the general public to understand what is done by the GIFT project, and internally to ensure a common understanding of the use-cases and architecture of the project.

1.2. ABOUT GIFT

GIFT is a project funded by the European Commission, that was launched in January 2019. It aims to decarbonize the energy mix of European islands. Therefore, GIFT has the objective to develop innovative systems that allow islands to integrate large share of renewable energies while not adding stress to the grid, through the development of multiple innovative solutions, that will be combined into a complex system. These solutions include a Virtual Power System (VPS), a state estimation of the grid, a better prediction of supply and demand and visualization of those data through a GIS platform, and innovative storage systems allowing synergy between electrical, heating and transportation networks. It will moreover help to implicate the consumers in the energy transition, through various, energy management systems for harbors, factories, battery and hydrogen storage and mobility that are being developed within the project.

In order to be representative and relevant when proposing solutions at the EU level, GIFT has selected several islands and demonstration sites having their own issues and specificities. The GIFT partners will therefore develop and demonstrate the solutions in two pilot islands, Hinnøya, Norway's largest island, and Procida, a small island in Italy, and study the replicability of the solution at least in the Greek island of Evia and the Italian island of Favignana.

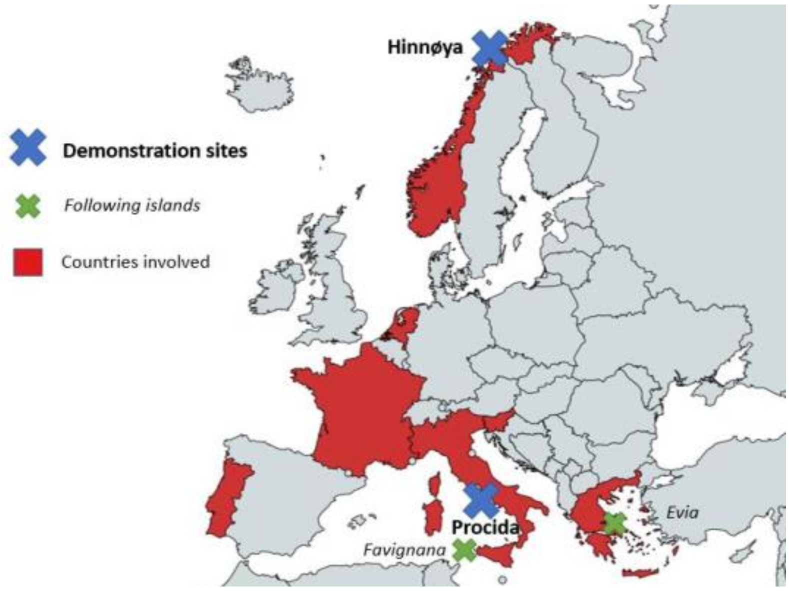

Figure 1: GIFT involved partners and pilot sites

1.3. GLOSSARY

1.3.1. Definitions

Term	Definition
Measure	The application of a methodology or the addition of a device to ensure the realisation of an aim.
Requirement	A basic need of the GIFT project detailed within this document.
Solution	Technology provided and used within the GIFT project to fill a need.
Specificity	An aspect of the requirement that represents a constraint to its development.

1.3.2. Acronyms

Term	Definition
ACE	Area Control Error
BESS	Battery Energy Storage Systems
BRP	Balance Responsible Party
DER	Distributed Energy Resources
DSO	Distribution System Operator
EMS	Energy Management System
ESB	Enterprise Service Bus
FCR	Frequency Containment Reserves
FRR	Frequency Restoration Reserves
GDPR	General Data Protection Regulation
GIS	Geographical information system
MDMS	Meter Data Management System
PFC	Primary Frequency Control
RES	Renewable Energy Sources
SCADA	Supervisory Control And Data Acquisition

S&D	Supply and Demand
SFC	Secondary Frequency Control
SOC	Statement Of Compliance
TSO	Transmission System Operator
UC	Use-Case
VPS	Virtual Power System

2. REQUIREMENTS

The system requirements are linked to functionalities to be implemented within the GIFT project. The functionalities will be executed by individual components, which are connected (from communication point of view) between themselves as defined by the system architecture presented in [1].

The GIFT architecture is composed of the following main components:

- Prediction of grid operation: performed based on weather forecasts, supply and demand prediction, and energy price information. The necessary inputs for prediction are acquired from external systems via the ESB. The most relevant outputs are predicted consumption and production in individual nodes of the grid during predefined time intervals in the future; the outputs are communicated to grid monitoring;
- Grid Observability System: based on data received from SCADA and MDMS systems, the grid observability system continuously monitors the state of the grid. In combination with results received from module for prediction of grid operation, the grid monitoring estimates the current and future operational conditions in the grid and detects present or potential threats (e.g. network congestions, deterioration of voltage conditions) that could endanger the reliability of grid operation and security of supply of energy to final customers. If the Grid Observability module estimates the detected threats can be solved by demand response, it asks VPS (via the Flex Agent, in form of flexibility request) for provision of demand response in the relevant areas of the grid;
- Energy Management System (EMS): systems implemented at final customers (consumers, producers, prosumers) for optimisation of energy consumption/production. In the GIFT system they provide information to VPS (via Flex Agent) about current and planned operation, and about flexibility potential (flex offers) available in individual time periods in the future. xEMS is a general term describing all types of EMSs (Ship/Harbour EMS, EV + Charging stations, Factory EMS, Smart Energy Hub, HBr storage – see also section 2.1.1.1);
- Virtual Power System (VPS): the core of the GIFT system that acquires flexibility requests from Grid Observability System and flexibility offers from xEMSs (all via Flex Agents), matches them and requires from selected xEMSs the activation of their flexibility potential. In relation to xEMSs the VPS acts also as the aggregator of services offered by xEMSs;
- Enterprise Service Bus (ESB): manages the information flow between systems developed in the project at the level of the control centre e.g. Prediction, Grid Observability; as well as external ones e.g. SCADA providing grid sensing data, MDMS providing measurements from smart metering equipment, weather services providing weather forecasts;
- Flex Agent (FA): manages the information flow between xEMSs and VPS, and between Grid Observability System and VPS.

Besides, GIFT will also have GIS based digital twin to visualise the information from DSO and Project through ESB. The GIFT system architecture is presented in Figure 2.**Error! Reference source not found.** (from the deliverable D2.1 [1]):

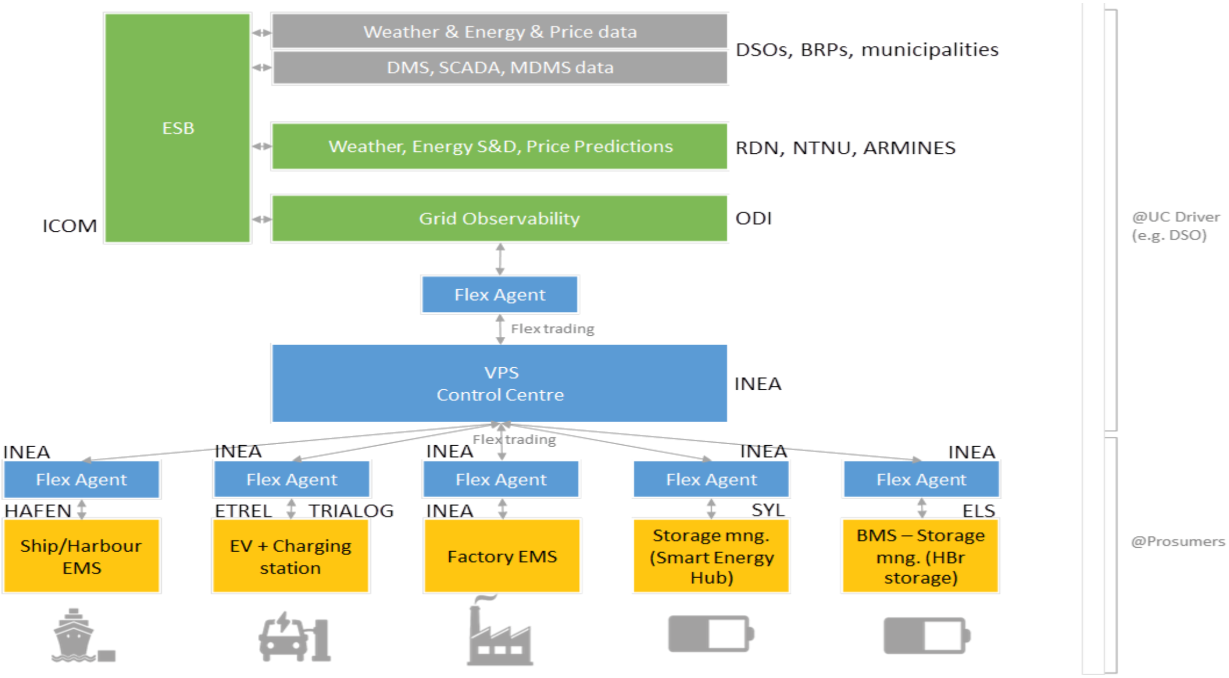

Figure 2: Interactions between the GIFT system components

2.1. INTEROPERABILITY

Interoperability is defined as “the ability of two or more networks, systems, devices, applications, or components to interwork, to exchange and use information in order to perform required functions” [2].

