General description of processes and data transfer within three EU-SysFlex demonstrators

Deliverable 6.4

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ABBREVIATIONS AND ACRONYMS

AMPL	A Mathematical Programming Language
API	application programming interface
BESS	Battery Energy Storage System
BUC	Business Use Cases
CGMES	Common Grid Model Exchange Specification
CIM	Common Information Model
CIM2PPconverter	Common Information Model to pandapower converter
DER	Distributed Energy Resources
DSO or DS_O	Distribution System Operator
EQ	Equipment profile
EU-SYSFLEX	pan-EUropean SYStem with an efficient coordinated use of FLEXibilities for the integration of a large share of renewable energy sources
ftp	file transfer protocol
ftps	file transfer protocol secure
GRIB 2	General Regularly-distributed Information in Binary form
HV	High Voltage
IED	Intelligent Electronic Device
JSON	JavaScript Object Notation
mFRR	manual Frequency Restoration Reserves
NCM	Network Congestion Management
NWP	Numerical Weather Prediction
OCS	Operations Control Systems
OPC UA	Open Platform Communications - Unified Architecture
OPF	Optimal Power Flow
OPT	Optimal Power flow Tool
PostGresSQL	POSTGREs Structured Query Language
RPC	Remote Procedure Call
RTU	Remote Terminal Unit
SCADA	Supervisory Control And Data Acquisition
SCP	Secure Copy Protocol
SE	State estimator
SGAM	Smart Grid Architecture Model
SSH	Steady state Hypothesis Profile
SUC	System Use Case
SUSE	Software Und System Entwicklung (Software and Systems Development)
SV	State Variable profile
TP	Topology Profile
TSO	Transmission System Operator
UML	Unified Modelling Language
WP	Work Package

EXECUTIVE SUMMARY

The EU-SysFlex H2020 project aims at a large-scale deployment of solutions, including technical options, system control and a novel market design to integrate a large share of renewable electricity, maintaining the security and reliability of the European power system. The project results will contribute to enhance system flexibility, resorting both to existing assets and new technologies in an integrated manner, based on seven European large scale demonstrators (WP 6, 7, 8 and 9). The overall objective of WP6 is the analysis of the exploitation of decentralized flexibility resources connected to the distribution grid for system services provision to the TSOs, by the means of three physical demonstrators located in Germany, Italy and Finland.

Following the objectives of the EU-SysFlex project and of its WP6 in particular, the three demonstrators are being set up in order to show how resources connected to the distribution system can help to address system needs by providing ancillary services to the transmission level and, at the same time, meet the requirements of both TSO and DSO while, also, improving the coordination between these two actors.

This deliverable analyses the requirements that the demonstrators have regarding the data exchanges between the different systems, operated by different actors. Based on the Smart Grid Architecture Model (SGAM) methodology and terminology such as showed in Figure 1, the study focuses on the information layer (i.e. data models and how the information is organized) and on the communication layer (i.e. communication protocols and how the information is packaged in order to be transmitted). The standards used during the implementation of the demonstrators are listed, and the gaps between the applications and functions which existed at the beginning of the EU-SysFlex project, and the needs of the demonstrators, regarding communication systems, are pointed out.

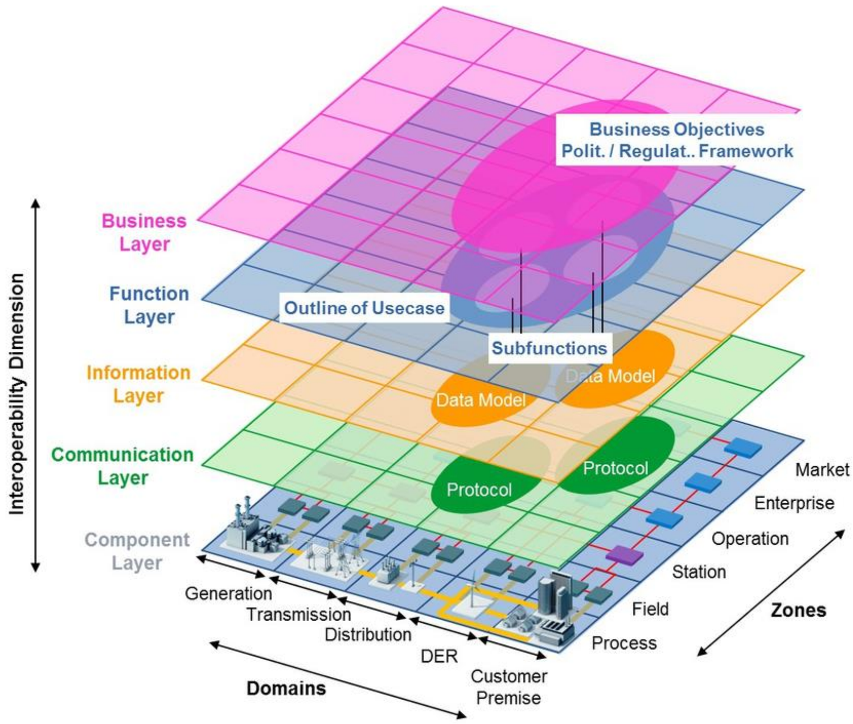

FIGURE 1 - REPRESENTATION OF THE SGAM MODEL, GIVING CONTEXT TO THE INFORMATION AND COMMUNICATION LAYERS

The most important results from the analysis regarding the information layer are that:

- the internal communication within the DSO, or aggregator, is still often based on proprietary data models. That is especially true for exchanges between different SCADAs or between systems developed for and integrated in the operation of the same actor,
- the communication between the DSO's (such as the SCADA) and others' systems or DSO devices (such as the Remote Terminal Units) is in most cases based also on
    a. the IEC 60870-5-104 or IEC 60870-5-101 standards
    b. the IEC 61850 standard

  This applies to the control signals sent by the SCADA to distributed units or for network status, data exchanges and for integration/interaction between DSO devices in the substations;
- the Common Information Model is used for exchanges between the demonstrator and DSO (see the German demonstrator).

Regarding the communication layer, we can note that IEC standards are used where they are important, i.e. at critical interfaces:

- The IEC 60870-5-101, IEC 60870-5-104 and IEC 60870-6 TASE.2 standards are used to communicate between the DSO and the distributed assets or the Remote Terminal Units (RTU), as well as between the TSO and DSO.
- More general secure file transfer protocol (FTPS) communication is also used in order to transfer data, which are not specifically network related, such as market signals, or weather or other types of forecasts. It is also used for communication between the DSO or aggregator with third-party data providers, such as weather data from forecasting actors, or some assets' status (e.g. data, stored on a third-party cloud, about the charging status of a fleet of electric vehicles or battery State of Charge)

During the implementation of the three WP6 demonstrators, most of the work related to data management will answer two types of needs. The first one is a need, such as in the German demonstrator, to create tools that will convert data to and from the CIM data models into a format that can be processed by their own systems at the required speed (some information, when packaged in a CIM format is too bulky for transfer and processing). The second one is a need to define and implement some of the data exchanges internal to some actors (i.e. between the DSO's or the aggregator's own systems). The specific requirements, some choices and the implementation will be realized during the course of the demonstrators. Figures 2 to 4 illustrate in a simplified way the communication architecture as identified by each demonstrator. They show the systems exchanging data as well as the protocols used to implement those interactions.

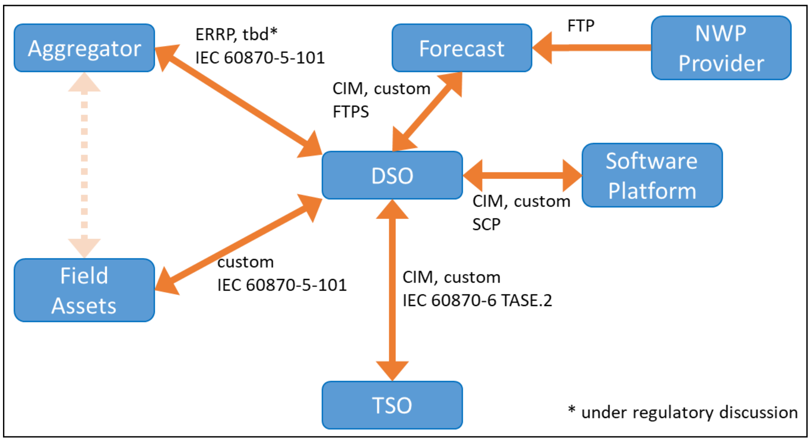

FIGURE 2 - SIMPLIFIED COMMUNICATION IN THE GERMAN DEMONSTRATOR (THE DASHED ARROW IS AN INTERACTION OUT OF THE DEMONSTRATOR'S SCOPE)

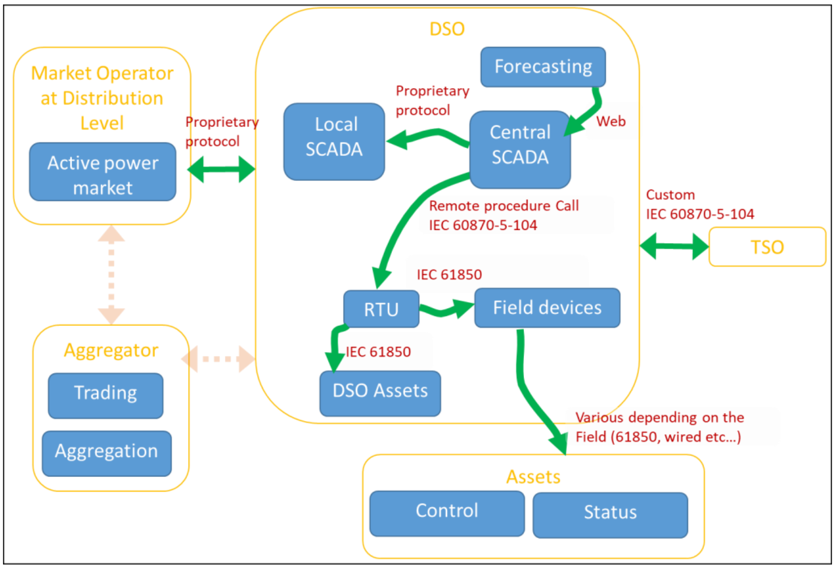

FIGURE 3 - SIMPLIFIED COMMUNICATION IN THE ITALIAN DEMONSTRATOR (THE DASHED ARROW IS AN INTERACTION OUT OF THE DEMONSTRATOR'S SCOPE)

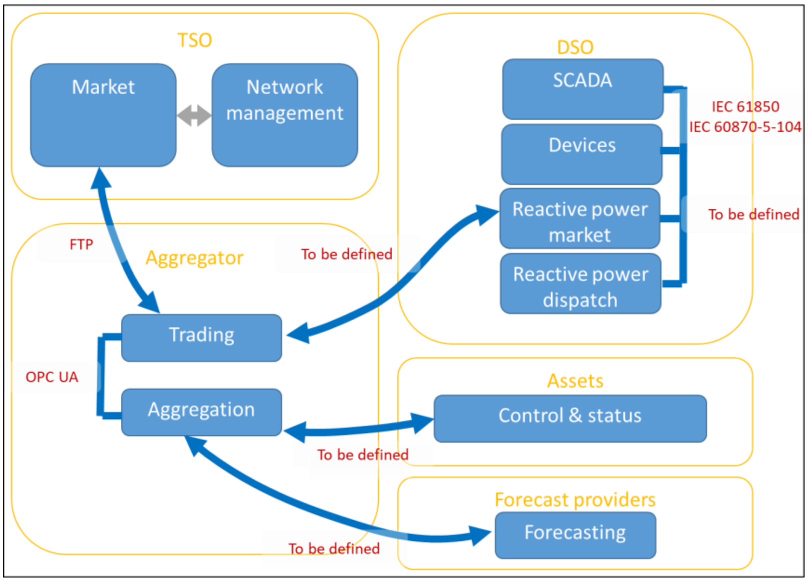

FIGURE 4 - SIMPLIFIED COMMUNICATION IN THE FINNISH DEMONSTRATOR (THE GREY ARROW IS AN INTERACTION OUT OF THE DEMONSTRATOR'S SCOPE)

The analysis of the data exchanges and communications needed in the demonstrators shows that communication will be based as much as possible on standards and that the required data models and protocols exist. The following aspects, however, have been identified where the needs of the demonstrators are not readily met by existing tools:

- Most systems require a conversion to take place in order to emit or process data exchanges. The conversion itself can be a cause of problems but, also, the information sent and received can be subject to different requirements, and coordination is required between the systems.
- Some systems were set up before the implementation of the standards, such as the communication between the DSO's own systems. They work well in their own environment, so an overhaul of the system is not a reasonable solution. This means that an interface needs to be created or adapted for new communications.
- The existing standards are not always adapted to the provision of new services (e.g. the Common Information Model, CIM, does not include fields for active or reactive flexibility ranges). In this case, an extension of those standards, by adding fields and descriptions, could help solve the gap.
- Some interactions in the project, mainly between tools and systems that are being created for the demonstrators, remain to be defined. The data requirements have been identified as being light, with small amount of data transmitted at a low frequency and with no very challenging security imperatives. This makes them not very critical in terms of system requirements and specifications. The data models and protocols definitions are going to be handled during the implementation phase of the project, when the missing data to be exchanged has been better defined.
- Some systems of third-party data providers (e.g. the data cloud of remote electric vehicles charging stations monitoring) have been designed for other purposes than serving the energy industry, thus having different needs and backgrounds. A better level of harmonization will most likely develop in the future as the data forecast providers work increasingly with the energy industry and as they adapt their system to be better in line with its needs.

In conclusions, the data transfers for the three EU-SysFlex WP6 demonstrators will be implemented by using the existing standards and protocols. Some cases have been identified where conversion work has been identified and will be carried out during the demonstrators. And finally, in the last cases, the identified gaps between the requirements of the demonstrators and the existing standardization will be reported in WP5, which will compile feedback and recommendations regarding communication and data needs for the whole project.

1. INTRODUCTION

This deliverable D6.4 *"General description of processes and data transfer within three Eu-Sysflex demonstrators"* is an output of the task T6.3 "Development of systems and tools" of the EU-Sysflex project. It covers the description of the data exchanges, data models, interface protocols and communication tools implemented in the three demonstrators of the project's Work Package 6 (WP6).

1.1 THE EU-SYSFLEX PROJECT AND WP6

The EU-SysFlex project seeks to enable the European power system to utilise efficient, coordinated flexibilities in order to integrate high levels of Renewable Energy Sources (RES). One of the primary goals of the project is to examine the European power system with at least 50% of electricity coming from RES, an increasing share of volatile, distributed sources connected through a power electronic interface such as wind and solar.

In order to achieve the project objectives the consortium pursues the identification of technical shortfalls requiring innovative solutions, the development of novel market designs to provide incentives for these solutions, and the demonstration of a range of innovative approaches. Other activities such as data management analysis, innovative tool development as well as integration and testing of new system services in DSOs and TSOs control centres are also included in the project approach. The project results will contribute to enhance system flexibility, resorting both to existing assets and new technologies in an integrated manner, based on seven European large scale demonstrators in Portugal, Germany, Italy, Finland, France, and the Baltic states (WP 6, 7, 8 and 9).

Work Package (WP) 6 *"Demonstration of flexibility services from resources connected to the distribution network"* analyses the opportunities arising from decentralized flexibility resources connected to the distribution grid to serve the needs of the overall power system, in coordination between DSOs and TSOs, by means of three demonstrators located in Germany, Italy and Finland.

1.2 WP6 OBJECTIVES AND PURPOSE OF TASK T6.3

The primary objective of WP6 is to analyse and test the exploitation of decentralized flexibility resources connected to the distribution grid, respecting the needs of both the DSOs and TSOs. Due to the current policies for the decarbonisation of the energy systems, DSOs are required to connect RES to a distribution network that has not been designed to host large volumes of generation capacity and, at the same time, they have to guarantee the security and resilience of their networks. Consequently, the DSOs have a need for a certain leverage in their network operation, to avoid congestions and constraints violations. At the same time the amount of flexibility resources in the transmission level decreases due to the traditional plants providing the services being displaced by RES in the distribution grid. The TSOs, therefore, need more and more these flexibility resources in the distribution grid to guarantee the security and resilience of their transmission system operation.

According to this, three sub-objectives have been identified:

- Improve the TSO-DSO coordination;
- Provide ancillary services to the TSOs from flexible units (generation, consumption and storage) connected to the distribution grid;
- Investigate how these flexibilities could meet the needs of both TSOs and DSOs.

The purpose of task T6.3, in WP6, is to develop systems and tools that allow the System Use Cases (described in D6.1 "Demonstrators' system use cases description" [1], based on the Business Use Cases developed in WP3 (D3.3 "Business Use Cases for Innovative System Services" [1], to be implemented in the three demonstrators running in Task T6.4 (Demonstrators/field tests) of the project.

This deliverable D6.4 is the first published of a set from task T6.3 *"Development of systems and tools"*:

- Deliverable 6.2 *"Forecast: Data, Methods and Processing. A common description"* presents the description of requirements of the DSO/TSO interface, in order to harmonize the data formats and models for all the trials;
- Deliverable 6.3 *"Grid simulations and simulation tools"* presents the first results about network models and simulations from the demonstrators;
- Deliverable 6.4 *"General description of the used data as a basis for a general data principle"* presents the description of communication interfaces between the actors involved in the demonstrators;
- Deliverable 6.5 *"Optimization tools and first applications in simulated environments"* presents the description of the optimization tools and the range of flexibilities used in the demonstrators;

1.3 SCOPE OF THE DOCUMENT

The scope of this document, besides detailing the implementation of the information and communication layers of the demonstrators, is to identify common data and communication principles, based on a holistic approach, which would allow provision of flexibility services by distributed resources. This means the exchanges of technical and commercial data between stakeholders such as the DSO, the TSO or the aggregator. The data exchanges include the data objects related to the measurements, operation, forecasts, etc. of distributed resources. The information collected includes a comprehensive list of the information to be exchanged, of the interfaces and protocols as well as of the data objects (e.g. asset specification, status, setpoints, forecasts, etc.).

