SOGNO

D4.1 v1.0

Definition of overall SOGNO System Architecture

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Abstract
The aim for a transition towards an energy supply based on renewable resources requires advanced monitoring and control solutions. This report specifies a suitable system architecture and defines necessary functionalities. Besides, the system architecture in each of the SOGNO pilots is described and related to the specified reference architecture.

Keyword list
System architecture, cloud-based architecture, distribution grid services

Disclaimer
All information provided reflects the status of the SOGNO project at the time of writing and may be subject to change.

Executive Summary

The aim for a transition towards an energy supply based on renewable resources involves the integration of distributed generation units with intermittent generation characteristics. This leads to the emergence of new challenges, especially for distributions grid operators (DSOs) at medium and low voltage level. Thus, advanced monitoring and control solutions are needed, allowing for an adequate insight into the state of distribution grids.

A fine-grained monitoring solution may enable a stable grid operation even in the presence of distributed generation. However, the implementation of centralized monitoring solutions demands massive data collection and introduces a single point of failure. Therefore, current research focuses on decentralized solutions which are based on substation automation.

SOGNO proposes to bring automation to the substation in a virtualized environment. Running the automation functionalities within a virtual machine brings an increased flexibility and the reduction of hardware investments. Low-cost and advanced measurement units gather the necessary data in a suitable granularity to provide the monitoring and control services. A fast and reliable data collection is achieved through 5G communication technology and smart decision taking supported by deep learning algorithms.

This report outlines the requirements for a suitable system architecture and specifies a SOGNO reference architecture which allows for the integration of the aforementioned technological advancements. The system architecture enables the provision of the SOGNO grid services state estimation, power control, power quality evaluation, generation and load prediction as well as FLISR. The descriptions include the architecture components for all relevant layers of the system, that is, from the physical layers, such as the electrical grid and device layer, over the communication and collection layer up to the IT layers, including e.g. data management and visualization. For each architecture component an explanation of the dedicated functionality is provided, thus giving a clearly defined SOGNO reference system architecture.

The second part of the report presents the hardware and software setup at the four different trial sites of the SOGNO project. An overview of deployed architecture components and their relation to the reference architecture is also given. This allows for a comparison of the different system architectures and the identification of key characteristics of the pilots.

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1. Introduction

The project Service Oriented Grid for the Network of the Future (SOGNO) is funded within the Work Program H2020-LCE-2017-SGS. It officially started in January 2018.

1.1 Related Project Work

The report is based on the work done in task T4.1 of work package WP4. The task deals with the specification of the overall system architecture of the SOGNO solution, which is used as a reference for the integration of the services developed in WP2 and WP3 and for the deployment of the software in the WP5 trials (see Figure 1). The report defines a reference architecture for the SOGNO project and a description of the corresponding architecture components reaching from the physical to information technology world.

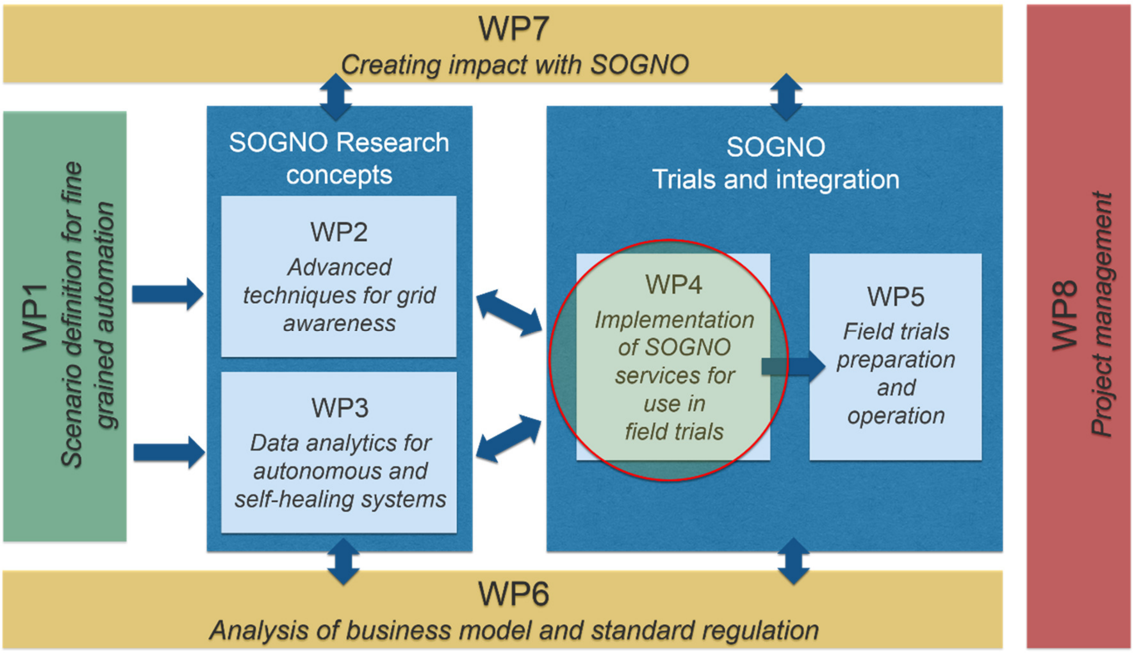

Figure 1: Overview of SOGNO activities

1.2 Objectives of the Report

The main objective of the report is to describe a system architecture that enables the provision of services for future networks. Targeted services within the SOGNO project are state estimation, power control, power quality evaluation, generation and load prediction as well as FLISR. To begin with, the report outlines system architecture requirements considering relevant European policies. While focusing on a suitable architecture for the targeted services within the project, the applicability of the outlined system architecture is not limited to them. The definition of a reference system architecture ensures a common understanding between project partners as well as third parties. In addition, the report clarifies the setup of the SOGNO pilots by relating their different platforms to the reference system architecture. Altogether, this gives a comprehensive overview of hardware and software components necessary for the provision of the considered grid services. Besides, it supports analysing and reasoning emergent behaviours of the systems considered within the pilots.

1.3 Outline of the Report

The first part of this report presents an overall system architecture for the provision of the targeted grid services and considers all relevant layers from the electrical grid to the visual user interface. The corresponding architecture components in each layer are named and described in detail, allowing for the use of a harmonized terminology and a clear understanding of their functionality. The second part of the report describes the concrete implementations of the system architecture which are applied in the pilots. It explains the hardware and software setup in the pilots and relates the employed components to the reference architecture.