Interoperability is important for coordinated operation of several technologies (system components), partners, and demo sites. If we adhere to the widely used standards for communication between components, we ensure that our components can be integrated into different environments. The use, in the same system, of devices (or software) from different vendors (manufacturers) allows to take advantage of the characteristics of a wider range of devices, with both technical and economic benefits.

In this project, interoperability will allow a seamless and easy integration of the components developed by the several partners.

2.1.1. Energy sector specificities

Energy sector with its ambition to decarbonize and enable high electricity production from RES drives the need for sector coupling and involvement of final customers in operation of the grid and energy market. Interoperability in that respect needs to address different systems, such as electric energy system, heating system, cooling system, water system and transport.

From the energy perspective, this requirement will need to address different energy vectors besides electric energy, such as heating and cooling energy.

In this energy sector, there is a wide range of standards that cover all possible applications. Among these standards according to IEC [3], some are seen as the backbone of future smart grids. These standards are the following:

- IEC 61970/61968: CIM (Common Information Model). Applying mainly to: Generation management systems, EMS (Energy Management System); DMS (Distribution Management System); DA

(Distribution Automation); SA (Substation Automation); DER (Distributed Energy Resource); AMI (Advanced Metering Infrastructure); DR (Demand Response); E-Storage

- IEC 62325: CIM (Common Information Model) based, Energy market information exchange. Applying mainly to: Generation management systems, EMS (Energy Management System); DMS (Distribution Management System); DER; AMI; DR; meter-related back-office systems; E-Storage
- IEC 61850: Power Utility Automation, Hydro Energy Communication, Distributed Energy Resources Communication. Applying mainly to: Generation management systems, EMS; DMS; DA; SA; DER E-Storage; E-mobility
- IEC 62056: COSEM. Applying mainly to: DMS; DER; AMI; DR; Smart Home; E-Storage; E-mobility Data exchange for meter reading, tariff and load control.
- IEC 62351: Applying mainly to Security for all systems
- IEC 61508: Applying mainly to Functional safety of electrical/electronic/programmable electronic safety-related systems.
- IEC/IEEE 80005-1 High voltage energy supplies from grid (port) to ships recommending 11 kV AC 50Hz, 690 V AC 50Hz and 400 V AC 50Hz. Norwegian electric ferries (eFerry) will have 22 kV system voltage from grid (DSO) and testing 11 + 11 kV sub-stations to handle both 11 kV and 22 kV.
- IEC/IEEE 80005-3 Low voltage energy supplies from grid to ships 690 V. Norway is recommending 400 V and 125 A.

Together with the above standards, there is also a subset of them that are deemed important for the operation of Smart Grids:

- IEC 62357: Power utilities Reference Architecture – SOA. Applying mainly to: Energy Management Systems; Distribution Management Systems; DER operation systems, market & trading systems, DR systems, meter-related back-office systems
- IEC 60870-5: Telecontrol. Applying mainly to: EMS; DMS; DA; SA
- IEC 60870-6: TASE2 Inter Control Centre Communication. Applying mainly to: EMS; DMS
- IEC/TR 61334: — "DLMS" Distribution Line Message Specification. Applying mainly to: AMI
- IEC 61400-25: Wind Power Communication. Applying mainly to: DER operation systems (Wind farms); EMS; DMS;
- IEC 61851: EV-Communication. Applying mainly to: E-mobility (related further to Home & Building energy management systems);
- ISO/IEC 15118 Road vehicles — Vehicle to grid communication interface. Applying mainly to: smart charging
- IEC 62051-54/58-59: Metering Standards. Applying mainly to: DMS; DER; AMI; DR; Smart Home; E-Storage; E-mobility
- IEC 61968: Application integration at electric utilities - System interfaces for distribution management.

Due to the large number of standards, the use of a specific framework, such as the Smart Grid Architecture Model (SGAM), allows a systematic approach in terms of interoperability and architecture analysis. The SGAM framework consists of different interoperability layers as shown in Figure 3, which includes components, communication, information, function and business processes. SGAM enables users to represent Smart Grid Use Cases graphically in a technology neutral manner facilitating the identification of key interoperability aspects.

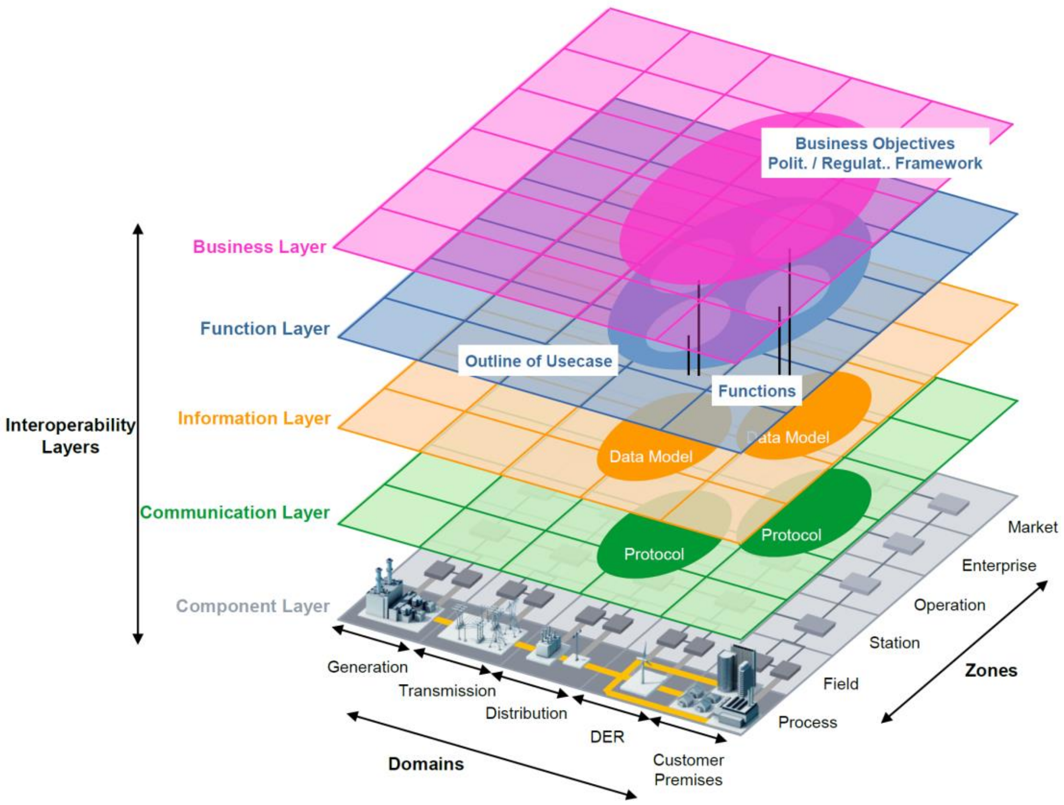

Figure 3: The SGAM framework [2]

In the domains/zones/layers of SGAM various subsets of relevant standards can be allocated. An exhaustive list of international standards and their mapping on the various SGAM domains is listed in [2].

Needs in GIFT

In GIFT project, there are two main interoperability needs:

a) The system is comprised by several modules, developed by different entities in need of information sharing, so that its functions can be fulfilled: Grid Observability, Prediction, GIS TWIN, etc.; whilst external systems need to be interfaces as well: MDMS, SCADA, weather services. This is tackled by the Enterprise Services Bus (**ESB**) developed by ICOM.

2.1.1.1. Grid Observability System and several EMS systems from different manufacturers must communicate with the same trading system – this is tackled by the **Flex Agent** elements using the **xEMS communication protocol** for communication between xEMS and Flex Agent, and the **Flex Offer** protocol for communication between VPS and Flex Agent (towards xEMSs and Grid Observability System), both developed by INEA.ESB

The information exchanges identified so far in GIFT, especially those exchanged with the different stakeholders and components of the energy system could follow the aforementioned standards.

For example, if it was chosen to follow the information model for measurement data described in CIM (i.e. IEC 61968-9), will increase the interoperability of the ESB and the components receiving data from metering units.

In addition, one must notice that the existence of information models for some type of information, such as forecast is not available in CIM. Nevertheless, CIM is highly extensible, hence existing classes of the standard can be utilized as a basis for structuring new information models.

2.1.1.2. Flex Agent, xEMS communication protocol and Flex Offer

Interoperability applies to FlexAgent, which connects external Energy management systems (EMS) at prosumer's level to VPS. These EMS systems are:

- Ship/Harbour EMS – battery,
- Electric vehicles + Charging stations,
- Factory / Commercial EMS – virtual storage – energy shifting in time and adapting energy,
- Smart Energy Hub – Battery and Hydrogen storage system,
- H-Br battery storage – "flow" battery.

Additionally, this dedicated Flex Agent is used for the connection of grid operator control system with the open market (VPS).

Flex Agent needs to address technical specifics for all system components and solutions at prosumer's level and properly translate them into communication parameters. This will lead, if required, to the upgrade of xEMS communication protocol with introduction of new identified parameters, adapted to technical properties of different EMS solutions and underlaying components.

2.1.2. Main measures to apply

2.1.2.1. ESB

Define a consolidated model of information exchange (Canonical Data Model) for information exchange with the ESB.

Survey if technology providers are interested in engaging in a CIM based design, hence increasing the interoperability of the overall solution.

