Documentation of Specifications of the Smart Grid Hub

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Demo

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At the heart of the German Demo lies the Smart Grid Hub, an extension of the Grid Control Center of the DSO. The Smart Grid Hub monitors and controls small scale flexibilities in the distribution grid in order to ensure safe and reliable grid operation under any circumstance.			
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EXECUTIVE SUMMARY

With the ongoing change of European energy systems towards a more sustainable generation of power we are faced with numerous challenges. One of these challenges is to keep the power grid stable and reliable at all times. With a growing share of fluctuating power generators it will become increasingly more difficult to achieve the necessary balance between generation and demand at all times.

InterFlex seeks to find solutions to these and other questions presented to us by the European transition towards a greener future. To achieve the delicate balance between generation and demand the system has to become smarter, more interconnected and much more capable at acquiring and processing local field data. Under the guidance of Avacon the German Demo of InterFlex aims at bringing the grid control center of a rural distribution system operator to the next level. We envision a future grid control center that is capable of making the best use of a vast amount of data that will be made available via new technologies like the smart meter in private households.

Private households of today are also becoming increasingly more capable of providing flexibility to the energy system. For example, operators of rooftop photovoltaic generators could, in theory, curtail their feed in when the stress on the grid is high. Modern electrical heating appliances, in combination with a heat storage, could be controlled in such a way that the energy for heat is drawn when general demand is low in order to balance the grid better and lessen the stress on the grid and generation.

Beyond the boundaries of local DSO´s small scale flexibilities could also be aggregated to one large virtual source of flexibility. With these larger and more powerful flexibilities a community of residential customers could provide flexibility to the national or even European energy system. Such virtual balancing powers could participate in local, national or European markets for balancing energy and provide a valuable service for a safe and reliable energy supply.

DSO´s in Germany today already have a mandate to curtail and control small scale generators to avoid violations of technical limits of the electrical infrastructure. The mechanisms are tightly regulated but have proven very effective and useful to keep the energy system safe and within its technical limits. The controlling mechanisms of today however have three major limitations:

1. They lack the communication infrastructure to control a large number of relatively small scale (LV-connected) sources of flexibility such as rooftop PV, residential energy storage or electrical heating appliances in a secure and reliable way.

2. They lack the data processing capabilities to handle and leverage a large amount of data from numerous sensors across the grid and hence cannot take full advantage of a smart meter roll out.
3. They lack the computing power to derive a plan of action from a massive amount of field data.

The Smart Grid Hub is envisioned as an extension of today´s grid control center of a DSO and is supposed to address all the challenges mentioned above. A fully operational Smart Grid Hub will enable the DSO to

1. Collect, process and store a vast amount of data acquired by a digitial metering infrastructure on the residential level.
2. Derive switching and dispatch schedules for all connected sources of flexibility regardless of technology to ensure a safe, efficient and reliable operation of local MV and LV grids.
3. Carry out these schedules and switching programs via an individual and secure communication infrastructure to ensure a maximum of security and reliability in the process.

The following document details the architecture of the Smart Grid Hub, its data hosting capabilities and functionalities and gives a brief insight how these functionalities correspond to the field test of later project phases.

TABLE OF CONTENT

LIST OF FIGURES

1 INTRODUCTION

As renewable energy becomes more competitive and industrialized countries strive to reduce their carbon emissions by replacing large-scale power stations with smaller decentralized units the pressure on local power grids to adapt to this new reality grows. Germany is among those countries, where the change from fossil fueled power stations towards decentralized renewable generators is already happening. This change from a few large controllable generators to numerous small ones that are fluctuating based on the current weather has massive implications for the rest of the national and European power system.

Distribution system operators (DSO) in Germany today have to deal with a significant increase in feed-in power from decentralized energy resources (DER). These DER are allocated based on local weather patterns, communal planning, private initiatives and the accessible open space. The capacity of the electrical network at any given location has no direct impact on the allocation of new generators and subsequently the rise of these new generators can create local and regional hotspots of fluctuating generation which cannot be handled by the existing grid at all times.

The solutions to this problem are manifold. For example, the DSO can opt to reinforce and expand the existing grid. This addition of assets however can be very costly, it takes time and recently the public acceptance of ever new overhead-lines has diminished.

If the continued expansion and reinforcement of the physical grid is not the answer then an alternative way out could be to make loads and generators more flexible and to control them in such a way that the system remains in balance. By ramping loads and generation up or down based on grid constraints or in response to a market signal, a significant portion of the estimated grid expansion could potentially be saved. Today's generators and loads along with recently developed technologies such as power storage devices or electric vehicles present a large pool of hitherto untapped potential of power-flexibility. The German DEMO of InterFlex aims to develop a central entity dubbed the "Smart Grid Hub" which could access this dormant flexibility and leverage it to increase the efficiency and utilization of the existing grid in order to avoid an expensive expansion of the physical grid.

This document shall provide an overview over the functionalities and architecture of the envisioned Smart Grid Hub and highlight its key features to be demonstrated over the course of the project.

1.1 Scope of the document

1.2 Notations, abbreviations and acronyms

The table below provides an overview of the notations, abbreviations and acronyms used in the document.