1.4 How to Read this Document

This is a standalone document. Further details regarding the data flow within the system architecture and the data analytics are part of the deliverables

- D4.4 Description of Advanced Data Analytics tool V1
- D4.5 Description of Advanced Data Analytics tool V2.

More detailed information on the trials, particularly regarding the hardware setup, are covered in the deliverable

- D5.1 Report on trial preparation and initial feedback from laboratory tests.

Besides, this document with its overview of system architecture components and the description of their functionality can facilitate the read of further project related deliverables.

2. Architecture Requirements

The SOGNO system architecture aims at providing services for a stable and secure operation of future networks. Enhancing the observability of distribution grids shall enable DSOs to ensure an optimal grid operation while facing the challenge of an increasing amount of volatile renewable energy resources connected to medium and low voltage. For this purpose, SOGNO proposes the substation automation in a virtualized environment based on advanced measurement units, fast and secure communication and the application of deep intelligence techniques.

The report delineates a suitable platform architecture combining the technological advancements within the SOGNO project. Therefore, it is necessary to encompass all the components used in the different pilots. In this way, a common understanding of architectural preconditions and requirements is established between project partners and third-parties. The SOGNO architecture shall consider the installation of measurement and control devices, reliable and fast communication for a fine-grained insight into distribution grids, suitable data collection and management and the integration of multiple software components for services and further application functionalities.

2.1 Relationship with SET-Plan and European policies

According to the Strategy Energy Technology (SET) Plan [5], the EU strives for becoming the number one in renewable energy. Therefore, the SET Plan outlines research and development targets for five renewable energy technologies: photovoltaic energy, solar thermal electricity, offshore wind energy, ocean energy and geothermal energy. In addition, it emphasizes the need for a change of paradigm towards placing the consumers at the centre. However, this might cause issues regarding grid management due to the power feed-in of intermittent sources like photovoltaic and wind. At this point, the SOGNO platform shall allow for maintaining an adequate observability and controllability of the grid. This is in line with the SET Plan's goal to make 80 % of electricity consumption controllable through ICT by 2030. The SOGNO project's focus on cost-effective solutions can facilitate the transition process and make it possible.

Another relevant policy has been defined by the Smart Grid Coordination Group. It defines the Smart Grid Architecture Model (SGAM), a universal model representing the smart grid architecture in an abstract, technology neutral manner and involving the viewpoint of various relevant stakeholders [6]. The SGAM provides a three-dimensional model to characterize smart grid use cases. The first dimension specifies five interoperability layers, while the other two dimensions are covered by the domains of the electrical conversion chain and the zones of the hierarchical levels of power system management. The SOGNO reference architecture focuses on the component, communication, information and function layers, while mainly leaving out the specification of business layer aspects. Regarding the electrical conversion chain, the SOGNO project encompasses the customers, DER and distribution domain. Besides, the SOGNO architecture covers the process, field, station and operation zones.

3. SOGNO Reference Architecture

3.1 Overall Architecture

The SOGNO reference architecture defines components that are necessary for the operation of services which are developed within the SOGNO project. The components are grouped according to their functionality.

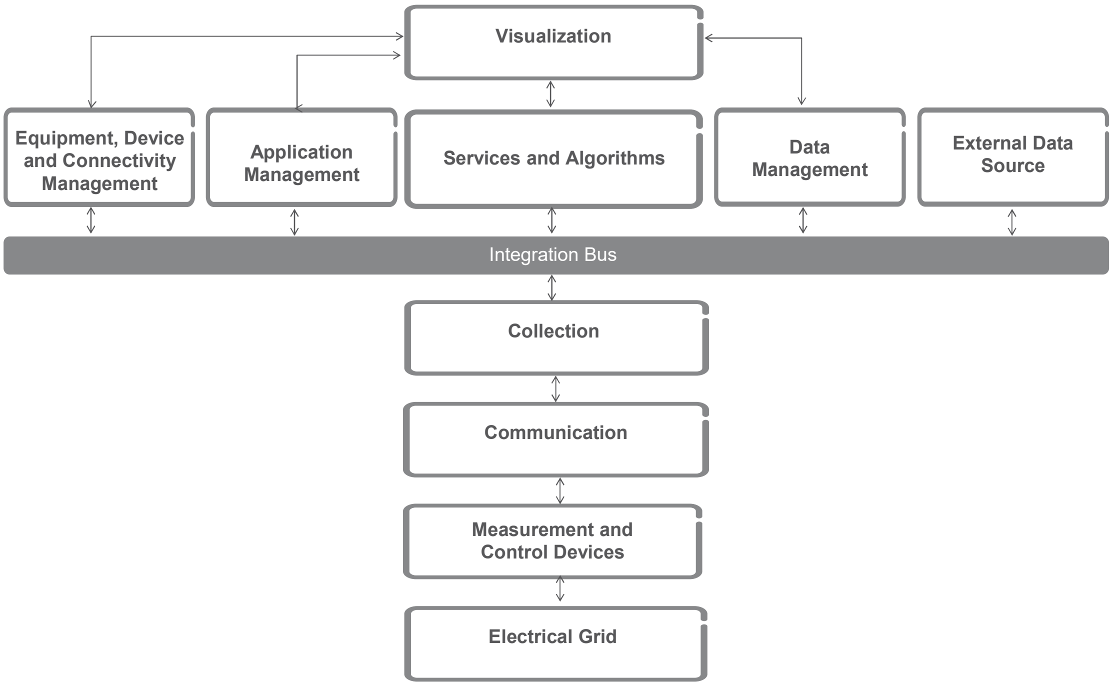

Figure 2 depicts the corresponding overview of the architecture and presents the component groups in layers which range from the physical to the information technology world. The following sections will describe the components and their functionalities in more detail.