2.1.2.2. Flex Agent and Flex Offer

Flex Agent needs to implement measures that will provide a complete and operational solution. This comprehends the hardware, a detailed definition of communication protocol, a physical layer and an informational one (such as Modbus TCP/IP, Modbus RTU (RS-485), JSON (REST or MQTT).

The importance of Flex Agent interoperability between building blocks is shown in GIFT System Architecture. On Figure 4 dashed red lines represent the system components using Flex Offer protocol as an exchange protocol and dashed green line represents xEMS communication protocols. Flex Offer protocol was initially developed in project MIRABEL and further enhanced in project GOFLEX .

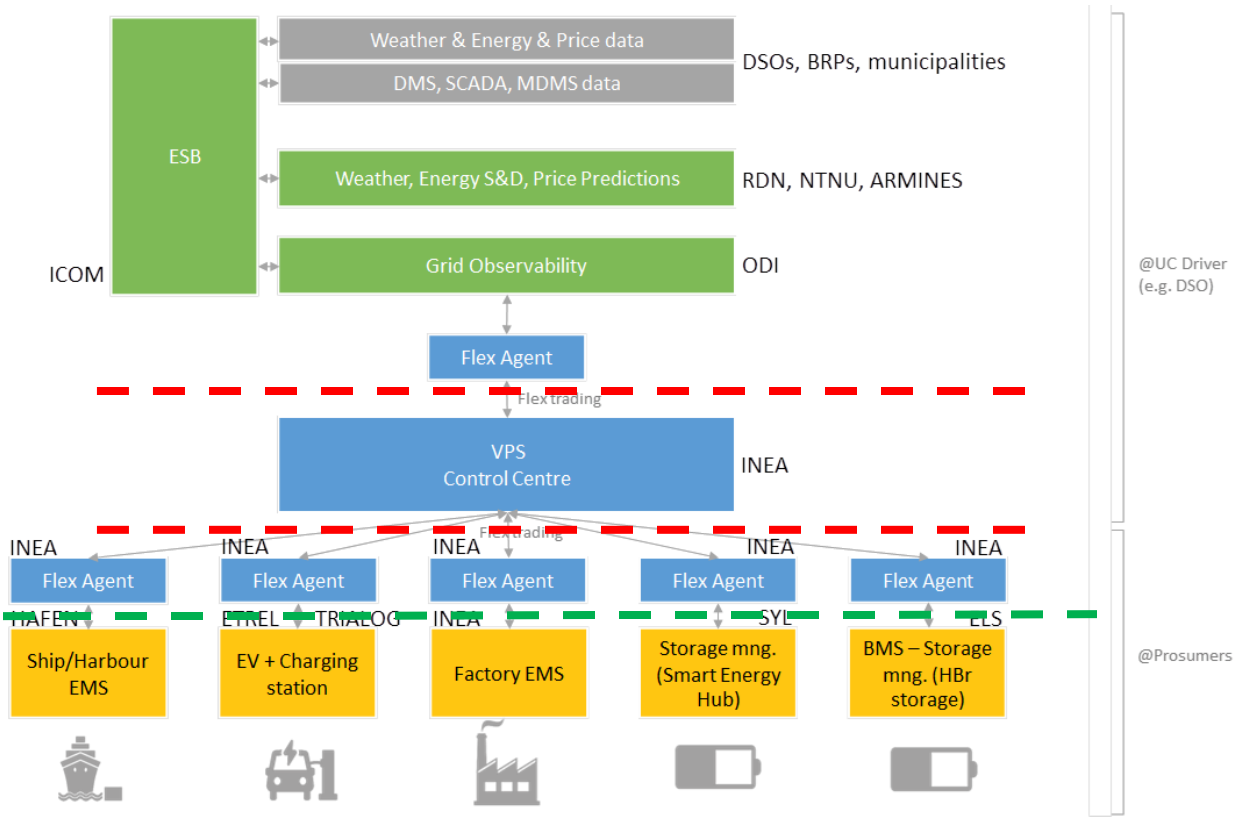

Figure 4: GIFT generic system architecture

The interoperability on prosumers level/location (different types of prosumers) is provided by the Flex Agents. They address different types of prosumers. That approach provides the potential for further expansion of the solution – the technology is interoperable and can include different types of prosumers.

On the higher level, modification of Flex Offer protocol with additional parameters for flexibility pricing is used for communication between VPS and Grid Observability system.

2.1.2.3. Summary

Table 1: Sub-requirements for Interoperability

ID	Description	Actors
Req. 1.1	Define a consolidated model of information exchanges (Canonical Data Model)	ESB
Req. 1.2	Survey if technology providers are interested in engaging in a CIM based design	ESB
Req. 1.3	Implement measures for hardware, detailed definition of communication protocol, physical layer and informational level, that will provide complete and operational solution.	FlexAgent

2.2. RESPONSE TIME

In smart grids the different components can introduce delays in their response which may result in sub-optimal, erroneous or unstable behaviour of the system. Thus, the corresponding components used in GIFT should meet some specific response time requirements. These requirements are analysed in the following sections.

2.2.1. Energy sector specificities

It can be safely assumed that the three main categories of components in a smart grid are control, communication and power components. Each of these components introduces a time delay in the process which may result in erroneous behaviour. Also, from a process phases point of view we can assume that in smart grids we have scheduling, and activation of flexibility as two distinct phases. Depending on the type of components and different process phases there are different response time requirements even though there is not a systematic approach with regard to every existing application. There are, however, in literature specific requirements with regard to activation time of flexibility for various types of ancillary services as defined in [4] and [5] as well as the scheduling time defined in [6]. These requirements are considered in order to determine the response time requirements of the GIFT solutions. A more analytical presentation of these requirements is given in Annex A.

2.2.2. Needs in GIFT

According to the selected UCs for demonstration GIFT deals mainly with procedures related to the Active Energy Flexibility. In such case the activation timescales of the various DER will range from 1hour and above even though the scenario of 15min activation and below should not be excluded. In this regard we should consider the minimum activation time as worst-case scenario for the response time requirements of the components. Also, the GIFT solutions deal mostly with the scheduling phase of the process rather than the real-time activation of flexibility which means that the response requirements are mostly related to the communication and control components and only partly to the power components. For the scheduling procedure we should consider a worst-case scenario in which the process is Intra Day with 1-hour minimum time horizon between scheduling and activation of flexibility. Depending on the temporal resolution of flexibility the scheduling procedure may be either 1 hour or 15 minutes, and going down to a few minutes (1 min) in future evolution of flexibility trading based on dynamic prices. As it can be seen in Figure 4 the composite system consists of various power components, control blocks and communication channels. During the flexibility activation time, the power components need to respond fast enough in order to avoid deviations between the scheduled and delivered energy during the activation time. As can be seen in Figure 5 a time delay in the response of a DER unit such as the ramp-up time may result in a deviation from the requested energy for the specific timeframe. This deviation if aggregated for all prosumers may have detrimental effects on the grid (i.e. congestion state or voltage deviations could be deteriorated instead of improved).

The response times discussed above are applicable to active energy flexibilities. The specific needs of reactive energy trading will be addressed within the design phase of concrete demonstration case.

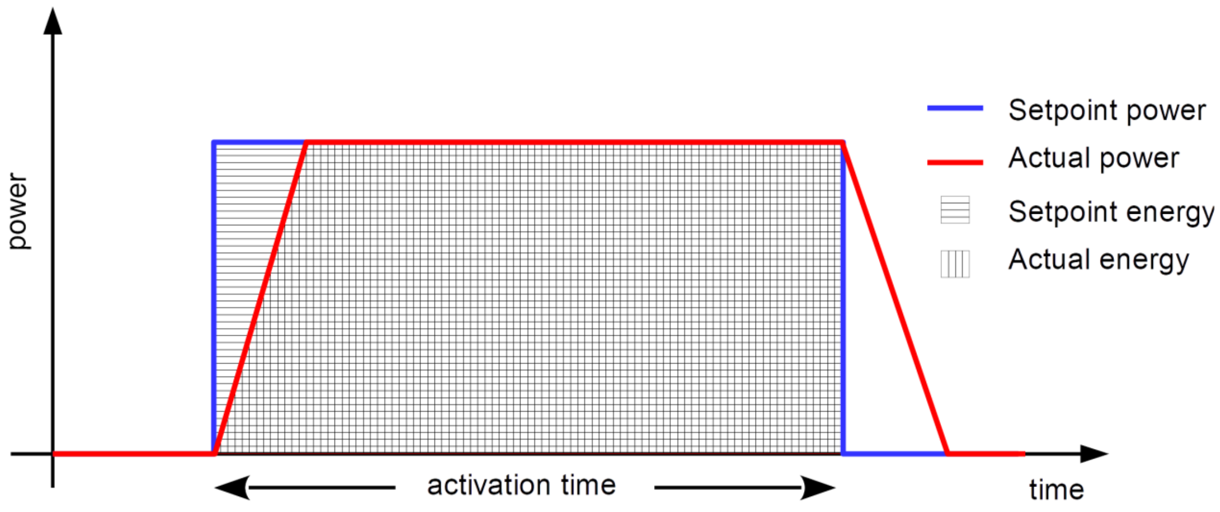

Figure 5: Example showing the influence of time delays in the energy delivery deviation

The DER components used in our demonstrations are Battery Energy Storage Systems (BESS), Electric Vehicle charging stations, Industrial / Commercial prosumers and electrically supplied ships. Each of these units communicate with a local Energy Management System (EMS) which specifies the set-points or schedule of active/reactive power in order for the unit to deliver/consume a specific amount of energy. Technologically speaking all these units, and in particular the batteries, shall have response times to set-point changes in the timescale of less than one second because they are interconnected to the grid via power electronics.