DSO	Distribution System Operator
EC	European Commission
EU	European Union
SGH	Smart Grid Hub
MV	Medium Voltage
LV	Low Voltage
DER	Decentralized Energy Resource
SMGw	Smart Meter Gateway
SMGWA	Smart Meter Gateway Administrator
MStBG	Messstellenbetreibergesetz
BSI	Bundesamt für Informationssicherheit

Figure 1: List of acronyms

2 THE SMART GRID HUB

The Smart Grid Hub (SGH) is part of an integrated concept to enable the grid control center of a DSO to access and directly control small scale flexibilities of any type in response to violations of technical grid constraints or even external market signals. Other crucial parts of this concept are the communication infrastructure and smart-meter gateway administration, intelligent (digital) metering devices and control boxes at the customer's premises.

The general protocol for the use cases during the Smart Grid Hub field test phase are as follows:

1. Grid control provides an estimate of the state of the MV- and LV-grid, based on technical data from grid sensors (voltage, current), customer sensors (consumption, feed-in) and external factors like the weather.

2. Based on these state estimates grid control can identify potential imbalances in specific areas of the grid or impeding or existing violations of technical limits like local voltage excess or current overload of assets (grid congestion). To bring the local grid back to a balanced state and / or to relieve local grid congestion a cascade of actions can be taken.

3. In the cascade of action grid control tries to re-balance the grid by altering the current state of operation with switching actions. The second step is to leverage local flexibility in order to relieve congestion and to return to a balanced state. If both these strategies fail, a more heavy-handed approach of grid safety measures has to be taken.

4. The SGH monitors the current status and availability of all sources of flexibility at all times.

5. If necessary grid control can request a certain amount of power ramp up or ramp down in a specific area of the grid. The SGH will then determine the optimal strategy to deliver these actions while keeping total intervention at a minimum and send control commands to achieve the desired outcome.

At its core the SGH is a control solution in the environment of intelligent metering systems. The SGH accepts control requests, processes data from sensors and metering devices, analyzes data, determines the optimal set of action to achieve the desired outcome and finally sends control signals to the flexibility source at the customer's premises.

The SGH is split into two separate units, namely the process unit and a data unit. The data unit is supposed to collect, host, aggregate and provide data for the process unit. The process unit on the other hand contains the algorithms and logical functions that a dynamic switching and control strategy for flexibilities requires. Because it has the ability to switch and control units in the field, the requirements for reliability, security and speed are comparably high. It is envisioned as a central high speed solution to provide metering, data analysis and controlling /switching schedules with a very high granularity. It is not only able to determine optimal switching schedules, but also to aggregate and assign dynamic grid-clusters that will subsequently be addressed with control signals.

2.1 Smart Grid Hub Architecture

The Smart Grid Hub is a control- and dispatch unit in a digital environment. The SGH accepts control signals from the grid control center, processes structural data and data from sensors and digital meters, analyses data and determines switching actions and schedules based on algorithms derived from technical guidelines, legal obligations or requirements from grid operation.

At its core the SGH consists of two parts:

- **A process unit** which is handling the requests and performs switching and controlling action with a reliability, security and availability to the standard of the grid control center itself. To ensure full compliance with the required standards the process unit must be located within the process IT environment.
- **A data unit** which consolidates and provides data from other sources within the company. The data unit synchronizes with other data bases on a regular schedule and provides data to the process unit at request. Crucially the data unit does not have to perform to the same standards as the process unit and can hence be located in the standard commercial IT environment.

2.2 Interfaces and integration with existing systems

The Smart Grid Hub will act as a central processing and data unit to leverage large amounts of data for grid optimization and automation Figure 2 shows how the SGH fits into the general architecture.

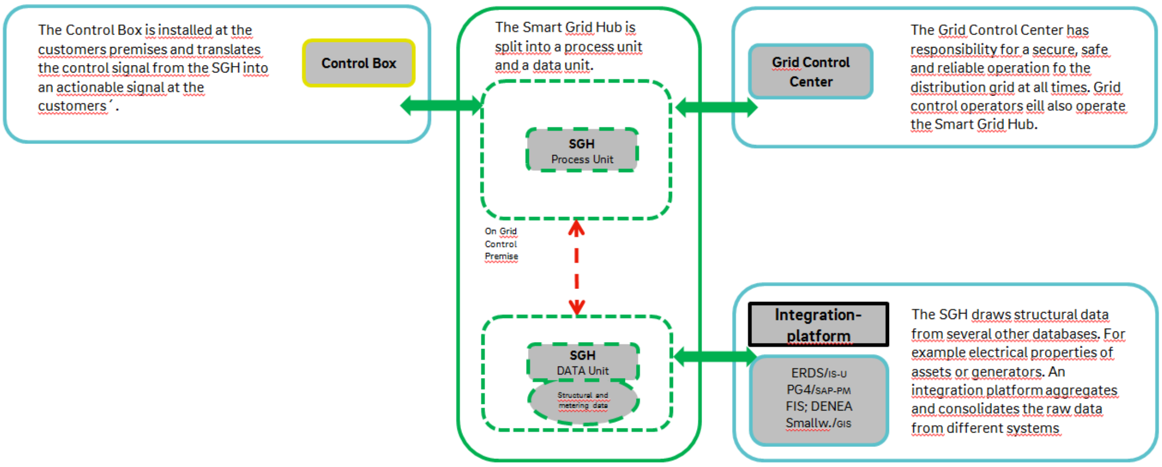

Figure 2: Location of the Smart Grid Hub and major Interfaces

2.2.1 Smart Meter Gateway, Control Box, Digital Power Meter

To get access to the flexibility on customers' premises there has to be a digital meter, which can provide the data necessary for efficient operation and which complies with all relevant guidelines on data security. To translate the control signals coming from the SGH there has to be a controlling device on site, which takes the form of a tried and tested control box. The control box can receive control signals and translate them into actionable commands for the local generator, load or battery. Finally to ensure a secure and legal mode of data transmission and communication a Smart Meter Gateway (SMGW) is added.