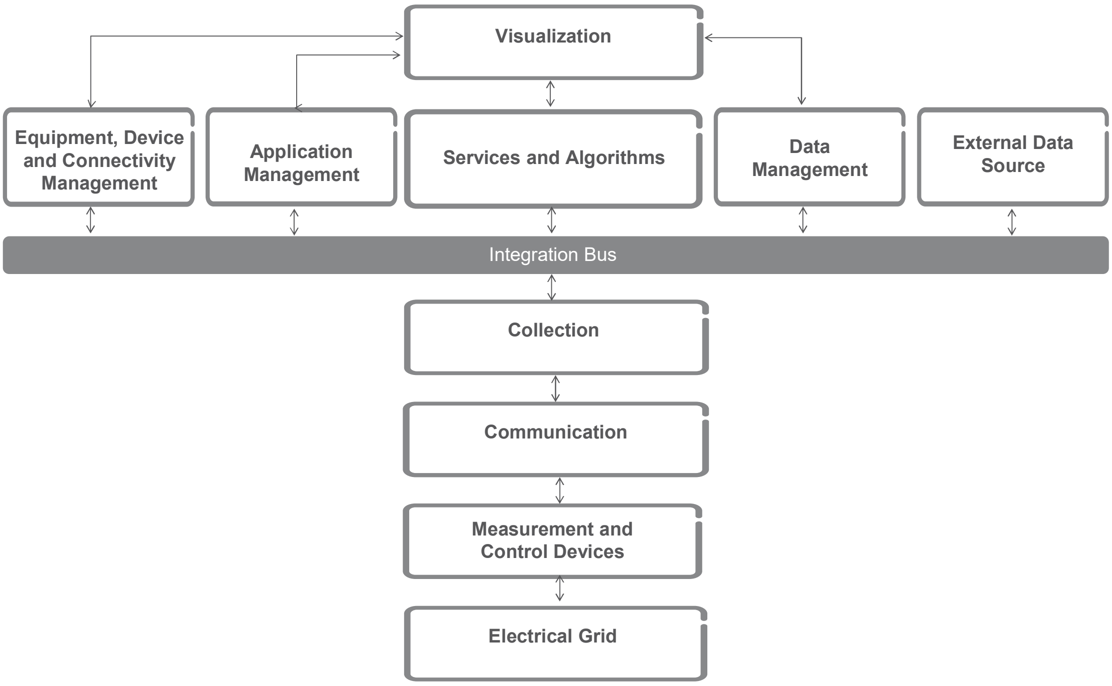

Figure 2: Overview of SOGNO reference architecture

3.2 Specification of Architecture Components

3.2.1 Visualization

The Visualization components, Figure 3, are necessary for displaying the results of Services and Algorithms and for helping network operators to make intelligent decisions based on the current and past situations.

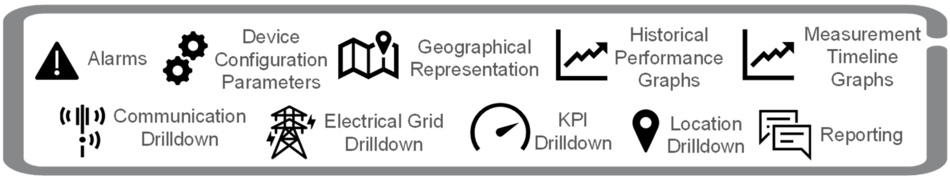

Figure 3: Visualization components of SOGNO reference architecture

Alarms

Alarms allow for informing the user about historical and current critical situations in the system.

Device Configuration Parameters

The component displays relevant parameters of equipment and devices. It helps with keeping track of the equipment and devices that have been installed on the field, understanding their behaviour as well as explaining automatic changes that algorithms have applied to improve the grid state.

Geographical Representation

This component visualizes the placement of electrical grid equipment and devices by geographically accurate locations on a map. This gives a better overview of alarm locations and in which context they are taking place.

Historical Performance Graphs

Historical performance graphs show changes of the network performance over time. It allows for the analysis of trends and how different actions, or algorithms have affected the system over time.

Measurement Timeline Graphs

This type of graph depicts measurements of specific devices on a timeline. They help in understanding the emergence of events and alarms as well as detecting occurrence patterns.

Communication Drilldown

The communication drilldown enables the user to browse through the communication network by traversing links between devices. It may be used to analyse communication problems occurring in the network.

Electrical Grid Drilldown

With the electrical grid drilldown component, the user can browse through the electrical network following connections between the elements to get from a general to a more detailed view (e.g. from a substation to its transformers, then to the corresponding incoming and outgoing feeders, etc.) and from one grid component to its connected component (e.g., from one substation to another one through the connecting feeders).

KPI Drilldown

The KPI drilldown demonstrates the underlying values of the corresponding KPI. For example, if a KPI is not as expected in some area of the electricity grid, one may find out which elements cause the low performance and decide which appropriate measures can fix it.

Location Drilldown

Location drilldown allows for the displaying of relations between different locations, where one location is within another. As an example, a maintenance area could contain several substations, which in turn contain multiple measurement points.

Reporting

The reporting component features the extraction of either current or historical data about the electrical grid, performance levels and grid states.

3.2.2 Services and Algorithms

The services and algorithms, Figure 4, are developed within WP2 and WP3 of the SOGNO project.

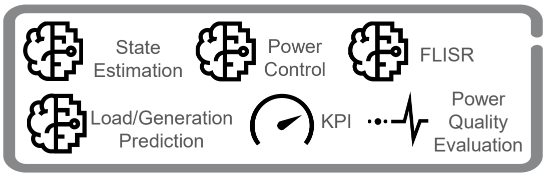

Figure 4: Services and algorithms of SOGNO reference architecture

State Estimation

The State Estimation (SE) service computes the operating state of the network for a given time instant, allowing the real-time monitoring of the grid in the presence of non-ideal measurements. The information provided by the SE algorithm is used by grid operators to detect possible anomalies in the grid operation and might be used as input for further calculations.

Power Control

The power control service defines the optimal set points for active and reactive power of the converters interfacing Distributed Generation (DG) units to the grid. The goal of service is to avoid critical grid states such as overvoltages and to minimize the curtailment of DG power.

FLISR

The algorithm for Fault Localization and Isolated Service Restoration (FLISR) localizes the faulty part of the grid and, correspondingly, makes changes in switching states to reconnect isolated parts.

Generation and Load Prediction

Predictions for generation and load are determined based on historical generation and consumption values.

KPI Evaluation

The algorithm determines relevant KPIs such as the System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) to evaluate the reliability of supply.

Power Quality Evaluation

The service identifies characteristic values such as Total Harmonic Distortion or Voltage Unbalance Factor to evaluate the grid operation in terms of power quality.

3.2.3 Integration Bus

The integration bus enables the exchange of data between different software components. Technically it can be a service bus, service mesh, queuing mechanism, or a different concept. For example, the integration bus delivers algorithm results to the data management or other components that use the result as input.

3.2.4 Collection

The components presented in Figure 5 are responsible for collecting the data coming from the measurement and control devices and providing them to the IT system via the integration bus.

Figure 5: Collection components of SOGNO reference architecture

Device Data Collection

The IT system interface towards measurement and control devices requests information or receives them if the devices push it themselves.