This deliverable shows the possibility, from a data exchange perspective, of integrating various types of resources connected to the distribution level for solving the needs of both the DSOs and TSOs by delivering ancillary services and other flexibility services via markets and technical operation of both the distribution and transmission networks. Figure 5, presented in D6.6 (Demonstrators for Flexibility Provision from Decentralized Resources, Common View [1]), shows how the three demonstrators could be placed in a theoretical common grid and complement each other to represent the whole chain from distributed assets to the transmission services. In addition to this picture, the demonstrators also cover communication between the assets, the aggregator business role and its connection to transmission and distribution level markets.

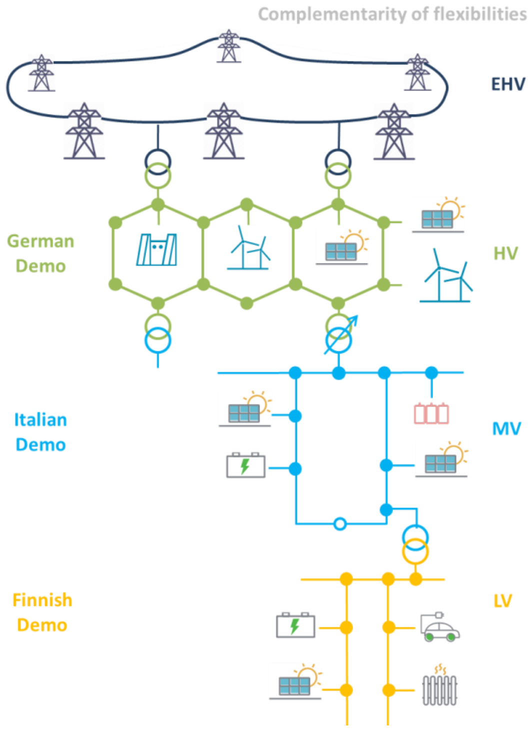

FIGURE 5 - SCHEMATIC REPRESENTATION OF HOW THE WP6 DEMONSTRATORS COULD BE LINKED TO UTILIZE THE ASSETS LOCATED ON LV TO HV LEVELS

1.4 STRUCTURE OF THE DOCUMENT

In order to outline the data exchanges, data models, interface protocols and communication tools of the three demonstrations, this deliverable opens with a short description of the SGAM model and the concept of communication layers. It follows in chapters 3 and 4 with details on how the information and communication layers are handled in each demonstrator. Chapter 5 details the tools that are used in the demonstrators and their impact in terms of information exchanges, as well as an analysis showing where developments are needed during the project in order to set up the demonstrators. The document ends with conclusions and lessons learned during this stage of the project.

2. THE SGAM MODEL, COMMON PROTOCOLS AND STANDARDS

This chapter introduces the Smart Grid Architecture Model (SGAM) and a short list of international standards and protocols. The SGAM model is used as a structure for the entire deliverable and the standards and protocols are referred to throughout the whole document.

2.1 THE SGAM MODEL AND THE INTEROPERABILITY LAYERS

The Smart Grid Architecture Model (SGAM, represented in Figure 3) has been put forward by the Smart Grid Coordination Group of CEN-CENELEC-ETSI. Its aim is to offer a support for the design of smart grids use cases with an architectural approach allowing for a representation of interoperability viewpoints in a technology neutral manner. It is a three dimensional model that is merging the dimension of five interoperability layers with the two dimensions of the Smart Grid Plane, i.e. zones and domains [2].

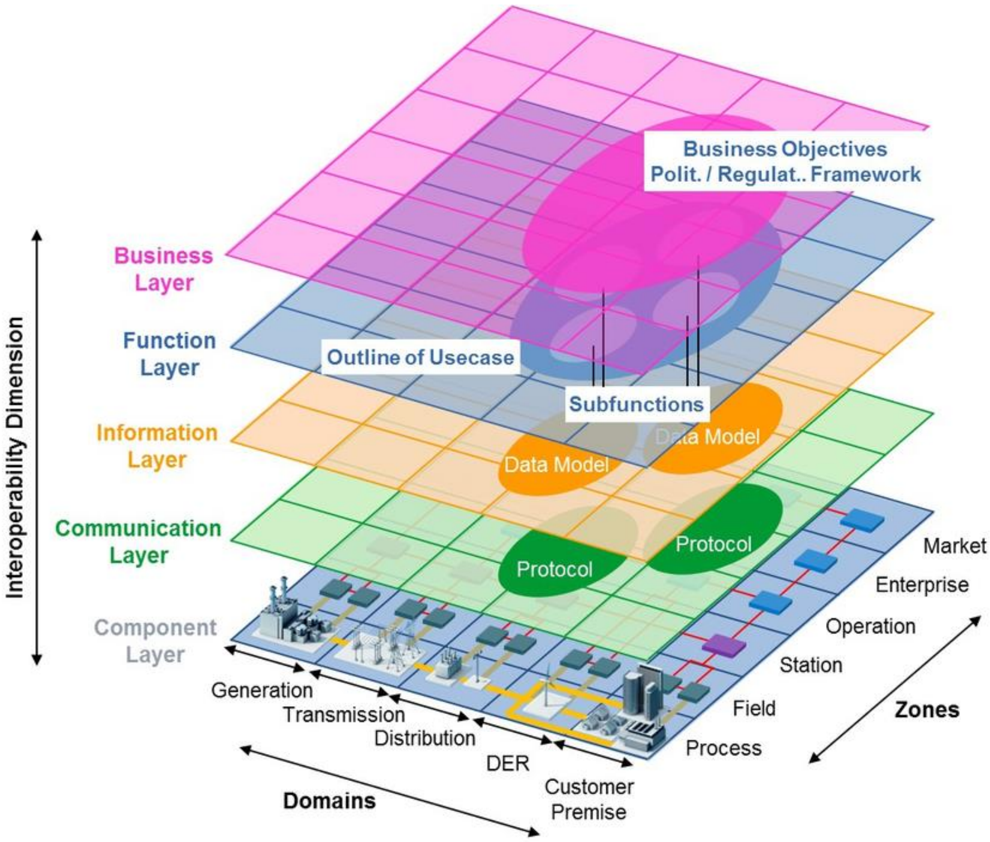

FIGURE 6 - REPRESENTATION OF THE SGAM MODEL, SHOWING HOW THE INFORMATION AND COMMUNICATION LAYERS MAKE THE BRIDGE BETWEEN THE SYSTEM USE CASES AND THE PHYSICAL IMPLEMENTATION

This deliverable deals with the Information and Communication Layers. The Function Layer is covered by the System Use Cases and some aspects of the component Layer will be handled in the other deliverables from T6.3 and especially in T6.4 which deals with the implementation of the demonstrators and the field tests (see chapter 1.2) about the various tools that will be developed. We focus here on the data models used in the demonstrators to represent the required data and on the protocols used to execute the exchanges in an appropriately reliable, secure and fast fashion.

The analyses of the communication needs for the demonstrators started in the definition of the different Business Use Cases (BUC) in WP3 (see D3.3 “Business use cases for innovative system services” [1]). The BUCs are a way of representing aspects of the Business Layer, such as interactions between the electricity business roles. The System Use Cases (SUC), such as described in D6.1 “Demonstrators’ system use cases description” [1], took the focus down to the Function Layer. They detailed the exchanges between systems and processes along with a general description of the contents of the information exchanged. At that point, the content of the information to be exchanged has already been defined. In this deliverable, the study focuses on how the information is formatted into data models that can be easily used by the systems needing them (Information Layer) and how this can be packaged in a secure and reliable way (Communication Layer) in order to be transferred via the actual physical communication devices (Component Layer, out of the scope of this document).

2.2 COMMON PROTOCOLS AND STANDARDS

A lot of international standards and communication protocols exist already. Their purpose is to give a solid basis for the interoperability of various communication systems. This means that, by applying common standards and protocols, the integration of the system is facilitated and should require minimal efforts in data conversions. This chapter lists the communication standards and protocols that are relevant for the demonstrators.

2.2.1 COMMON INFORMATION MODEL (CIM)

The Common Information Model (CIM) [3] is an UML (Unified Modelling Language) based data model describing power systems. It was developed by the power industry and officially adopted by the International Electrotechnical Commission (IEC). CIM is describing a common model which can be used as description of the electric grid as well as a relation between information like transformer models or state of switches and grid topology. The basic model is described in IEC 61970 which contains basic classes and descriptions for the electrical system. It is dedicated to transmission grids but can also partly be used to describe distribution grid elements. This model is expanded by IEC 61968, which contains descriptions of modelling interfaces, asset information and metering activities. Energy market communications and data exchange are defined in IEC 62325 which also based on the Common Information Model.

2.2.1.1 COMMON GRID MODEL EXCHANGE SPECIFICATION (CGMES)

The CIM also allows the user to define profiles which are a subset of the semantic model and selected for the used application. The Common Grid Model Exchange Specification (CGMES) is such a profile of CIM maintained by ENTSO-E [4]. It is dedicated to the exchange of grid information between TSOs in Europe for performing European wide power flow calculations and analysis. It is also used to describe the data exchange within the Generation Load Data Provision Methodology (GLDPM).

2.2.1.2 RESOURCE DESCRIPTION FRAMEWORK (RDF)

The CIM uses RDF (Resource Description Framework) files for exchanging grid information. RDF is a standard for en-coding knowledge and was adopted as a recommendation by the World Wide Web Consortium (W3C) in 1999. It uses statements about resources in the form of subject-predicate-object expressions (triples). An example for triples could be: the voltage amounts to 220 kV. In this case “the voltage” is the subject, “amounts to” is the predicate and “220 kV” is the object. For RDF many serialization formats could be used, for example JSON or XML files. The common information model uses XML serialization format of RDF to exchange data.

2.2.2 IEC 61850

IEC 61850 is a standard which was originally used for communication in substations, but it can also be used in many other ways. This standard defines communication with the individual systems, as well as a data model for different device types. The data model and the communication are configured by a server in an XML-based language (SCL: System Configuration Description Language) which describes the provided information. A client can download this file and thus receives the information on how the incoming data (for example measurement values) are to be interpreted (see [2]). The SCL file is structured as follows:

1. Communication: Information regarding the connection, e.g. IP address.
2. IED: The IED section describes the complete configuration of an Intelligent Electronic Device (IED). This is the main field. All the provided data is described here. The data must correspond to the defined data model in the DataTypeTemplates area. Each IED can configure several so-called logical devices. Every logical device is described by several classes
3. DataTypeTemplates: The used IEC 61850 data model is described here. The classes and data attributes are defined in IEC 61850, e.g. the class MMXU describes measurements of voltage or current.

2.2.3 IEC 60870-5-104/101

IEC 60870 part 5 [3] is one of the IEC 60870 set of standards which define systems used for telecontrol (supervisory control and data acquisition) in electrical engineering and power system automation applications. Part 5 provides a communication profile for sending basic telecontrol messages between two systems, which uses permanent directly connected data circuits between the systems.

IEC 60870-5-101 is a standard for power system monitoring, control & associated communications for telecontrol, teleprotection, and associated telecommunications for electric power systems.

Its main features are:

- Support of unbalanced (only master initiated message) and balanced (can be master/slave initiated) modes of data transfer.
- Link address and ASDU (Application Service Data Unit) addresses are provided for classifying the end station and different segments under the same.
- Data is classified into different information objects and each information object is provided with a specific address.
- Facility to classify the data into high priority (class-1) and low priority (class-2) and transfer the same using separate mechanisms.
- Possibility of classifying the data into different groups (1-16) to get the data according to the group by issuing specific group interrogation commands from the master & obtaining data under all the groups by issuing a general interrogation.
- Cyclic and spontaneous data updating schemes are provided.
- Facility for time synchronization
- Schemes for transfer of files-Example: IED's will store disturbance recorder file in the memory, When electrical disturbance is occurred in the field.

IEC 60870-5-104 protocol is an extension of IEC 60870-5-101 protocol with the changes in transport, network, link and physical layer services to suit the complete network access. The standard uses an open TCP/IP interface to network to have connectivity to the LAN (Local Area Network) and routers with different facility (ISDN, X.25, Frame relay etc.) can be used to connect to the WAN (Wide Area Network). Application layer of IEC 60870-5-104 is preserved same as that of IEC 60870-5-101 with some of the data types and facilities not used. There are two separate link layers defined in the standard, which is suitable for data transfer over Ethernet & serial line (PPP - Point-to-Point Protocol). The control field data of IEC 60870-5-104 contains various types of mechanisms for effective handling of network data synchronization.

3. INFORMATION LAYER

According to the SGAM definition, the information layer describes the information that is used and exchanged between functions, services and components. It contains information objects and the underlying canonical data models.

Information exchanges can be identified by analysing the data exchanges appearing between roles in the System Use Cases.

The relevant information in our case for the information layer consists of:

- General information about the data to be transferred (such as volumes of data, frequency of the exchanges, required reliability)
- Data models used in the demonstrators' systems to exchange the information

In the following chapters (3.1 to 3.3), information is compiled about the data exchanges identified in the demonstrators' System Use Cases (described in D6.1 "Demonstrators' system use cases description" [1]). The objective is to list the different data exchanges, their requirements in terms of bandwidth (volume and frequency of the data transfers), reliability as well as the data models associated with them and the possible needs to convert the data when sending or receiving it.

The information collected for each demonstrator is the following:

- Name: Short name or ID for the information exchange.
- Description: The purpose and contents of the exchange.
- Sender: System that sends the information
- Receiver: System that receives the information
- Volume[1]: An idea about the size of the exchange. The volume will be indicated as "very small", "small", "large" or "massive".
- Frequency[1]: For example 1/day, 1/15min, 1/5sec, etc.
- Reliability: Need for reliability: "high" or "low". It should be high if no mistakes are allowed. It can be low if the receiver is designed to handle missing or erroneous data.
- Data model: Data model, possibly standard, used to transfer the data.
- Conv. in: Is there a need to convert the data to another model for the receiver to process it? "No" or name of other model.
- Conv. out: Is there a need to convert the data that leaves the sender to another model in order to transmit it? "No" or name of other model.
- Change: The degree of change in the data that is due to the project. "new" if the data exchange did not exist previously. "high" if the exchange existed but has now completely different specifications. "low" if only minor changes are made, such as adding or removing an element of the data object. "none" if the exchange remains the same as before the project.

[1]: Regarding volume and frequency, the key idea is to identify data exchanges that would be both large and frequent as being the ones that set requirements for the system.

The idea behind collecting this information is to identify critical data exchanges that would give minimal requirements to the communication systems (high bandwidth and/or high reliability requirement) as well as tools that would be required to convert data between two systems.

3.1 GERMAN DEMONSTRATOR

In this chapter the data exchanges, their requirements in terms of bandwidth and reliability, the data models associated to them and the possible needs to data conversions are being listed for the German demonstrator.

In the German demonstration the data exchanges between the DSO and external roles are described in one SUC, namely "*DE–COM - Perform data communication for the German Demo*". The data exchanges that the Forecast Provider needs with external roles is described in the SUC *"DE–FC - Forecast of load and in-feed for German Demo"*. The processing of the data is described in the other SUCs. The German demonstrator's internal communication is described in the SUC *"DE–DATA Perform data management for the German Demo".*

The SUCs of the German demonstration are as followed:

- DE – COM, *Perform data communication for the German Demo*
- DE – DATA, *Perform data management for the German Demo*
- DE – FC, *Forecast of load and in-feed for German Demo*
- DE – OPF, *Optimize network state for the German Demo*
- DE – APC, *Enabling Provision of Active Power Flexibility from DSO for TSO in the German Demo*
- DE – RPC, *Enabling Provision of Reactive Power Flexibility from DSO for TSO in the German Demo*

Due to the scope of this document, the description in this chapter is limited to SUC *"DE – COM"* in 3.1.1, *"DE – DATA"* in 0 and SUC *"DE – FC"* in3.1.2, but it contains implicit the requirements of all the other SUCs regarding data exchange and management. For more detailed information on those other SUCs refer to D6.1 "Demonstrators' system use cases description" [1].

3.1.1 DATA COMMUNICATION BETWEEN THE DSO, TSO, FORECAST, SOFTWARE PLATFORM AND FIELD ASSETS

The DSO sends every 5 minutes measurements in CIM CGMES format, including topology data as well as master data which contain also geographic locations and installed capacity. For the data that are not included in CIM CGMES format, a custom format will be used to transmit the needed data. For the calculation of the setpoints the forecast provider sends data for the required field assets and aggregated data on certain connection points.

Subsequently, the Software Platform calculates an operating schedule for active/reactive power for the day ahead and intraday. If the TSO has requirements for the DSO, the following data are sent to the DSO: flexibilities for active and reactive power as well as for voltage, also status information for the reception of requests and information from the TSO as well as the status of actual processing of those requests. The DSO then converts the operating schedules into operating signals and sends them to the aggregator and field assets.