2.2.2 Gateway Administrator Environment

Under the umbrella of "EniM" E.ON has created the platform to comply with legal obligations for the current and upcoming roll out of intelligent metering devices.

According the legal definition an intelligent metering system is "a metering device that is integrated into a communication network and which can monitor and measure the actual energy consumption and time of use".

An intelligent metering system consists of a digital electricity metering device and a communication module, the so called Smart Meter Gateway (SMGw). A SMGw can be connected to one or more metering devices. The intelligent metering system is monitoring the consumption on site and can transmit the consumption data via a secure encrypted channel fully automatic to qualified third parties, the customers merchant or grid operator. For customers these devices can open the door to more flexible, time variable tariffs, while the high-granularity data can help grid operators to better utilize his infrastructure and avoid critical situations.

The SMGw is being operated by a service provider who fulfils the role of a Smart Meter Gateway Administrator (SMGWA) and is responsible for the secure and reliable operation of the SMGw. A SMGWA has to comply with all requirements derived from the National Law for Meter Operators (Messstellenbetreibergesetz MsbG) and to have his Information-Security Management System certified by a third party auditor. Additionally the SMGWA has to comply with further requirements regarding the security of data transmission and hosting. For example the federal agency for cyber security (BSI) requires SMGWA to comply with the technical guideline TR-03109-6.

2.2.3 Grid Control Center

The Smart Grid Hub will work closely with the grid control center of Avacon. The current SCADA system monitors the situation of the grid, determines switching schedules collects and stores data and provides state-estimates for the entire network operated by Avacon. The SGH will be connected directly to the SCADA and will receive request and control signals from there.

2.2.4 Integration Platform

The integration platform (IP) is based on SAP PI technology. It will provide the interface between the SGH data unit and all other data sources at the DSO. The IP itself does not store any data, but it establishes connections to other data sources. At request the IP provides data to the SGH via web services (push-services).

2.2.5 Other Data Sources in the DSO Environment

In addition to data from sensors and meters across the grid the SGH will also utilize structural data such as electrical properties of generators or assets, weather or load data. Depending on the function and challenge at hand, the SGH will take into account any number of data.

2.3 Data Architecture

The Smart Grid Hub will have to leverage a large amount of different types of data in order to deliver the envisioned gains in efficiency and effectiveness. Reflecting the two-stage architecture of process- and data unit the data model itself will also discriminate between:

- **Basic Data** which includes information about the relevant elements for operation and which are required for ongoing processing. Base data consist of information about assets and active elements (generators and loads), Smart Meter Gateways, metering devices and control boxes. Base data are sourced via the data unit and integration platform from other data sources.

- **Operational Data** that are being created constantly during operation. The operational data consist of metering data (current, voltage, power), switching schedules and other information relevant for switching and metering actions. Operational data is sourced from sensors and meters across the grid.

- **Guideline-Data** which include scenarios and protocols for carrying out field tests. Guideline-Data is being provided via manual input from the operator.

To account for the fundamentally different requirements for the different types of data especially for persistence, actuality and availability the SGH has to be designed as a two-stage system with two different technical entities, namely the aforementioned process- and data unit. These units are separated, the data models for base data and operational data are separated as well. There is a redundancy for base data built in between the two units, for operational data there is no redundancy. Instead, the operational data is stored only temporary in the process unit and regularly backed up in the data unit.

2.3.1 Smart Grid Hub Base Data

The Basic Data System hosts all general data about the relevant elements for operation. These sets of data are acquired from other system in the DSO environment and fed into the Data Unit via the integration platform. Within the Smart Grid Hub architecture the Data Unit is considered the leading source of data. If data is being stored redundantly and differences between two sets of data are recognized, the leading source of data is considered the correct one. The Process Unit obtains data via an interface that is capable of being parametrized.

2.3.2 Initial Data Collection and Updates

The Data Unit obtains all data via the integration platform (IP). The IP acts as a central data hub with access rights to all other relevant data sources and data bases within the corporation. The IP provides web services through which the Data Unit can request and receive all the data necessary. These web services are designed in such a way that the Data Unit can directly generate base data objects. The initial process of gathering all the base data and the following cycles of data updates are triggered manually by the operator via the user interface. Results of each base data update have to be simulated first and get documented in an update log file.

2.3.3 Base Data Updates

Updates of base data in the process unit are being carried out on a regular basis. The actual duration between data updates can be determined by the operator.

2.3.4 Base Data User Interface

To access, view and document base data that is stored in Process and Data Unit, the Data Unit contains an user interface. Via this user interface the base data in the Data Unit can also be modified if necessary.

2.3.5 Monitoring of Base Data

The initial data collection, all updates of base data and all synchronizations of base data between Data and Process Unit are being logged in the Data Unit. Monitoring logfiles can be accessed and viewed via the user interface.