Message Queues

Message queues provide an asynchronous communication protocol, meaning that the sender and receiver of the message do not need to interact with the message queue at the same time. Messages placed onto the queue are stored until the recipient retrieves them. For example, data collection uses message queues to cache messages.

Data Integrity Assurance

Data integrity assurance is a security component that checks the integrity of incoming data as well as data in the data management components. It is usually based on blockchain technology.

3.2.5 Communication

The communication layer defines different communication technologies that are used to deliver data from and to field devices, Figure 6.

Figure 6: Communication components of SOGNO reference architecture

4G

4G is the fourth generation of broadband cellular network technology.

5G

5th generation wireless systems, abbreviated 5G, are improved wireless network technologies deploying in 2018 and later. 5G provides key features such as low latency, high transmission capacity, network slicing and edge processing. They are the basis for a fast and robust communication system as required for grid monitoring and control.

NbIoT

Narrowband Internet of Things (NbIoT) communication is in place to support a high number of small embedded devices. The major advantage of this type communication is the low energy consumption, less complex hardware and the extension of coverage range. NbIoT does not really depend on a specific core network technology, but can operate together with technologies such as LTE, GSM or CDMA.

Cat-M1

Unlike NbIoT, Cat-M1 supports full mobility of the devices, as needed for vehicles in smart cities and fleet management scenarios. Two further capabilities of Cat-M1 are LTE eDRX (Extended Discontinuous Reception) and LTE PSM (Power Saving Mode).

3.2.6 Measurement and Control Devices

This layer contains measurement and control devices, as shown in Figure 7, which are connected to the electrical grid.

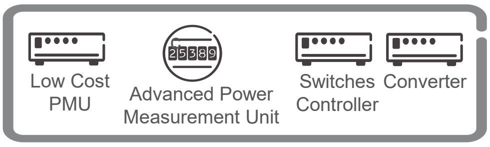

Figure 7: Measurement and control devices of SOGNO reference architecture

Low Cost PMU

The low-cost Phasor Measurement Unit (PMU) provides measurements of voltage (magnitude and phase-angle), current (magnitude and phase-angle), frequency and Rate of Change of Frequency (ROCOF). All the measurements are time-stamped to an accurate time synchronization with respect to the UTC time obtained via GPS.

Advanced Power Measurement Unit

This is a measurement unit which is able to quantify classical electrical quantities (such as voltage, current and power) as well as some advanced power quality parameters (such as harmonics).

Switches Controller

A control unit which can change the position (on/off) of the switches in the electrical grid.

Converter

Hardware component based on power electronics being responsible for interfacing renewable energy sources with the grid.

3.2.7 Electrical Grid

The layer involves the actual equipment forming the electrical grid, Figure 8.

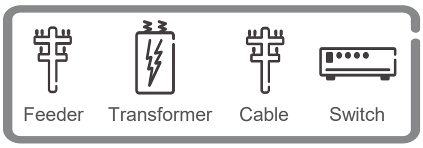

Figure 8: Electrical grid components of SOGNO reference architecture

Feeder

Power line that delivers electricity from generation to consumers.

Transformer

A transformer is a central piece of substation equipment, transferring electrical energy between two or more circuits with different voltage levels.

Cable

Cables make up the feeder.

Switch

Device that is able to open or shut off power for a certain part of the electrical grid.

3.2.8 Equipment, Device and Connectivity Management

This group of management components feature the configuration of electrical equipment, measurement, control and communication devices as well as the interconnections between them, Figure 9.

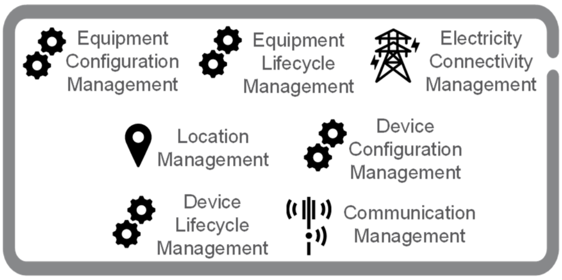

Figure 9: Equipment, device and connectivity management components of SOGNO reference architecture

Equipment Configuration Management

Enables the setting of equipment configuration to reflect the actual situation in the grid.

Equipment Lifecycle Management

Equipment Lifecycle management handles installation and replacement of electrical equipment on the field through status information. This helps different parts of the system (algorithms, electrical grid drilldown etc.) to have up-to-date information on equipment actually deployed and in operation on the field.

Electricity Connectivity Management

Defines the connectivity between electrical equipment within the electrical grid. This enables electrical grid drilldown visualization.

Location Management

The location management component specifies different locations in relation to and within each-other. As an example, for the latter, a transformer area may be located within a maintenance area. This enables location drilldown functionality.

Device Configuration Management

Enables setting of device configurations which are directly applied on the field devices if these are remotely configurable.

Device Lifecycle Management

Device lifecycle management handles installation and replacement of devices on the field through status information. It provides up-to-date information e.g. to the services and algorithms or the communication drilldown.

Communication Management

Holds information regarding the connectivity between communication devices inside the network as well as between them and the IT system. It enables communication drilldown visualization and communication troubleshooting.

3.2.9 Application Management

Application management components, Figure 10, allow operators to limit access to authorized persons and configure the system to operate according to requirements of the organization.

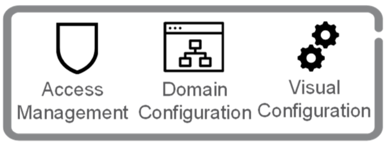

Figure 10: Application management components of SOGNO reference architecture

Access Management

Access management guarantees that only authorized persons are able to access the IT system and its critical infrastructure.

Domain Configuration

Domain configuration describes the equipment, devices, connectivity elements and locations that are available in the system. The separate domain configuration module is necessary in case the domain is flexibly described in the IT system; otherwise it can be considered as statically defined by the data model.

Visuals Configuration

Visuals configuration enables the setting of options on what to visualize, e.g. which components are displayed for which domain objects or alarms.

3.2.10 Data Management

Data management components, Figure 11, store and make available necessary data within the system architecture.