Figure 7 summarizes the processes and their exchanges, as just described, for the Use Case DE – COM "*Perform data communication for the German Demo"*

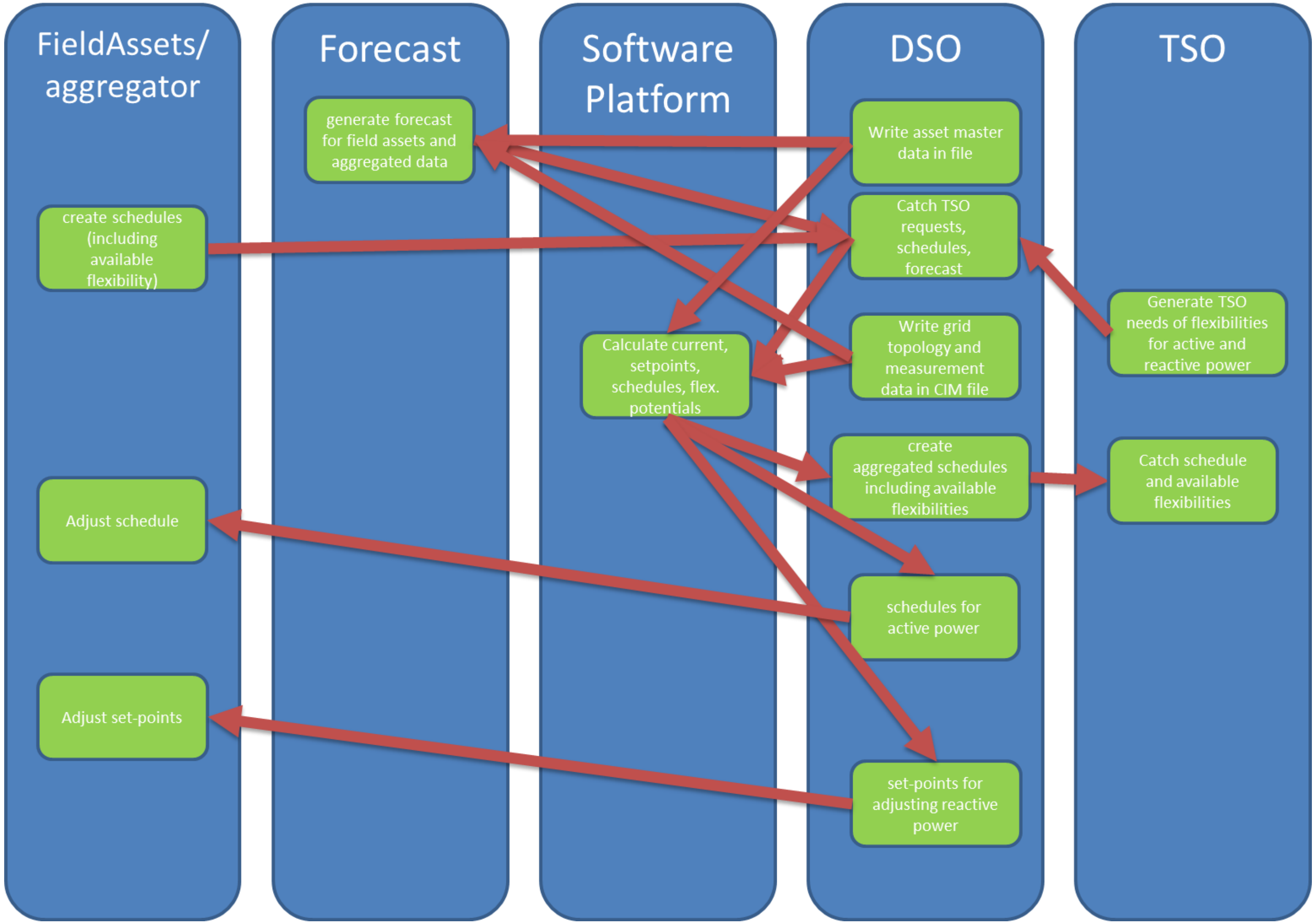

FIGURE 7 - DATA COMMUNICATION BETWEEN THE DSO, TSO, FORECAST, SOFTWARE PLATFORM AND FIELD ASSETS IN THE GERMAN DEMONSTRATOR

3.1.2 DATA COMMUNICATION FOR THE FORECASTING

The DSO sends measurements, including topology data to the Forecast Provider, every 15 minutes in the CIM data format. Master Data, which contains the installed capacity of the DER and their geographic locations, will be sent to the Forecast Provider if changes in the meta data occur.

The Numerical Weather Prediction Provider (NWP-Provider) sends weather forecast in GRIB 2 (WMO Data format) every 3 to 12 hours to the Forecasts Provider, depending on the weather model and NWP- Provider.

Based on the measurements from the DSO and the NWP data, the forecast provider generates a forecast for the DER and the loads at the forecasts points (mainly transformer stations) and sends the results to the DSO using custom forecast data format.

- Figure 8 summarizes the processes and their exchanges, as just described, for the Use Case DE – FC "*Forecast of load and in-feed for German Demo*".

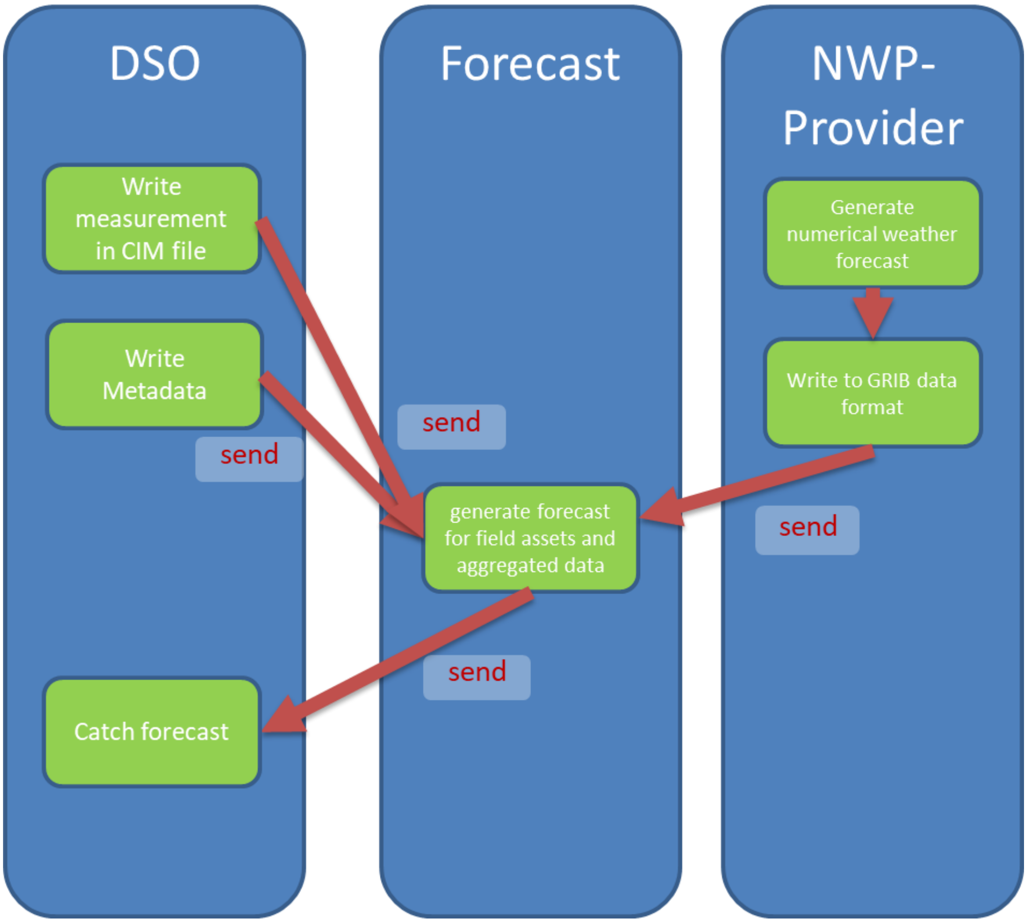

FIGURE 8 - DATA COMMUNICATION FORECAST IN THE GERMAN DEMONSTRATOR

3.1.3 DATA COMMUNICATION FOR THE GRID ANALYSIS TOOL AND OPTIMIZATION TOOL

The forecasted asset state and the grid configuration and measurement in CIM will be converted to a network model in the internal loadflow format (pandapower) through a converter (CIM2PP), which will then be used by the state estimation tool, so that the status of the grid, especially the load flows on branches and the power injections at the substations level, can be evaluated for the real time as well as for the future. The estimated grid state will be sent to the network congestion management (NCM) tool for the N-1 contingency check and active power-setpoint adjustment in case of grid congestion. The congestion-free grid state will be sent back to the software platform for the optimization tool.

This optimization tool, created in Python, is used to calculate generator set-points within a given grid, based on different TSO requests, using a developed optimization core written in AMPL. The grid layout, described as a network model in pandapower, is being provided by the Congestion Management service of the Grid Analysis Tool. The core of the optimization tool is a grid calculation/optimization program written in AMPL, using the “knitro”-solver. Data provision (information about grid data and TSO request) to AMPL is file based. Whereas the files, containing grid data information, can be used for several different calculations, a single file containing request information has to be updated regularly. Within the main program, an AMPL-API-object is being used to perform the optimization as well as to access the calculation results. Finally, these results which mainly consist of set-points for the generators and flexibility potentials for interconnection points and generating units within the grid, are saved to a database as a CIM model.

- Figure 9 summarizes the processes and their exchanges, as just described, for the Use Case DE – DATA “*Perform data management for the German Demo”*.

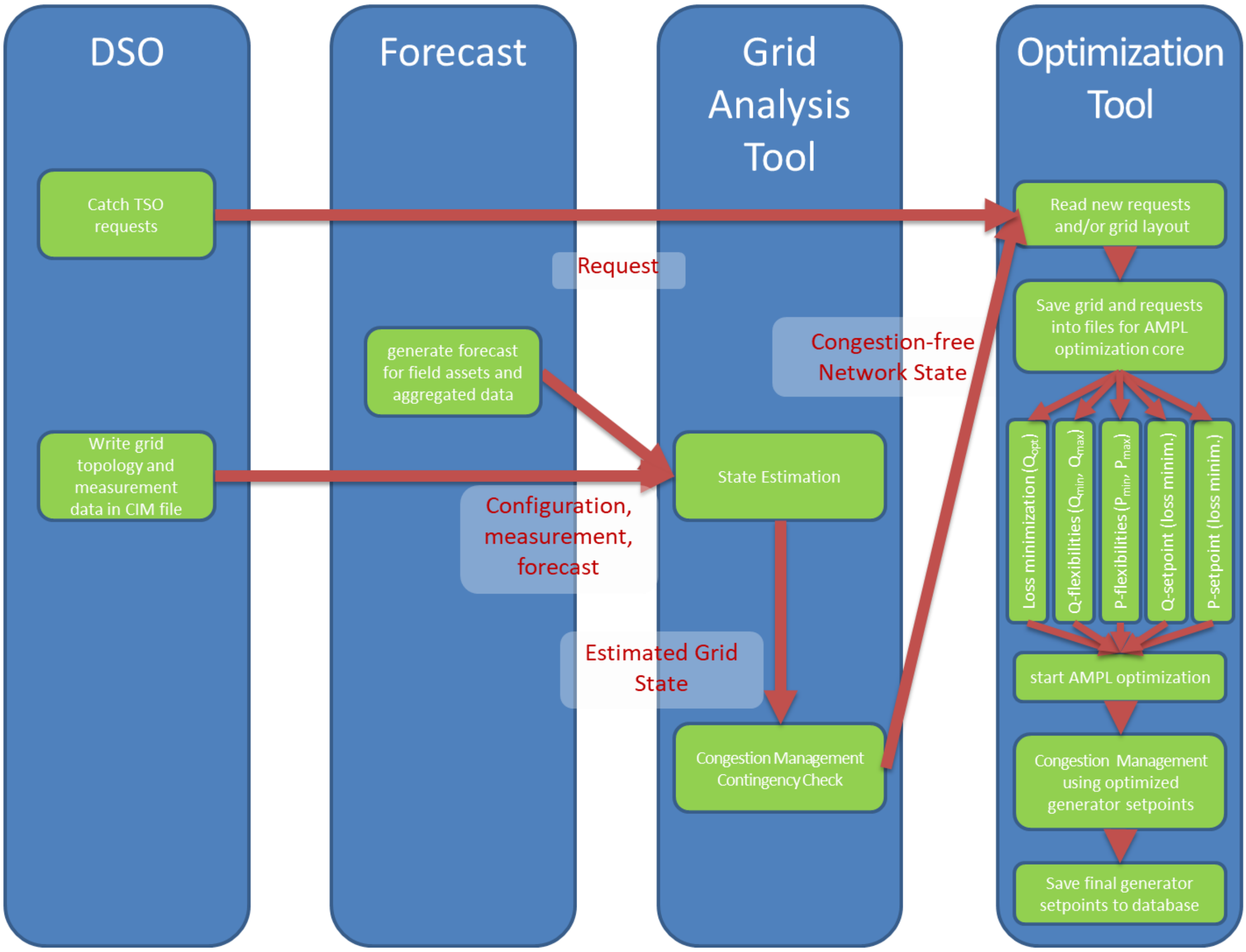

FIGURE 9 - DATA COMMUNICATION GRID ANALYSIS TOOL/ OPTIMIZATION TOOL IN THE GERMAN DEMONSTRATOR

3.1.4 SUMMARY TABLE FOR THE GERMAN DEMONSTRATOR'S INFORMATION LAYER NEEDS

Based on the diagrams showed in the chapters before, Table 1 gives an overview of the information exchanges and of their requirements for the German demonstrator. A description of each field can be found in the introduction for Chapter 3.

TABLE 1 - INFORMATION LAYER SUMMARY FOR THE GERMAN DEMONSTRATOR

Name	DESCRIPTION	SENDER	RECEIVER	VOLUME	FREQUENCY	RELIABILITY	DATA MODEL	CONV. IN	CONV. OUT	CHANGE
Operating schedule for active/reactive power	Day ahead and intraday operating schedule	SOFTWARE PLATFORM	DSO	SMALL	1/15 MIN	HIGH	ENTSO-E RESERVE RESOURCE PROCESS (ERRP) FOR CONVENTIONAL >10MW; REGULATORY UNDER DISCUSSION FOR RES, DUE TO DRAFT LAW	CIM	NO	LOW
Flexibilities for active/reactive/voltage	Flexibilities for active and reactive power as well as for voltage. Also status information for the reception of requests and information from TSO as well as the status of actual processing of those requests	TSO	DSO	SMALL	1/DAY	HIGH	CIM	CIM	NO	LOW

Name	DESCRIPTION	SENDER	RECEIVER	VOLUME	FREQUENCY	RELIABILITY	DATA MODEL	CONV. IN	CONV. OUT	CHANGE
Computed Forecast	Forecast for required field assets and aggregated data on certain connection points	FORECAST PROVIDER	SOFTWARE PLATFORM	LARGE	1/15 MIN	LOW	CUSTOM	CIM	CUSTOM	LOW
Operating signal	Operating signal adjusting the actual reactive power output	DSO	AGGREGATOR/ FIELD ASSETS	SMALL	1/15 MIN	HIGH	IEC 60870-5-101	NO	IEC 60870-5-101	NONE
Measurement in CIM format	Measurements in CIM CGMES format including topology data as well as master data which contain also geo locations and installed capacity	DSO	SOFTWARE PLATFORM	LARGE	1/5 MIN	LOW	CIM	NO	CIM	NONE
Asset master data	Asset master data, that are not included in CIM format	DSO	FORECAST, SOFTWARE PLATFORM	SMALL	INITIAL + WHEN CHANGES OCCUR	LOW	CUSTOM	CUSTOM (FORECAST)	CIM	LOW
Measurement in CIM format	Measurements in CIM CGMES format including topology data as well as master data which contain also geo locations and installed capacity	DSO	FORECAST	MEDIUM	1/5 MIN	LOW	CIM	CUSTOM	CIM	LOW

Name	DESCRIPTION	SENDER	RECEIVER	VOLUME	FREQUENCY	RELIABILITY	DATA MODEL	CONV. IN	CONV. OUT	CHANGE
Numerical weather prediction data		NWP-PROVIDER	FORECAST	LARGE	3 HOURS	MEDIUM	GRIB 2	CUSTOM	GRIB 2	LOW
Grid Configuration, Measurement and Forecast	Grid model converted from CIM File with measurement and computed forecast	SOFTWARE PLATFORM	GRID ANALYSIS TOOL	LARGE	1/5 MIN	LOW	CUSTOM (PANDAPOWER NETWORK)	NO	NO	NONE
Estimated Grid State	Estimated grid state based on measurement and forecasted aggregated data	GRID ANALYSIS TOOL	GRID ANALYSIS TOOL	LARGE	1/5 MIN	LOW	CUSTOM (PANDAPOWER NETWORK)	NO	NO	NONE
Congestion-free Grid state	new P-setpoint to avoid congestion based on congestion management and N-1 contingency checks within the estimated grid state	GRID ANALYSIS TOOL	OPTIMIZATION TOOL	LARGE	1/5 MIN	HIGH	CUSTOM (PANDAPOWER NETWORK)	NO	NO	NONE

Name	DESCRIPTION	SENDER	RECEIVER	VOLUME	FREQUENCY	RELIABILITY	DATA MODEL	CONV. IN	CONV. OUT	CHANGE
Operational setpoints	Setpoints for generators within the given grid layout based on different TSO requests such as loss optimization, active as well as reactive power flexibilities, using an optimization core written in AMPL	DSO, GRID ANALYSIS TOOL	SOFTWARE PLATFORM		depends on usage (new grid layout or request)	HIGH	CUSTOM (PANDAPOWER NETWORK)	NO	NO	HIGH

3.2 ITALIAN DEMONSTRATOR

In this chapter the different data exchanges, their requirements in terms of bandwidth and their reliability, the data models associated to them and the possible needs to data conversions are being listed for the Italian demonstrator.

The Italian demonstrator is based on the following four System Use Cases (SUCs):

- IT– NT SE*, Perform network state estimation for Italian Demo*
- IT – RPC, *Perform reactive power capability calculation for the Italian Demo*
- IT – AP OP, *Perform distribution network optimization after local market closure for the Italian Demo*
- IT – RP OP, *Perform distribution network optimization for the Italian Demo*

An analysis of the processes in the Italian Demonstrator shows that it aims at exploiting the smart device solutions in an interoperable system, allowing to fulfil a set of sub-objectives and the project objectives such as stated in chapter 1.2. Then, within the SUCs, the interactions between the different systems operated by the TSO, DSO as well as field assets and the market operator are detailed. They are used as the basis for the following analyses. The first of them, "*IT - NT SE Perform network state estimation for Italian Demo"*, is focused on the improvement of optimization and management processes linked to the exchange of updated network information between the systems involved. The second one, *"IT - RPC Perform reactive power capability calculation for the Italian Demo",* deals with the data exchanges about the total reactive power capability of the network connected to the DSO/TSO interconnection point. The last two SUCs describe the processing of the data for the grid optimization, both for reactive and active power.
For each of the four SUCs listed above, the following chapters detail the data exchanges between the systems identified and the aspects relevant to the information layer are listed in the summary table after them.