For example, the Sylfen hydrogen rSOC system module, due to electrochemical and thermal limitations, reacts in less than 1 hour. As the Sylfen system contains both technologies, the response time will be less than 1 sec for the battery module (up to +/- 25 kW depending of the state of charge, then the rSOC module will join the battery with a power of (+5 kWe max in fuel cell mode and – 40 kWe in electrolyser mode). Considering now that the activation time is in the scale of hour(s) (or 15 min; or 1min) it is self-evident that the response time of the selected DER is rather negligible. Also, the time delay to communication between the local EMS and the corresponding DER is significantly less than this activation time. Thus, it has minimal impact on the overall system behaviour.

This is also the case for the Elestor battery that has a technical response time that is between a part of a second and, in case the battery is in a standby mode where its electrolyte pump is switched off, potentially a few seconds. It will be possible to control in which standby mode the battery is made available. Also, in these operative modes, the response time is significantly less than the required scale of the activation time.

A similar observation is valid also for EV charging system. The reaction time of EV battery management system is negligible – the charging power is modified according to load set point received from EV station within few seconds. Some delays can be experienced if there are several EV stations installed at the same final customer (i.e. fed via the same grid connection point). In this case the charging system must distribute the EV charging set point (which is common for all current charging sessions) to individual EVs (charging sessions). The algorithms used for distribution of common required load to individual sessions are quite complex and involve user needs (delivery of required amount of energy till departure time), technical characteristics (rated current, number of phases) of power supply, EV chargers' components and charging cable, and technical characteristics of EV on-board charger (number of phases, rated current/phase). The calculation might take several (<5) seconds.

During the scheduling phase, on the other hand, various control blocks interact with each other in order to do the following actions:

- Observe the power grid
- Forecast supply and demand as well as market parameters
- Negotiate/trade flexibility
- Dispatch commands on energy setpoints

Component	**Iteration**	**Activation horizon**
VPS (including negotiation and commands dispatching)	5min, 15min, 1hour or 1day	5min, 15min, 1hour or 1day
Observability	5min, 15min, 1hour or 1day	5min, 15min, 1hour or 1day
Forecasting	5min, 15min, 1hour or 1day	5min, 15min, 1hour or 1day
GIS Twin	5min, 15min, 1hour or 1day	5min, 15min, 1hour or 1day

Table 2: Indicative iteration and implementation times for the various ICT components

All these actions can take place either within the same timeframe or in different timeframes as can be seen in Table 2. Also, these procedures can take place in a specific number of timeframes (implementation horizon) before the actual implementation of flexibility. If we assume as commonly used time frames the duration of 5min, 15 min, 1 hour and 1 day and the same intervals as implementation horizons too, we can assume that the worst-case scenario in terms of response time for these components is the one with the shortest timeframe (5min, 15 min) for all components. In this scenario within an interval of 5 or 15 minutes the various blocks perform all four of the abovementioned actions sequentially like in the example of Figure 6. According to this example the actions start at the beginning of the timeframe. In the upper diagram the timely completion of the actions is shown. In this case the completion of actions and the setpoints dispatching takes place timely, before the end of the timeframe. In the bottom diagram, we assume a delayed response due to one or more of the components. It is obvious that the whole procedure in this case ends after the end of Timeframe_n leading to dispatching setpoints from one timeframe to the next (Timeframe_{n+1}). Things can be deteriorated even more in the case where scheduling should take place shortly before the activation time.

It is worth noting here that the communication latencies during this phase are expected to be rather negligible (timescale of sub-seconds) compared to the response time of the various algorithmic blocks.

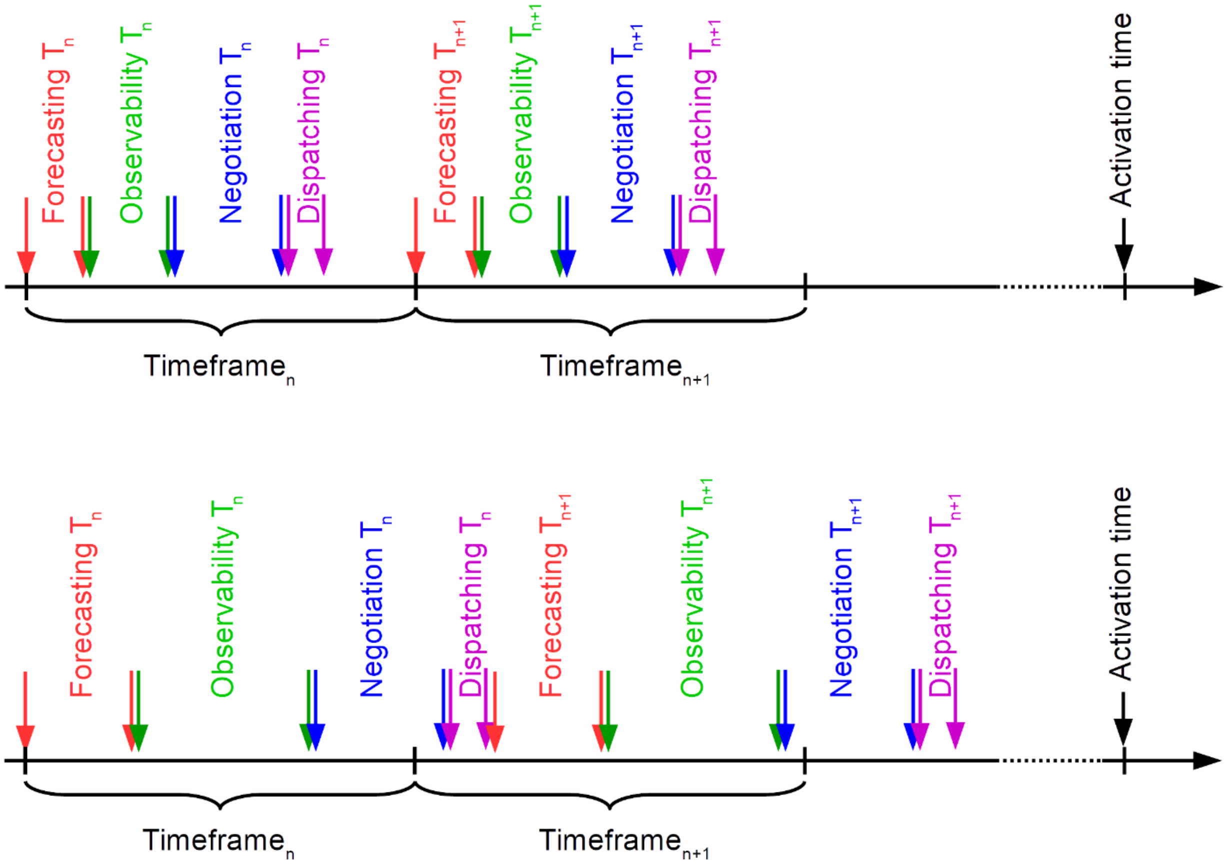

Figure 6: Examples of timely (up) and delayed (down) completion of actions during a timeframe

2.2.3. Main measures to apply

Considering the concepts presented in the previous two subsections we can assume some concrete requirements regarding the various GIFT components. It is noteworthy here that the response time of the power components could result in overshoots of power due to oscillations around the setpoint especially in step changes. Because of that in some cases the introduction of ramp-up or down time limitation may be beneficial. In any case, in order to ensure that there is no impact on the flexibility activation the total response time of the subsystem EMS+DER should not exceed 5 seconds which is <1% of the typical minimum activation time (15min). We can assume that an acceptable response time of <1% should apply in any implementation scenario even for longer time steps. If time delays during activation are inevitable, they should be accounted for the resulting energy in order for the dispatching algorithm to be able to compensate them.

Concerning the response of control components including forecasting, observability, negotiation of VPS with agents etc., and in order to be able to implement some fine-grained scenarios with timeframes below 15 min, the aggregate time of the whole procedure should be < 5 min. Therefore, the implemented algorithms should be optimised in terms of computational time to the extent that this is possible. It should be noted that no significant issues are expected concerning this part during the implementation phase of GIFT. Also, the latencies of the communication components should be at the scale of sub-second. Table 3 summarises the requirements with regard to response time.

ID	Description	Actors
Req. 2.1	Ensure that the total response time of the subsystem EMS+DER does not exceed 5 seconds.	EMS, DER
Req. 2.2	Account for time delays during activation in the resulting energy.	Dispatching algorithm
Req. 2.3	Ensure the aggregate response time of the whole procedure of control components is less than 5min.	Observability system, VPS
Req. 2.4	Ensure the latencies of the communication components are at the scale of sub-second.	ESB, FlexAgent

Table 3: Sub-requirements for Response time

2.3. COMMUNICATION SECURITY

Cybersecurity in energy sector projects is essential, as cyberattack on the communication medium of a device could lead to an outage, and possibly cascading effects. Therefore, the communication security is required to be considered and specified in all the solutions that will be deployed within the project GIFT.