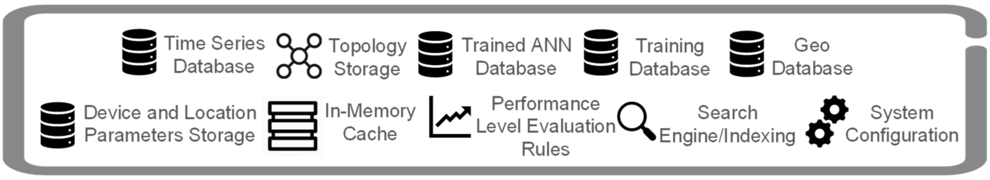

Figure 11: Data management components of SOGNO reference architecture

Time Series Database

The time series database is particularly optimized regarding quick insertion and fast access of time-indexed data. It is necessary for storing and accessing large amounts of measurements as well as changes in states and performance and delivers input data e.g. for historical performance and measurement timeline graphs.

Topology Storage

Topology storage saves and allows access to data about electrical equipment, devices and their connections.

Trained ANN Database

The database contains Artificial Neural Networks (ANN) which are obtained as result of training processes.

Training Data Database

Component for storing the data that serve as input for the training process which is part of learning algorithms.

Geo Database

Geo database allows for the storing of geographical coordinates locations of devices and equipment. Besides, specific components may be placed in a geographically accurate way, e.g. inserting a cable into a feeder.

Device and Location Parameters Storage

Stores configurations, status information and locations of measurement and control devices as well as electrical equipment.

In-memory Cache

In-memory cache is necessary to keep large amounts of constantly changing data in memory for quick access. In the case of the SOGNO project, it is necessary for keeping grid state and grid data available for the whole network.

Performance Level Evaluation Rules

Performance level evaluation rules allow evaluation of KPIs including power quality; prioritised alarms and visualize historical performance levels.

Search Engine / Indexing

This component allows for the finding of any electrical grid element, device or location through a GUI by any parameter, e.g. in case the user needs to find an element that is not displayed as part of an alarm.

System Configuration

Basic data storage with parameters necessary for the IT system to run in a specific deployment environment, e.g. IP addresses and ports of databases or time zone.

3.2.11 External Data Sources

These components provide external data necessary within the SOGNO reference architecture, Figure 12.

Figure 12: External data sources of SOGNO reference architecture

Base Map Provider

Offers a geographical map which serves as a basis for locating measurement and control devices as well as electrical equipment.

Weather Forecast Provider

Weather forecasts allow for the prediction in the behaviour of system components such as photovoltaic generation units.

4. Pilots Architecture

This section describes the details of the platforms that will be deployed in the four trial sites, namely: CEZ Romania, Ericsson Estonia (EEE), ESB Ireland, and RWTH Aachen (Germany).

4.1 CEZ

The CEZ pilot is largely based on the Gridhound platform.

Visualization

To evaluate the operating condition of the power distribution systems, the Gridhound ADMS Graphical User Interface (GUI) provides information about the system topology, the installed measurement devices, the suggestions for optimal measurement placements, state estimators, estimated system states and the alerts related to the contingencies conditions.

Services and Algorithms

In the first phase, it is planned to test the state estimation algorithm. The second phase will also feature load and generation forecasting, power quality evaluation and potentially FLISR, see Appendix 4.1. In addition, Gridhound offers algorithms for sensor placement calculation and KPI evaluation. These are not necessary components of the pilot but they are included in the Gridhound solution.

Collection

Gridhound uses RabbitMQ both for message queues towards devices and synchronization between different IT system components.

Communication

Telekom Romania performed an analysis on the coverage of the mobile network in the area of the field trials. CEZ has five candidate grids that can be used as trials of which two mixed MV/LV grids are going to be used in phase one. Depending on the grid, a different mobile communication technology is employed. Details on this matter can be found in deliverable D5.1.

Measurement and Control Devices

ALTEA sensors in combination with MAC Advanced Power Measurement Units provide the grid measurements for medium voltage network. MAC sensors in combination with MAC Advanced Power Measurement Units provide grid measurements for low voltage network.

Electrical Grid

Gridhound supports any electrical grid model based on the Common Information Model (CIM). This in turn makes easier the sharing of power grid information between different platforms. The CIM is object-oriented and consists of classes, attributes and relationships among them to describe the behaviour of the electrical system components. CIM is defined by IEC 61968 and IEC 61970 related standards for power transmission and distribution systems.

Data Management

GridHound covers most required aspects of data management with lack of in-memory cache at this point. This might be necessary for storing grid data and state for on-the-fly analysis.

4.2 EEE

In the EEE trial with Elektrilevi, a combination of Voyager and IoT Accelerator platforms will be used to support the load prediction, generation prediction and power quality evaluation services. In Appendix 4.2 you can see the complete mapping of functionalities between systems.

Voyager platform (developed by Ericsson Estonia) handles the analytics, equipment, device & connectivity management, application management and data management as well as communication between systems. Services are installed as standalone services that integrate with the Voyager API to display results of services in the GUI.

IoT Accelerator (developed by Ericsson Germany) handles the collection and integration towards field devices.

Visualization

Voyager is natively delivering the full real-time monitoring visualization functionality for the Elektrilevi trial. It can visualize sensors on a map laid out on the electricity grid. The grid is fully navigable, allowing for an electrical grid, communications and location drilldown. For each of the elements, any property and measurement timeline is shown as graphs. Alarms for problematic elements are visualized in different colours and listed in the monitoring view. In addition, historical data can be presented.

Services and Algorithms

The purpose of the lab trial in Estonia is to test some of the services and to focus on the testing of specific data analytic components of the cloud platform. EEE is going to test following services and algorithms:

Power Quality service: the data collected for this service comes from the APMU (Advanced Power Measurement Unit). From this, it is possible to monitor power quality parameters in the grid (LV and MV network) to detect possible anomalies. In the Ericsson Lab/Field trial, it will be possible to test the installation, implementation, integration, use and collection data features from the APMU cutting edge devices. Another objective of this test is to document the installation process and register improvements for the future development of these devices.

Load and generation prediction service: The load / generation prediction (LP/GP) service is a tool composed of two main components. The load prediction (LP) component provides the power grid with future electricity demands, based on the historical information of customers' power consumptions. The generation prediction (GP) service provides the information on the future power generated in photovoltaic (PV) systems based on weather information, such as solar irradiance, temperature, humidity, etc. The information obtained by both LP and GP algorithms is utilized in power grid planning and operation to ensure operation stability and reliability.

Collection

All data coming from the measurement devices will be sent to IoT Accelerator which acts as a data collection service with high processing capability. These data are then imported into Voyager through IoT Accelerator direct integration to Voyager data management system to ensure prompt propagation.