3.2.1 DATA COMMUNICATION BETWEEN THE SCADA SYSTEMS, THE REMOTE TERMINAL UNITS AND THE FIELD DEVICES FOR NETWORK STATE ESTIMATION

In the SUC *"IT - NT SE, Perform Network state estimation for Italian Demo"* the information exchanged are:

- A request for measurements is sent by the Central SCADA (OCS) to the Remote terminal units.
  The OCS asks to the Primary Substation RTU (Remote Terminal Unit) the information collected from each field device. It also asks the information about breaker status from the Secondary Substation RTUs.
- Field devices send measurement data to the RTUs. Every Fault Detector sends the real time measurements (voltage, current, reactive and active power) with a variable timeframe (generally of 10 s). The measurements at the HV busbar are collected from the integrated protection of transformer and wired devices.
  The measurements at the MV busbar are collected from:
  - the Integrated protection devices of the transformers
  - the feeders' protections devices
  - the fault detectors installed along the feeders.
- In addition, the field devices send status information to the RTUs. Every Fault Detector sends the breaker status (close, open, unknown and fatal error) with a variable timeframe (generally after a status change).

The current state of HV switches is received from the integrated protection of transformers and wired devices. The current state of MV switches is received from feeders' protections.

- After collecting data from the field devices, the RTUs transmit it to the Central SCADA (OCS) with the current state of MV switches collected from all the automated and remote controlled secondary substations.
- The Central SCADA sends updated network topology, characteristics and measurements information to the Local SCADA. This data consist of:
  - Voltage and current measurements;
  - The current state of breakers and assets;
  - Primary Substation network topology (x,y coordinates and the coupling of each elements: switches, busbars, feeders, HV/MV transformers, coils, static compensators, words etc…);
  - Secondary Substation network topology (x,y coordinates and the coupling of each elements: switches, MV/LV transformers, generators, words, substation codes etc…);
  - Medium voltage distribution network topology (x,y coordinates and the coupling of each elements: the primary substation, feeders, switches, secondary substations etc…);
  - Electrical characteristics of network components (several electrical parameters are associated to each element: cables, transformers, line length, resistance etc…);
- The local SCADA also collects load and generation forecasts from the Central SCADA databases. A server sends the metering information about classes of customers. Taking into account the tracing of the historical curves of different sets of customers, the Active and Reactive Power profiles of each load and generation customer are built. The Active and Reactive Power profiles of forecast generation are obtained by computing the information coming from an external weather provider.
- Every time the network state is changed (reconfiguration, restoration after fault, …), or at intervals of 15 minutes, whichever occurs first, the algorithm for the State Estimation (SE) is triggered:
  - The quantities are estimated in each node of the network.
  - The estimation is calculated at HV side of the Primary Substation which corresponds to the interconnection point between DSO and TSO.

  The information about the update of the State Estimation algorithm is sent from the Local SCADA to the Central SCADA.

Figure 10 summarizes the processes and their exchanges, as just described, for this Use Case.

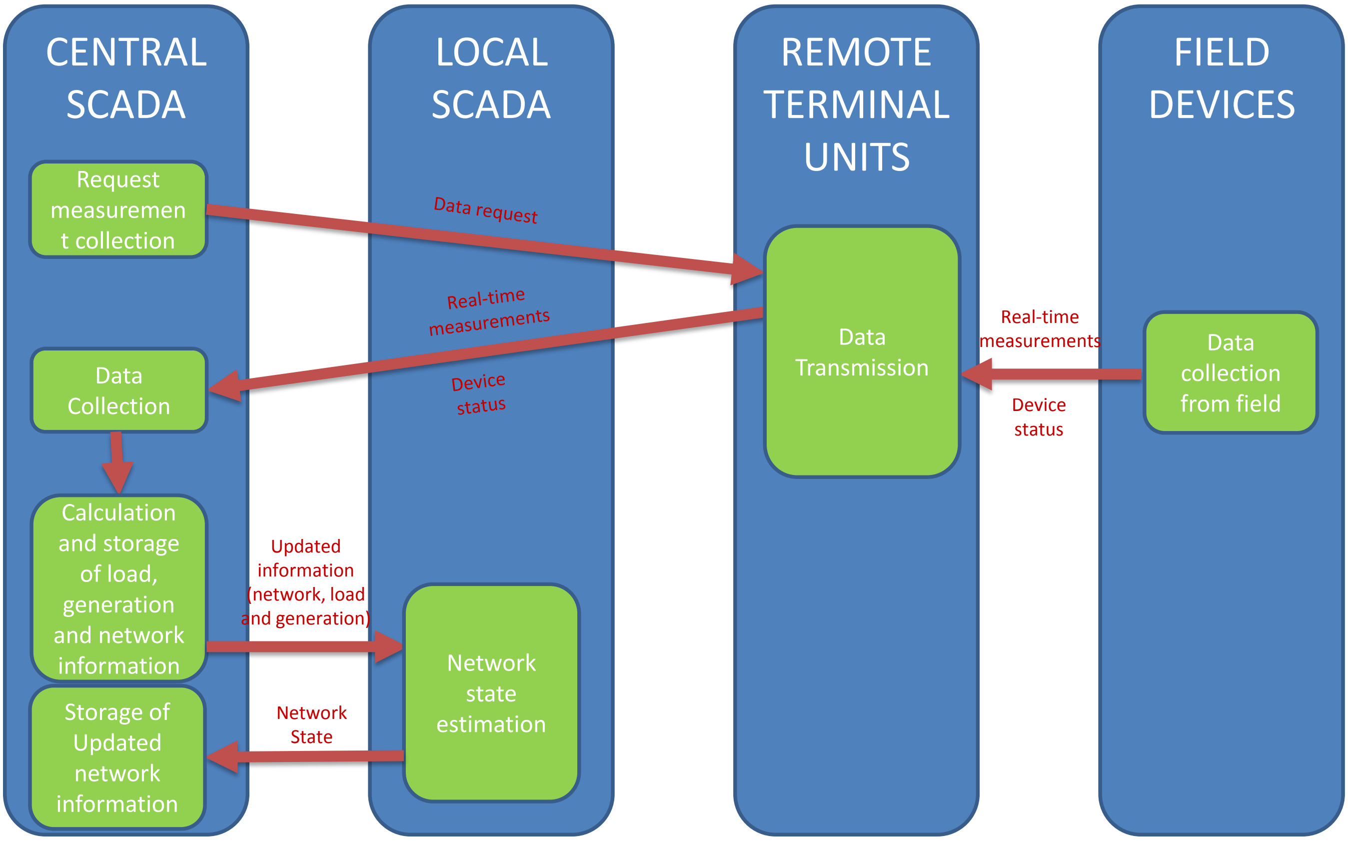

FIGURE 10 - COMMUNICATION ARCHITECTURE OF STATE ESTIMATION IN THE ITALIAN DEMONSTRATOR

3.2.2 DATA COMMUNICATION BETWEEN THE CENTRAL AND LOCAL SCADA SYSTEMS

In the SUC *“IT – RPC, Perform reactive power capability calculation for the Italian Demo”* the information exchanged are:

- The same network topology, characteristics and measurements information as described in 3.2.1 is collected by the Local SCADA from the Central SCADA.
- The Central SCADA provides the capability curves (as requested by the TSO) of the participating resources, to the Local SCADA.
- The Local SCADA, through a loop control operation and considering data received by the Central SCADA, calculates the total Reactive Power capability at the interconnection point. The information is then sent to the Central SCADA and stored in a database.

Figure 11 summarizes the processes and their exchanges, as just described, for this Use Case.

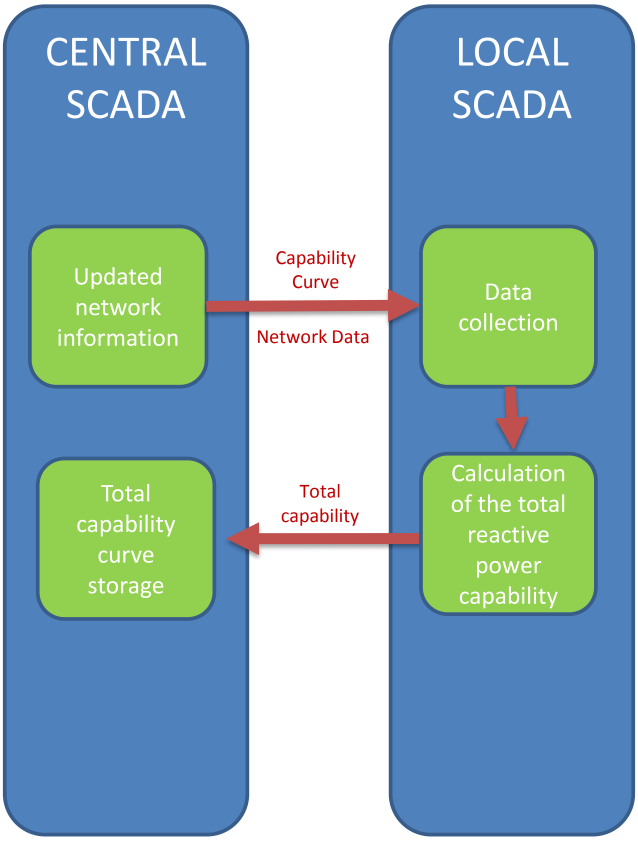

FIGURE 11 - COMMUNICATION ARCHITECTURE OF REACTIVE POWER CALCULATION IN THE ITALIAN DEMONSTRATOR

3.2.3 DATA COMMUNICATION BETWEEN THE DSO'S CENTRAL SCADA AND THE MARKET OPERATOR

In the SUC *"IT – AP OP, Perform distribution network optimization after local market closure for the Italian Demo"* the information exchanged are:

- The same network topology, characteristics and measurements information, as well as load and generation forecasts as in 3.2.1 are sent by the Central SCADA to the Market Operator's SCADA.
- The Central SCADA also sends the capability curves of the participating resources (as in 3.2.2) to the Market operator's SCADA.
- At the end of the local flexibilities market, the DS_O analyses the distribution network to retrieve the updated network state. Then the Central SCADA provides it to the Market Operator SCADA, including the info about congestions and constraints.

Figure 12 summarizes the processes and their exchanges, as just described, for this Use Case.

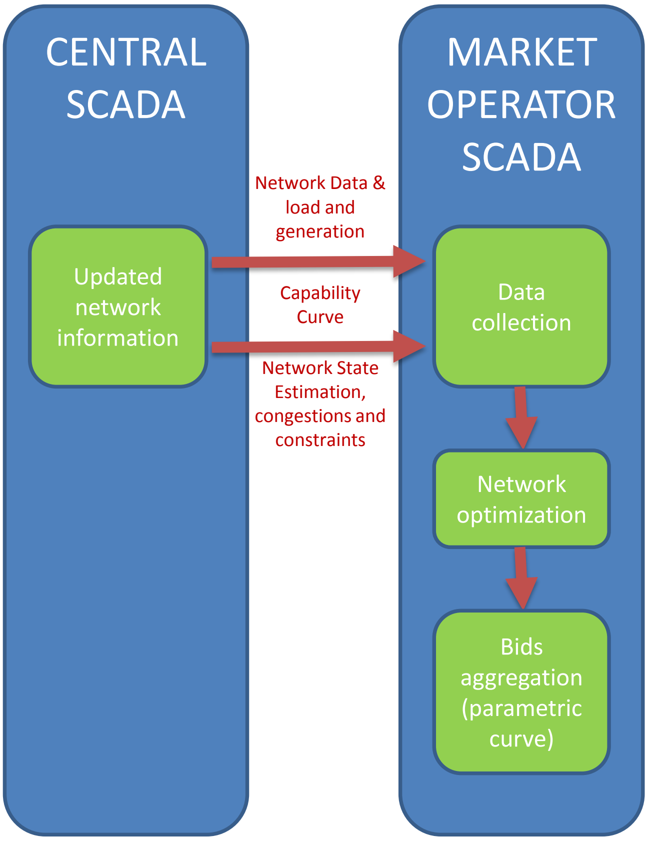

FIGURE 12 - COMMUNICATION ARCHITECTURE OF NETWORK OPTIMIZATION-ACTIVE POWER IN THE ITALIAN DEMONSTRATOR

3.2.4 DATA COMMUNICATION BETWEEN THE SCADA SYSTEMS, THE REMOTE TERMINAL UNITS AND THE FIELD DEVICES FOR NETWORK OPTIMIZATION

Finally, in the SUC *"IT – RP OP, Perform distribution network optimization for the Italian Demo"* the information exchanged are:

- The same network topology, characteristics and measurements information, as well as load and generation forecasts as in 3.2.1 are sent by the Central SCADA to the Local SCADA.
- The Central SCADA also sends the capability curves of the participating resources (as in 3.2.2) to the Local SCADA.
- The Central SCADA sends, again to the local SCADA, the network state estimation, congestions and constraints information as described in 3.2.3.
- The Local SCADA allocates all the resources in order to satisfy the capability request from the TSO and determines the set-points for each resource. Then these set-points are sent to the Remote Terminal Units.
- The Remote Terminal Units transfer the set-points to the Field Devices.
- A particular class of Field Devices can address the set-points to the flexibilities.

Figure 13 summarizes the processes and their exchanges, as just described, for this Use Case.

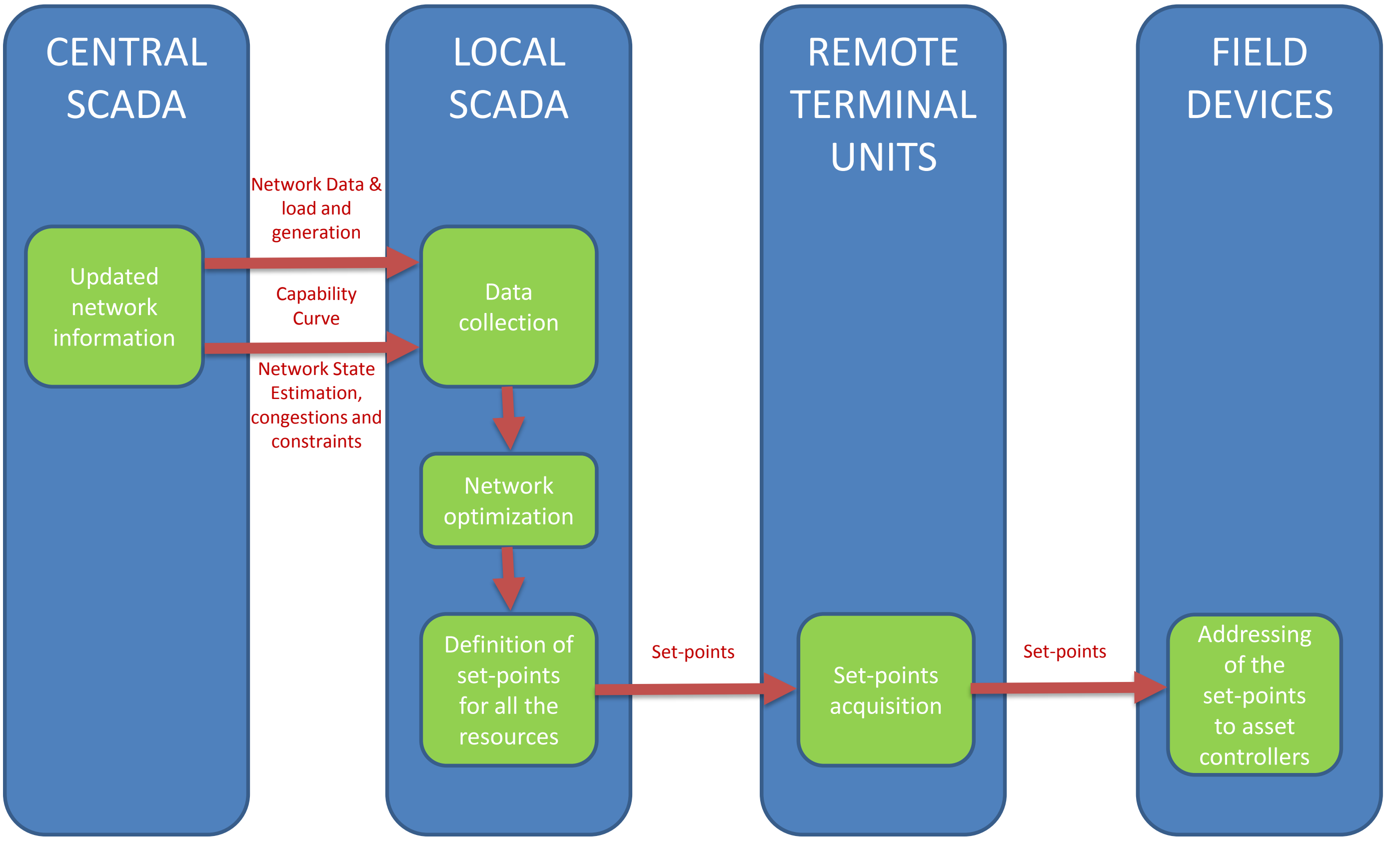

FIGURE 13 - COMMUNICATION ARCHITECTURE OF NETWORK OPTIMIZATION-REACTIVE POWER IN THE ITALIAN DEMONSTRATOR

3.2.5 SUMMARY TABLE FOR THE ITALIAN DEMONSTRATOR'S INFORMATION LAYER NEEDS

Based on the diagrams in the chapters before, Table 2 gives an overview of the information exchanges and of their requirements for the Italian demonstrator. A description of each field can be found in the introduction for Chapter 3.