2.3.1. Energy sector specificities

The energy sector has some specificities that have to be considered when designing the communication security, and it needs to stay secure and operable under any circumstances. These specificities should be addressed while designing the communication devices and security protocols. According to the Commission Recommendations on cybersecurity in the energy sector published by the European Commission [7], three main specificities should be considered:

- Cascading effects: in energy networks, a fault at one device can have repercussions in the overall network.
- Legacy technology: the legacy of devices that have a lifetime of 30-60 years have to interact with the most recent technologies.
- Real-time requirements: many devices in the energy sector must respond in real-time, which puts a very high constraint to the overall system.

Depending on the context, additional specificities should be considered, such as availability: energy systems communication networks need to stay available and operable, even when external communication networks are down.

2.3.2. Needs in GIFT

The security in communications in GIFT extends from communication between devices to communication among systems. These are enabled by two systems: the ESB handles the communication at the level of the control centre, among the Prediction system, the Grid Observability system, and the systems of BRP, DSO and municipalities (e.g. MDMS) as well as external systems (e.g. weather services); the Flex Agent manages the communication between the VPS and the flexibility providers and Grid observability system. Moreover, the EMS systems ensures the communication to the field devices, and therefore are concerned by the communication security issues.

Secure communications must be established among the above elements as well as to interfaces to end-users.

2.3.3. Main measures to apply

The solutions should ensure physical devices, communication protocols and stored data are protected against cyberattacks. This implies at least implementing the following measures.

The following standards should be considered to implement the cybersecurity measures within the GIFT Project:

- The Cybersecurity Act [8] aims to share a common cybersecurity framework within the EU. It also provides a certification framework [9].
- ISO/IEC 27100 Cybersecurity – Overview and Concepts, ISO/IEC PDTS 27101 Cybersecurity Framework Development Guidelines [10]
- ISO/IEC 27103 Cyber security and ISO and IEC standards [11] providing guidance on how to leverage existing standards in a cybersecurity framework
- IEC Technology Report: Cyber security and resilience guidelines for the smart energy operational environment [12]

2.3.3.1. Physical measures

Flex Agent and the ESB potentially need to communicate with some legacy devices/systems (i.e. MDMS). Therefore, they should ensure that devices added to sites including legacy devices have a level of security adapted to the site criticality.

For legacy devices, additional (local) proxy/firewall physical devices may be required to achieve the required level of security. Then physical protection will be required to secure the link between the proxy device and the legacy device. Moreover, critical nodes within the system should be identified, as candidate for addition of redundancy nodes.

2.3.3.2. Protocols

The communication protocols among systems in GIFT solution like the ESB, Flex Agent, VPS should apply at least the following principles, in order to ensure a sufficient level of security:

- Choose secure communication protocols, with encryption etc. for guaranteeing confidentiality of information exchanged, e.g. using cryptographic protocols over HTTP.
- Follow best practice in certificate management for digital certificates,
- Follow standards practice like the one suggested in ISO/IEC PDTS 27101 Cybersecurity Framework Development Guidelines based on ISO/IEC 27100 Cybersecurity – Overview and Concepts [10].
- Introduce authentication, authorisation and revocation mechanisms

The entities should implement the proper identification and alarming processes for extraordinary events like communication breakdown, data loss, authentication failure, etc.

2.3.3.3. Conservative approach of controlling algorithms

The communication protocol and controlling algorithms in VPS and Flex Agent should preserve the end user load and electricity grid in case of extraordinary events like communication breakdown. If this happens, the default behaviour of prosumer EMS controlling algorithms should override any information from Flex Agent and avoid propagating the damage to the user equipment. It should control the system as was before the introduction of Flex Agent to offer flexibilities. This is in the scope of EMS system provider.

2.3.3.4. Anomaly detection from data

For devices that are not able to provide cryptographically secure computation capacity, particularly those legacy devices, attacks on the data integrity should be modelled and methods for anomaly detection from data stream should be designed and deployed to address these adversarial models.

2.3.3.5. Summary

Table 4: Sub-requirements for Communication Security

ID	Description	Actors
Req. 3.1	Ensure new devices have a level of security adapted to the site criticality	Flex Agent
Req. 3.2	If necessary, to achieve the required level of security, add an additional (local) proxy/firewall device for legacy devices, and physical protection to secure the link between the proxy device and the legacy device.	Flex Agent, ESB
Req. 3.3	Choose secure communication protocols, with encryption etc. for guaranteeing confidentiality of information exchanged.	Flex Agent, ESB
Req. 3.4	Introduce authentication, authorisation and revocation mechanisms	Flex Agent, ESB
Req. 3.5	Identify critical nodes within the system, as candidate for addition of redundancy nodes	Flex Agent, ESB
Req. 3.6	Implement the proper identification and alarming processes for extraordinary events	Flex Agent, ESB
Req. 3.7	Preserve the end user load and electricity grid in case of extraordinary events	EMS
Req. 3.8	Model attacks on the data integrity for devices that are not able to provide cryptographically secure computation capacity and design and deploy methods for anomaly detection from data stream to address these adversarial models	Flex Agent, EMS

2.4. PRIVACY AND DATA PROTECTION

The data that will be used in this project needs to be handled with precautions in order to ensure the respect of the privacy of the users and the confidential data of companies.

2.4.1. Energy sector specificities

The main objective of the GIFT project is to decarbonise the energy mix of islands. This general ambition is supported in the project by the following clear, measurable, realistic and achievable objectives:

- Allow a high level of local renewable energy sources penetration
- Provide visibility of the energy grid to better manage its flexibility and plan its evolutions
- Develop synergies between the electricity, heating, cooling, water and, transport networks
- Reduce the use of hydrocarbon-based energies
- Ensure the sustainability of the solutions and their replicability in other islands

In order to achieve these objectives, the GIFT project will have to collect data related to the following fields: energy, transport (mobility), weather and climate change.

The energy data, as described in the Data Management Plan, are for some of them private data of the consumers and companies. These can be considered critical data in terms of privacy and should therefore be handled with precautions.

2.4.2. Needs in GIFT

In the GIFT project, energy data are collected and handled by the Weather, Energy, S&D, Price Predictions systems developed by RDN, NTNU and ARMINES, and by the Grid observability system performed by ODI. Those information flows are facilitated by ESB (ICOM), flexibility and price data are collected and used by the VPS (INEA).

Moreover, the ESB and Flex Agents systems are used for communication between devices, and therefore handle sensible data.

All data in energy flexibility trading are contractual data between the trading parties and access to them is limited to these parties.

The following standards should be considered to implement the data protection measures within the GIFT Project:

- GDPR [13] for data protection and storage
- ISO/IEC TR 27019 [14] Information security management guidelines based on ISO/IEC 27002 for process control systems specific to the energy utility industry (for controlling and monitoring the generation, transmission, storage and distribution of electric power, gas and heat in combination with the control of supporting processes).
- ISO/IEC 29101Privacy architecture framework (focusing on ICT systems that are designed to interact with PII principals) [15]
- ISO/IEC 27018 Code of practice for PII protection in public clouds acting as PII processors [16]

2.4.3. Main measures to apply

2.4.3.1. Data collection, handling and storage

The project will avoid and prevent any unnecessary collection, use and storage of personal data. In case personal data are nevertheless processed, ethics requirements in this regard will be taken into account, especially in regard to the GDPR [13].

The personal data and data concerning privacy that need protection should be identified, then, depending on specific types of data and their usage, adapted methods for protecting them should be adopted, such as data aggregation, homomorphic encryption, blind signature, or local energy cache units. All contractual data will be protected through access and retrieval rights.

2.4.3.2. Data communication

When applicable, only aggregated data will be transmitted between nodes, reducing the amount of personal identifying data exchanged.

All data will be protected during transit.

Table 5: Sub-requirements for Privacy and Data Protection

ID	Description	Actors
Req. 4.1	Avoid and prevent any unnecessary collection, use and storage of personal data	Weather, Energy, S&D, Price Predictions system, Grid observability system, VPS, Flex Agent, ESB, GIS Twin
Req. 4.2	Take into account ethics requirements when processing personal data, especially in regard to the GDPR	
Req. 4.3	Identify the personal data and data concerning privacy that need protection	
Req. 4.4	Adopt adapted methods for protecting data, depending on specific types of data and their usage.	
Req.4.5	Adopt methods for access and retrieval rights of all contractual data in flexibility contracts	Flex Agent, VPS, Price Predictions system, Grid observability system, ESB
Req. 4.6	When applicable, only transmit aggregated data between nodes.	Flex Agent, ESB, GIS Twin
Req. 4.7	Protect all data during transit.	Flex Agent, ESB

2.5. ACCURACY

The GIFT system modules that must comply with accuracy requirements are the grid observability module and the forecasting module. They should be accurate enough to be able to detect congestion in advance and avoid blackouts.

2.5.1. Energy sector specificities

In the case of grid observability system, the estimated parameters are the voltage plan and the load of defined critical assets. A voltage or power flow value is detected as a violation of the requirements if it is out of the range of limits defined by the regulatory entity or the safety rules. Those limits are specific to each demonstration site.