2.3.6 Operational Data

Operational Data is created when electrical values are being measured by the intelligent metering systems at the customers’ site and include voltage, current and power. Additionally all data relating to the state (or change thereof) of the control box is considered part of operational data. All operational data has a timestamp and enable the Smart Grid Hub to infer feed-in, consumption, energy volumes and state of the grid. Operational data is stored temporarily in the Process Unit and transferred and stored in Data Unit on a regular basis. Once transferred to the Data Unit operational data is being deleted from the Process Unit.

3 FUNCTIONALITIES

The function "Smart Grid Hub Process Unit" follows a workflow with 3 process steps as shown in Figure 3. A command initially goes through general function blocks, such as authorization checks and/or grouping. The second function block maps the individual functions. The third function block is processing results and handling transmission to the customer. The execution of the command is independent of whether the command is transmitted by the network control center or the SGH Data Unit.

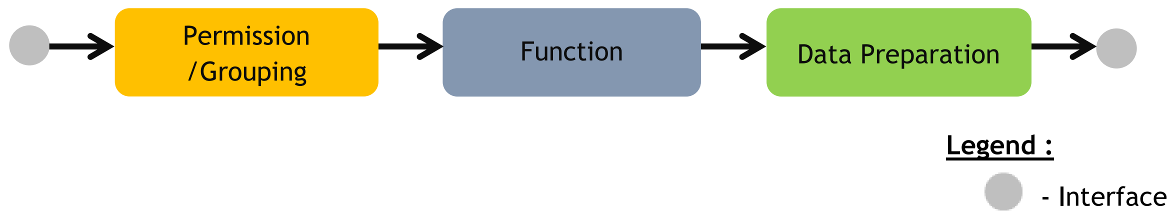

Figure 3: Workflow of Smart Grid Hb Process Unit

3.1 Creating and Assigning Groups

The "Create group" function is used for the aggregation and breakdown of the units, which are distributed in the network, into groups.Additionally existing groups shall be aggregated into higher-level groups. A unit or a group can be assigned to several (superordinate) groups. The assignment of a unit or a group to a (superior) group is dynamic. Consequently attachments or groups, which are already allocated, can be removed or new units or groups can be added. This results in a hierarchical arrangement of the units or groups.

The network area group is the highest hierarchical level. A network area comprises of one or more local MV/LV substations. Consequently on the second hierarchical level groups of the local network stations will be located. Below these two levels any number of additional levels can be set. At present, at least 5 hierarchy levels are required.

For the creation of a new group, a new group name is sufficient. The assignment to a hierarchy level depends on the assignment of the created group (assignment to a higher-level group as well as the subordination of units or further groups). If no assignment is made, the group is assigned to the hierarchy level of the network areas.

Therefore a group is directly or indirectly subordinated to a specific number of units across several hierarchical levels as well as subgroups. Figure 4 shows a possible group structure. This example shows that system 1 is directly assigned to the group "> 10 kW installed power PV". Unit 2 is also part of this group. For example, if the measured values of this group shall be read out, only the measured values of the two subordinate units will be determined. The group "Photovoltaic", which is superordinated to this group, also includes installations 3 and 4. Independently from the subordinate groups, installations 1 to 4 can be addressed via the "Photovoltaic" group.

Overall the measured values can be divided into network area, local area network, plant type or others, and be viewed deliberately and differentiated from the large number of measured values.