TABLE 2 - INFORMATION LAYER SUMMARY FOR THE ITALIAN DEMONSTRATOR

Name	DESCRIPTION	SENDER	RECEIVER	VOLUME	FREQUENCY	RELIABILITY	DATA MODEL	CONV. IN	CONV. OUT	CHANGE
Data Exchange and measurements collection	The Central SCADA operates a request to the Primary Substation RTU and to the Secondary Substation RTUs	CENTRAL SCADA	RTUS	LARGE		HIGH	RPC (PROPRIETARY DATA STRUCTURE) IEC 60870-5-104	NO	NO	NONE
Data collection from field	Real Time Measurements collection (V, I, P, Q...)	FIELD DEVICES	REMOTE TERMINAL UNITS	LARGE	10s	HIGH	IEC 61850	NO	NO	NONE
Device status	Current state of the breakers are measured by Field Devices	FIELD DEVICES	REMOTE TERMINAL UNITS	LARGE	After change status	HIGH	IEC 61850	NO	NO	NONE

Name	DESCRIPTION	SENDER	RECEIVER	VOLUME	FREQUENCY	RELIABILITY	DATA MODEL	CONV. IN	CONV. OUT	CHANGE
Data Transmission	Data collected in the field are transmitted to the Central SCADA	REMOTE TERMINAL UNITS	CENTRAL SCADA	LARGE	10s	HIGH	RPC (PROPRIETARY DATA STRUCTURE) IEC 60870-5-104	NO	NO	NONE
Network topology, measurements and characteristics updated information	Updated Information (network topology, electrical characteristics of network components, real time measurements and the current state of the breakers) are sent to the Local SCADA	CENTRAL SCADA	LOCAL SCADA/ MARKET OPERATOR SCADA	VERY LARGE	10s	HIGH	Proprietary	NO	NO	NONE
Load and generation forecast	Updated information about customers are sent to the Local SCADA	CENTRAL SCADA	LOCAL SCADA/ MARKET OPERATOR SCADA	VERY LARGE	10s	MEDIUM	Proprietary	NO	NO	NONE

Name	DESCRIPTION	SENDER	RECEIVER	VOLUME	FREQUENCY	RELIABILITY	DATA MODEL	CONV. IN	CONV. OUT	CHANGE
Network state estimation	The updated information of the State Estimation is sent from the Local SCADA to the Central SCADA.	LOCAL SCADA	CENTRAL SCADA	MEDIUM	15m	HIGH	Proprietary	NO	NO	NONE
Capability curves of the participating resources	The Central SCADA provides Power capability profile (request by the TSO) of the participating resources to the local SCADA.	CENTRAL SCADA	LOCAL SCADA/ MARKET OPERATOR SCADA	LOW	6h	HIGH	Proprietary	NO	NO	NONE
Calculation of the total reactive power capability	The Total Reactive Power capability at the interconnection point, calculated by local SCADA, is sent to the Central SCADA	LOCAL SCADA	CENTRAL SCADA	LOW		HIGH	Proprietary	NO	NO	NONE

Name	DESCRIPTION	SENDER	RECEIVER	VOLUME	FREQUENCY	RELIABILITY	DATA MODEL	CONV. IN	CONV. OUT	CHANGE
Network state estimation, congestions and constraints information	The Central SCADA provides information to the Market Operator SCADA (including the info about state estimation, congestions and constraints)	CENTRAL SCADA	MARKET OPERATOR SCADA	MEDIUM		HIGH	Proprietary	NO	NO	NONE
Set-points acquisition	RTUs take charge of the set-points request from Local SCADA.	LOCAL SCADA	REMOTE TERMINAL UNITS	LOW	6h	HIGH	Proprietary	NO	NO	NONE
Addressing of the set-points to asset controllers	Set-points received by the Field devices are addressed to asset controllers/regulat ors	REMOTE TERMINAL UNITS	FIELD DEVICES	LOW	6h	HIGH	IEC61850	NO	NO	NONE

3.3 FINNISH DEMONSTRATOR

In this chapter the different data exchanges, their requirements and reliability, the data models associated to them and the possible needs to data conversions are listed for the Finnish demonstrator.

The Finnish demonstrator is based on four System Use Cases (SUC). In those the interactions between the different systems operated by the TSO, DSO as well as field assets and the market operator or between the different systems of the aggregator are detailed. They are used as the basis for the following analyses. The SUCs for the Finnish demonstrator are:

- FIN – FC, *Forecast available resources for the Finnish Demo*
- FIN – FL AG, *Aggregate flexibilities for the Finnish Demo*
- FIN – RP MN, *Manage reactive power for the Finnish Demo*
- FIN – RP MK, *Perform DSO reactive power market for the Finnish Demo*

First, in chapter 3.3.1, the information exchange that is needed for active power trading on the TSO market is described. In the following chapter, 3.3.2, the same is done for trading reactive power on the DSO market. However, in the Finnish demonstrator, the two first SUCs, namely *"FIN – FC"* and *"FIN – FL AG"* are needed for both active and reactive power trading. Forecasting (*"FIN – FC"*) and aggregation (*"FIN – FL AG"*) are the two needed steps in proceeding to the FCR-N market or to the mFRR market for active power as well as for proceeding to the DSO reactive power market place. Reactive power trading on the DSO market includes additionally the SUCs *"FIN – RP MN"* and *"FIN – RP MK"*, which together determine the operation of the DSO's market place.

The Finnish demonstrator almost entirely focuses on developing new systems and features, and also a novel market approach for reactive power is examined on a proof of concept basis. This is why most of the data models in the information layer as well as protocols will be determined in a later stage of the project, when the other tools developed are implemented and integrated with each other. Existing protocols and data models will be used but since the development of the systems is still on-going, the information and communication layers have not yet been defined.

3.3.1 DATA COMMUNICATION BETWEEN THE TSO, FORECASTING TOOL, AGGREGATION PLATFORM AND FIELD ASSETS FOR ACTIVE POWER

The scope of the SUC *"FIN – FC"* is to forecast the availability of distributed assets in order to aggregate them and offer them to various markets. Based on this SUC, a forecasting tool is developed in the Finnish demonstration.

The development of this tool is currently in an early phase and the preliminary specifications regarding communication and information exchanges have already been defined. The forecasting action starts when the aggregation platform sends an update-request to the asset forecasting tool. The assumption is that this is done twice a day. The following step in turn is for the asset forecasting tool to send an update-request to the asset data management system to get updated data concerning the status and operation of a specific asset. This data in combination with other data form external sources, such as weather forecast, is used as the basis for creating the

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773505.

updated forecast. When the forecasting process is done, the asset forecasting tool saves the created forecast in a database, from where the aggregation platform is able to acquire it.

The scope of the Finnish system use case "*FIN – FL AG*" is to aggregate the flexibilities from different distributed assets. This is done by creating bids from their forecasted behaviour. Currently, the assumption is that the bids are created at least twice per day. The bids are submitted to the TSO or DSO and later dispatched to the specific resources in case they are activated. The bids will be submitted to the TSO ancillary services several times a day (e.g. currently three times) and the last bid received by the TSO before the market closure will be taken into account in the market clearing process.

The information flow starts from the aggregation platform with the bid creation. The aggregation platform requests forecast and market updates from the database. It should be noted that the forecasting tool will be developed in the Finnish demonstration of EU-SysFlex and currently, the database of asset forecasts or market forecasts does not exists. The market forecasts should include the list of forecasted markets and the information should include the market ID, price forecast, expected deviation or forecasting error and if relevant to the market, the probability of bid activation. The forecast information about a specific resource should at least include the resource ID, forecasted available flexibility and the forecasted times of availability.

As a part of the internal process of the aggregation platform, the platform assigns the assets to the markets in which they are expected to create the largest profit. The next step is to send the information of allocated assets to the aggregator's trading system. The reliability of this step is high, because without this information flow, the aggregator is not able to either create bids or offer the flexible assets to the markets. The information sent from aggregation platform to the trading system should include following arrays: markets ID, times, volumes, prices, and the ID of assets assigned to the bid.

The aggregators trading system stores the asset allocation and after that it submits the bids to the TSO's system managing the ancillary services provision (active power). The bid should include at least the market ID, aggregator's ID and the times, volumes and prices. The TSO (Fingrid in Finland) defines which information the bid should contain and in which format the bid should be sent. At the moment, e.g. in FCR-N yearly market, the bids must be received by the TSO before 6 p.m. The importance of this information exchange is very high, because if it does not succeed, the bidding process will not be successful.

Figure 14 summarizes the processes and their exchanges, as just described, for the aspects of these Use Cases related to active power services provision.

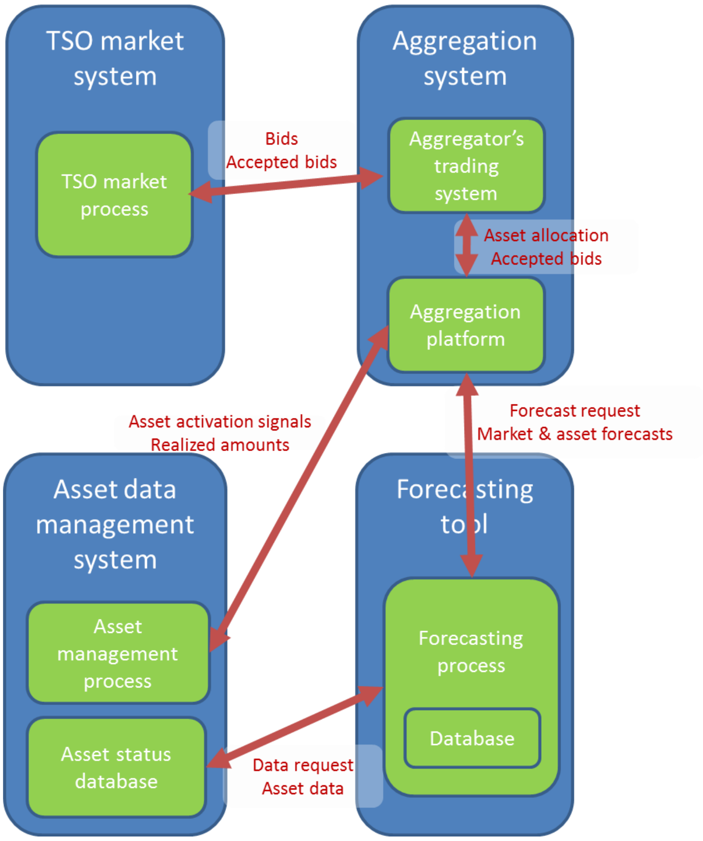

FIGURE 14 COMMUNICATION ARCHITECTURE OF ACTIVE POWER TRADING IN THE FINNISH DEMONSTRATOR

3.3.2 DATA COMMUNICATION BETWEEN THE DSO, FORECASTING TOOL, AGGREGATION PLATFORM, FIELD ASSETS AND Q MARKET PLACE FOR REACTIVE POWER

In the Finnish demonstrator, all the four SUCs are needed for the trading of reactive power. In the previous chapter, the data communication of the forecasting of reactive power (SUC *"FIN – FC"*) and the aggregation of the reactive power (SUC *"FIN – FL AG"*) has been described. These two SUCs are needed to form the bids to the reactive power market place. At the DSO's market place, the DSO's need for reactive power is formed with the SUCs *"FIN – RP MN"*. The actual market mechanism of the reactive power is included in the SUC *"FIN – MK"*. The preliminary data communication of these two SUCs *"FIN-RP MN"* and *"FIN-RP MK"* is described below.

The main scope of the Finnish system use case *"FIN – RP MN"* is to determine whether reactive power will be asked from the DSO reactive power market place (SUC *"FIN – RP MK"*) or not. The DSO reactive power market does not exist at the moment and the proof of concept of this market will be developed in the EU-SysFlex project. Currently, the reactive power control is mainly based on the DSO's 110 kV reactor and capacitors. The control of 110 kV devices is automated and based on the reactive power measurements and the limits of the PQ window. This automated control of 110 kV devices will continue as it is regardless of the ancillary reactive power market that is examined in the EU-SysFlex Finnish demonstration. This SUC makes a decision whether the ancillary reactive power market is started or not. This decision is made with a reactive power dispatch tool. The development of this DSO reactive power dispatch is in an early phase and its technical specifications regarding communication and information exchange haven't yet been defined beyond preliminary estimations. The tool receives the historical measurement data of the PQ window and calculates the need for reactive power from the DSO market place. All the market based reactive power data is hourly data. The output of this SUC is the need for hourly reactive power from the ancillary market. The need is expressed as Mvarh/h for each hour for the next month.

The main scope of the Finnish system use case FIN - RP MK is the market mechanism for the ancillary service of reactive power. This SUC starts when the SUC FIN - RP MN sends an activation signal and the need of hourly reactive power from the ancillary market for the next month (Mvarh/h). The process is thus initiated. The aggregator sends bids through the aggregator interface to the QMarket database where the reactive power offers are compiled. The market is cleared in the QMarket place where the inputs are the needs and the bids of reactive power. The market is cleared. As a result, the QMarket place sends the results to QMarket Database and activation requests to aggregators or asset operators.

The reactive power market place does not exist at the moment. Thus, at this stage there are the first plans for the information flows between various actors. In the demonstration, a proof of concept for the ancillary markets is created and the market will be tested with only a couple of assets. The Figure 15 below presents the information flows between different systems.

Figure 15 summarizes the processes and their exchanges, as just described, for the aspects of these Use Cases related to reactive power services provision

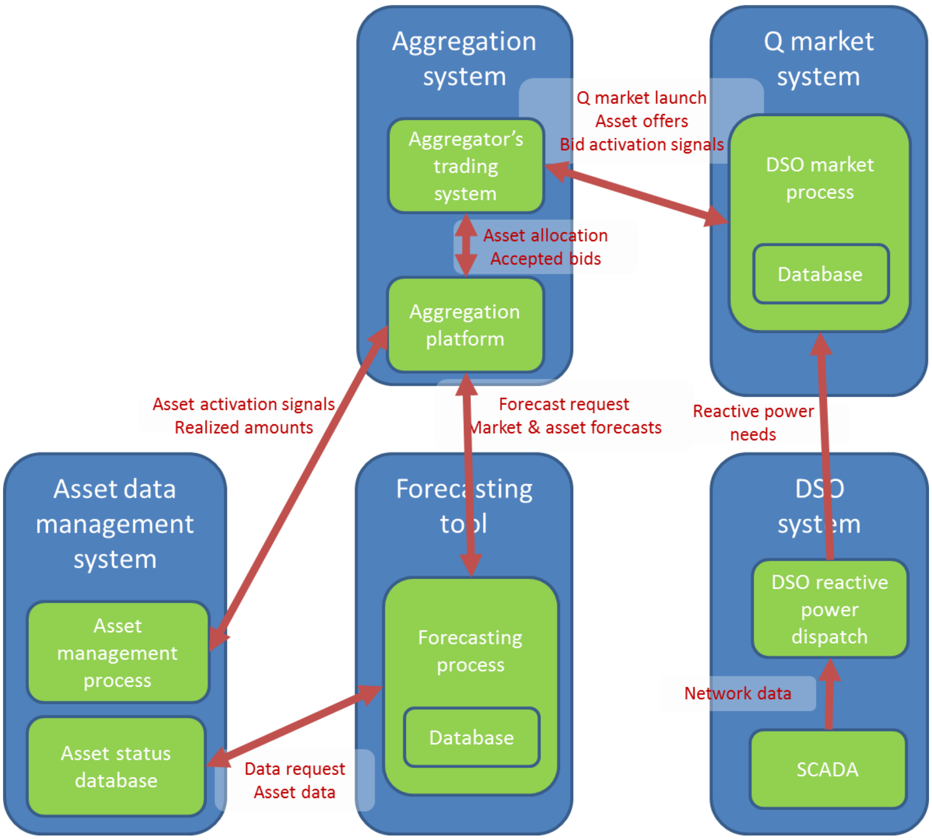

FIGURE 15 - COMMUNICATION ARCHITECTURE OF REACTIVE POWER TRADING IN THE FINNISH DEMONSTRATOR

3.3.3 SUMMARY TABLE FOR THE FINNISH DEMONSTRATOR'S INFORMATION LAYER NEEDS

Based on the diagrams in the previous chapters , Table 3 gives an overview of the information exchanges and of their requirements for the Finnish demonstrator. A description of each field can be found in the introduction for Chapter 3. It can be noted that many exchanges are marked as "To be defined" and "New". They are related to the internal data exchanges between the aggregator's systems as well as to exchanges between the aggregator and the DSO's reactive power market. In both cases, the systems are still in the process of being defined at the time of the publication of this deliverable.

TABLE 3 - INFORMATION LAYER SUMMARY FOR THE FINNISH DEMONSTRATOR

Name	DESCRIPTION	SENDER	RECEIVER	VOLUME	FREQUENCY	RELIABILITY	DATA MODEL	CONV. IN	CONV. OUT	CHANGE
ForecastUpdate Request	The aggregation platform requests the different forecasting tools to update their forecasting. It includes: - ID of the resources to forecast - Time period to forecast	AGGREGATION PLATFORM	ASSET FORECASTING TOOL	SMALL	2/DAY	LOW	TO BE DEFINED			NEW
DataUpdateRequest	Request from the forecasting tools to update the data related to a specific type of resources or market. It includes: - type of resource ID - time period to forecast	ASSET FORECASTING TOOL	ASSET DATA MANAGEMENT SYSTEM	SMALL	2/DAY	LOW	TO BE DEFINED			NEW

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773505.