Load prediction and generation prediction algorithms are installed as standalone services. Voyager connects to them periodically to provide the next set of data and get the next set of predictions.

Data Management

Voyager uses a Postgres database along with PostGIS plugin for geodata and Timescale plugin for time series database. The data model has integrated both, metadata and geographical and timeseries-type information, into one flexible domain-agnostic data model.

Communication

The APMU devices have a Pluggable Communications Module 3/4/5G with Short Range Wireless, which will be exploited for the communication in the Lab/Field tests.

Measurement and Control Devices

APMU devices will be deployed to enable the power quality service. In addition, in the Elektrilevi field trial, LG industrial balance meters are used to test load prediction and generation prediction algorithms.

Electrical Grid

For the Elektrilevi trial, the sensors will be installed in the laboratory substation and other 6 field substations to test the power quality algorithm. Each one of the chosen substations has some generation capacity behind them. From the selected substations, two of them (Maardu-Mõisa – and Kabeli substations) will be used for the initial tests. For the load prediction algorithm, balance-meter measurement units deployed in different locations of the Elektrilevi grid will be used.

4.3 ESB

At the Irish trial site the ESB plan to use the SERVO system in the operation of gird services on the Irish network. SERVO is a system wide energy resource and voltage optimization software platform that interacts with system operators and energy markets.

The aim of SERVO is to take in many different sources of data information from across all DSO information systems and to store it in a common information model. From there, tools can be used to optimise energy flow and unlock the full capacity of the DSO and TSO networks in real time. SERVO enables energy actors to interact, and extract opportunities from a system that is used within real time energy markets.

In a SOGNO reference architecture comparison to SERVO available functionality, Appendix 4.3, it can be seen that SERVO supports all the back-end functionality to a high degree (including collection from field devices, data management and connectivity management) whereas visualization and device and equipment configuration and lifecycle are handled by other systems that are integrated to SERVO.

Visualization

SERVO does not strictly have visualization functionality, SERVO offers software API's that allow this visualization functionality be provided by other systems that are integrated to SERVO.

For example, the SERVO Planner visualization takes the common information on sub-stations that has been gathered from SCADA and MV90 data and present it in a way that would allow load planners evaluate the sub-stations load over a period of time.

Services and Algorithms

Algorithms, as designed and developed by 3rd parties, in the case of SERVO, can be installed in to the SERVOLive component. All services within it are in Docker containers and connection between container services are managed via a framework called Conduit [3].

The power system services that will be tested here are: state estimation and power quality evaluation (phase 1), and FLISR (available in phase2).

Collection

SERVO supports the collection of information to a high level. Service mesh also supports synchronization of this information between different components in the system architecture.

Communication

All mobile coverage communication, which includes GPRS (2.5G), HSPA (3G), and LTE (4G), is provided via a third-party supplier (Vodafone) with narrow band communications provided by ESB Telecom.

Measurement and Control Devices

Altea sensors in combination with MAC Advanced Power Measurement Units provide the grid measurements.

4.4 RWTH

The RWTH pilot is used in two different scenarios: lab trial and field trial. The difference between the two trials lies in the way the electrical power system components are represented.

For the field trial, a real grid is equipped with sensors that can be used to test monitoring algorithms. The same software as for the field trial is also employed for the lab trial. However, all power system components are in this case simulated.

An overview diagram representing the components of the reference architecture that are going to be evaluated in this trial site is included in the Appendix 4.4.

Visualization

VILLASweb [1] is integrated into the RWTH pilot for real-time monitoring and control actions. It can visualize data coming from different simulators and sensors. Furthermore, VILLASweb can generate figure showing the grid topology from data in the CIM format.

Services and Algorithms

RWTH is going to test, either in the lab or in the field trial, all the power system automation algorithms developed in the SOGNO project. In the lab trial, RWTH deploys:

- State estimation from RWTH ACS and GH

- Power control from RWTH ACS

- FLISR from RWTH TI

In the field trial, the following algorithms are evaluated:

- State estimation from RWTH ACS and GH

- Load/generation forecasting from RWTH TI

- Power quality evaluation from MAC

Collection

All data coming from simulators or real hardware are first sent to an MQTT broker. The most recent data can be requested from the MQTT broker. To interface the devices to the MQTT broker, VILLASnode will be used to translate between IEC61850 and MQTT.

Data Management

A time series database is recording all data that is pushed to the broker. Then, algorithms can request historical data from the database. A second database holds the meta data which defines scenarios and what data is stored in the time series database.

Communication

5G and / or other mobile communication network technologies are used for the lab trial. This depends on the availability of communication equipment of Ericsson Germany. In the RWTH field trial, less capable communication technologies will be installed to reduce the cost. The options include: Wi-Fi, Ethernet and GPRS.

Measurement and Control Devices

Depending on the scenario, lab or field trial, the devices are either real or simulated. In the lab trial, all power system components are simulated by a real-time simulator. The field trial includes real devices such as:

- Low Cost PMU

- Advanced Power Measurement unit from MAC

Both devices are installed in combination with Altea sensors.

Electrical Grid

For the field trial, sensors are installed at several nodes in the RWTH Campus grid to test monitoring algorithms. The same software as for the field trial is also employed for the lab trial. However, all power system components are simulated and hence, it is possible to test algorithms that include control actions.

5. Conclusions

This report presents the system architecture components necessary for the provision of services for future networks according to the SOGNO vision. As services, the SOGNO project considers state estimation, power control, power quality evaluation, generation and load prediction as well as FLISR. The presented SOGNO reference architecture specifies the required components for physical as well as IT layers and ensures a clear understanding of their functionality and the definition of a common terminology.

Besides, the report gives an overview of the architecture components deployed in the SOGNO pilots and relates them to the reference system architecture, hence allowing for the identification of key aspects of each pilot. For example, it shows that the system architecture of the EEE pilot comes with an extensive set of visualization functionalities as well as application, data and device management features. Instead, the pilots of RWTH focus on testing most of the SOGNO services which are provided by RWTH, GH and MAC. The diversity of the pilots helps the SOGNO project to represent industry and level up SOGNO possibilities.

Further work will involve a more detailed specification of the data flow within the system architecture and will be reported as part of deliverables D4.4 and D4.5.

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7. List of References

[1] https://fein-aachen.org/projects/villas-web/

[2] https://fein-aachen.org/projects/villas-node/

[3] https://conduit.io/

[4] Angioni, G. Lipari, M. Pau, F. Ponci and A. Monti, "A Low Cost PMU to Monitor Distribution Grids," 2017 IEEE International Workshop on Applied Measurements for Power Systems (AMPS), Liverpool, 2017, pp. 1-6.

