D5.2 1st Version of the Asset Management Tool Suite for TSOs, DSOs and RES Operators

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Big Energy Data Value Creation within SYNergetic enERGY-as-a-service Applications through trusted multi party data sharing over an AI big data analytics marketplace

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Abbreviations and Acronyms

Acronym	Description
AM	Asset Management
App	Application
AR	Augmented Reality
AS	Ancillary Services
DC	Direct Current
DER	Distributed Energy Resources
DSO	Distribution System Operator
EPM	Enhanced Performance Monitor
EV	Electric Vehicle
FOIMO	Fault Occurrence Inspector and Maintenance Optimizer
FBNM	Flexibility Based Network Manager
LV	Low Voltage
ML	Machine Learning
MV	Medium Voltage
NASE	Network Asset Sizing Engine
NPAE	Network Performance Assessment Engine
OPF	Optimal Power Flow
OSO	Operational Scheduling Optimizer
PV	Photovoltaics
RES	Renewable Energy Resources
SaaS	Software as a Service
SCADA	Supervisory Control and Data Acquisition
SOH	State of Health
TSO	Transmission System Operator
VR	Virtual Reality
WP	Work Package

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Executive summary

The current deliverable D5.2 “1st Version of the Asset Management Tool Suite for Network and RES plant Operators” reports the results and developed functionalities of all WP5 tasks, T5.1, T5.2, T5.3 and T5.4. All four tasks develop “Advanced Grid-level Analytics for Optimized Network and Asset Management Services and Applications”, targeting network operators as well as DER aggregators and RES operators. Each task develops one application and thus all four of them consist the Asset Management Tool Suite, which comprises four applications in total:

Infrastructure Sizing and Grid Planning Application implements different features that target the operation and planning responsible operators of DSOs and TSOs, with the objective of providing valuable insights in terms of capacity and sizing requirements of network assets. The application utilizes available historical data and statistics such as expected next year forecasts of peak demand/generation data to create stochastic scenarios of demand and generation and perform power flow calculations to provide suggestions for optimal sizing and planning.

Flexibility based Network Management and DSO-TSO Common Operational Scheduling Application implements all necessary features to allow network operators to operate their networks and schedule the available resources including flexible demand for the intra-day and day ahead in a coordinated manner. By exploiting all available data, including the flexibility potential of aggregators’ portfolio, the application facilitates the optimal scheduling of the flexible assets by TSOs and DSOs who aim to request specific congestion management and balancing services.

Advanced Performance Monitoring/Forecasting and Predictive Maintenance Application targets the management of RES plants by ensuring their optimal operation, predictive maintenance and proactive avoidance of equipment faults. The tool steps on the forecasting and predictive analytics baseline algorithms and appropriate machine learning techniques towards identifying in near real-time predictive maintenance needs, increasing PV technology reliability and efficiency and improving power trading functions on the plant operator side.

Asset Management Optimization for Power Grids Application implements different features that target the maintenance responsible operators of DSOs and TSOs, with the objective of providing different models that optimize the maintenance management by enriching the available data with the results of a number of analytics and forecasts.

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The purpose of this deliverable is to present the 1st version of each of the applications and document the implemented functionalities and services. For each of the applications, the status of the proposed functionalities is presented, along with the planned enhancements and refinements which are expected on the forthcoming months, that is before the start of the 1st demo run. Additionally, the technology stack and implementation tools, API documentation, assumptions and restrictions and access are provided for the four applications. At this stage, the applications are in the process of being integrated into the SYNERGY platform and are being prepared to perform also data exchange with the platform or other applications.

Tasks 5.1, 5.2, 5.3 and 5.4 will remain active until the end of the project (M42) and the WP5 Tool Suite will be progressively updated, enhanced and validated during the demonstration phase. The final version of the Asset Management Tool Suite will be released in M42 with D5.3 documenting the final release of the energy applications, taking into consideration the feedback, findings and any new requirements that emerge from the demonstration phase in WP8.

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1 Introduction

1.1 Purpose of the document

The current deliverable D5.2 of the SYNERGY project named "1st Version of the Asset Management Tool Suite for Network and RES plant Operators" released as the 2nd deliverable of WP5, aims to present the prototype version of the four applications consisting the Asset Management (AM) tool suite, relevant to asset management which are developed in the SYNERGY project, leveraging also the functionalities of the SYNERGY Big Data Platform & AI Marketplace (developed in WP3-WP4).

The implemented functionalities and developments provided are based on the work that has been performed by the SYNERGY project up to the moment of writing. This also incorporates all the work presented in D5.1 regarding the features specification and components design. The AM tool suite includes a set of applications that process grid data in order to perform critical power system functionalities, like optimal network planning, performance assessment and DSO/TSO coordination, to name a few. These applications will be provided as services to the different network operators, e.g. Power Transmission and Distribution operators. The services proposed in each application are in a web-based form (the end-user utilizes a web interface to navigate through the various features and functionalities), and a complementary AR-based mobile application. Their prototype design is illustrated in the UI screenshots provided and the reader can also access the 1st version of the apps via the access instructions given in the corresponding section.

This document acts as subsequent step towards the implementation of the functionalities that compose the AM tool suite, following D5.1. Several enhancements will occur during the development phase of the application and the feedback from the involved partners. Also, for the implemented functionalities, those that are partially implemented at this stage will be implemented on M24 before the start of the 1st demo run (next release of the apps). After this release, the applications will continue to be updated throughout the 1st and 2nd demo run. Therefore, it is expected that the developments presented in this document do not represent the final version of the applications but a pivotal one. Each potential modification and update will be thoroughly described and reported in the final deliverable of WP5, D5.3.

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1.2 Scope of the document

This document presents the core functionalities and all the developments relevant to the four applications which consist the AM tool suite and will be delivered as energy services. The document includes the description of the functionalities of the specific components of each app with the aim to address the interests and the needs of TSOs, DSOs and RES Operators.

For each component within a specific application, the status of features that accompany the components is documented, the relevant APIs for data retrieval that are/will be configured are delivered, along with the specific steps that potential users need to follow to be able to take advantage of the applications. For each of the delivered functionalities, details on the methodology used are given, screenshots of the current state of the UIs are provided, technical details on the technology stack and API documentation are provided, as well as details on the plans relevant to integration with the SYNERGY platform and other expected features for the next release of the tool suite. All the implemented features and functionalities follow the work presented in D2.1 regarding use cases and requirements and D2.6 regarding the SYNERGY framework architecture, as well as design specifications given in D5.1.

Last but not least, planned features for the next release are described for the four applications, aiming to provide fully integrated and functional services before the 1st demo run.

1.3 Structure of the document

The document is a demonstrator material, summarizing the current developments and implementation details of the four applications. The core of deliverable D5.2 is provided in chapters 2 to 5, where the status of development of applications and their components are detailed. These chapters provide an overview for each one of the four applications being developed within WP5. For each application, the following details are provided:

An overview of the application is provided, along with a table which includes the status and details of all implemented functionalities. For partially implemented functionalities, a plan regarding the pending contributions is given. The user interface of the application is presented through a user journey and description of every page of the app. Technology stack and implementation tools are listed to document the methods and software used to implement the different modules of the applications.

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The APIs documentation concerning integration with the SYNERGY platform and internally consumed REST APIs is provided in the next subsection. Then, installation instructions, assumptions and restrictions regarding data, technical background, licensing and access are also described providing an overview of the requirements imposed to retailers and operators willing to integrate with and make use of the applications. Finally, planned features for the next release are documented in the last subsection. Next release of the application has been agreed to be on M24 of the project, since on M25 the 1st demo run for the demo cases is anticipated to start, therefore it is important to have a stable version of the application ready by then.

Section 6 concludes the document.

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2 Infrastructure sizing and grid planning application

2.1 Overview

The *Infrastructure Sizing and Grid planning Application* implements different features that target the operation and planning responsible operators of DSOs and TSOs, with the objective of providing valuable insights in terms of capacity and sizing requirements of network assets. The application utilizes available historical data and statistics such as expected next year forecasts of peak demand/generation data to create stochastic scenarios of demand and generation and perform power flow calculations to provide suggestions for optimal sizing and planning. The following figure depicts the application and its internal architecture, as well as interactions with actors and the SYNERGY Platform. Any interested actors, such as the DSO and the TSO will be able to access the application upon being authenticated by the SYNERGY Platform.

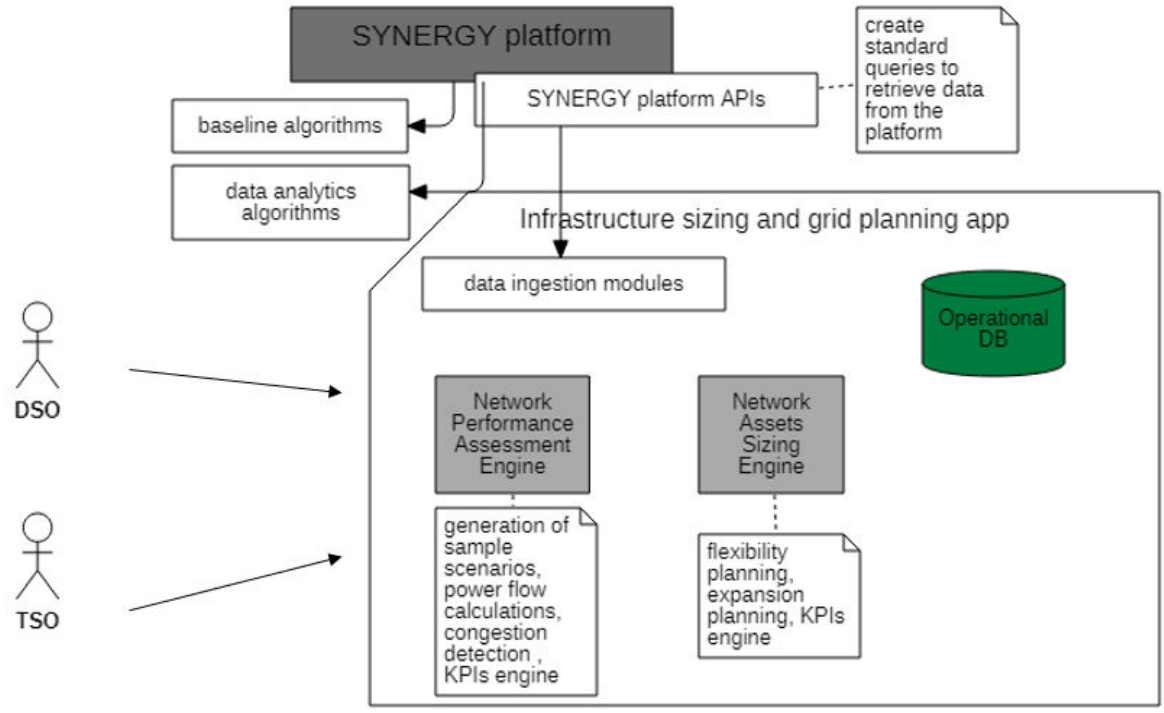

Figure 1: Infrastructure Sizing and Grid Planning Application

The application consists of two components:

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The *Network Performance Assessment Engine (NPAE)* is responsible for the simulation of the operation of the network and assesses the state of the network in terms of performance, and power quality metrics. The assessment involves the evaluation of the electricity network steady state aspects using power flow calculations. Congestion issues and operational constraints, such as voltage violations, line/transformer over-loadings are considered in the assessment. The component involves the assessment of various operating conditions, incorporating the analysis of stochastic demand and generation profiles.