Name	DESCRIPTION	SENDER	RECEIVER	VOLUME	FREQUENCY	RELIABILITY	DATA MODEL	CONV. IN	CONV. OUT	CHANGE
AssetData	This includes historical and status data for a specific asset or group of aggregated assets. It may include: - Historical data - Status - Planned operations (e.g. planned maintenance, advance booking, etc)	ASSET DATA MANAGEMENT SYSTEM	ASSET FORECASTING TOOL	SMALL	2/DAY	LOW	TO BE DEFINED			NEW
DataUpdated	Notification that the data related to a specific asset has been updated.	ASSET DATA MANAGEMENT SYSTEM	ASSET FORECASTING TOOL	VERY SMALL	2/DAY	HIGH	TO BE DEFINED			NEW
AssetForecast	Forecast information about a specific resource. It may include: - Resource ID - Times - Production/Consumption - Available flexibility	ASSET FORECASTING TOOL	DATABASE	SMALL	2/DAY	HIGH	TO BE DEFINED			NEW
AcceptedBid	- Bid ID - Times - Prices - Volume	AGGREGATOR’S TRADING SYSTEM	AGGREGATION PLATFORM	VERY SMALL	1/DAY	HIGH	OPC UA			NONE
		TSO INTERFACE	AGGREGATOR’S TRADING SYSTEM	VERY SMALL	1/DAY	HIGH	PROPRIETARY			NONE

Name	DESCRIPTION	SENDER	RECEIVER	VOLUME	FREQUENCY	RELIABILITY	DATA MODEL	CONV. IN	CONV. OUT	CHANGE
		DSO QMARKET DATABASE	AGGREGATOR'S TRADING SYSTEM	VERY SMALL	1/MONTH	HIGH	TO BE DEFINED			NEW
ForecastUpdate Request	The aggregation platform requests the different forecasting tools to update their forecasting. It includes: - ID of the resources to forecast - Time period to forecast	AGGREGATION PLATFORM	DATABASE	SMALL	2/DAY	LOW	TO BE DEFINED			NEW
MarketForecast Request	Request for an update of the markets forecasts. It includes: - ID of the markets to forecast.	AGGREGATION PLATFORM	DATABASE	SMALL	2/DAY	LOW	TO BE DEFINED			NEW
AssetForecast	Forecast information about a specific resource. It may include: - Resource ID - Times -Production/Consumption - Available flexibility	DATABASE	AGGREGATION PLATFORM	SMALL	2/DAY	LOW	TO BE DEFINED			NEW

Name	DESCRIPTION	SENDER	RECEIVER	VOLUME	FREQUENCY	RELIABILITY	DATA MODEL	CONV. IN	CONV. OUT	CHANGE
MarketsForecast	Forecasts for a list of markets. It includes: - Market ID - Price - Expected deviation / forecasting error - Probability of activation (if relevant)	DATABASE	AGGREGATION PLATFORM	SMALL	2/DAY	LOW	TO BE DEFINED			NEW
AssetAllocation	- Array of markets ID - Array of times - Array of volumes - Array of prices - ID of the assets assigned to the bid	AGGREGATION PLATFORM	AGGREGATOS'S TRADING SYSTEM	SMALL	2/DAY	HIGH	TO BE DEFINED			NEW
Bid	Bid for active or reactive power market. It may include: - Market ID - Aggregator's ID - Times - Volumes - Prices	AGGREGATOR'S TRADING SYSTEM	TSO / MARKET INTERFACE	SMALL	VARYING, 3/DAY, LATEST BEFORE 18:00	HIGH	PROPRIETARY			NONE
		AGGREGATOR'S TRADING SYSTEM	DSO QMARKET DATABASE	VERY SMALL	1/MONTH	HIGH	TO BE DEFINED			NEW

Name	DESCRIPTION	SENDER	RECEIVER	VOLUME	FREQUENCY	RELIABILITY	DATA MODEL	CONV. IN	CONV. OUT	CHANGE
MeasurementDataRequest	Request for measurement data, including: - Assets ID or network component ID - Time periods - Data to be sent (eg. active power, reactive power, capacity...)	SCADA	DEVICES	SMALL	TRIGGERED FROM CHANGE	HIGH	IEC61850	NO	NO	NONE
NetworkData	Data about the static and dynamic state of the DSO network, including: - position, the graphic symbol and the connection mode of each grid component - electrical characteristic of each grid component - measurements and events from PQ window - control step position and on/off status of the 110 kV reactor/capacitors.	DEVICES	SCADA	SMALL	SEVERAL	HIGH	IEC61850 IEC 60870-5-104			NONE
		SCADA	SCADA	SMALL	SEVERAL	HIGH	IEC61850 IEC 60870-5-104			
		SCADA	DSO REACTIVE POWER DISPATCH	SMALL	1/MONTH	LOW	TO BE DEFINED			NEW
		DSO REACTIVE POWER DISPATCH	DSO REACTIVE POWER DISPATCH	SMALL	1/MONTH	LOW	TO BE DEFINED			NEW
ReactorCapacitorSetPoints	- Network asset ID - Set Point	SCADA	DEVICES	SMALL	3/HOUR	HIGH	IEC61850 IEC 60870-5-104			NONE

Name	DESCRIPTION	SENDER	RECEIVER	VOLUME	FREQUENCY	RELIABILITY	DATA MODEL	CONV. IN	CONV. OUT	CHANGE
ReactivePowerNeeds	Needs for reactive power. - ID of a part of the network - time periods - reactive power needed (in kvar) for each time period	DSO REACTIVE POWER DISPATCH	QMARKET PLACE	VERY SMALL	1/MONTH	LOW	TO BE DEFINED			NEW
QMarketLaunch	Initiation of a reactive power market. - Market ID - Time periods - Network part ID - Reactive power needs	QMARKET PLACE	AGGREGATOR INTERFACE, QMARKETPLACE	VERY SMALL	1/MONTH	LOW	TO BE DEFINED			NEW
AssetOffer	Information about the assets and their willingness to provide reactive power for the upcoming time period. - Asset ID - Reactive power that can be provided during the next time period (kvar) - Price (€/kvar)	AGGREGATOR INTERFACE	QMARKET DATABASE	VERY SMALL	1/MONTH	LOW	TO BE DEFINED			NEW
		QMARKET DATABASE	QMARKETPLACE	VERY SMALL	1/MONTH	LOW	TO BE DEFINED			NEW
QMarketResults	- Bid ID - Acceptance (full or partial) or rejection of the bid	QMARKET PLACE	QMARKETDATABASE	VERY SMALL	1/MONTH	LOW	TO BE DEFINED			NEW

Name	DESCRIPTION	SENDER	RECEIVER	VOLUME	FREQUENCY	RELIABILITY	DATA MODEL	CONV. IN	CONV. OUT	CHANGE
BidActivation	- Bid ID - Time period - Activation (total, partial or not at all)	QMARKET DATABASE	AGGREGATOR INTERFACE	VERY SMALL	1/MONTH	LOW	TO BE DEFINED			NEW

3.4 COMMON VIEW

The three demonstrators have specific needs regarding communication in general and it reflects on their needs regarding the Information Layer. The Italian and German demonstrators take the perspective of the DSO. They focus on the DSO's role in flexibility management, exchange network status data and signals such as operating points and schedules required for the operation of the network. The German one also includes forecasting data to be used by the DSO. in the Finnish demonstrator, the retailer becomes the main actor. It acts as the aggregator of LV-distributed flexibilities for the system and the focus is more on the forecasting and operation of assets from its point of view.

Looking at the demonstrators as a whole, they include different and complementary forms of data exchanges and control signals between the assets, the DSO, the aggregator and the TSO or market operators, covering both the technical and the commercial operations of the resources.

It can be seen that, in general:

- the communication between the DSO's (such as the SCADA) and others' systems or DSO devices (such as the Remote Terminal Units) is in most cases based on
    a. the IEC 60870-5-104 or IEC 60870-5-101 standards
    b. the IEC 61850 standard

  for the control signals sent by the SCADA to distributed units or for network status, data exchanges and for integration/interaction between DSO devices in the substations;
- the Common Information Model is used for exchanges between the TSO and DSO.

These worldwide used standards ensure interoperability of systems for the supervision, control and communication in power systems. In the cases where they overlap, the demonstrators apply the same standard-based data models. This is the purpose of developing standardized communication and is a big step towards allowing interoperability between the systems. The demonstrators, however, implement different actions between different actors with varied information contents and data models. This introduces more specific communication needs and creates a more complete architecture.

It was identified during the planning phase of the demonstrators that the measurement information and the data exchanges between the SCADAs or custom systems are not always well suited to be converted to standardized data models such as the CIM. The reason is that it represents large amounts of data, that need to be transferred fast and thus, adding the weight of the structure surrounding data models such as in the CIM would make the system too slow.

Regarding the development of communication tools during the EU-SysFlex project, the remaining points that require work are the communication between the custom made systems (some of them, such as the Finnish demonstrator, being entirely developed during the project) and the need, in the German demonstrator, to convert some inputs and outputs to the CIM data models using smart data recovery mechanisms.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773505.

4. COMMUNICATION LAYER

In the SGAM framework, the communication layer describes protocols and mechanisms for the interoperable exchange of information between components in the context of the underlying use case, function or service and related information objects or data models.

The communication layer defines how the data defined in the information layer can be converted into the actual messages, i.e. string of bits that will be exchanged between the systems. It should make it possible for the messages to be exchanged in a reliable and cyber-secured way and can restrict what types of exchanges are possible (real-time, one-way, bi- or multidirectional, request based, etc.).

In the following sections (summary in Tables 4, 5 and 6) the pairs of systems that exchange information in each demonstrator are listed. For each of them, the following information is presented:

- the two systems exchanging data: System 1 and System 2,
- the protocol that is used in the demonstrator in order to transfer the data/information between System 1 and System 2,
- and the reason why that protocol has been chosen (historical, security, reliability, cost…).

Those tables are each accompanied by a figure summarizing the status of the communication between the systems for the demonstrators. The figures show the interaction, but also the data models and protocols used in the demonstrators. For example, in the German demonstrator (Figure 16), the exchanges between the DSO's and the TSO's systems are realized using the CIM and custom-made data models and the IEC 60870 protocols.

Only the interactions that are relevant for the purposes of the demonstrators are represented in the tables and figures. For that reason, not all the actors or roles (e.g. the aggregator) are present in each of them.

Short descriptions of the different protocols mentioned in the demonstrators' chapters can be found in the common view (Chapter 4.4).

4.1 GERMAN DEMONSTRATOR

The exchange of information in the German demonstration is described in this chapter. The protocols used in the German demonstration are already used by the DSO for various other data exchange purposes. Therefore, no new additional protocol is needed.

In the German demonstrator, the control room's operating system sends Zip files via SCP (Secure Copy) to a Windows server outside of their security area every 5 to 15 minutes. The zip file contains four CIM files, one file per CGMES profile, namely:

- Equipment profile (EQ) for device information.
- Topology profile (TP) for grid topology information.
- Steady state hypothesis profile (SSH) for load flow simulation.
- State variable profile (SV) for measurement information.
- Additional asset master data, like flexibility costs

as well as data not included in CIM files, namely:

- Additional asset master data, like flexibility costs and protection parameters.

From this Windows server (available locally at the DSO), the Zip files are then further copied via SCP to a Linux server (SUSE, also localized at the DSO) where the unzipping of the .zip file is done. The Windows server works as a terminal server for the Linux server. The Software Platform validates and captures the CIM files to transfer their contents to a database (PostGresSQL). Other applications (e.g., calculation of the operating schedule) have access to the data via a REST (REpresentational State Transfer, software architecture used for Web services) interface. The data for the forecast (.csv files) are sent in the same way from the DSO to the Software Platform. The operating schedules are displayed by the Software Platform, in an XML file defined by the grid control centre software manufacturer, and sent back to the grid control centre via the same route.

The communication between DSO and TSO is set up as a secure connection between the two grid control centres. The standardised protocol of IEC 60870-6-TASE.2 enables the permanent exchange of data and information. If there is new information, it will be transmitted. Also CIM data is transferred within the GLDPM process.

Addressing the field assets with new setpoints is performed through the protocol of IEC60870-5-101 with a customised data model.

The DSO grid control centre sends measurements from the grid nodes via ftps (file transfer protocol secure) to the Forecast Providers packed as a .zip file. The .zip file contains four CIM files, one file per CGMES profile, namely:

- Equipment profile (EQ) for device information.
- Topology profile (TP) for grid topology information.
- Steady state hypothesis profile (SSH) for load flow simulation.
- State variable profile (SV) for measurement information.

Furthermore, the DSO sends meta information about geographic location and installed capacity to the Forecast-Provider via FTPS (File Transfer Protocol Secure). These data are only sent if changes occur.

FTPS was chosen because it guarantees secure encrypted traffic that is difficult to infiltrate with malicious code. The FTPS server is located at the Forecast-Provider and is administered by him.

The NWP-Provider delivers weather forecast to the FTP (file transfer protocol) Server located at the Forecast-Provider or makes the data available on its own FTP server. FTP is used by default by the providers because the data is not highly classified, but the data volume is quite large with several GB per delivery. By using FTP it is taken care that no excessive data overhead and efforts for encryption arise.

Table 4 and Figure 16 summarize, for each pair of systems, the information exchanged in the German demonstrator, what kind of systems communicate, the protocol used for the data transfer and the reason for choosing that protocol. In Figure 16, the plain arrows show communication channels used and implemented in the demonstrator. They are tagged with the data models (e.g. CIM) and the communication protocols (e.g. IEC 60870-5-101) used for the exchanges. The dotted arrow represents communication that is relevant for the system but are out of scope of the demonstrator.

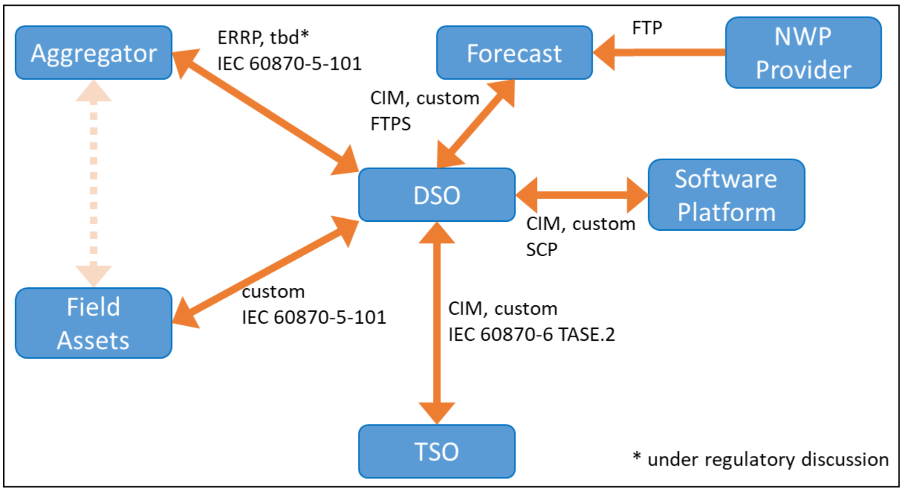

FIGURE 16 - SIMPLIFIED COMMUNICATION IN THE GERMAN DEMONSTRATOR

TABLE 4 - COMMUNICATION LAYER SUMMARY FOR THE GERMAN DEMONSTRATOR

SYSTEM 1	SYSTEM 2	PROTOCOL	REASON
DSO	FIELD ASSETS	IEC 60870-5-101	Historical, security
DSO	AGGREGATOR	Regulation under discussion	Historical
AGGREGATOR	DSO	IEC 60870-5-101	Security
DSO	SOFTWARE PLATFORM	SCP	Security
SOFTWARE PLATFORM	DSO	SCP	Security
DSO	FORECAST	FTPS	Security
FORECAST	DSO	FTPS	Security
TSO	DSO	IEC 60870-6 TASE.2	Security
DSO	TSO	IEC 60870-6 TASE.2, CIM	Security
NWP PROVIDER	FORECAST	FTP	System given by Provider

4.2 ITALIAN DEMONSTRATOR

In this chapter, solutions for sending data between the systems in the Italian Demonstrator are detailed. Most of the protocols are already defined because the majority of the systems were in place at the beginning of the demonstrator. The innovations of the demonstrator regarding the communication lie mainly in updating and extending the existing data models and profiles in order to integrate new devices (e.g. STATCOM) or extensions of functionalities.

The Primary Substation RTUs communicate with the Central SCADA by RPC protocol (the structure of data is proprietary).

The Secondary Substation RTUs used in MV/LV substations include a special on-board DC/DC converter that provides the power supply for the GSM communication module used in more than 100.000 already remote controlled substations in Italy.

The communication between Secondary Substation RTUs and SCADA exploits a wireless network (e.g. 4G LTE) and a private wired network adopting a router. The application protocol is fully compliant with the IEC 60870-5-104 profile. Secondary Substation RTUs are fully programmable through a PC based local configuration terminal which can be also used for diagnostic purposes. The application program and all the main important parameters are downloadable from the control centre. These RTUs are able to run algorithms based on the automata theory for the fault isolation and fast restoration of the service along the MV.

The central SCADA is located in the Operative Centre in charge of managing the MV grid. It communicates with the Local SCADA located in the HV/MV Substation, sends requests and receives information from devices located both in HV/MV and MV/LV Substations. Moreover, it sends to the Local SCADA the topological description of the network connected to the HV/MV Substation on which the Local SCADA itself is located.

Table 5 and Figure 17 summarize for each pair of systems, information exchange in the Italian demonstrator, what kind of systems communicate, the protocol used for the data transfer and the reason for choosing that protocol. In Figure 17, the plain arrows show communication channels used and implemented in the demonstrator. They are tagged with the communication protocols (e.g. IEC 60870-5-104) used for the exchanges. The dotted arrows represent communication that is relevant for the system but out of scope of the demonstrator.