[5] European Commission, “The Strategic Energy Technology (SET) Plan.”

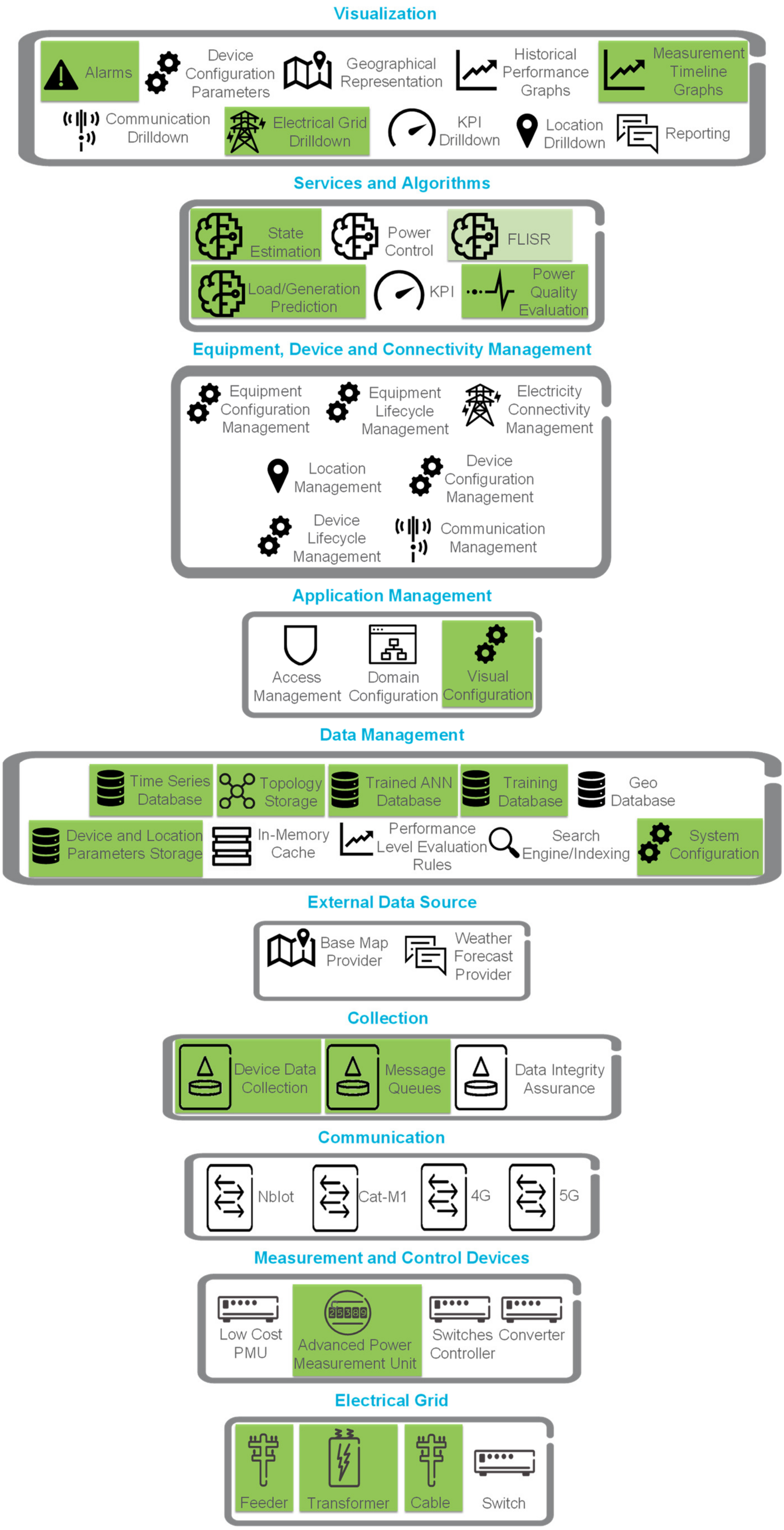
[6] CEN-CENELEC-ETSI Smart Grid Coordination Group, “Smart Grid Reference Architecture.” Nov-2012.