In the case of forecasting energy supply and demand, the error metric is inherently dependent on the type of system being forecasted. The error of an aggregation as a National power system or a single household have different ranges. For example, in [17], the Mean Absolute Percentage Error (MAPE) ranges between 1%-2% for wide areas and between 20%-100% for individual consumers. Hence, for each one of the systems being assessed, a relative improvement should be used comparing with a reference forecast result (or persistence in the absence of one).

2.5.2. Needs in GIFT

GIFT project will establish a (near) real-time market of flexibilities. One of the needs of this market is to know when problems will occur on the grid (congestion, voltage excursion, etc.) and what flexibility is needed to solve the problem.

The module “Modelling and observability of the grid” contributes to fulfil those needs and the main objective of the project that is to decarbonise the energy mix of islands and is in particular highly linked to the specific objective SO2: “Provide visibility of the energy grid to better manage its flexibility and plan its evolutions”.

This module will also contribute to the specific objective SO1 which is to “allow a high level of local renewable energy sources penetration”, by enabling the use of flexibilities to solve congestion issues that renewable energy sources might create on the grid.

The grid observability system will be used in GIFT project’s use cases to estimate voltage and current congestion and to select the flexibilities to be activated to avoid and to mitigate these congestions.

The forecasting module addresses the specific objective SO2: “Provide visibility of the energy grid to better manage its flexibility and plan its evolutions”. It provides short-term forecasting of energy supply and demand, as well as day-ahead foresight on the prosumers’ opportunities for providing flexibility. These forecasts are necessary to inform the negotiation in the local markets.

2.5.3. Main measures to apply

2.5.3.1. The first step is to provide a grid model: cf. deliverable 3.3

Network topology

- The network topology is obtained by analysing the relationships between voltages: the closest voltages are, the closest the corresponding meters are. The influence of the medium voltage brings complexity in this analysis as its fluctuation is important compared to the variation due to the low voltage network. Several processes are used to remove this influence, to ensure the obtained topology is radial, and to connect the three phases within the feeders.

Influence Matrix

- The influence matrix is built to show the influence of the power consumptions / productions on the voltage map. The difficulty here is to only keep the direct connections: if A influences B and C, then B and C are correlated, but that does not mean there is a direct link between them. Then, the challenge is to find for each voltage, which power values are necessary to explain its fluctuations.

Network model

- In order to comply with the operational constraint which is the unavailability of smart meters data in real time, another feature needs to be built. The new model should indeed be able to provide this same estimation of the voltage map but using only the data of some selected smart meters – the ones providing flexibility as they will send information to the control centre – and the data coming from the substation. The challenge here is to be able to estimate the whole voltage map only from few measurements. This will be done by relying on the previously found “influence matrix”, that gives us the network behaviour.

2.5.3.2. Second step flexibility operation

This operation follows the scheme described in Figure 7. Both Forecast and Network model will be used to predict the status of the grid in real time and in the next time step and to estimate the impact of the activation of a flexibility on a given forecasted issue.

The visualisation part described in Figure 7 does not interfere with the operation of the system but allows the user to see the main part of the process and assess its relevance.

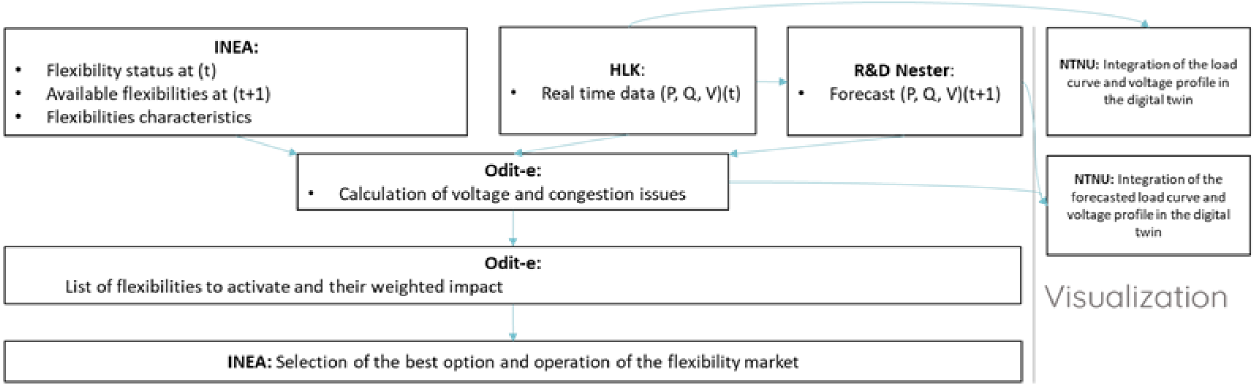

Figure 7: Data exchange in relation with the operational phase

2.5.3.3. Accuracy requirements for the two steps

The issue at stake with the accuracy in the flexibility market is economical. The more accurate are the prediction and estimation, the smaller the flexibility to be activated will be. Therefore, the value for money of the market for the DSO will be higher.

As described in the energy sector specificities, voltages must be maintained within the limits given by the regulator while loads must be kept within the defined safety conditions of the critical asset.

The whole accuracy is impacted at each level by the accuracy of each module:

Figure 8: Accuracy implications at module level

For instance, the first experimentation on the grid of Hinnøya shows that the modelling by itself will generate an error on the voltage prediction of less than 2V at LV level (400/230 V). Considering this accuracy, keeping the voltage plan within the limits requires an accuracy from the other modules, including the activation of the flexibilities, small enough to keep the global chain in a level of accuracy that allows the operation of the system.

2.5.3.4. Measuring the accuracy of energy supply and demand forecasting

Forecasting of energy supply and demand is measured by a relative comparison between the accuracy of the GIFT forecasting system and some reference method (persistence method, in the absence of other), on the same application. This is because the accuracy range varies significantly depending on what is being forecasted [17], [18]. This means that absolute accuracy targets should vary accordingly. To reflect this requirement, it is proposed that the GIFT forecasting solution improve the reference method in each area by 10%.

Another relevant aspect to the accuracy measurement is the fact that MAPE cannot be calculated in certain applications. By definition, this error measure cannot be applied to quantities with zero real values. Nevertheless, in these cases Root Mean Square Error (RMSE) is going to be used.

2.5.3.5. Measuring the accuracy of state estimation

As the state estimation system is a machine learning based algorithm, it will constantly learn from the comparison of its state estimation results with the real value. The error will be monitored to adjust the model. To communicate and follow the accuracy of the model, MAPE over a defined period will be used.

The objective set for the GIFT project is linked to the frequency of valid prediction of a congestion, so the flexibilities are purposefully activated. This metric will be monitored as well, and the objective is to keep it over 90%.

2.5.3.6. Measuring the accuracy of flexibility impact study

The accuracy of the impact study is critical in order to activate the relevant flexibility and solve the previously forecasted issue. This accuracy is part of the KPI 1.2 “Avoid congestion: reduction of peak demand” which refer to a global objective of the project as voltage issues are being considered too. It will be measured comparing the forecasted impact with the real impact monitoring the MAPE at each activation of a flexibility and comparing it with the MAPE of the state estimation without the activation of a flexibility.

2.5.4. Main measures to apply

Table 6: Sub-requirements for Accuracy

ID	Description	Actors
Req. 5.1	Keep error levels form other modules small enough to keep the global chain in a level of accuracy that allows the operation of the system	All components
Req. 5.2	GIFT forecasting solution should improve the reference method in each area by 10%	Forecasting solution
Req. 5.3	Use Root Mean Square Error (RMSE) when MAPE cannot be calculated.	Forecasting and observation systems
Req. 5.4	Monitor the error to adjust the model using MAPE over a defined period	Forecasting and observation systems
Req. 5.5	Keep frequency of valid prediction of a congestion over 90%	Forecasting and observation systems
Req. 5.6	Measure voltage issues comparing the forecasted impact with the real impact monitoring the MAPE at each activation of a flexibility and compare it with the MAPE of the state estimation without the activation of a flexibility.	Forecasting and observation systems

2.6. EQUITY

The different flexibility providers should be transparently requested and rewarded. This should be taken into account regardless of their source type, technical specifics and type of prosumer (i.e. household, corporate, business entity …). We have taken into account the assumption that price mechanism will properly address CO_2 free flexibility. Non-CO_2 free prosumers will not be price competitive on the market due to fuel costs,

CO_2 coupons and other possible green policy mechanisms. However, in the project we aim at CO_2 free flexibility prosumers already during prosumer acquisition.

2.6.1. Energy sector specificities

The economy and cost optimisation are the key element of the energy generation and distribution therefore this needs also to be taken into account at flexibility assignment [19]. The following issues need to be considered at prosumer's flexibility activation:

- Like ordinary sources, the flexibilities should also have cost assignment and the system may provide the corresponding preference when generating adaptation requests to optimise cost. Grid operators can use flexibility offered by prosumers to solve issues on the grid if this is cost effective or improve grid operation.
- The location of the prosumer also influences the prosumer's selection and their reward if it causes an additional cost for energy transport to the location of transient. This same location has an influence on the ability of the flexibility to solve the voltage or congestion issue. The assessment of the impact of the activation of a flexibility provision should be constantly done and its value shall be communicated to secure transparency in the selection process.
- The flexibility selection process is running regularly.
- The reliability of the prosumer adaptation may significantly affect the efficiency of the system and equal participation, therefore this element also should take part in the selection and rewarding.