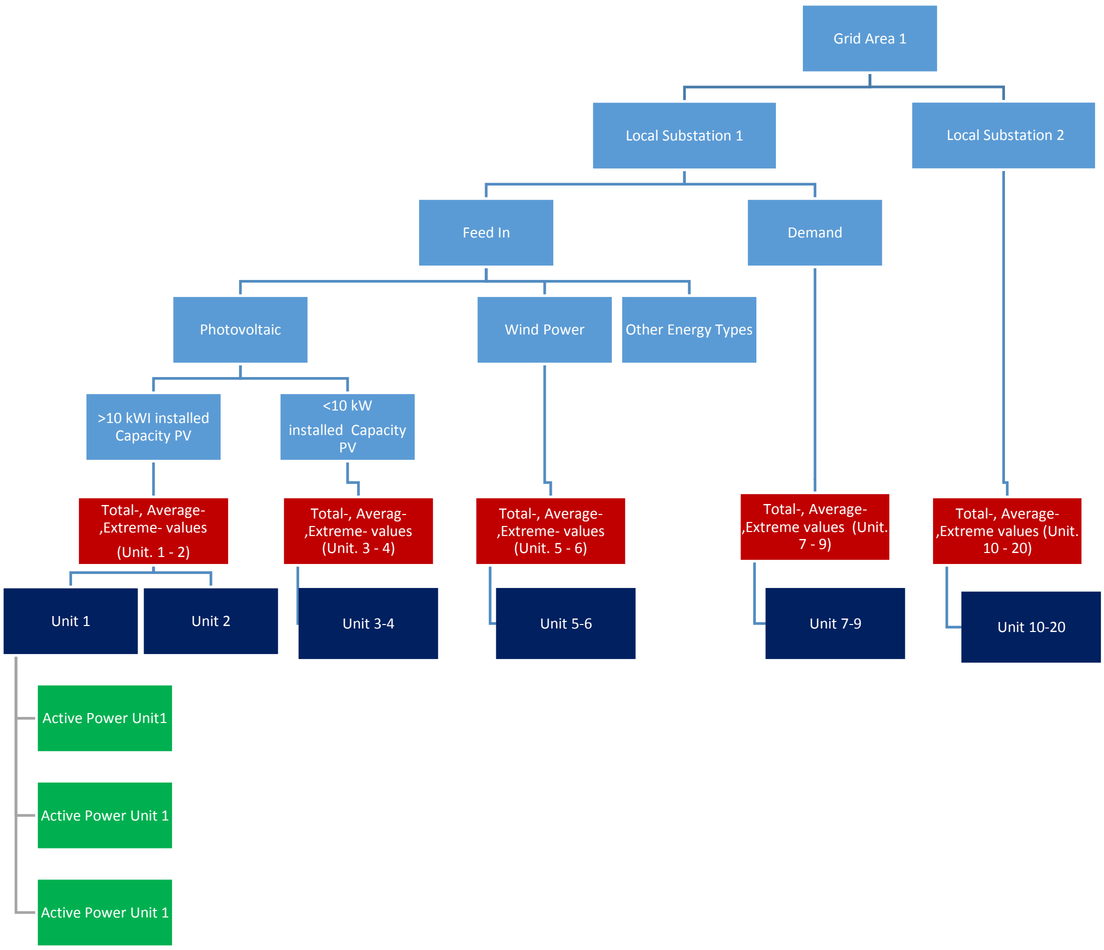

Figure 4: Hierarchy of Objects in the SGH Environment

The characteristic "Flexibility yes / no" should be assignable to a group. If the characteristic is set, the respective reserve for the group is calculated automatically.

3.2 Measurement

The function "Measurement" is used to carry out individual measurements in the network.

The measurements or possibilities of the measurements are given in the technical guideline (TR03109-1). As shown in Figure 5 the measured value of different groups and units can be assigned to a local network station.

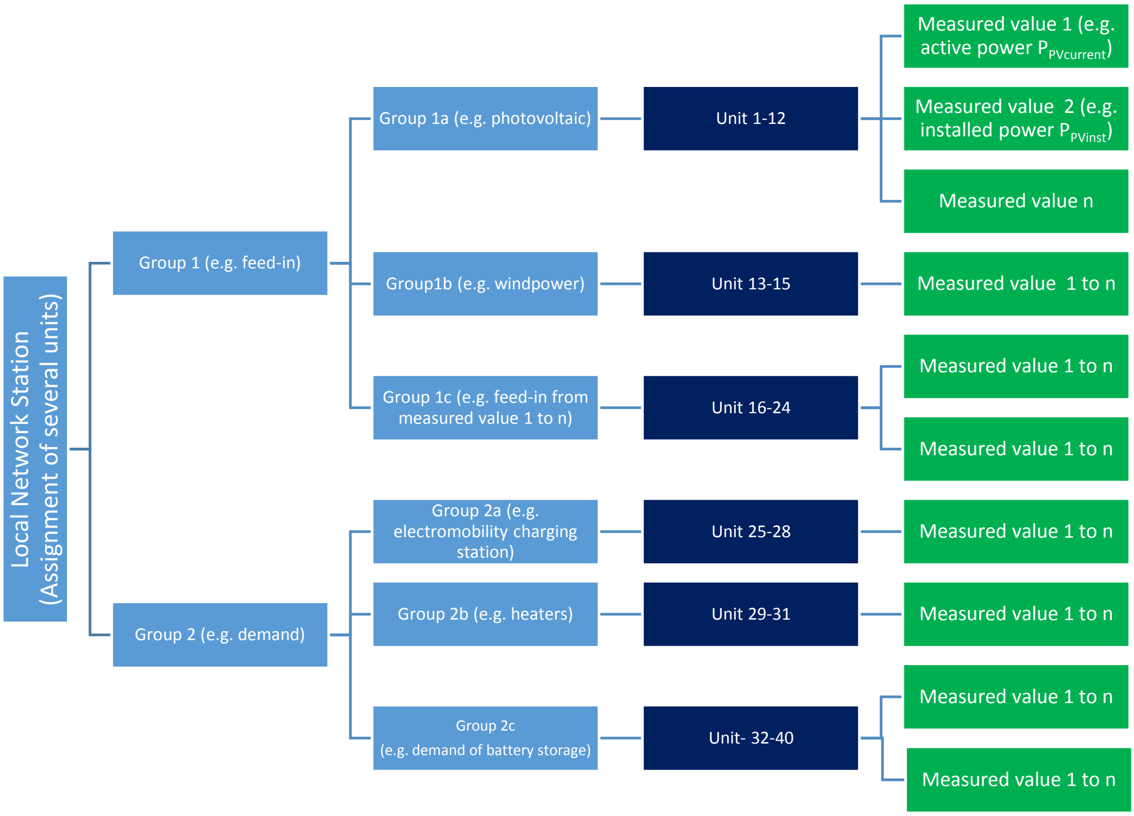

Figure 5: Example of the assignment of measured values to an local network station

In addition, the installed SMGw provide information about possible measuring types (Measurement of voltages, current, power values, phase shifts, etc.).