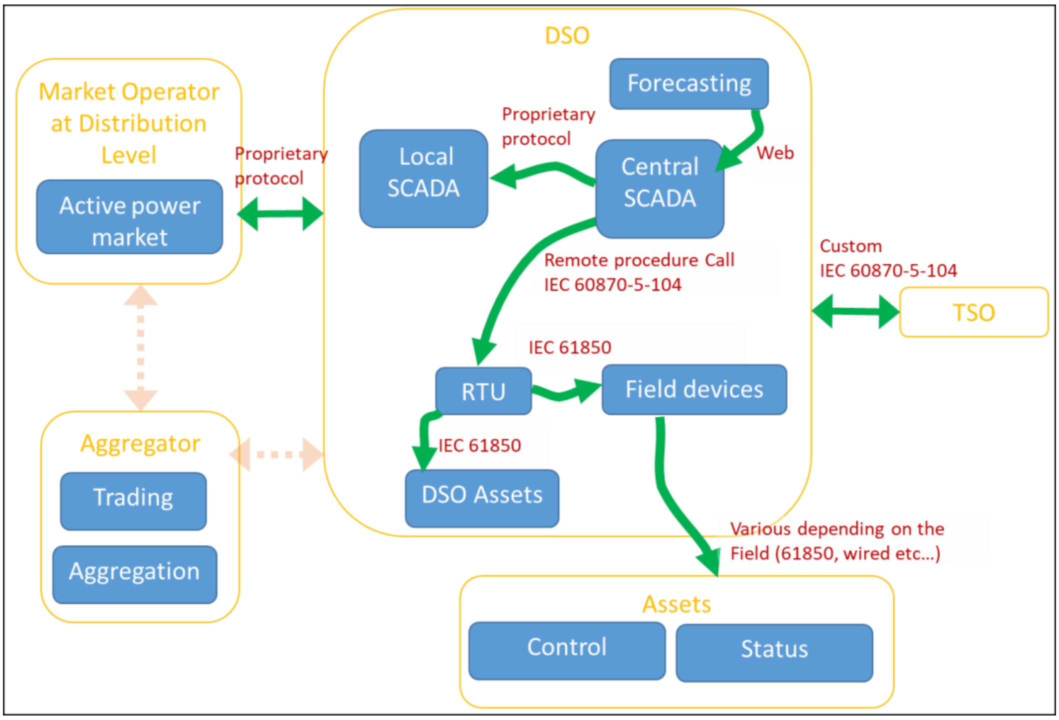

FIGURE 17 - SIMPLIFIED COMMUNICATION IN THE ITALIAN DEMONSTRATOR

TABLE 5 - COMMUNICATION LAYER SUMMARY FOR THE ITALIAN DEMONSTRATOR

SYSTEM 1	SYSTEM 2	PROTOCOL	REASON
CENTRAL SCADA	RTUS	RPC (PROPRIETARY STRUCTURE) IEC 60870-5-104	HISTORICAL SECURITY
FIELD DEVICES	RTUS	IEC 61850	INNOVATION
RTUS	DSO ASSETS	IEC 61850	INNOVATION
CENTRAL SCADA	LOCAL SCADA	PROPRIETARY	SECURITY
CENTRAL SCADA	MARKET OPERATOR SCADA	PROPRIETARY	SECURITY
DSO	TSO	IEC 60870-5-104 TELEPHONE MAIL	SECURITY
TSO	DSO	TELEPHONE MAIL	SECURITY
DSO	FORECAST	FTPS	SECURITY

4.3 FINNISH DEMONSTRATOR

This chapter defines the protocols used to send data between systems. Because the majority of the systems in the Finnish demonstrator are new and being developed during the EU-SysFlex project, most of the protocols are currently still undefined. However, for the existing systems the used protocols and the reasons are presented in Table 6 below.

The used protocol between the aggregator's trading system and the TSO interface is FTP (file transfer protocol). The TSO determines which protocols and formats should be used in the communication with its own interface. The protocol between aggregation platform and aggregator's trading system is OPC UA for security reasons.

Communication between the 110 kV devices (capacitors and reactors) and SCADA is realized with standard IEC 61850 and IEC 60870-5-104 protocol.

In Figure 18, the communication protocols used between the systems is summarized. It should be noted however that the aggregation platform, the asset forecasting tool, the asset data management system and the database are included in the "Aggregation" box because, in practise, they will be implemented in the same system. The same applies to the reactive power market place and its database, both included in the "Reactive power market" box. The grey arrow represents communication that is relevant for the system but out of scope of the demonstrator.

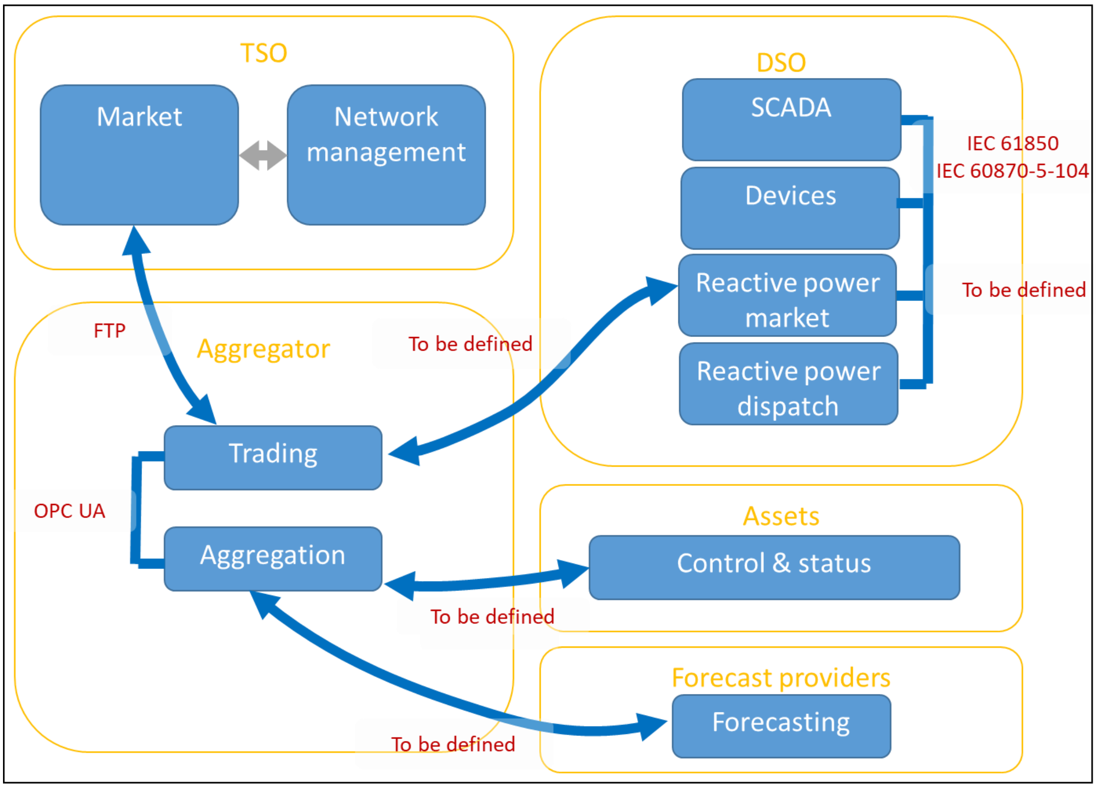

FIGURE 18 - SIMPLIFIED COMMUNICATION IN THE FINNISH DEMONSTRATOR

TABLE 6 - COMMUNICATION LAYER SUMMARY FOR THE FINNISH DEMONSTRATOR

SYSTEM 1	SYSTEM 2	PROTOCOL	REASON
AGGREGATION PLATFORM	ASSET FORECASTING TOOL	TBD	
ASSET FORECASTING TOOL	ASSET DATA MANAGEMENT SYSTEM	TBD	
ASSET DATA MANAGEMENT SYSTEM	ASSET FORECASTING TOOL	TBD	
ASSET FORECASTING TOOL	DATABASE	TBD	
AGGREGATOR'S TRADING SYSTEM	TSO / MARKET INTERFACE	FTP	HISTORICAL
AGGREGATION PLATFORM	DATABASE	TBD	
AGGREGATION PLATFORM	AGGREGATOR'S TRADING SYSTEM	OPC UA	SECURITY
SCADA	DEVICES	IEC 61850 IEC 60870-5-104	HISTORICAL
SCADA	DSO REACTIVE POWER DISPATCH	TBD	
DSO REACTIVE POWER DISPATCH	REACTIVE POWER MARKET PLACE	TBD	
REACTIVE POWER MARKET PLACE	AGGREGATOR INTERFACE	TBD	
AGGREGATOR INTERFACE	REACTIVE POWER MARKET DATABASE	TBD	
REACTIVE POWER MARKET DATABASE	REACTIVE POWER MARKET PLACE	TBD	

4.4 COMMON VIEW

After having analysed the communication layer of the three demonstrators, we draw a common view on the demonstrations in this section.

We can note, regarding the communication layer, that the IEC standards are used adequately:

- International standards IEC 60870-5-101, IEC 60870-5-104 and IEC 60870-6 TASE.2 are used to communicate between the DSO and the distributed assets, as well as between the TSO and DSO.
- More general FTPS communication is also used in order to transfer data that is not specifically network related, such as market signals or weather or other types of forecasts, in a cyber-secure way.

Table 7 summarizes the protocols used in the different demonstrators.

TABLE 7 - PROTOCOLS USED IN THE DEMONSTRATORS

PROTOCOL	GERMAN DEMO	ITALIAN DEMO	FINNISH DEMO
IEC 60870-5-101/104	x	x	x
IEC 60870-6 TASE.2	x		
IEC 61850		x	x

Table 8 summarizes the main features some of the standard protocols as used in the demonstrators, detailing their latency, transport and support possibilities.

TABLE 8 - MAIN FEATURES OF THE STANDARD PROTOCOLS

PROTOCOLS	LATENCY	INTERFACE	HARDWARE TECHNOLOGY
IEC60870-5-104	SECONDS	TCP/IP	WIRELESS 4G OR PRIVATE WIRED NETWORK
IEC61850 (CLIENT-SERVER)	SECONDS	TCP/IP	WIRELESS 4G OR PRIVATE WIRED NETWORK
IEC61850 (GOOSE)	<100 MS	ETHERNET	TELEPROTECTION GATEWAY WIRELESS 4G OR PRIVATE WIRED NETWORK
RPC	SECONDS	TCP/IP	WIRELESS 4G OR PRIVATE WIRED NETWORK

5. COMMUNICATION AND DATA EXCHANGES: WORK IN PROGRESS AND NEXT STEPS

This chapter shows communication aspects from each demonstrator that require developments in the EU-SysFlex project. At first the applications that will be created or modified for the project, their requirements and their impact on the communication systems are presented. Then, the support functions, which are used for data handling only, are presented. In the end, an analysis of the development needs in the demonstrators is conducted comparing the status of the applications and support functions before the beginning of the EU-SysFlex project on the one hand, and on the other hand with the requirements of the applications and support functions for the demonstrators.

5.1 COMMUNICATION AND DATA EXCHANGE TOOLS FOR THE GERMAN DEMONSTRATOR

Within the German Demonstrator, there are two kinds of processes which exchange data with each other and their environment. One kind are applications fulfilling main tasks, which are relevant for the specific use cases. The other kind are supportive functions which provide the applications with required data and information.

In the following chapters, brief descriptions about those applications and support functions and their data exchanges (internal and external) are given.

5.1.1 APPLICATIONS

In this chapter, the applications which are under development in the framework of this project are described. The descriptions focuses on the main purposes of the tools, and the data which are exchanged inside them.

Optimization Tool

This tool, mainly created in Python, is used to calculate generator set points within a given grid and based on different requests (here: TSO requests). One request could be, for example, to calculate the flexibilities available at the grid connection points. To fulfil the targeted goals some communication to other services is needed. One of the most important input is the grid. All bottlenecks need to be removed, so the output from the NCM tool is the input for the optimization tool. From a technical perspective the optimization tool “follows” the NCM tool. This means when the NCM tool puts a message on the message bus, the optimization gets triggered and automatically retrieves the grid layout via a proxy in the system platform. This grid layout has to be described as a pandapower network. To meet additional requirements, the grid layout also needs to be provided as input, which means that when this service gets triggered the additional data automatically will be retrieved from another service. This service, named “input setpoint service”, provides data such as grid connection points, on which the optimization should run. In addition, optional input generator setpoints will be received from the “input setpoint service”. The core of the optimization tool is a grid calculation/optimization program written in AMPL, using the “knitro”-solver. The data exchange between the python and AMPL program is file based. The grid description itself is split into two files. The structures of these files base on the matpower/pypower case-file layout. In order to keep the main grid data file nearly identical to a grid description of a matpower file, additional data, necessary for an optimal power flow, are written into a second file ("ampl_DAT_GridData.dat", "ampl_ADD_GridData.dat"). Additionally, grid dependent variables as well as individual optimization objectives are implemented in an additional file also using AMPL syntax ("ampl_VAR_Python.mod"). Performing several optimizations with the same grid layout, these three files have to be created only once. Only in case (n-1)-problems are detected considering the optimized generator setpoints, further data describing the (n-1)-cases have to be added. Furthermore, there is a fourth file defining the optimization problem to be solved ("ampl_PRB_Python.mod"). Thus, only this single file has to be modified with every new request performing several different optimizations using the same grid layout. Within the main program, an AMPL-API-object is being used to perform the optimization as well as to access the calculation results. Taking the optimized generator set points into account, an (n-1)-calculation is performed in order to ensure grid stability. In case of (n-1)-results, in addition to the (n-0) grid layout, all grid layouts in which an (n-1)-problem occurs, are assigned to the AMPL optimization problem via the described files processing an additional optimization cycle. In case the optimized setpoints do not create any problems ((n-0) as well as (n-1)), these results, which mainly consist of setpoints for the generators within the grid, are saved to a database as CIM objects. To identify this setpoints, a unique version object will be created and stored in the database. Finally, a message will be put on the message bus using the b proxy to broadcast about new available setpoints witch can be retrieved by other services.

State Estimation Tool

This tool uses the CIM files converted pandapower Networks and the forecasted asset state to estimate the network state in the future, or estimate the grid state with measurements delivered from the grid control centre. The result of the estimation tool will be transferred for the NCM process with pandapower networks.

NCM TOOL

The NCM Tool is used to check and solve violations on N-1 contingency on the high voltage grid with the grid configuration and estimated state from the state estimation tool. This tool will also use the pandapower network as input data. The resulting network state with new P-setpoints will be transferred to the optimization tool in the pandapower network data format.

Forecast

TheForecaster.DayAheadGridNode

Calculates the generation forecast by a DER or the load at a single feed-in point. Therefore, it uses weather forecasts from deterministic or ensemble models from one or several NWP provider.

The forecast is valid for lead times from 0 to 72 hours. The prediction is based on trained models of artificial intelligence or physical approaches. The output of the module will be a deterministic or a quantile forecast. The update cycle of the forecast depends strongly on the selected weather model.

TheForecaster.IntraDayGridNode

Similar to the TheForecaster.DayAheadGridNode the Intra-Day module calculates a forecast for a single feed-in point, but for shorter lead-times up to 8 hours. Therefore, an update of the forecast is calculated every 15 minutes. This module uses online measurements of active power to further improve the prediction quality compared to the Day Ahead module. This improvement has only an effect for lead times up to eight hours. The output is the same as in Module TheForecaster.DayAheadGridNode

TheForecaster.SeamlessPrediction

Intra-Day and Day-Ahead forecast modules create forecast for different lead times. In addition, they will generate slightly different forecasts through different input data sets (weather model, online measured power data). In order to generate a consistent prediction, the predictions must be nudged in an intelligent way, which will be done by this module.

TheForecaster.TheAggregator

The calculated forecasts of the DER and the forecasted loads has to be aggregated at the grid nodes depending on the switching state of the electrical grid. Therefore the module accesses the meta data from the DSO to estimate which DER is currently assigned to which transformer in the grid. Based on this information the energy sources and loads are aggregated and the resulting forecast is then send to the Reporter Module (0).

5.1.2 SUPPORT FUNCTIONS

In this chapter, the supportive functions that provide the applications with required data and information are being presented.

OperatingScheduleXMLConverter

This tool sends the calculated operating schedule for active/reactive power from the Software Platform to the control room software of the DSO. For this purpose, an XML file defined by the control room software manufacturer is sent via SCP.

Forecast2CIMConverter

This tool is used to capture the forecast data from the provider. For this purpose, the forecast data from the CSV files are modulated according to CIM and stored in a database.

TheConverter.CIM (forecast)

The Forecast Framework is not yet able to read CIM data directly. Therefore a new importer has to be included, which converts the actual measured loads from the CIM files into the custom format of the Forecast Framework. The tool should be configurable in many ways, so that it will be possible later to read other parameters from the CIM file or to handle different CIM structures.

TheReporter.ForecastMitnetz (forecast)

For exporting the forecast from Forecast Framework own format to the custom format used by the DSO a new converting module must be build.

5.1.3 DEVELOPMENT NEEDS FOR THE GERMAN DEMONSTRATOR

In order to operate the German Demonstrator, there are several needs for development in regards to the communication systems. Most of all, it is the delivery of schedules and accurate forecasts, regularly and frequently updated, for active and reactive power infeed and demand. Therefore, converter tools to enable the data processing are needed. The OperatingScheduleXMLConverter and the Forecast2CIMConverter to implement schedules and forecasts in the software platform. The TheConverter.CIM and the TheReporter.ForecastMitnetz are needed in the forecasting tool to read the input from the DSO and send the output back to the DSO. Additionally within the OPF, a converter (CIM2PPConverter) is needed to integrate the grid configuration in pandapower format and the measurements, schedules and forecasts in the CIM. The OPF also needs estimated grid states processed in StateEstimationTool, congestion free grid states processed in NCMTool and the Optimisation Tool for optimising pandapower formatted grid in an AMPL written optimisation core. The data exchange from software platform to grid analysis tool is realised via CIM2PPConverter. The data processing within the grid analysis tool is realised via the State Estimation Tool and the data exchange back to the software platform is realised via the NCMTool.

5.2 COMMUNICATION AND DATA EXCHANGE TOOLS FOR THE ITALIAN DEMONSTRATOR

This section presents the applications and support functions of the Italian demonstrator identifying the development needs to take the systems from their status before the start of the EU-SysFlex project to a successful implementation of the demonstrator.

5.2.1 APPLICATIONS

In this chapter, the applications which are under development in the framework of this project are described. The descriptions focus on the main purposes of the tools and the data which is exchanged inside.

Forecasting Tool

Starting from the necessity to collect and process data related to distributed generations, e-distribuzione uses a specific tool. It can provide measurements (after 24 hours) and forecasts (72 hours ahead) of active power generated by renewable energy sources. Basically the forecast tool uses information coming from asset management Data Bases[2], and SCADAs in order to provide data to the State Estimation Tool and Optimal Power Flow Algorithms.

The adopted method is based on the well-known PVUSA[3] model for PV plant, exploiting only power generation measurements and theoretical clear-sky irradiance in a scenario where measurements of meteorological variables (i.e. solar irradiance and temperature) at the plant site are not available.

The proposed approach efficiently exploits only power, and is characterized by very low computational effort and it is built upon a model-based approach to the solution of the power forecasting problem in the partial information case. The method consists in the estimation of the parameters of the above mentioned PVUSA model of the plant using only historical data of generated power, and temperature (but not irradiance) forecasts.

It is launched every 24 hours with a time horizon of 72h, with time step of 60 minutes due to the availability of weather forecast by providers. The output of the algorithm is the active power generated by each PV plant connected to the distribution network.