The *Network Assets Sizing Engine (NASE)* is responsible for providing solutions regarding optimal planning and sizing of the network assets. Solutions shall involve optimal capacity for new substations and lines in case further reinforcements are needed, as well as optimal sizing of new demand connections or DERs. The NASE is a complementary component to the NPAE, exploiting results such as reinforcement and flexibility needs to propose operational planning solutions in the mid-term (up to a month ahead) and in the long term (up to a year) for the provision of critical services such as congestion management in medium voltage distribution grids.

2.2 Implemented functionalities

The following table summarizes the current status of all the features to be provided by the application.

Table 1: Implemented features of Infrastructure Sizing and Grid Planning application

Feature	Status	Notes
NPAE_1: Generation of demand and production scenarios	Implemented	This function uses historical time series data of at least one year to create representative 24-hour profiles of demand and generation for different seasons and day types, including their statistical parameters. Those parameters are matched with certain probability distributions (such as beta and normal) and random profiles are generated for demand and generation. Functionality is running 'offline', in local servers and results are depicted in the application's UI. Pending actions are to develop the scheduler to request new inputs data from the SYNERGY platform every 'X' amount of timesteps, rerun the functionality offline and produce updated results.
NPAE_2: Power flow calculation	Implemented	Static power flow and network calculations are performed via the utilization of pandapower[1] package, which combines the data analysis

[1] http://www.pandapower.org/

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Feature	Status	Notes
		library pandas and the power flow solver PYPOWER. Power flow analysis is performed in timeseries, for all the generated scenarios, as a chronological probabilistic power flow simulation (Monte Carlo). Functionality is running 'offline', in local servers and results are depicted in the application's UI. Pending is to develop the scheduler to request new input(s) data from the SYNERGY platform every 'X' amount of timesteps, rerun the functionality offline and produce updated results
NPAE_3: Identification of critical operational events	Implemented	The estimation of probability of assets overloading (loading above the nameplate rating) is calculated for standard test scenarios (e.g min-max generation) and for a Monte Carlo simulation of the generated scenarios. In those circumstances, critical nodes and lines of the infrastructure are determined, and critical loading situations are identified. Functionality is running 'offline', in local servers and results are depicted in the application's UI. Pending is to develop the scheduler to request new input(s) data from the SYNERGY platform every 'X' amount of timesteps, rerun the functionality offline and produce updated results.
NPAE_4: Detection of congestion problems	Implemented	For this function, test networks provided in pandapower package have been initially used. Results coming from the power flow analysis, such as loading of the components (lines) are compared with the maximum current loading of the component to identify and report line overloadings. Similarly, the resulting voltage magnitude from power flow calculation is compared with maximum and minimum accepted voltage levels of the network to identify and report overvoltages/undervoltages. Functionality is running 'offline', in local servers and results are depicted in the application's UI. Pending is to develop the scheduler to request new input(s) data from the SYNERGY platform every 'X' amount of timesteps, rerun the functionality offline and produce updated results.
NPAE_5: KPIs calculation - basic status indicators	Partially implemented	So far frequency of congestions, size of congestions, capacity reinforcement needs are calculated. Pending is to calculate maximum hosting capacity, to help identify the range of new DER integration that can be absorbed in existing infrastructure. Functionality is running 'offline', in local servers and results are depicted in the application's UI. Pending is to develop the scheduler to request new inputs data from the SYNERGY platform every 'X' amount of timesteps, rerun the functionality offline and produce updated results.
NPAE_6: Data ingestion	Partially implemented	Workflows have to be constructed, contracts have to be signed with DSOs and retailers, and finally the appropriate data retrieval queries have to be configured to allow data ingestion through the SYNERGY platform.

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Feature	Status	Notes
NASE_1: List operational planning alternatives and horizon	Partially implemented	Depending on the outcomes of the Monte Carlo analysis and the severity of the events, custom decisions can be made for a network, understanding on whether the grid issue is long standing, short term, irregular (happening in a rare occurrence) or periodic. The suggested planning alternatives are line reinforcement, substation reinforcement, capacity coming from flexible resources, new DER hosting capacity. It is suggested that flexible capacity is a short and medium term solution, whereas reinforcement and new DER installations solutions are long term. In the next release, results of the Monte Carlo analysis, would indicate to the user which type of planning alternative and horizon satisfies the grid requirements and needs.
NASE_2: Mid – term flexibility planning	Partially implemented	In case flexibility resources is an available option within network operation, the identified capacity needs (resulting from congestions that have been reported in Monte Carlo power flow calculations) are resolved through the utilization of flexible resources. The flexible capacity needed for the mid-term is identified per network bus (MW of flexible capacity needed per bus). Functionality is running 'offline', in local servers and results are depicted in the application's UI. Pending is to develop the scheduler to request new input(s) data from the SYNERGY platform every 'X' amount of time, rerun the functionality offline and produce updated results In the next release, more accurate results can be obtained replacing power flow calculations, with optimal power flow calculations.
NASE_3: Long term expansion planning	Partially implemented	The identified capacity needs (resulting from line congestions that have been reported in Monte Carlo power flow calculations) indicate the line reinforcements that are needed. Functionality is running 'offline', in local servers and results are depicted in the application's UI. Pending is to develop the scheduler to request new input(s) data from the SYNERGY platform every 'X' amount of time, rerun the functionality offline and produce updated results. In the next release, the frequency and the size of those congestions will be the decision factor on whether this reinforcement is necessary or whether these congestions can be avoided from the use of flexibility. Also in the next release, specific planning scenarios will be also studied, where anticipated load growth, DER integration and forecasted peak demand are incorporated in the planning parameters.
NASE_4: KPIs calculator – performance indicators	Partially implemented	The identified capacity and reinforcement needs will be associated to appropriate costs (cost of utilizing flexibility, cost of reinforcement) to facilitate the user take a planning decision. Those features will be implemented in the next release.
NASE_5: Data ingestion	Partially implemented	Workflows have to be constructed, contracts have to be signed with DSOs and retailers, and finally the appropriate data retrieval queries have to be configured to allow data ingestion through the SYNERGY platform.

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2.2.1 Login

The user interface will be provided in the form of a web application. Login is implemented as an integration with the SYNERGY Platform's Security, Authentication and Authorization mechanisms through Keycloak[2], an open-source identity service provider implementing a set of well-known authentication and authorization protocols.

Figure 2: Infrastructure sizing and grid planning application- log in

The access to the application will be provided by using the same credentials as the DSOs and TSOs operators use in the SYNERGY Platform.

[2] https://www.keycloak.org/

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2.2.2 Network performance assessment- network topology

In the network topology window, the user can get an overview of the network parameters and retrieve the single network diagram of the network under study.

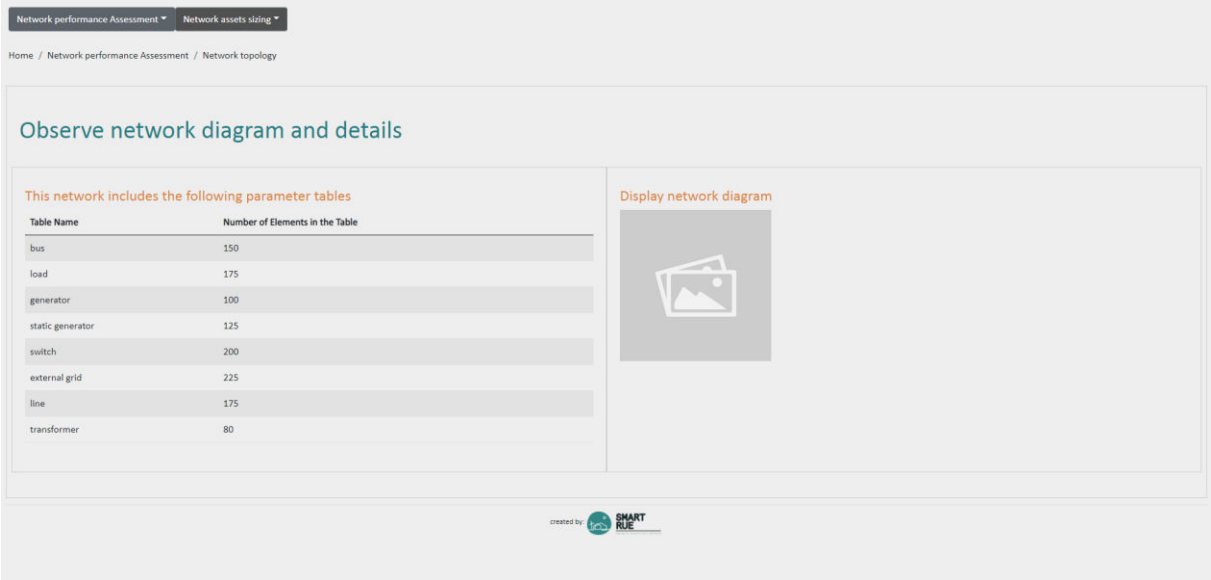

Figure 3 : Infrastructure sizing and grid planning application- network topology

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2.2.3 Network performance assessment- generation and demand scenarios

The user can select type of day, type of data and the anticipated percentage penetrations of DERs and load growth. Then, one can see variations of demand/generation through boxplots, displaying seasonal variations and also time series profiles for the 24 hours of day. Those characteristics, extracted as statistical information from available historical data, will be used to generate probabilistically (through random numbers and distributions), N sample scenarios of 24-hour profiles which will be used for the Monte Carlo power flow analysis.