The "Measurement" function processes the parameters

- Group or network area to be queried
- Query interval in sec.
- Command type; Start or stop
- Optional: Period of Validity in min.
- Infeed or Demand
- OBIS counter depending on the expected measured value

If the function is called with the command "Start", the parameter set for TAF9 or TAF10 of the SMGw will be sent to the GWA. In consequence the corresponding SMGw can be parameterized and the measured values will be send directly to the HES of the EMT. Depending on the measured values, the TAF9 or TAF10 will be parameterized or not, which for example can be a feed-in value or a network state like the voltage.

During the response to a group, all associated SMGw and the transfer of the respective TAF via the GWA will be parameterized simultaneously.

The measured values received and decrypted by the HES, will be forwarded and stored in the SGH by passing the module "Routing". If necessary, further automatic functions for the KPI calculation are triggered during the storage of the measured values. Therefore all required current measured values (transferred and calculated) will be continually accessible in the SGH.

Figure 5 shows a possible structure of the assignment measures values of different groups to a local network station.

3.3 Switching

With the function “Switching”, either a direct command is sent to the control box via the protocol IEC61850, or a corresponding schedule will be created, transferred and activated to control box. Beforehand a proxy channel must be established between the control box and the SGH.

The function processes the following parameters:

- Group or network area to be switched
- Switching operation (value 0/30/60/100% of nominal power)

After the switching command or schedule is transmitted to the control box, the relay outputs of the control box will be set according to the desired switching operation.

The function returns a status signal, which indicates success or fail.

In case of a group switching, all associated control boxes will be controlled and receive a switching command simultaneously.

3.4 Rules based on performance values or relative values

The "rules based on performance values or relative values" function is a combination of measurement, switching and a control algorithm, which is in between.

The processed parameters are:

- Group or network area to be controlled
- Percentage or absolute change (% or kW) (target value)
- Feed-in or load power

Prerequisite for this function is the start of the "Measure" scenario, so that current measured values are available via the system group in the SGH. The sequence of this function is as follows:

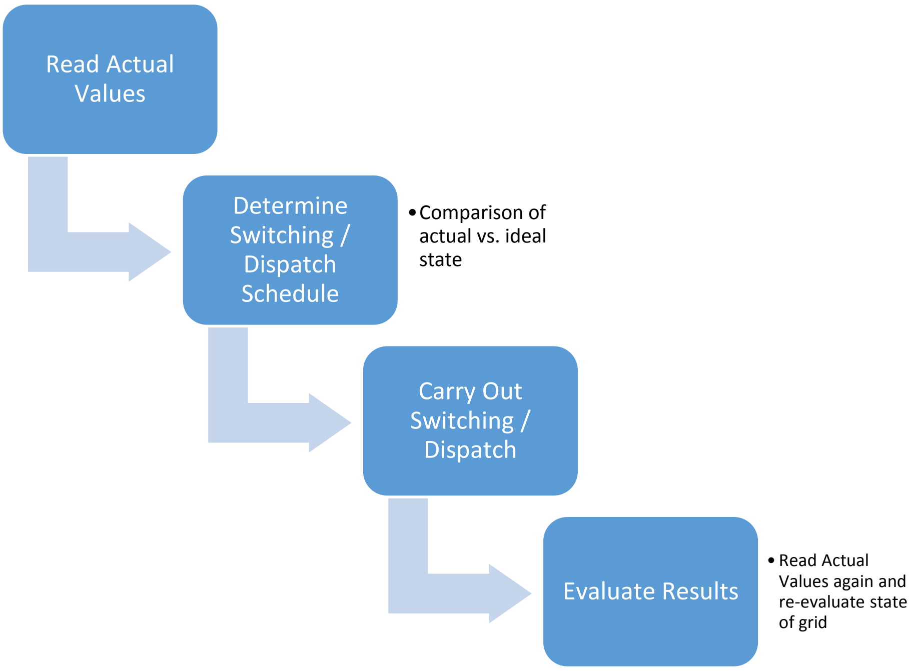

Figure 6: Process Sequence « Rules based on performance values or relative values»

The switching requirement, which has been determined, is identical to the content of a group of units, which are switched to the ascertained property value. In the next step, the switching operation is performed by calling the function “switching”. The next step checks the result and decides whether a further control cycle should take place or the control process has to be completed. After completion of the function, the system registers whether the target value could be reached or not.

3.5 Determine the level of curtailment

The “Determine the degree of curtailment” function determines the reduction level (relay status) of the control boxes via the IEC61850 protocol and stores these in the system-related SGH including unit-related date and time. For this, the proxy channel between the control box and the SGH must be set up in advance.

The function processes the following parameters:

- Group or network area to be queried

The current reduction level is stored in the SGH and can be further processed from there.

3.6 Determine and provide flexibility

The function "Determine and provide flexibility" checks whether in the grid switchable loads are available and displays them. A detailed description of the term "flexibility" can be found in the chapter "Glossary" (see 10.1.1 Flexibility).

For one or various previously selected group flexibility has to be determined for several selected groups. First, the "Measure" function is used to collect measured values for the determination of the flexibility. The measured values will be aggregated per group. The aggregation of the measured values will automatically take place in the database at the level of the defined group.

As show in Figure 7 feeders and loads are differentiated and processed separately within the group. As a result, the flexibility for the

- Feed-in and
- Demand

is determined within the group and stored as a calculated value in the SGH. Time and date will be stored group related. When the database receives a whole package of measured values, the aggregation will start automatically. The time intervals between the individual measured values must be determined in practice.