State Estimation Tool

The State Estimation (SE) algorithm, developed under the Grid4EU grants, is composed by three main modules:

- Power Flow
- Simple State Estimation
- Complete State Estimation

The Power Flow module is based just on the voltage measures of the Primary Substation HV bus-bar and on the load and generation profiles of the MV connections (Generators, Passive Customer, “Prosumers” and MV/LV transformers).

[2] e.g. network connection status, measurements, data coming from electronic meters, weather forecasts provided by third parties, etc.
[3] Photovoltaics for Utility Scale Applications

The Simple State Estimation is based on all the relevant measurements available at the Primary Substation level (HV and MV bus-bar voltages, MV feeder currents, active and reactive power flows on the HV/MV transformers).

Lastly, the Complete State Estimation is able to compute even the available measures on the MV network (voltages on MV bus-bars, active and reactive power flows on branches, current flows on branches).

The algorithm has a sampling time of 15 minutes or it reacts after network changes (such as remote control reconfigurations or automatic manoeuvres for network restoration).

The State Estimation (SE) tool receives as inputs the grid topology, the measurements and the forecasts, and generates a description of the system in terms of P, Q, V at MV nodes.

Reactive Power calculation tool

This function, mainly developed in Matlab, allows the DSO to determine the reactive power that can be provided by local resources to the TSO, in real time (based on actual data) or the future availability of the network to provide voltage control (using forecasts). The limits introduced by the distribution networks (lines loading, voltage limits, etc.) as well as the operational procedures of the DSO have to be included.

The algorithm is based on the use of the OPT block (VoCANT, see the following), an Optimal Power Flow algorithm described in the following. The aggregated reactive power capability is computed by the means of a virtual unit connected to the Primary Substation interface. The costs associated to the virtual unit are designed so that the OPF determines the state of the network (generators set-points, OLTC position…) that allows the maximum exchange of reactive power (in absorption and in injection) with the transmission network. The information required by the tool are the same of the OPT block.

Optimal power flow tool

The OPT block (VoCANT) has the goal of minimizing a desired objective function, while satisfying the technical constraints (voltage at nodes, current in branches, and the power exchange at the Primary Substation). The objective function is mainly defined from the power exchange of each flexible resource: for every flexibility resource that can exchange power with the network a proper ‘cost’ is set with respect to the reactive and active power injection and absorption. The objective function is then the sum of all these contributions. With particular setting of costs it is possible to reach different control strategies, such as the reduction of active power losses or a desired exchange of power in primary substation. The algorithm can include storage units (BESS), operated by the DSO, into the mathematical problem by means of completely configurable parameters.

When the control system is in operation, the Voltage and Power Flow regulator is triggered by the general scheduler in the cases seen above for the State Estimation (time trigger, network changes, events). Offline, it can be used for evaluating different scenarios in term of DER participation, technical characteristics (DER capabilities), and economic aspects (remuneration for services).

The calculation is based on matrixes, exchanged with the calculation platform:

Inputs from the State Estimation Block:

- Nodes
- Lines
- Transformers and OLTC
- Generators
- Costs /priorities for using flexibility resources
- BESS state
- Load forecast
- Generation forecast
- Directives for the optimization (objective function, number of time periods, exit criteria, etc.)

Outputs to the calculation platform (NCAS):

- Setpoint P, Q for controllable DER
- Setpoint OLTC, STATCOM, BESS
- BESS forecast (for operational planning purposes).
- Network state (voltage and current)

5.2.2 SUPPORT FUNCTIONS

Apart from the configuration files to be sent to the State Estimator and the Optimal Power flow, there are no relevant support functions to be mentioned.

5.2.3 DEVELOPMENT NEEDS FOR THE ITALIAN DEMONSTRATOR

Currently, the Italian standard for connecting active customers to the distribution networks already foresees a communication channel with the DSO for monitoring and control functionalities, based on IEC 61850. The details on data models and profiles are not yet defined, mainly because the regulatory framework for local services was lacking.

Meanwhile, the ancillary service market was opened to DERs (act 300/17 of the National Regulatory Authority); in this case, generators interacting directly with the TSO platform, have to adopt standard IEC 104.

In order to integrate new requirements deriving from enlargement of the Ancillary service market to DERs (interfaces with TSO, DSO, and aggregator), and from the implementation at the national level of the European network code SO GL (monitoring of *Significant Grid Users*), changes to the Standard are under discussion.

In the Italian Demonstrator, these perspective evolutions are already taken into account, also because representatives of EU-SysFlex partners participate to the involved Standardization Committees.

5.3 COMMUNICATION AND DATA EXCHANGE TOOLS FOR THE FINNISH DEMONSTRATOR

Within the Finnish demonstrator, the communication and data exchange tools are divided to applications and supporting functions. The applications include forecasting tool, reactive power market mechanism, and the DSO's need for reactive power dispatch. The needed supporting function in the Kivikko PV plant is the manual set-point control. These applications and supporting functions are being presented in the following sections. Then, an analysis is conducted to identify the needs and requirements of the applications and support functions for the demonstrators.

5.3.1 APPLICATIONS

In this chapter, the applications which are under development in the framework of this project are described. The descriptions focus on the main purposes of the tools and the data which is exchanged inside.

Forecasting Tool

The asset forecasting tool is an essential and central tool that is developed during the project. It is a software that receives input data from internal and external sources (e.g. asset properties data, weather forecast, historical data and market data) and gives as an output the hourly capacity (MW) that is available from a specific type of distributed asset for a certain market place. In the case of reactive power, the forecasting tool gives as an output an estimation of the hourly available reactive power compensation potential of an asset. For active power, the forecasting tool will allow for the aggregator party to make appropriate bids to the TSO ancillary services. The forecast extends at least 1-2 days ahead, but the exact specifications of the output are not yet defined. Applying reactive power forecast, the aggregator party can formulate the bids to the DSO's reactive power market.

The software is running on an external server and thus a communication channel and an interface between the forecasting tool and the aggregation platform is needed. Through this interface, the aggregation platform can request and receive an updated forecast from the tool as well as provide data to the forecasting tool if necessary. Another interface needs to be established between the forecasting tool and the assets. Through this interface, the forecasting tool can access asset related data such as current status and historical data. As the tool does not yet exist and the development is in an early phase, further communication requirements and specifications may well occur as the project proceeds.

Reactive Power Market Mechanism

A proof of concept will be formulated for the reactive power market. That kind of market mechanism does not exist at the moment. The data to be processed is hourly average reactive power (Mvarh/h). In the beginning, the reactive power market will be run once a month. As input data for the market mechanism, the reactive power need from SUC – FIN RP MN and the bids of reactive power from the aggregator (from SUC – FIN FL AG) are needed. After clearing the market, the results are saved to a database and activation signals are sent to an aggregator.

DSO's Need for Reactive Power Dispatch

The scope of the tool of reactive power dispatch is to decide if it would be economically efficient to request reactive power from the reactive power market. The tool is included in the SUC – FIN RP MK. It is a new tool that does not exist at the moment. The main information flow as an input to the tool is the historical reactive power data of the PQ window. In addition, weather data will be included. The tool analyses the historical data and formulates the need of ancillary reactive power for the next month. The information flow as an output from the tool is the formulated reactive power need for each hour for the next month to be supplied from the reactive power market. The data is hourly average reactive power data (Mvarh/h). In the EU-SysFlex project a proof of concept of this reactive power management and market is developed. Thus, there is not at the moment any decision e.g. about the communication protocols.

5.3.2 SUPPORT FUNCTIONS

Manual set-point control of Kivikko PV plant

The reactive power compensation capability of the inverters of Kivikko PV plant is to be demonstrated in the reactive power market. For the measurements at the moment, AMR metering is available. The monthly set-point changes of the controls should be done by visiting at the PV plant. Within the EU-SysFlex project this procedure will be continued. The reactive power market is run only once a month and thus, the control program can be installed manually. The AMR measurements are used to prove the operation of reactive power controls.

5.3.3 DEVELOPMENT NEEDS FOR THE FINNISH DEMONSTRATOR

This chapter for the Finnish demonstrator describes the identified communication needs between different systems that are currently not addressed and prevent the market operation of these assets. Currently, there are needs in the communication channels of BESS and the trading system, in the technical control of AMR heating loads, and between the third-party cloud assets and the trading system.

The communication channel between BESS, aggregation platform and trading system

Suvilahti BESS is one of the distributed assets in the Finnish demonstration of EU-SysFlex. The BESS will participate with active power in the FCR-N market of the TSO, and with reactive power in the Q market place of the DSO, which does not yet exist but is being developed (proof of concept) during EU-SysFlex. TSOs ancillary markets are working, however, insufficient communication infrastructure is currently preventing the BESS to work on these markets. The communication channel between the BESS and Helen's aggregation platform is established but the communication from the aggregation platform to Helen's trading system is incomplete, and this is being developed during the project.

The technical control of AMR heating loads

Electric heating loads controlled via AMR meters are another asset to be demonstrated in the project. They are planned to participate to the Fingrid's mFRR market and the market rules determine the requirements of time frames and information. If the asset is approved to the market, the asset should be activated within 15 minutes. Three commands have to be delivered within 15 minutes:

1) to measure the present status of the asset
2) to send an activation signal and
3) to measure the realized amount of control.

The channel for the information flow is operating and the controls are sent from DSO's measurement data base via automatic meter reading system (operated by third party) to AMR meters. From DSO's measurement data base to the automatic meter reading system the TCP/IP protocol is in use. At this stage of the EU-SysFlex project, some preliminary tests have been performed with a single asset. The results revealed that with the present system, it is not possible to control thousands of assets using the channel within the required time frames. The present channel was optimized a decade ago for slower data management needs. Other solutions are to be considered.

The communication between third-party cloud assets, aggregation platform and trading system

Utilization of electric vehicle charging stations and customer-scale batteries on TSO's ancillary markets poses similar challenges than the Suvilahti BESS (see above). The data from these resources is gathered and aggregated by a third party cloud service, and then sent forward to the aggregation platform. This communication channel exists. However, the internal data transfer from the aggregation platform to the trading system is still under development.

5.4 COMMON VIEW AND LESSONS LEARNED

It is important to note that this deliverable is written during the planning phase of the demonstrators. This means that the implementation has taken place only partially in the different demonstrators and therefore is still ongoing at the point of deliverable submission. In the German demonstrator several of the interconnections and communication channels could be set up already, but on the other hand, the Finnish demonstrator has only had the opportunity to define the processes and the communication needs.

As much as possible, the communication will be based on standards and the data models and protocols already available. The actual implementation can however be more complicated. Most systems require a conversion to take place, in order to emit or process exchanges. The conversion itself can be the cause of problems but, also, the information sent and received can have different requirements and coordination can be required between the systems. For example, the CIM uses a node-breaker modelling representation and in order to solve a power flow computation, a bus-branch model has to be created from the former one. Even to update a single switching event, it requires the full processing and conversion from node-breaker to bus-branch.

It has been recognized that transferring and processing large amounts of data can cause bottlenecks in the system and that being careful not to request and generate unnecessary data can relieve stress on the communication system and increase the reaction time of the overall system. In general, CIM-based files have been seen as being too cluttered for large, fast transfers such as, measurement values from a large number of resources. In that case, leaner data models may be preferred and, if the CIM remains the option of choice, intelligent mechanisms to capture large CIM files are required (some exist, such as the CIM Difference Model. It is however rarely used, but a similar approach can be implemented).

It has also been identified that some information contents, such as reactive power, upper and lower boundaries for reactive power, cap value for the generation of a curtailed plant or load, are not included in the current version of the CIM and that it would be helpful if they were included in the future CIM standards.

Another lesson learned concerns in the use of a distributed services architecture. The conclusion is that it improves robustness and scalability of the software system and supports better the development of new processes, but reduces the reaction speed for the energy system.

Finally, the APIs from third-party data providers (forecasts or cloud services for asset monitoring and control) are not always suited for the daily operation of reserves provision. The acquisition of data sometimes had to be done manually at the early stages of the demonstrators and new agreements needed in order to automatize the access.

6. CONCLUSIONS AND OUTLOOK

This deliverable D6.4 presents the data models and communication protocols that are required in order to run the three EU-SysFlex WP6 demonstrators. The first key conclusion is that a major part of the communication can be based on existing standards. Standardization is not the same as harmonization, but in this case it makes choices easier and reduces the possibilities for data formats, leading to easier implementation and interoperability capabilities.

Figure 19 shows a summary of the communication and data exchanges that is being implemented in the three demonstrators. It can be seen that the exchanges between all the different roles (except for the TSO/market operator one, grey arrow) are covered by at least one of the three demonstrators. By combining them in this theoretical way, it can be asserted that most of the communication needs in order to make the flexibility from distributed assets available for services provision are touched upon in the demonstrators. It does not mean that all the problems are solved. The communication between actors varies as well between the countries implementing the same interaction. In short, the implementations in WP6 will show ways to implement the required communication systems, but, due to specific needs and regulations, the actual implementation will vary from country to country, or even from system to system.

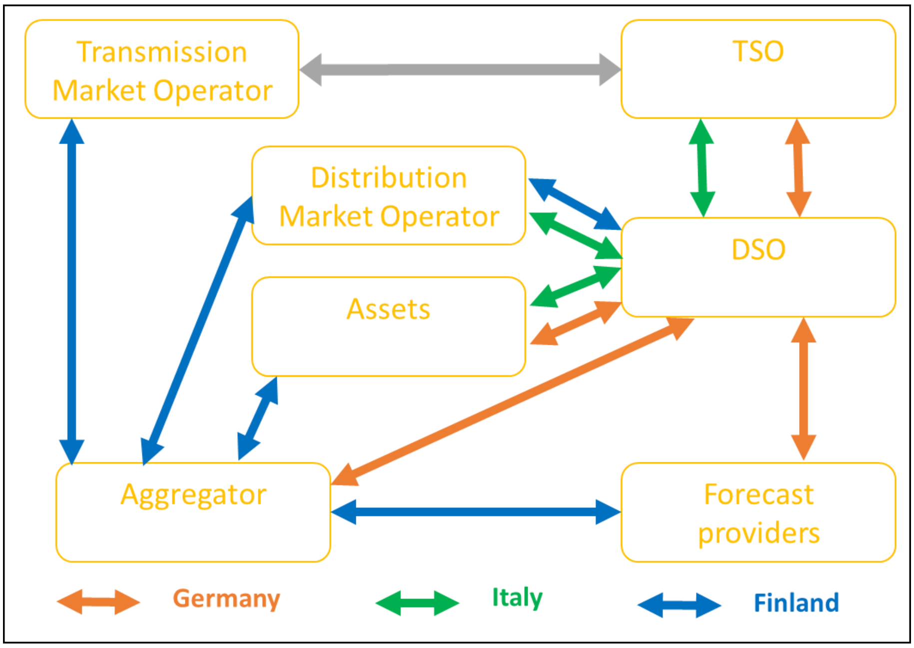

FIGURE 19 - SUMMARY VIEW OF THE COMMUNICATION EXCHANGES COVERED BY THE THREE DEMONSTRATORS

The main objectives of WP6 are to improve the coordination between TSO and DSO, to show that ancillary services can be provided by flexible resources located in the distribution grid and that they can be used to meet the requirements from both the distribution and transmission system operators. The last one is not influenced by the communication architecture beyond what is found in the improved coordination between the TSO and DSO. The following can be said for the two first ones:

- ***Improving the coordination between TSO and DSO***

  The push by ENTSO-E[4], since 2009, for the TSOs to adopt the Common Information Model, has been effective in harmonizing the exchanges, not only between the TSOs, but also for the DSOs, as they often have to communicate with their TSO. The improvements to the coordination in the EU-SysFlex project come from improving the processes and the architecture of the system, but the foundations for smooth integration exist in the form of well-established standards.

- ***Providing ancillary services to the TSO from flexibilities in the distribution system***

  Two different cases present themselves in the WP6 demonstrators. The first one is where the DSO controls the flexibilities directly. In that case, the exchanges between the resources and the DSO are designed to be integrated with the DSO's SCADA system and are made based on IEC standards. There are still gaps in data exchanges with external forecast providers, either weather forecasts or direct forecasts of the resources flexibility.

  The second case is the one where an aggregator controls the flexible resources. Here, in the case of the demonstrator, the measurements, status and forecasting data for the resources are stored in proprietary clouds by third-party resource operators. The design of the system for those operators has not been made with the needs of the energy industry in mind and, therefore, harmonization has not happened there yet.

The main conclusion from this deliverable is that regarding the exchanges between the different energy industry actors, the existing standards for data models and protocols are sufficient for the project's purposes. There are several reasons why exchanges do not list existing data model or protocol standards. The first is that in some cases the systems were set up before the implementation of the standards. The second is that sometimes the existing standards are not adapted to the provision of the new services (such as reactive power) and an extension of those standards, by adding fields and descriptions, could help solve the gap. In the last cases, the ones where the interactions remain to be defined, the data requirements have been identified as being light (small amount of data transmitted at a low frequency and with no very challenging security requirements) and the data models and protocols definitions is going to be handled during the implementation phase of the project.

There is however a more important gap identified for the exchange of information with forecast providers and third-party data providers. A reason for this could be that the systems of those providers have been designed for other purposes than serving the energy industry, thus having different needs and backgrounds. A better level of harmonization will most likely develop in the future as the data forecast providers work increasingly with the energy industry and as they adapt their system to be better in line with its needs. These observations will be used in the WP5 of EU-Sysflex in order to draw recommendations.

Although the exchanges between actors are mostly covered by existing standards, some work regarding communication is still needed when it comes to interactions between tools within a same actor or in converting the data between the internal systems and the external channels. The reason for this is the existence of proprietary and custom-made data models and protocols created and used in the internal systems of some actors, in this case the DSO and aggregator. Large scale pushes for standardization, such as the ENTSO-E push to adopt the CIM [4], are focused on the exchanges between different actors. It understandably can take a while for the standards to force their way into the actors' own systems. The adoption takes time and money while not improving the functioning of the system, until parts need to be added of replaced. At the same time, modern available systems, such as bidding or aggregation platforms, are designed to be more interoperable than they used to, meaning that the standards for communication are also finding their way into the actors' own systems when the different parts are upgraded.

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