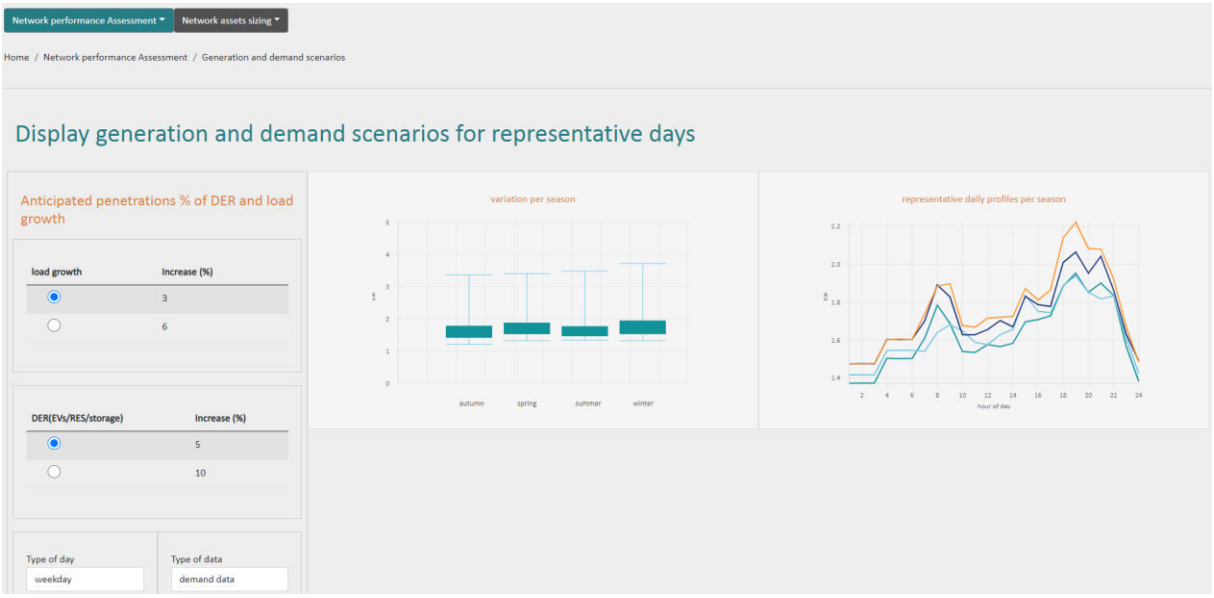

Figure 4: Infrastructure sizing and grid planning application- generation and demand scenarios

2.2.4 Network performance assessment- power flow results, status indicators

Overview of Monte Carlo power flow results

Power flow calculations are repeated for the N samples of generated scenarios of demand and generation. In this window, the user is able to see an overview of the power flow results, and more specifically on the loading conditions of the network's components, i.e. buses and lines. For lines, the loading condition is presented in percentage form, which is calculated as the ratio of the line loading (as resulted in the power flow) to the nominal capacity of the line (maximum current loading). For buses, the voltage loading is presented in per unit, which comes as the voltage level of a bus with respect to its rated voltage. These graphs provide the user with a first insight of possible over-loadings.

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Figure 5: Infrastructure sizing and grid planning application- Monte Carlo power flow results

Selected power flow results

The user can select to display hourly power flow results of one representative day. Indicative outputs are the injected active power and the injected reactive power at the network's buses. Alternatively, the user can select to display results of a specific snapshot of interest, such as a selected combination of load and generation or peak values.

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Figure 6: Infrastructure sizing and grid planning application- selected representative results

Heatmap:

Critical lines and buses can be identified through a heat map, where red colour indicates the components with high contingency probability. The user can visualize the heatmap results from selected snapshots.

Figure 7 : Infrastructure sizing and grid planning application- heatmap for selected test cases

Frequency and size of congestions:

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This window provides another set of status indicators with information regarding the criticality of congestions. Average frequency of congestions per 8760 hours for the N sample scenarios, are depicted for lines and buses. Also, histograms show how the size of the congestions is distributed across the number of sample scenarios.

Figure 8: Infrastructure sizing and grid planning application- frequency and size of congestions

Capacity needs:

The last tab related to the status indicators of Network Performance Assessment displays the amount of capacity needs per lines and substation and in aggregated mode for the selected time horizon.

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Figure 9 : Infrastructure sizing and grid planning application- capacity needs

2.2.5 Network assets sizing – planning preparation

The planning preparation tab includes the selection of the operational planning horizon and the operational planning alternatives that should be considered in the analysis, for example whether flexible demand is an available option for a mid-term solution, or they also want to consider equipment upgrades or DER new capacity for a more long-term solution. The planning alternatives are listed in the UI and the user could make a selection between them.This functionality is still under development and will be available in the next release.

Figure 10: Infrastructure sizing and grid planning application- planning preparation

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2.2.6 Network assets sizing – KPIs

After the planning preparation phase, the user can navigate through the planning results, selecting the horizon of interest and viewing a list of relevant indicators categorized in flexibility-based planning indicators and expansion planning indicators. Flexibility-based planning indicators may include active power deviation from flexible units, congestion alleviation, number of flexibility activations requested by the operator. Expansion planning indicators may include average time of fault mitigation, flexible capacity, cost savings for the operator and DER hosting capacity. This functionality is still under development and will be available in the next release.

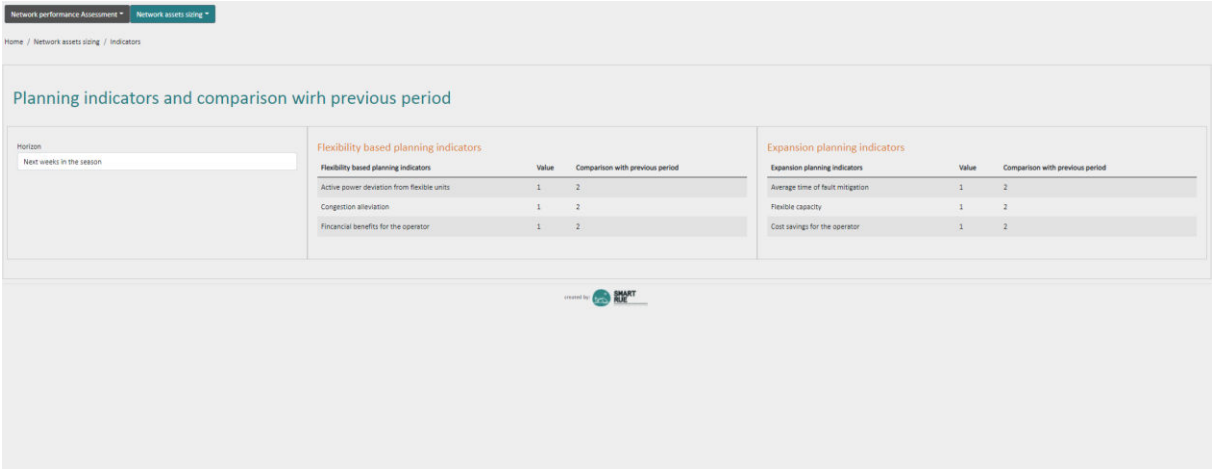

Figure 11: Infrastructure sizing and grid planning application- planning indicators

2.3 Technology stack and implementation tools

The following table lists the libraries and technologies used to develop the application.

Table 2: Technology stack of Infrastructure Sizing and Grid Planning application

Library	Version	License	Purpose
Mysql-connector-python	8.0.25	BSD 3-Clause "New" or "Revised" License	Communicating offline python results to institute server
Mysql-common	8.0.25	BSD 3-Clause "New" or "Revised" License	Communicating offline python results to institute server
numpy	1.20.3	BSD 3-Clause "New" or "Revised" License	Functionalities development
pandapower	2.7.0	BSD 3-Clause "New" or "Revised" License	Power flow calculations

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Library	Version	License	Purpose
pandas	1.3.2	BSD 3-Clause "New" or "Revised" License	Functionalities development
Scipy	1.6.0	BSD 3-Clause "New" or "Revised" License	Statistical calculations- Functionalities development
networkx	2.6.2	BSD 3-Clause "New" or "Revised" License	Network analysis- Functionalities development
python	3.8.10	BSD 3-Clause "New" or "Revised" License	Functionalities development
matplotlib	3.4.3	BSD 3-Clause "New" or "Revised" License	Offline results visualisation- Functionalities development
axios	0.21.1	MIT	Promise based HTTP client for node.js
body-parser	1.19.0	MIT	HTTP body parser for node.js
bootstrap	5.0.0	MIT	Frontend framework w/ predefined styles
Express	4.17.1	MIT	Web framework for node.js
express-session	1.17.2	MIT	Session middleware for Express
index:	0.4.0	MIT	Next.js dependency
jshint	2.13.1	MIT	Static analysis tool for js
Keycloak-connect	13.0.1	Apache License, Version 2.0	Keycloak Connect middleware
keycloak-js	13.0.1	Apache License, Version 2.0	Keycloak adapter for js
moment	2.29.1	MIT	Date handler for js
mysql2	2.2.5	MIT	Node.js driver for mysql
next	10	MIT	React.js framework for node.js that enables server rendering
nodemon	2.0.7	MIT	Monitoring script for node.js
react	16.8	MIT	Ui library for Js
react-datetime	3.1.1	MIT	Datetime picker component for React.js
react-dom	16.8	MIT	React.js package manipulate DOM
react-vis	1.11.7	MIT	Charts library for React.js by Uber

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Library	Version	License	Purpose
reactstrap	8.9.0	MIT	React components w/ Bootstrap 4 support
sass	1.32.10	MIT	Js implementation for Sass
sequelize	6.6.5	MIT	Multi dialect ORM for Node.js
swr	0.5.5	MIT	React hooks for data fetching
typescript	4.2.4	Apache-2.0	Language on top of Js that adds types

2.4 API documentation

2.4.1 Integration with SYNERGY Platform via REST API

The application requires a set of data from the DSOs and TSOs who are interested to take advantage of the application. All of the datasets needed for the application will be ingested in the application through appropriate data retrieval queries that can be configured once appropriate contracts are signed via the SYNERGY Marketplace. This activity will be performed in the next release of the application. So far, all functionalities have been tested with mock/sample data. The SYNERGY platform allows data retrieval through the exploitation of the SYNERGY APIs as explained in the SYNERGY Deliverable D3.4. A list of the required datasets is given in section 2.6. Authentication mechanisms are implemented within the SYNERGY Platform in order to ensure that only authorized parties (components of the *Infrastructure Sizing and Grid Planning Application*) are granted access.

Apart from the historical data to be retrieved from the DSOs and TSOs and used for the generation of probabilistic scenarios as explained above, the application could also utilize analytic solutions offered through the SYNERGY platform either as outputs of other applications in SYNERGY or as pre-trained analytic solutions offered within SYNERGY (as described in the SYNERGY Deliverable D4.2). Those analytics required by the application might also be configured as *analytic workflows* that will be executed by the SYNERGY Platform. In order to access the results of such analytics, different *data retrieval queries* will be configured, all of them exposing specific REST endpoints.