8. List of Abbreviations

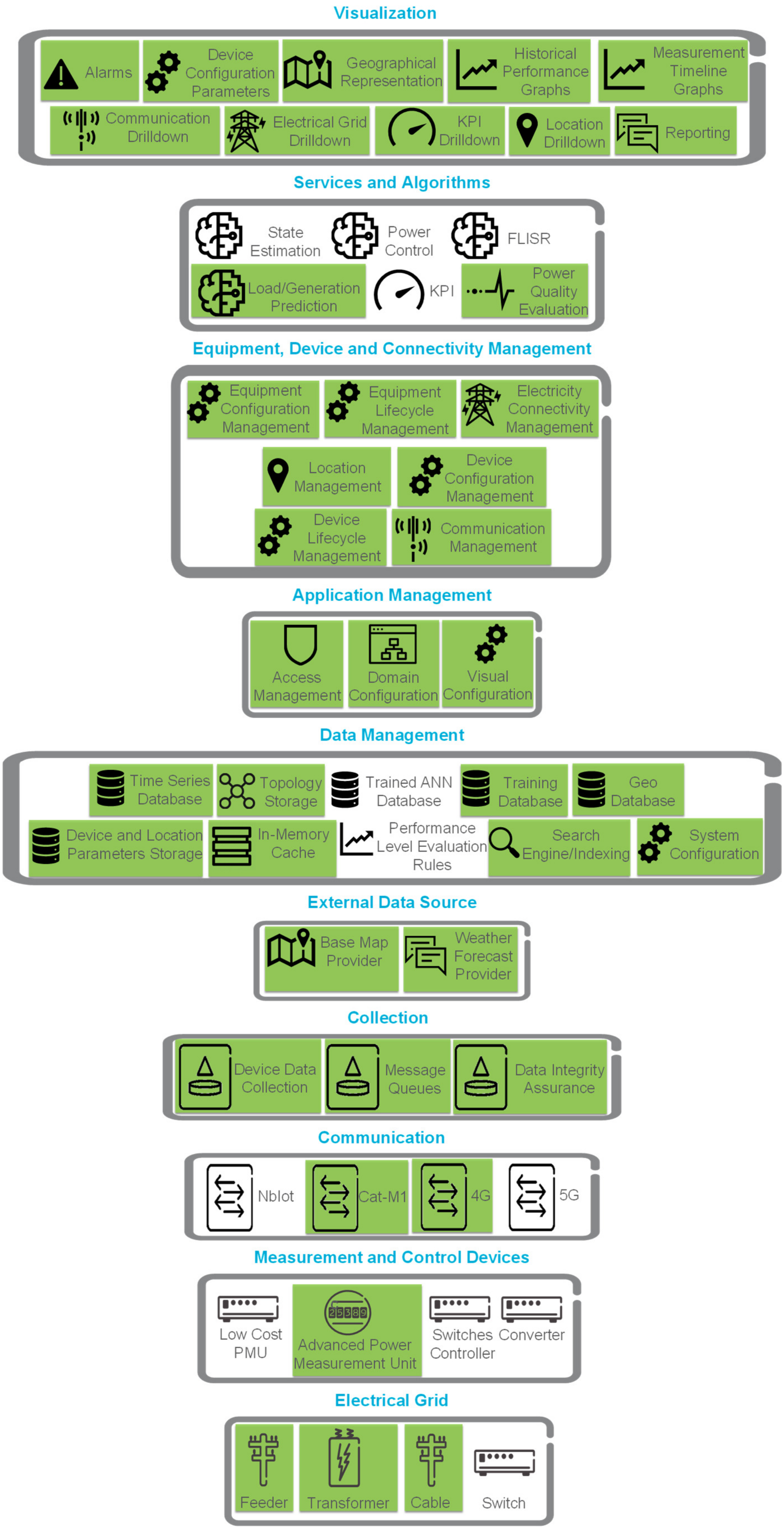
APMU	Advanced Power Measurement Unit
(Nb)IoT	(Narrowband) Internet of Things
ANN	Artificial Neural Networks
API	Application Programming Interface
DER	Distributed Energy Resources
DG	Distributed Generation
DSO	Distribution System Operator
EU	European Union
FLISR	Fault Localization and Isolated Service Restoration
GP	Generation Prediction
GPS	Global Positioning System
GUI	Graphical User Interface
IT	Information Technology
KPI	Key Performance Indicator
LP	Load Prediction
PMU	Phasor Measurement Unit
PV	Photovoltaic
ROCOF	Rate of Change of Frequency
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SE	State Estimation
SET Plan	Strategy Energy Technology Plan
SGAM	Smart Grid Architecture Model
SOGNO	Service Oriented Grid for the Network of the Future

A.1 Mapping of Pilots to Reference Architecture

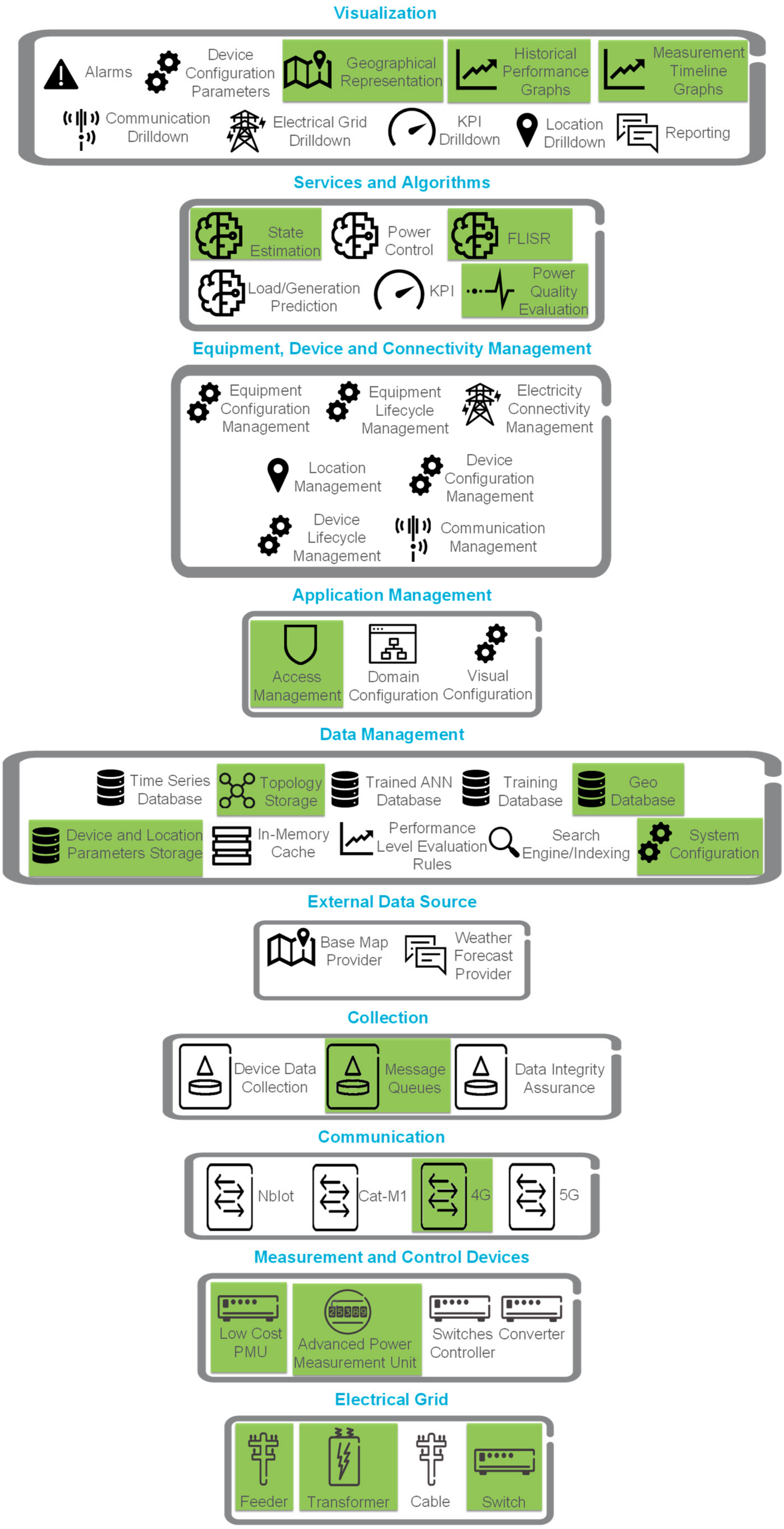
A.1.1 CEZ Pilot Overview



A.1.2 EEE Pilot Overview



A.1.3 ESB Pilot Overview



A.1.4 RWTH Pilot Overview