2.6.2. Needs in GIFT

The described equity requirements apply to the Flex Agent, VPS and Grid Observability:

- The Flex Agent assigns the price to the prosumer flexibility.
- The flexibility market component in VPS selects the flexibilities for adaptation.
- The Grid Observability System has access to data so it can rank the prosumers according to their location by costs of energy transfer to the topological location of congestion or disbalance.
- The prosumer should supply the accounting energy/power according to the timeframes defined in the Response time requirement.

2.6.3. Main measures to apply

The solution in GIFT needs to implement the following measures:

- The price parameter of the flexibility should be accessible by its issuer – the prosumer. The prosumer should be able to set up its own price policy at participation on the market.
- The GIFT flex energy activation should be based on cost to enable its user (grid operator) to compare its effect to other available mechanisms, and on usage prediction and utilisation rate.
- The grid observability should provide a ranking of the prosumers according to their location, which would enable to estimate grid transport cost dependant on the prosumer's location.
- The algorithm for measuring the adaptation realisation should be used to measure the adaptation effect and prosumer's reliability. The algorithm should be simple and verifiable by the prosumers.
- The algorithm for measuring the ability of a flexibility to solve a grid issue should provide feedback to assess transparently its accuracy and legitimate the use of a weighting system to compare different offers.

Table 7: Sub-requirements for Equity

ID	Description	Actors
Req. 6.1	Make the price parameter of the flexibility accessible by its issuer – the prosumer.	FlexAgent, VPS
Req. 6.2	Ensure that the prosumer is able to set up its own price policy at participation on the market.	FlexAgent, VPS

Req. 6.3	Ensure that the GIFT flex energy activation is based on cost to enable its user (grid operator) to compare its effect to other available mechanisms	FlexAgent, VPS
Req. 6.4	Provide the information about grid transport cost dependent on the prosumer's location	Grid observability system
Req. 6.5	Use algorithm for measuring the adaptation realisation to measure the adaptation effect and prosumer's reliability.	FlexAgent, VPS
Req. 6.6	Ensure that the algorithm is simple and verifiable by the prosumers	FlexAgent, VPS
Req. 6.7	Provide assessment of the effectiveness of the weighting system between offers to solve voltage issues.	Grid observability system

2.7. VISUALISATION OF FLEXIBILITY INCENTIVES

Monitoring of the demand response process requires the proper information visualisation from the various components. The visualisation is needed by the users (grid operators) as well as by the prosumers [20]:

- The visual information should enable the prosumer to inspect the actual and future status of its adaptation capacity, realisation of requirements for adaptation and amounts of incentives.
- The user should get the proper aggregated information of the system's adaptation capacity and adaptation realisation.

The visualisation should consist of graphical elements like line charts, bar charts, …, as well as textual elements like tables, messages, etc [21].

2.7.1. Energy sector specificities

In Europe, the level of information in the energy bills just matches the minimum legal requirements imposed by national regulations. Such a scarcely understandable information does not motivate consumers to reflect on their level of energy consumption, pattern and possibility to act on it. This occurs for the current energy bill. While, the incoming further services to be accounted and displayed such as the flexibility pose further challenge. The information in flexibility consists of the energy and price which should be reflected also in visualisation. It should provide real time or near real time information of energy and cost status of the flexibility flow and its realisation.

The presented information should use the elements of the organized market. The visualisation should clearly present the direction of the energy flow – distinction between production and consumption, with matching prices.

2.7.2. Needs in GIFT

A more user-friendly information presentation on the energy bill may induce increased awareness, laying the grounds for behaviour changes required to achieve the goals of renewable energy penetration in the market. Furthermore, some new version of energy bill in terms of structure and time resolution as well as interaction with home automation should be made up. This change can allow algorithms to dialogue, using more precise information.

The visualisation algorithms need to be applied to the VPS's flexibility manager component to offer the corresponding monitoring of the adaptation capacity, participating prosumer status and operation of the whole VPS.

The Flex Agent should offer the flexibility and adaptation information for the individual prosumer. The prosumer should be able to receive the visual information about offered energy with price and required operation schedule.

2.7.3. Main measures to apply

The VPS's flexibility manager component should offer the web application enabling concurrent access from several users. The web application forms shall support monitoring the real time information by regular content refreshing, as well as easy and fast access to the historical information. The presented information should handle information from a large number of prosumers. The introduction of hierarchical structure and various types of grouping enables the user fast and user-friendly access to required information. The component should offer the reporting service providing the proper information about the past operation and generated incentives/costs. Where the Energy Management Systems will be applied, communication protocol should be considered to deliver data and meta-data to inform the prosumers that can provide the flexibility to help them manage their electrical loads and production units.

The Flex Agent component offers web access for the Flex Offer process monitoring. The information available should present the status of the sent Flex Offers and received schedules. The component should enable the presentation of the history operation and assigned incentives.

GIS Twin will present the historic, real time and forecasted information of Grid and demand. When Flexibility information is required by DSO, the GIS Twin will present monitoring information at map.

Table 8: Sub-requirements for Visualisation of flexibility incentives

ID	Description	Actors
Req. 7.1	Offer the web application enabling concurrent access from several users	VPS
Req. 7.2	Support monitoring the real time information by regular content refreshing, as well as easy and fast access to the historian information	VPS
Req. 7.3	Handle information from a large number of prosumers	VPS
Req. 7.4	Offer the reporting service providing the proper information about the past operation and generated incentives/costs	VPS
Req. 7.5	Deliver data and meta-data to inform the prosumers that can provide the flexibility to help them manage their electrical loads and production units	VPS
Req. 7.6	Present the status of the sent Flex Offers and received schedules	FlexAgent
Req. 7.7	Enable the presentation of the historical operation and assigned incentives	FlexAgent
Req. 7.8	Offer the historic, real time and forecasted information of Grid and demand on the map	GIS Twin
Req. 7.9	Support monitoring the real time flexibility information by request from DSO on the map	GIS Twin

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4. ANNEXES

4.1. ANNEX A: RESPONSE TIME REQUIREMENTS AND ENERGY SECTOR SPECIFICITIES

Power systems welfare requires some operation procedures that ensure stability and optimal behaviour. This requirement is becoming more challenging with the advent of RES and DER in the system. Problems like sub-optimal operation or even instabilities and blackouts are caused by deviations of the actual power flows from the predicted ones or oscillatory behaviours of controllers and subsystems. Concerning these deviations, response time of the system components plays a crucial role since it can influence the accuracy with which a component delivers specific power or even cause unstable operation in case of significant time delays.

Response time is defined as the “time a system or functional unit takes to react to an input signal” [22]. Most automated subsystems in smart grids are composite systems comprising control, communication and power components. Each of these components introduces different types of time delays in the system which can influence the time response, resulting in erroneous behaviour. Thus, the components used should ensure that the control procedures are carried out smoothly without unacceptable time delays which can lead to instabilities and blackouts of the system.

A smart grid is a composite system that incorporates various types of components in specific configurations. Even though in GIFT the exact system setup depends on and varies with the selected use cases, some generic assumption regarding the overall structure and the different types of components can be made. Therefore, we assume that our solutions consist of:

- Control components
- Communication components
- Power components

Each of these components affect the response time due to time delays they introduce. For instance, control components could introduce significant delays due to computational time required by the algorithms implemented by them. Communication parts themselves introduce latencies due to bandwidth restrictions etc. Last but not least power components can introduce time delays in their power response due to physical characteristics inductances, capacitances, mechanical constants etc. Furthermore, in most cases power components incorporate control blocks. Therefore, it is possible for a power component to introduce delays due internal controllers' delays and communication latencies. Each of these components play an important role in the response time depending on the procedure they participate in. In order to evaluate how crucial the response time can be for a process like the ones implemented in GIFT we should first divide the processes regarding flexibility management in two main phases:

- Scheduling of flexibility which happens before any activation by the system is required
- Activation of flexibility in real-time when it is needed by the system due to operating conditions

In the scheduling procedure which is more relevant to GIFT all negotiations and actions that are required for the commitment of flexibility are carried out before the actual use of this flexibility. Such procedures involve forecasting, system observability, optimisation scheduling etc. Since the actual response of power components does not take place during scheduling, the types of time delays that can influence this phase are mainly the controller and communication ones. Response time of these components may result in significant delays in dispatching the correct power setpoints to the system. If we assume that the process takes place in concrete time steps (e.g. every 1 minute) and the implemented algorithms are slow this will result in dispatching commands that correspond to one timeframe to the next ones. As a result, significant deviations between actual and forecasted power flows emerge and this can lead to either suboptimal operation or even instability and blackout of the system. On the other hand, during the activation phase we have the actual use of flexibility according to the type of service that it is scheduled for. For example, a DER unit could change its output power in a frequency deviation in case of frequency control or at predetermined times in case of balancing control in order to deliver a certain amount of power/energy to the system. During these activations, time delays from the various components can result in unstable operation. Below an analysis of requirements for each phase is provided.

Real-time activation procedures: In present-day as well as in future smart grids flexibility is a property of prosumers that can be used in order to facilitate grid operation stability at various levels and timescales. Since there are different types of services that flexibility can be used for there are also different requirements in terms of response time. These requirements are usually determined by System Operators through technical and regulatory frameworks at national, regional or pan-European level. The following diagram (Figure 9, source ISGAN [23]) illustrates the various timescales of flexibility applications. As can be seen in Figure 9, there are four different types of flexibility.