A list of data retrieval queries to be required and will be configured by the application is given below:

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Table 3: Data Retrieval Queries of Infrastructure Sizing and Grid Planning application

Data Retrieval Query	Type	Implementer	Purpose
Forecast of long term DER generation	HTTP GET	SYNERGY Platform	Monthly peak and average values (over a year) to enhance planning decisions in the network asset sizing engine
Forecast of long-term demand	HTTP GET	SYNERGY Platform	Monthly peak and average values (over a year) to enhance planning decisions in the network asset sizing engine
Predicted hours of peak demand at grid level	HTTP GET	SYNERGY Platform	Predictions which hours in the day we expect peak demand at grid level (over a year) to enhance planning decisions in the network asset sizing engine
Prediction of peak and average energy generation at portfolio level	HTTP GET	SYNERGY Platform	Prediction of peak and average energy generation at portfolio level in specific TSO/DSO areas (over a year) to enhance planning decisions in the network asset sizing engine

2.4.2 Internally consumed REST API

Rest APIs are also deployed internally to facilitate communication between UI layouts and the server. The Open Api 3.0 specification is being used as the descriptive medium to document data exchanges and prerequisites for effective communication between python scripts and the server. The communication domains are split into two groups of interest, Network Performance Assessment and Network Assets Sizing:

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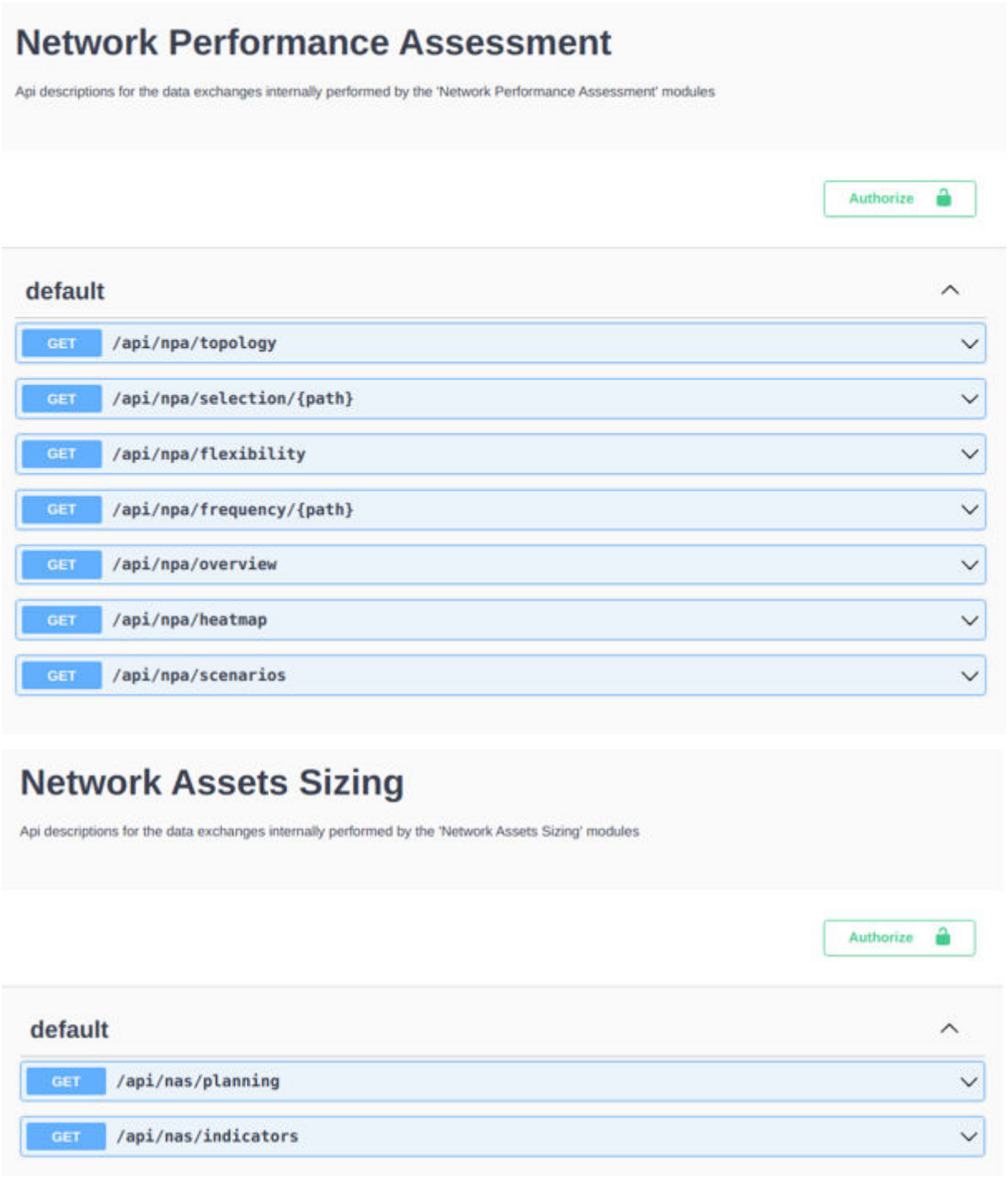

Figure 12: Infrastructure sizing and grid planning application - Internally consumed APIs

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

2.5 Installation instructions

All the components of the application have been developed as independent functions and classes in Python running in the backend of the application. Those scripts communicate internally with the front end of the application, sending output results from the features to the application's internal database. The process at the moment is refreshed manually, but in a future release, all tasks will be scheduled to run, retrieve appropriate input data and update results each 'x' instants of time.

Initially, the app lived under a test domain to facilitate early development phase where requirements keep updating. In the current status of the app, it is transferred in the SYNERGY domain and communicates exclusively with the respective subdomain enabled by the SYNERGY platform.

Due to the nature of the software, being offered in the form of SaaS, no installation procedure is required by final users.

2.6 Assumptions and restrictions

The architecture of the *Infrastructure Sizing and Grid Planning Application* relies on the data ingestion services provided by the SYNERGY Platform. In order to be able to use the application, following configuration steps need to be taken for every new DSO/TSO that wishes to integrate with the application:

- DSO and TSO are required to be registered as users of the SYNERGY Platform
- DSO and TSO are required to configure the necessary data check-in jobs, so required datasets get accessible through the platform

Table 4: Datasets required by users to integrate with the application

Dataset	Content	Description
Network Topology Data	Bus id Line id Switch id Generator id Load id External grid id Transformer id Shunt id	Network topology to be used in the power flow analysis

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

Dataset	Content	Description
	Impedance id	
Historical smart meter data	Timestamp Total energy imported Total energy exported	Time series of energy imported/exported counters at customer's supply point, on an hourly basis of at least a year historical data
Historical SCADA measurement data	Timestamp Active power + (consumption) Active power – (production) Reactive Power	Time series of historical SCADA measurements on an hourly basis of at least a year historical data
Historical energy generation from DER in the area	Timestamp Total energy exported	Time series of energy exported counters at customer's RES connection point, on an hourly basis of at least a year historical data

- DSO and TSO are required to grant access to application manager to the required datasets, so those can be incorporated to the application workflows, by signing the appropriate contracts with the application within the SYNERGY Platform
- Application manager configures the preprocessing steps in the SYNERGY Platform – which ensures that existing datasets from any DSO and TSO (following the SYNERGY CIM described in the SYNERGY Deliverable D3.1) are transformed to meet the structure required by the application

2.7 Licensing and access

Component	Licensing details
Infrastructure Sizing and Grid Planning UI	ICCS is the owner of all intellectual property rights of this component. All rights are reserved.
Network Performance Assessment Component	ICCS is the owner of all intellectual property rights of this component. All rights are reserved.
Network Assets Sizing Component	ICCS is the owner of all intellectual property rights of this component. All rights are reserved.

A demo version of the application is accessible at https://grid-planning.synergy-bigdata.eu[3] .

[3] Test credentials can be made available upon request.

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

2.8 Planned features for next release

Next release of the application is expected to take place on M24 of the project, for the purpose of being harmonized with WP8 'demo run 1' activities which start on M25. Apart from the forthcoming release, the application will be updated in terms of back end, front end and implemented functionalities throughout the 1st demo run duration (M25 – M33).

For the next releases of the application, the following actions are planned with the following priority. Items 1 to 5 are expected to be ready at the beginning of the 1st demo run, whereas item 6 is planned to take place during the 1st demo run.

1. For the partially implemented functionalities, the full version of the functionality will become available.
2. Create scheduled jobs and tasks to refresh and recalculate the results from the algorithms running in the background every 'X' amount of timesteps.
3. Data retrieval queries and contracts will be created for the DSOs, TSOs' datasets of interest so that they become accessible to the application through the SYNERGY platform.
4. Data retrieval queries and analytic workflows will be created for the analytics of interest so that they become accessible to the application through the SYNERGY platform.
5. Enhance implemented functionalities. For instance, include in the network modelling analysis additional DER components. At the moment, PVs are the available components. Batteries shall also be included. Also, power flow simulations could be replaced by optimal power flow simulations to better calculate flexibility requirements.

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3 Flexibility Based Network Management and DSO-TSO Common Operational Scheduling Application

3.1 Overview

The *Flexibility based Network Management and DSO-TSO common operational scheduling Application* implements all necessary features to allow network operators to optimally and securely schedule the available resources including flexible demand for the intra-day and day ahead in a coordinated manner. By exploiting all available data, including the flexibility potential of aggregators' portfolio, the application facilitates the optimal scheduling of the flexible assets by TSOs and DSOs who aim to request specific congestion management and balancing services. The following figure depicts the application and its internal architecture, as well as interactions with actors and the SYNERGY platform. Any interested actors, such as the DSO and the TSO will be able to access the application upon being authenticated by the SYNERGY Platform.

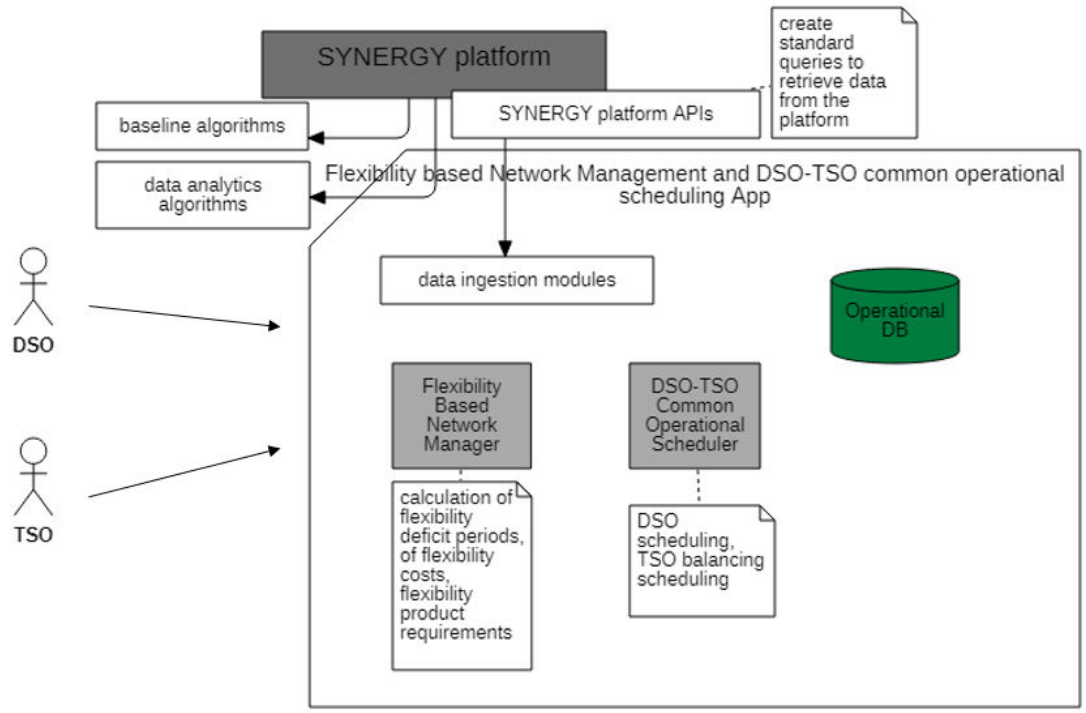

Figure 13: Flexibility based Network Management and DSO-TSO common operational scheduling Application

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

The application consists of two components, the flexibility-based network manager and the DSO-TSO common operational scheduler:

The *Flexibility-Based Network Manager* is responsible for assisting network operators to perform their short-term planning activities by utilizing available flexibility. The manager involves the process of data ingestion regarding flexibility availability from flexibility providers, identification of aggregated flexibility in substation and feeders' level, calculation of flexibility deficit periods and calculation of flexibility requirements for network operators to facilitate their short-term planning and needs for congestion management and balancing.