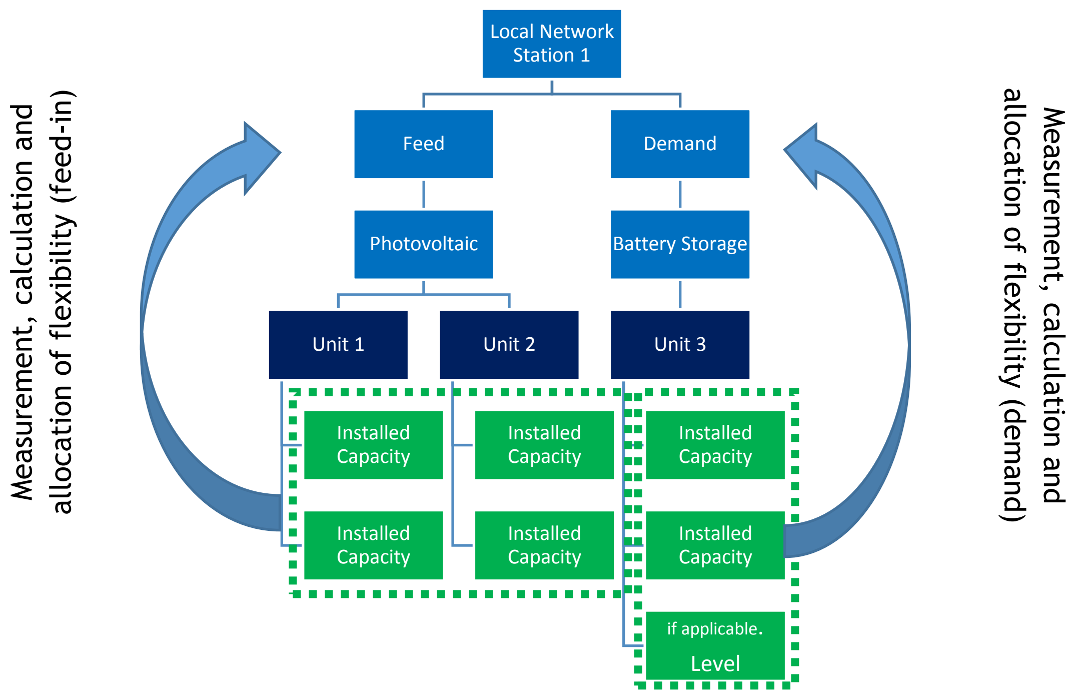

Figure 7: Example of the allocation of flexibility

3.7 Set and receive threshold values

The setting of threshold values is specified in the technical guideline (TR03109-1). The TAF10 is parameterized for each system.

The "Thresholds" function processes the parameters:

- Group or network area to be queried
- OBIS counter for the measured value to be monitored
- Threshold value
- Operator (greater / smaller / ...)
- Command type; Start or stop monitoring

The function will be called with the command "Start". During the call, the parameters for TAF10 of the SMGw will be sent to the GWA so that the corresponding SMGw can parameterize and monitor the corresponding measured values and send threshold violations directly to the EMT.

A parallel parameterization of all associated SMGw and the transfer of the respective TAF via the GWA will be performed, when a group is approached.

SMGw reports a threshold violation and statistical filter.

The threshold violations received and decrypted by the HES are forwarded directly to the SGH through the "Routing" module and stored in a plant-specific manner.

Incoming threshold violations will be monitored within a group by a statistical filter function. The statistical function will monitor the incoming messages per group and per unit of time. When a certain value is reached, a relevant message will be saved as a KPI of the unit or group. The parameters processed in the function are:

- Group or network area to be monitored statistically
- OBIS counter for the measured value to be monitored
- Number of messages
- Period in which the messages must arrive

Function "Determination, calculation and provision of totals, average and extreme values in groups"

When creating groups, automated KPI functions are used for total, min. Max. values or statistical filters. Depending on which measurement values are requested and received for a group of units, the associated KPI's of the group will be calculated. Whenever a complete package of measured values has been completely stored in the SGH, the corresponding KPIs will be formed. The following KPIs will be generated as a function of the incoming measurement values and status data within the group.

3.8 Scaling of measured values

Due to the small number of 200 plants in this pilot project (small number of iMS per total number of all measuring systems in one area), scalability of the measured data shall be enabled so that the influence of the measured values on the observed network area in the network control system increases. A freely selectable integer multiplier shall enable the scalability.

Example:

- The active power of a photovoltaic system is 5kW
- Scaling multiplier is set to 100
- the measurement values will be increased by a factor of 100 to 500 kW
- the scaled measured value is now 500kW (active PV system)

The scaling multiplier is selectable for one or more groups and applies to all attachments within the selected group.

The resulting values are to be processed as measured values by means of further functions (eg the function "determination, calculation and provision of total, average and extreme values in groups") without noticeable time delay and consequently shall be rapidly available for the network control system. The scaled measurement data will be stored as independent measured values. Scaled measured values should be visibly highlighted / highlighted.

3.9 Provide CLS Switch Channel

The "provide CLS switch channel" function is used to open a control channel in advance, if controls are known or high likely beforehand. This function prevents a peak of data volumes in the WAN. In addition, the switching operations can be performed faster with an open channel.