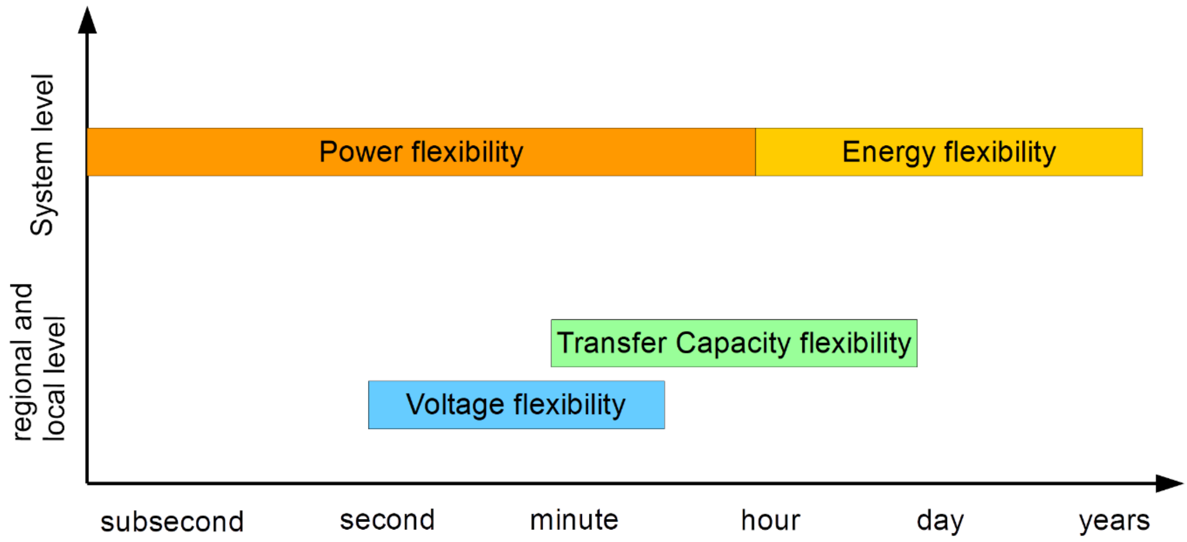

Figure 9: Activation level and timescale of flexibility in different categories of service[2]

Two of them, namely power and energy flexibility, concern the system behaviour as a whole because they can influence global system parameters such as frequency. The timescale of power flexibility activation ranges from fractions of second (i.e. synthetic inertia response) to minutes (i.e. tertiary or replacement reserves) whereas energy flexibility refers to longer activation periods. At local level the other two types of flexibility, namely transfer capacity and voltage, are of interest while their activation time is shorter than that of energy flexibility. The abovementioned activation times are indicative of the response time that is required by the constituent parts of the system. Also, in a future perspective response time of flexibility for frequency control is depicted in the following diagram [5] (Figure 10). This diagram illustrates different timescales of flexibility activation which can range from less than 1 sec for very fast acting reserves (enhanced response) to several hours referred to as reserves. It is worth noting that the division between positive and negative reserves here refers to their ability to generate or absorb power in order to arrest and restore a negative or positive frequency deviation.

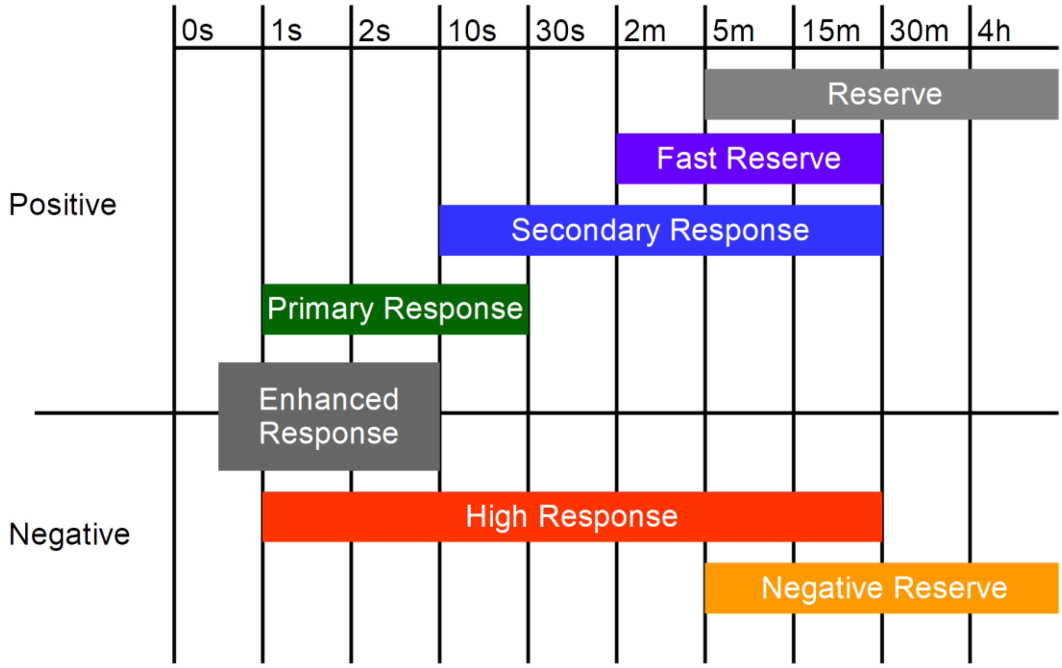

Figure 10: Future perspective on activation timescale in different categories of frequency reserves[3]

Also, specific response time requirements are defined by ENTSO-E with regard to Primary and Secondary Frequency Control [5]. For example, in the case of PFC the Frequency Containment Reserves (FCR) ought to respond to an incident as follows; a few seconds after the incident the primary controller starts its action. For 50% or less of the total FCR activation the maximum time should be 15 seconds. For the rest 50% to 100% the maximum deployment time rises up to 30 seconds, therefore FCR should be fully deployed in 30 seconds after an incident. Concerning frequency restoration, 30 seconds after the incident at the latest, the secondary controller must start the control action by change in the set-point values for secondary control and consequently Frequency Restoration Reserves (FRR) to initiate corrective control actions. As a result of secondary control, the return of the Area Control Error (ACE) must continue with a steady process of correction of the initial ACE as quickly as possible, without overshoot, being completed within 15 minutes at the latest.

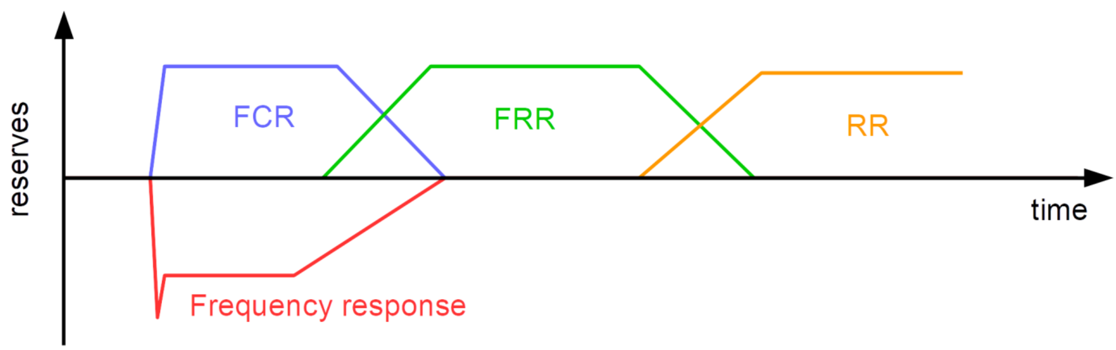

Figure 11: Indicative sequence of frequency reserves activation

Correction of ACE can also be done by means of manual FRR, thus distinguishing the latter from the automatic FRR. Also, in order to make FRRs available for possible future incidents Replacement Reserves (RR) can be used to fully or partly replace FRRs. In Figure 11 an indicative illustration of the sequence of activation is depicted.

Scheduling procedures: Scheduling in general is a highly diverse procedure in terms of response time requirements. Depending on the components used and the services that are facilitated by them, scheduling may have different temporal resolutions. However, some generally acceptable temporal resolutions for scheduling include hour(s), day(s), week(s) and year(s). More often than not, in real-life applications i.e. electricity markets Day-Ahead and Intra-Day procedures are applied in order to be in line with the market rules of each country/region. Concerning flexibility for ancillary services[5] each country in Europe follows different rules, however, we distinguish that commodities like FCR (both capacity and energy) have a resolution of hour(s) to week(s) whereas the distance between auctions and real-time use of the reserve (implementation horizon) varies between day(s) and week(s). Likewise FRR have a similar resolution and activation in real time in terms of capacity whereas in terms of energy the resolution is finer (in the scale of 15min to 1h) and the distance from the TSO activation to the real use is in the range of 1hour ahead or less.

Algorithms play a most crucial role in this phase which is rather slow. Algorithms used for example for forecasting or optimising portfolio may require significant time depending on the problem complexity and computational burden they have to deal with. As a result, these parts of the system may cause inaccuracies and significant deviations between the actual and forecasted power flows. Communication delays may also exist here even though their influence may be insignificant whereas power components do not participate by delivering power response, therefore they do not introduce time delays in the procedure except for measurements and communication signals that may broadcast.