The *DSO-TSO Common Operational Scheduler* is responsible for providing a common interface for the DSO and the TSO to facilitate common operational scheduling, considering the flexibility requirements for both actors for congestion management needs, balancing needs and other relevant ancillary services. The scheduler also proposes an appropriate coordination scheme clarifying the sequence of actions between the two operators and identifies the definite short term operational scheduling for both actors.

3.2 Implemented functionalities

The following table summarizes the current status of all the features to be provided by the application.

Table 5 : Implemented features of Flexibility based Network Management and DSO-TSO common operational scheduling Application

Feature	Status	Notes
FBNM_1: Data exchange between flexibility service providers and network operators	Partially implemented	At this version of the application, assumptions have been made for the available flexibility per feeder/substation in the test networks used and analysed: Flexible demand is a percentage of total demand, which has been assumed to be controllable. In the short future, available forecasted DER flexibility from aggregator portfolios will become available to the application via the SYNERGY platform as an output result from a WP6 application (Flexibility Analytics and Consumer-Centric DR Optimization Application). The respective data retrieval queries will be configured in the next release of the application, and an appropriate scheduler for data retrieval will be decided such that forecasted available flexibility is updated in a frequent pattern for the identification of short-term scheduling (0-72 hours).

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Feature	Status	Notes
		Ingested flexibility forecasts will be aggregated and allocated per substation or feeder at the network under analysis.
FBNM_2: Identification of requirements for flexibility	Implemented	Static power flow and network calculations are performed via the utilization of pandapower package, which combines the data analysis library pandas and the power flow solver PYPOWER. Power flow analysis is performed in timeseries, utilizing sample forecasts for DER generation and energy demand located in the sample network under study. Power flow results are compared against network and operational constraints (line capacity limits and voltage violation limits) and the requirements for flexible capacity are calculated so that resulting network congestions would have been avoided if that flexible upward/downward capacity existed. Pending actions are to develop the scheduler to request new input(s) data from the SYNERGY platform every 'X' amount of timesteps, rerun the functionality offline and produce updated results.
DSO-TSO_1: DSO-TSO coordination scheme	Implemented	The coordination scheme between the DSO and the TSO has been decided and it is based on the 'local ancillary services market' scheme proposed in the literature where priorities are shifted towards the DSO. That is, the DSO has the priority over flexibility located at the distribution network. The TSO can only contract DER indirectly, after the DSO has aggregated these resources and has transferred them to the TSO ancillary services market. Those priorities will be reflected in a *priority strategy* algorithm embedded at the short-term operational scheduling feature.
DSO-TSO_2: Flexibility Conflict Identifier	Partially implemented	Requirements for flexibility are calculated in the functionality FBNM_2 for the next 1 to 72 hours, respectively for the DSO and the TSO. These are the necessary inputs to be utilized within the flexibility conflict identifier to identify not only the hours that the DSO and the TSO have conflicting requests but also the amount of capacity which is located in the DSO network and required by both operators. The algorithm is under development and it will be fully implemented in the next release. Pending actions are to develop the scheduler to request new input(s) data from the SYNERGY platform every 'X' amount of timesteps, rerun the functionality offline and produce updated results.
DSO-TSO_3: Short-term operational scheduling	Partially implemented	The feature calculates the final short term operational flexibility scheduling for the DSO and the TSO, incorporating the flexibility conflict identifier outputs and implementing the priority strategy algorithm for the next 72 hours.

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Feature	Status	Notes
		The algorithm is under development and it will be fully implemented in the next release. Pending actions are to develop the scheduler to request new input(s) data from the SYNERGY platform every 'X' amount of timesteps, rerun the functionality offline and produce updated results.

3.2.1 Login

The user interface will be provided in the form of a web application. Login is implemented as an integration with the SYNERGY Platform's Security, Authentication and Authorization mechanisms through Keycloak, an open-source identity service provider implementing a set of well-known authentication and authorization protocols.

Figure 14 : Flexibility based Network Management and DSO-TSO common operational scheduling Application – log in

The access to the application will be provided by using the same credentials as the DSOs and TSOs operators use in the SYNERGY Platform.

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3.2.2 Flexibility based network manager – identification of requirements and deficit

The user is prompted to select the hours ahead the date of interest, in the short-term period to follow, in order to navigate through the short-term power flow results. Relevant results might be flexibility capacity requirements per bus, available flexible capacity and flexibility deficit time series profile for the number of selected hours ahead.

Figure 15 : Flexibility based Network Management and DSO-TSO common operational scheduling Application – identification of requirements and deficit

3.2.3 Flexibility based network manager – flexibility requests

The next feature the user can be presented with, is a summary which lists the flexibility products in need. The user shall select the short-term period and a list with identified product needs is displayed, indicating amounts of flexible demand needed, direction of flexibility, timeslots or periods of interest.

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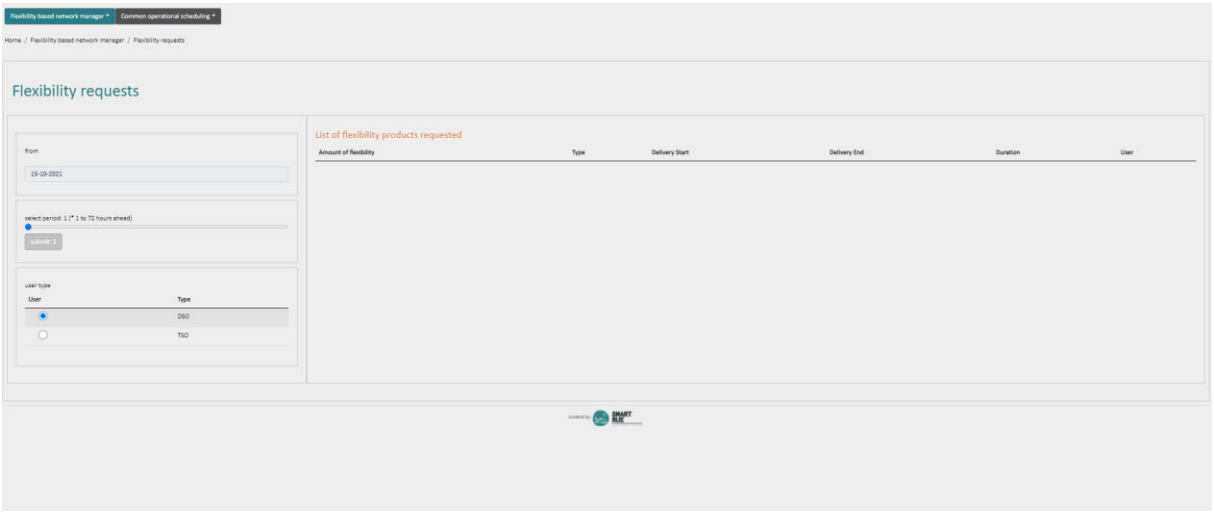

Figure 16 : Flexibility based Network Management and DSO-TSO common operational scheduling Application – flexibility product requests

3.2.4 DSO-TSO Common Operational Scheduler – flexibility scheduling

At the short-term scheduling tab, the user shall select the dates of interest, the number of hours they want to look ahead and see flexibility scheduling. Thereinafter, they can view the resulting flexibility scheduling bids from the operator, with the resolution of displayed data adjusted from 15 minutes to hourly depending on the service in question. In the next release, the user can select the type of the grid service they refer to, congestion management service or balancing service. At the moment congestion management has been addressed.

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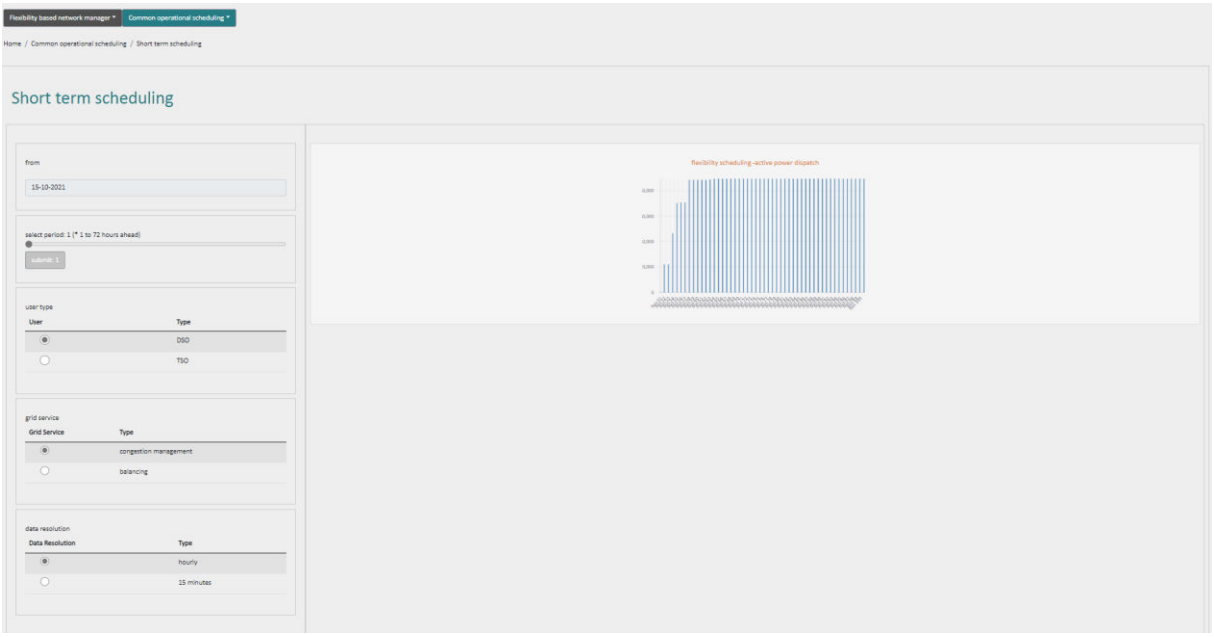

Figure 17: Flexibility based Network Management and DSO-TSO common operational scheduling Application – short term scheduling

3.2.5 DSO-TSO Common Operational Scheduler – conflicts and priority

Finally, the user can visualize any associated alerts from the resulting scheduling, such as conflicting requests between operators, or between different services and thereinafter the prioritization of those requests according to the adopted coordination scheme. This functionality is still under development and will be available in the next release.