The parameters used are:

- Group or network area to be monitored statistically
- Time of channel maintenance

4 USE CASES AND FIELD TESTS

The objective of this Demo is to design and implement the Smart Grid Hub and demonstrate its capabilities to increase the efficiency and utilization of existing grid structures. In order to do so the field tests are designed around three Use Cases that will be addressed by the SGH.

4.1 Use Case 1 – Feed In Management

Under current legislation grid operators in Germany have the obligation to integrate as much renewable energy into their networks as possible as long as technical parameters are kept within limits. If the grid operator identifies an impeding violation of technical parameter or grid congestion he can curtail the feed-in from those generators which cause the congestion for a limited duration. With the technical architecture of today however most grid operators have no direct access to generators in mid and low voltage networks and can only send control- and curtailment signals to large groups of these units. Since these small generators make up for the majority of units the feed-in management of today is not very efficient and neither precise. With a growing number of grid congestion incidents grid operators are now at risk of having to curtail more energy than what would be necessary, because of their lack of precision when sending curtailment signals to small scale generators. Today grid operators rely mainly on long wave radio signals, which is neither very precise nor does this mode of communication provide a backchannel, hence the grid operator never really knows whether or not the control signals were received and acted upon. The Smart Grid Hub should provide the capability of controlling small scale generators even at the low voltage level via digital switching and by leveraging the digital metering infrastructure of the future. Subsequently the SGH also enables the grid operator to perform a much more efficient and effective feed-in management to relieve grid congestion.

The goals the SGH should achieve are:

1. Increase stability and reliability of distribution networks.
2. Increase transmission and distribution capacity of local grids.
3. Increase security of supply particularly on lower voltage levels.
4. Anticipate and leverage the rollout of a future Smart Meter Gateway infrastructure.

The Use Case "Feed-In Management" in the sense of this Demo can target one or more areas of the grid. These grid-sections are not necessarily static, but they can vary and evolve depending on technical constraints, local demand, generation and restriction from grid operation like maintenance or faults. The goal of creating the Smart Grid Hub is to take the feed-in management of grid operators to the next level by significantly increasing the number of accessible elements and by controlling these elements with much greater precision.

The entire process will be initiated by the grid control center for different objectives and levels of priority.

4.2 Use Case 2 – Demand Response

To keep the grid within technical limits and to avoid the overload of assets or excess voltage at customer's premises the grid must be kept in balance. Ideally the balancing strategy of grid operators follows the principle of subsidiary, trying to achieve the best possible balance at each voltage level before handing over any imbalance to the next higher voltage level. In low voltage networks for example an excess of renewable feed in from small scale generators can cause an imbalance and excess voltage at the residential level is a real issue even today. To address these challenges the grid operator can opt for a number of strategies, for example to expand the network or to utilize nw technologies such as voltage regulating distribution transformers. On an operational level the grid operator could in theory steer generation and demand in such a way as to keep both in balance as long a s possible. While Use Case 1 "Feed-In Management" aims to address the efficient control of local generation Use Case 2 “Demand Response” deals with the other side of the equation. In order to balance the grid on a local level, grid operation could send control signals to flexible residential loads, such as

1. Charging points for electric vehicles
2. Controllable heat pumps
3. Electrical heaters
4. Batteries
5. Electric boiler

to increase or decrease local demand as necessary. In practice one could imagine to ramp down flexible loads during times of high demand and little or local feed-in. Likewise, these loads could be ramped up when local generation picks up again to avoid a spike in feed-in.

In order to identify potentially critical imbalances in time the grid control of today already employs a sophisticated state-estimate algorithm which relies on sensors across the grid. The Smart Grid Hub adds the data from residential metering devices to increase the precision and reliability of these state-estimates and aides identification of critical imbalances. Once a critical situation is identified the SGH can send control signals to the flexible loads to rebalance the network. For the purpose of the field tests over the course of Interflex households can participate on a voluntary basis.

4.3 Use Case 3 – Ancillary Service Provision

This third use case is a combination of the first two and combines the flexibility of both generators and flexible loads. The general idea is to aggregate the flexibility from small scale generators, flexible loads and batteries and either leverage it to support the local grid on a larger scale or even to provide flexibility to third parties such as other grid operators or market agents.

For example:

1. Local flexibility could be aggregated to provide primary, secondary or tertiary control power to the transmission system operator. In that scenario the DSO would act as an aggregator and participate in the bidding market for balancing energy and sell flexibility to the TSO.

2. Local flexibility could respond to requests from grid control in order to support higher voltage levels or to relieve congestion on higher voltage feeders. Even though there is no market mechanism for DSOs in Germany to procure flexibility from third parties or to

take advantage of local flexibility, this might become an option in the future. Under this scenario he focus is to demonstrate the technical viability and effectiveness, regardless of the current market design or regulatory barriers.

3. Local flexibility could be provided at request to other third parties. For example, the SGH could aggregate flexibility and provide it to larger aggregators. It could offer flexibility to industrial customers who maintain their own balancing circle or run their own power generation in order to optimize their power supply portfolio.

In general these third party models and aggregator function depend largely on the regulatory framework and market design at the time of operation. While we cannot anticipate the direction of new developments in those areas, we can take this opportunity to demonstrate the technical capabilities and the flexibility of the SGH to provide value in a number of scenarios.