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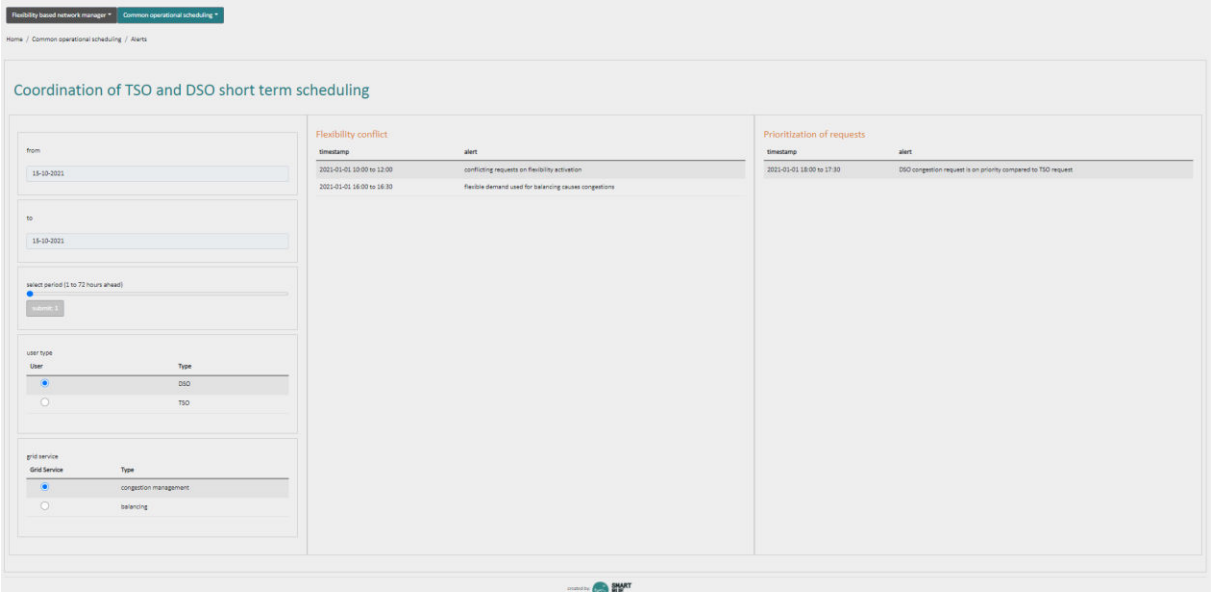

Figure 18 : Flexibility based Network Management and DSO-TSO common operational scheduling Application – coordination

3.3 Technology stack and implementation tools

The following table lists the libraries and technologies used to develop the application.

Table 6: Technology stack of Flexibility based Network Management and DSO-TSO common operational scheduling Application

Library	Version	License	Purpose
Mysql-connector-python	8.0.25	BSD 3-Clause "New" or "Revised" License	Communicating offline python results to institute server
Mysql-common	8.0.25	BSD 3-Clause "New" or "Revised" License	Communicating offline python results to institute server
numpy	1.20.3	BSD 3-Clause "New" or "Revised" License	Functionalities development
pandapower	2.7.0	BSD 3-Clause "New" or "Revised" License	Power flow calculations
pandas	1.3.2	BSD 3-Clause "New" or "Revised" License	Functionalities development
Scipy	1.6.0	BSD 3-Clause "New" or "Revised" License	Statistical calculations- Functionalities development
networkx	2.6.2	BSD 3-Clause "New" or "Revised" License	Network analysis- Functionalities development
python	3.8.10	BSD 3-Clause "New" or "Revised" License	Functionalities development

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Library	Version	License	Purpose
matplotlib	3.4.3	BSD 3-Clause "New" or "Revised" License	Offline results visualisation-Functionalities development
axios:	0.21.1	MIT	Promise based HTTP client for node.js
body-parser:	1.19.0	MIT	HTTP body parser for node.js
bootstrap:	5.0.0	MIT	Frontend framework w/ predefined styles
Express:	4.17.1	MIT	Web framework for node.js
express-session:	1.17.2	MIT	Session middleware for Express
index:	0.4.0	MIT	Next.js dependency
jshint:	2.13.1	MIT	Static analysis tool for js
Keycloak-connect:	13.0.1	Apache License, Version 2.0	Keycloak Connect middleware
keycloak-js:	13.0.1	Apache License, Version 2.0	Keycloak adapter for js
moment:	2.29.1	MIT	Date handler for js
mysql2:	2.2.5	MIT	Node.js driver for mysql
next:	10	MIT	React.js framework for node.js that enables server rendering
nodemon:	2.0.7	MIT	Monitoring script for node.js
react:	16.8	MIT	Ui library for Js
react-datetime:	3.1.1	MIT	Datetime picker component for React.js
react-dom:	16.8	MIT	React.js package manipulate DOM
react-vis:	1.11.7	MIT	Charts library for React.js by Uber
reactstrap:	8.9.0	MIT	React components w/ Bootstrap 4 support
sass:	1.32.10	MIT	Js implementation for Sass

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Library	Version	License	Purpose
sequelize:	6.6.5	MIT	Multi dialect ORM for Node.js
swr:	0.5.5	MIT	React hooks for data fetching
typescript	4.2.4	Apache-2.0	Language on top of Js that adds types

3.4 API documentation

3.4.1 Integration with SYNERGY Platform via REST API

The application requires a set of data from the DSOs and TSOs who are interested to take advantage of the application. All of the datasets needed for the application will be ingested in the application through appropriate data retrieval queries that can be configured once appropriate contracts are signed via the SYNERGY Marketplace. This activity will be performed in the next release of the application. So far, all functionalities have been tested with mock/sample data. The SYNERGY platform allows data retrieval through the exploitation of the SYNERGY APIs as explained in the SYNERGY Deliverable D3.4. A list of the required datasets is given in section 3.6. Authentication mechanisms will be implemented within the SYNERGY Platform in order to ensure that only authorized parties (components of the *Flexibility Based Network Management and DSO-TSO Common Operational Scheduling Application*) are granted access.

Apart from the network topology data and consumption/production data to be retrieved from the DSOs and TSOs, the application could also utilize analytic solutions offered through the SYNERGY platform either as outputs of other applications in SYNERGY or as analytic solutions offered within SYNERGY. Those analytics required by the application might also be configured as *analytic workflows* that will be executed by the SYNERGY Platform. In order to access the results of such analytics, different *data retrieval queries* will be configured, all of them exposing specific REST endpoints.

A list of data retrieval queries to be required and will be configured by the application is given below:

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Table 7: Data Retrieval Queries of the Flexibility Based Network Management and DSO-TSO Common Operational Scheduling Application

Data Retrieval Query	Type	Implementer	Purpose
Prediction of energy demand at grid level in short-term	HTTP GET	SYNERGY Platform	15 minutes/hourly predictions of energy demand at grid level for the next 0-72 hours to be utilized for flexibility scheduling studies
Prediction of energy demand at district level in short-term	HTTP GET	SYNERGY Platform	15 minutes/hourly predictions of energy demand at district level for the next 0-72 hours to be utilized for flexibility scheduling studies
Prediction of energy demand at portfolio level	HTTP GET	SYNERGY Platform	15 minutes/hourly predictions of energy demand at portfolio level for the next 0-72 hours to be utilized for flexibility scheduling studies
Prediction of energy generation at DER level in short term	HTTP GET	SYNERGY Platform	15 minutes/hourly predictions of energy generation at DER level for the next 0-72 hours to be utilized for flexibility scheduling studies
Prediction of energy generation at portfolio level in short term	HTTP GET	SYNERGY Platform	15 minutes/hourly predictions of energy generation at portfolio level for the next 0-72 hours to be utilized for flexibility scheduling studies
Prediction of energy generation at grid level in short term	HTTP GET	SYNERGY Platform	15 minutes/hourly predictions of energy generation at grid level for the next 0-72 hours to be utilized for flexibility scheduling studies
Prediction of generation flexibility at DER level - short-term	HTTP GET	SYNERGY Platform	15 minutes/hourly predictions of generation flexibility at DER level for the next 0-72 hours to be utilized for flexibility scheduling studies
Prediction of demand flexibility at DER level - short-term	HTTP GET	SYNERGY Platform	15 minutes/hourly predictions of demand flexibility at DER level for the next 0-72 hours to be utilized for flexibility scheduling studies
Prediction of storage flexibility at DER level for utilization in peak hours	HTTP GET	SYNERGY Platform	15 minutes/hourly predictions of storage flexibility at DER level for the next 0-72 hours to be utilized for flexibility scheduling studies

3.4.2 Internally consumed REST API

Rest APIs are also deployed internally to facilitate communication between UI layouts and the server. The Open Api 3.0 specification is being used as the descriptive medium to document data exchanges and prerequisites for effective communication between python scripts and the server. The communication domains are split into two groups of interest Flexibility based Network Management and Common Operational Scheduling:

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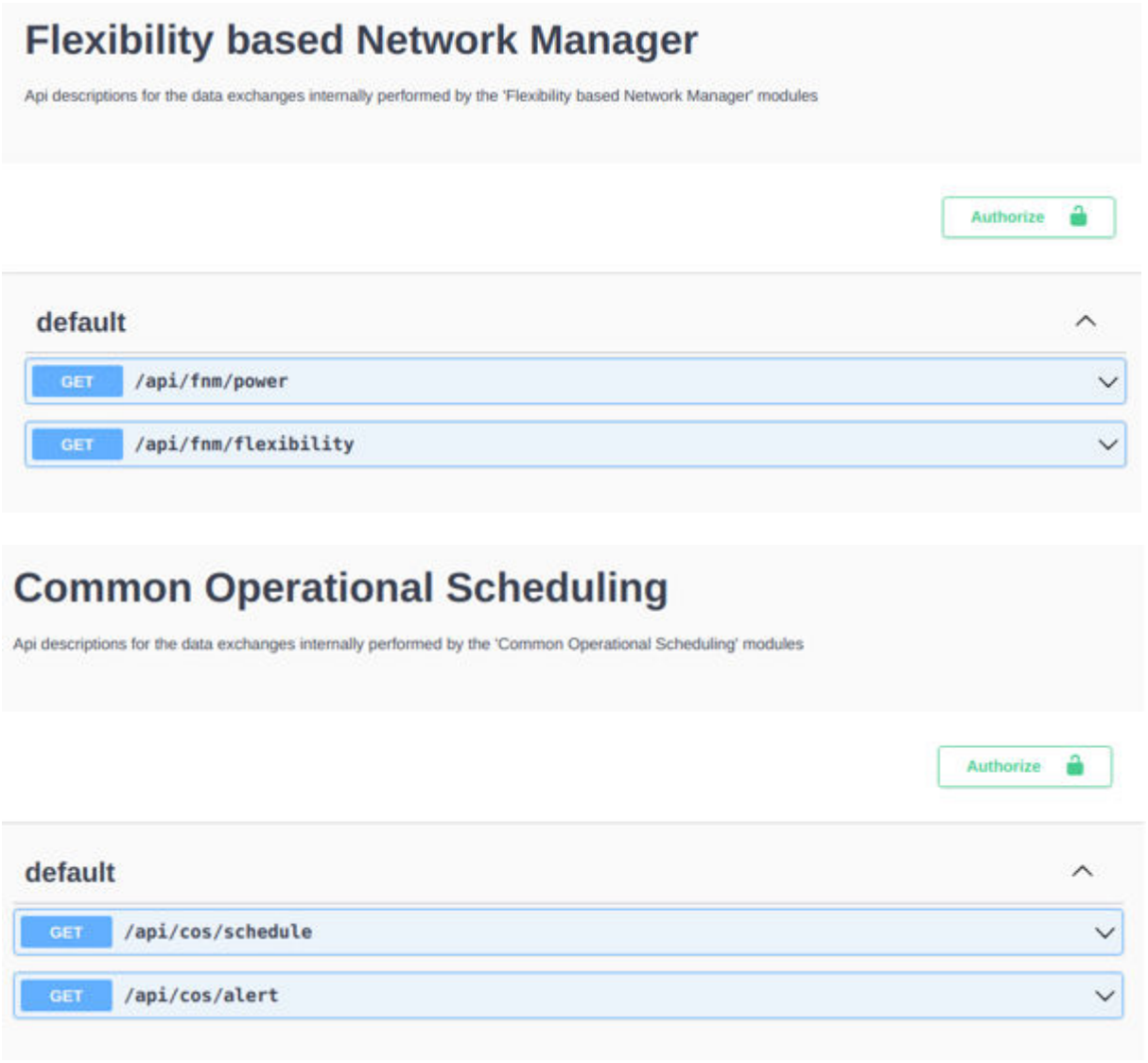

Figure 19 : Internally consumed APIs - Flexibility Based Network Management and DSO-TSO Common Operational Scheduling Application

3.5 Installation instructions

All the components of the application have been developed as independent functions and classes in Python running in the backend of the application. Those scripts communicate internally with the front end of the application, sending output results from the features to the application's internal database. The process at the moment is refreshed manually, but in a future release, all tasks will be scheduled to run, retrieve appropriate input data and update results each 'x' instants of time.

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Initially, the app lived under a test domain to facilitate early development phase where requirements keep updating. In the current status of the app, it is transferred in the SYNERGY domain and communicates exclusively with the respective subdomain enabled by the SYNERGY platform.

Due to the nature of the software, being offered in the form of SaaS, no installation procedure is required by final users.

3.6 Assumptions and restrictions

The architecture of *Flexibility based Network Management and DSO-TSO common operational scheduling Application* relies on the data ingestion services provided by the SYNERGY Platform. In order to be able to use the application, following configuration steps need to be taken for every new DSO/TSO that wishes to integrate with the application:

- DSO and TSO are required to be registered as users of the SYNERGY Platform
- DSO and TSO are required to configure the necessary data check-in jobs, so required datasets get accessible through the platform

Table 8 : Datasets required by users to integrate with the application

Dataset	Content	Description
Network Topology Data	Bus id Line id Switch id Generator id Load id External grid id Transformer id Shunt id Impedance id	Network topology to be used in the power flow analysis
Historical energy inputs from the TSO	Timestamp Total energy imported	Time series of energy imported counters at the TSO DSO connection substation (external TSO grid to the distribution grid under study), on an hourly basis of at least a year historical data
Forecasted energy inputs from the TSO	Timestamp Total energy imported	Prediction of energy inputs from the TSO at the TSO DSO connection substation (external TSO grid to the distribution grid under study) for the next 0 to 72 hours

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

Dataset	Content	Description
Historical aggregated net load of distribution system at high voltage bus of TSO DSO connection	Timestamp Aggregated net load	Time series of aggregated net load of distribution system at high voltage bus of TSO DSO connection, on an hourly basis of at least a year historical data
Forecasted aggregated net load of distribution system at high voltage bus of TSO DSO connection	Timestamp Aggregated net load	Prediction of aggregated net load of distribution system at high voltage bus of TSO DSO connection for the next 0 to 72 hours

3.7 Licensing and access

Component	Licensing details
Flexibility based Network Management and DSO-TSO common operational scheduling UI	ICCS is the owner of all intellectual property rights of this component. All rights are reserved.
Flexibility Based Network Manager Component	ICCS is the owner of all intellectual property rights of this component. All rights are reserved.
DSO-TSO Common Operational Scheduler Component	ICCS is the owner of all intellectual property rights of this component. All rights are reserved.

A demo version of the application is accessible at https://flexibility-mng-coordination.synergy-bigdata.eu[4] .

3.8 Planned features for next release

Next release of the application is expected to take place on M24 of the project, for the purpose of being harmonized with WP8 'demo run 1' activities which start on M25. Apart from the forthcoming release, the application will be updated in terms of back end, front end and implemented functionalities throughout the 1st demo run duration (M25 – M33).

For the next releases of the application, the following actions are planned with the following priority. Items 1 to 5 are expected to be ready at the beginning of the 1st demo run, whereas item 6 is planned to take place during the 1st demo run.

[4] Test credentials can be made available upon request.

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

1. For the partially implemented functionalities, the full version of the functionality will become available.
2. Create scheduled jobs and tasks to refresh and recalculate the results from the algorithms running in the background every 'X' amount of timesteps.
3. Data retrieval queries and contracts will be created for the DSOs, TSOs' datasets of interest so that they become accessible to the application through the SYNERGY platform.
4. Data retrieval queries and analytic workflows will be created for the analytics of interest so that they become accessible to the application through the SYNERGY platform.
5. Enhance implemented functionalities. For instance, include in the network modelling analysis additional DER components. At the moment, PVs are the available components. Batteries shall also be included. Also, power flow simulations could be replaced by optimal power flow simulations to better calculate flexibility requirements. Also, the priority strategy algorithm shall be updated to a more sophisticated optimization. At the moment it is based on heuristics and priority rules.

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4 Performance Monitoring and Predictive Maintenance Application

4.1 Overview

The main aim of this innovative tool for the management of RES plants is ensuring their optimal operation, predictive maintenance and proactive avoidance of equipment faults. The tool steps on the forecasting and predictive analytics baseline algorithms (developed in WP4 and initially documented in the SYNERGY Deliverable D4.2) and appropriate machine learning techniques towards identifying in real-time predictive maintenance needs, increasing PV technology reliability and efficiency and improving power trading functions on the plant operator side. For such purpose, the app presents three main functionalities. Any interested actors, such as the RES plant operators will be able to access the application upon being authenticated by the SYNERGY Platform.

- The Enhanced Performance Monitor (EPM) module will be the control centre of the performance of a PV plant. It will consist of several dashboards showing the main production parameters and specific Key Performance Indicators (KPIs) defined and used to easily visualize the performance of the plant.
- The Fault Occurrence Inspector and Maintenance Optimizer (FOIMO) module aims to introduce new approaches for fault diagnosis and predictive maintenance of PV plants, using the information collected by the EPM module.
- The Operational Scheduling Optimizer (OSO) will be responsible for forecasting the energy production for different time horizons, for large PV plants.

4.2 Implemented functionalities

The following table summarizes the current status of all the features to be provided by the application.

Table 9: Performance Monitoring/Forecasting and Predictive Maintenance Application - Implemented functionalities

Feature	Status	Notes
EPM_1	Implemented	This feature aims to continuously collect and aggregate all information and variables coming from different data sources as Plant SCADA data base, meters, weather stations and locally deployed sensors, through the Synergy platform. No algorithms needed.

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

Feature	Status	Notes
EPM_2	Implemented	This dashboard will provide the visualization of the ongoing parameters and KPIs in real time or with a short-time horizon. This will allow to verify and control the performance of the asset in the day-to-day business. It will provide the possibility of displaying at the different detail levels included in the EPM: full plant, inverter level, string box and panel
EPM_3	Implemented	Strategic dashboard: the main aim of this functionality will be to report information from the EPM, mainly for long-term visualizations. It will allow to summarize the performance over set time frame
EPM_4	Implemented	This feature will help to identify performance of the different inputs at inverter level. New KPIs for assessing the operation at inverters' input will be defined and graphically displayed.
FOIMO_1	Partially Implemented	Development of the code is still on going. A beta version is nearly ready, but still needs to be improved. Clustering (KMeans), classification and deep learning methods are being compared in order to select the algorithm that fits the best. The algorithms are focused on identifying malfunctioning at different levels, defining the optimal number of clusters and classifying the inputs within the clusters previously defined.
FOIMO_2	Partially Implemented	Based on the previous feature, this feature will provide the visualization of the control charts and reliability indexes at the different detail levels defined in the EPM. This will allow to component failures in the day-to-day business.
FOIMO_3	Partially Implemented	Based on FOIMO_1 feature, this will be the reporting tool of the FOIMO for future anomalies. It will allow to summarize the detected failures and to identify long-term trends indicating the evolution of the health of the components. The reports will be obtained at the different detail levels included in the EPM.
OSO_1	Partially Implemented	Development of the code is still on going. A beta version is nearly ready, but still needs to be improved. A custom deep neural network has been used to solve this problem. It consists of a perceptron multilayer with two hidden layers and an output layer with 1 neuron. It will use the weather forecast to estimate the energy generation.
OSO_2	Partially Implemented	Using the same core developed under OSO_1 feature, this feature will cross-check the actual power profile generation with the profile forecasted. The forecasting algorithm is based on a perceptron multilayer with two hidden layers and an output layer with 1 neuron.
OSO_3	Partially Implemented	Using the same core developed under OSO_1 feature, this feature will be focused on the energy forecasting in the short-term for a PV asset, with the main aim of providing insights to PV RES operators to define maintenance strategies and optimise the market positioning. The forecasting algorithm is based on a perceptron multilayer with two hidden layers and an output layer with 1 neuron. Development of the code is still on going. A beta version is nearly ready, but still needs to be improved.
OSO_4	Partially Implemented	Using the same core developed under OSO_1 feature, this feature will be focused on the energy forecasting in the mid-long-term for a PV asset, with the main aim of providing insights to PV RES operators to define maintenance strategies and optimise the market positioning. The

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Feature	Status	Notes
		forecasting algorithm is based on a perceptron multilayer with two hidden layers and an output layer with 1 neuron. Development of the code is still on going. A beta version is nearly ready, but still needs to be improved.

4.2.1 Login

The user interface will be provided in the form of a web application. Login is implemented as an integration with the SYNERGY Platform's Security, Authentication and Authorization mechanisms through Keycloak, an open-source identity service provider implementing a set of well-known authentication and authorization protocols.

Figure 20: Performance Monitoring/Forecasting and Predictive Maintenance Application - Login

The access to the application will be provided by using the same credentials as the maintenance operators use in the SYNERGY Platform.

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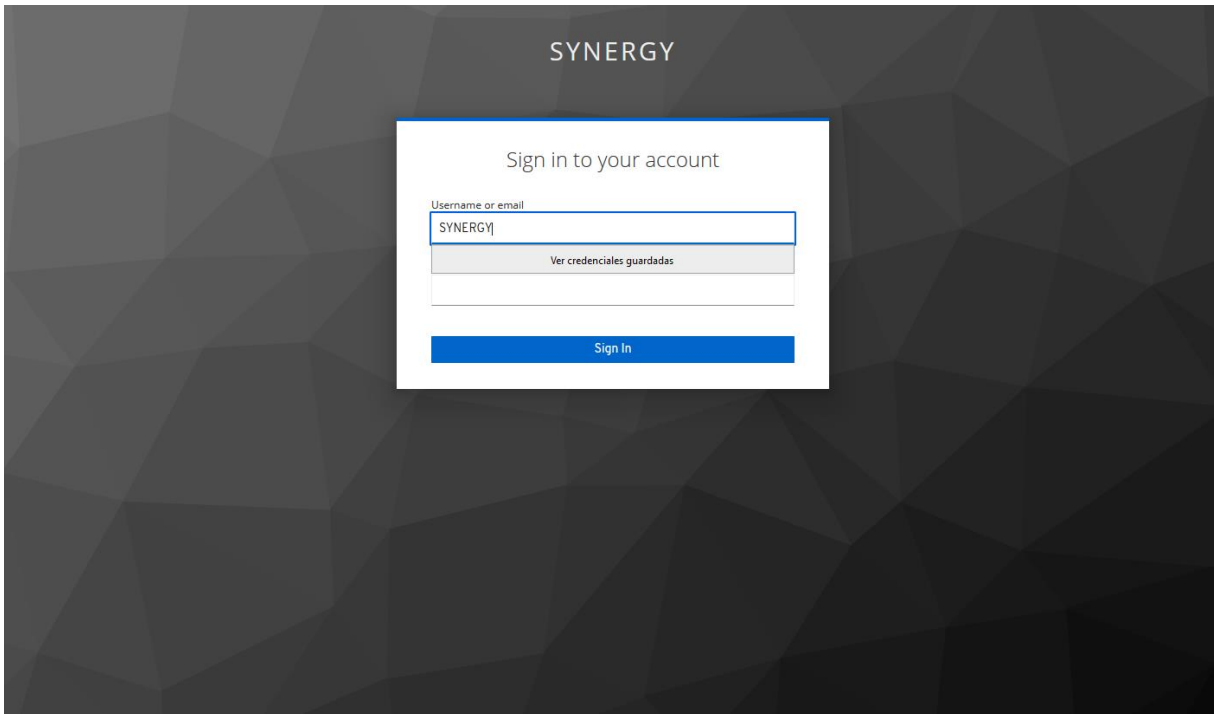

Figure 21: Performance Monitoring/Forecasting and Predictive Maintenance Application - Login (ii)

4.2.2 Enhanced Performance Monitoring

The Operational Dashboard encompasses the features of the Enhanced Performance Monitoring will provide the visualization of the plant under operation. The top site will display a summary of the instantaneous main operation parameters of the assets and the available conditions. A set of strategic indexes defined within the app is shown in the middle of the screen. These will allow operators to identify malfunctioning of the plant visually. Finally, generic information and weather data are shown at the bottom.

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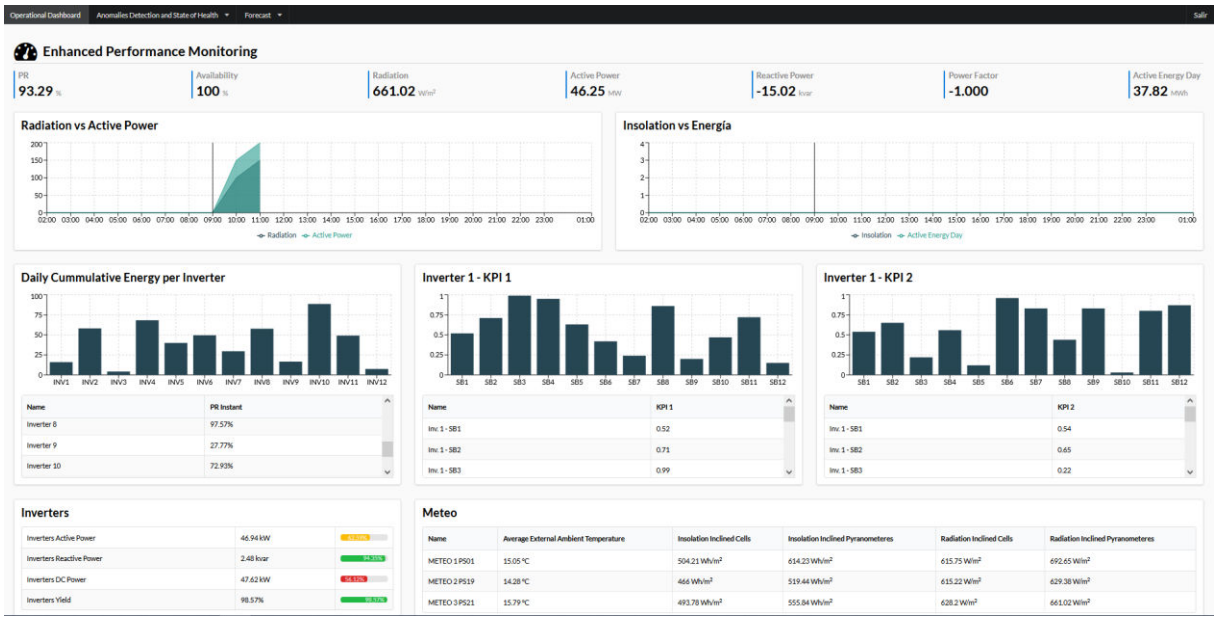

Figure 22: Performance Monitoring/Forecasting and Predictive Maintenance Application - Enhanced Performance Monitoring

4.2.3 Fault Occurrence Inspector and Maintenance Optimiser

The Anomalies Detection and Status of Health gives access to the Fault Occurrence Inspector and Maintenance Optimiser features. In the Fault Occurrence Inspector, a table summarising the alerts given by the app with the anomaly probability is shown on the left. On the right, a graphic visualization of the actual performance of the plant vs the expected is shown, which would allow to identify generation anomalies at plant level. At the bottom, a table with the numeric values of the energy generation and the expected energy generation are shown.

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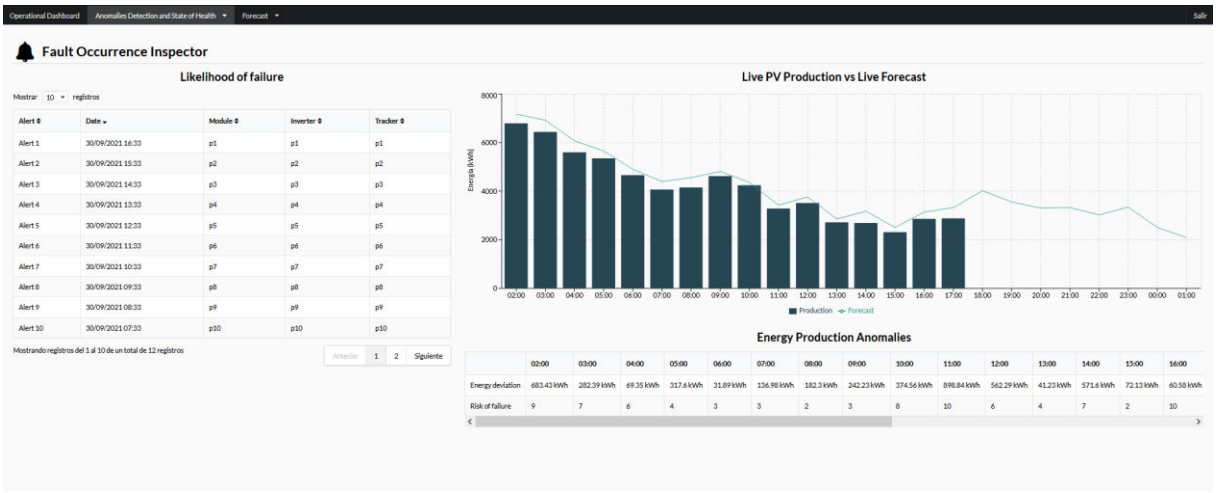

Figure 23: Performance Monitoring/Forecasting and Predictive Maintenance Application - Fault Occurrence Inspector and Maintenance Optimiser

The trend analysis for predictive maintenance shows the historic trend of the equipment/asset analysed, used to prevent failures in the short-term. For such purpose, representative values of the operation of each device will be analysed and the probability of failure predicted.

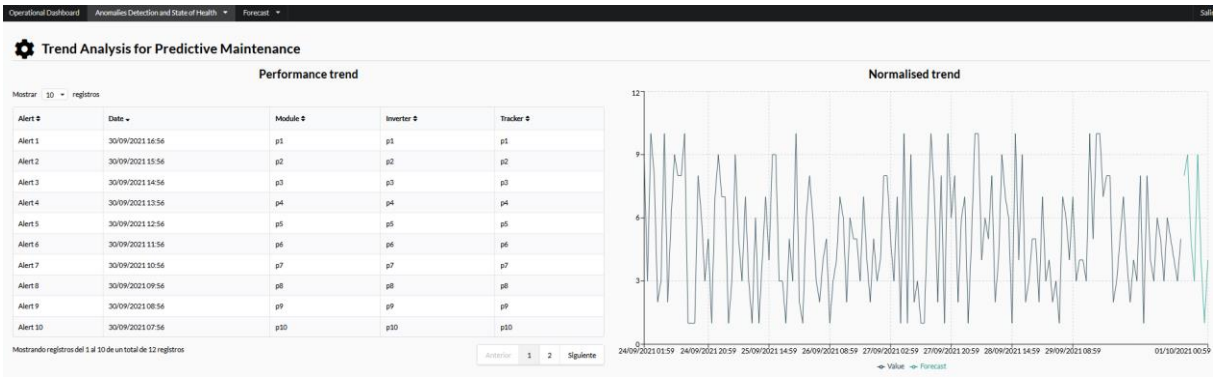

Figure 24: Performance Monitoring/Forecasting and Predictive Maintenance Application - Fault Occurrence Inspector and Maintenance Optimiser (ii)

4.2.4 Operational Scheduling Optimiser

Within the Forecast section, three different menus can be selected. Firstly, the short-term forecasting. This will provide an estimate of the energy expected in the short-term (i.e. 6 to 48 hours). The long-term forecasting will allow the user to predict the energy generation for a maximum time horizon of 14 days. Finally, the energy validation profile will check that the generation profile does not differ of the energy forecast.

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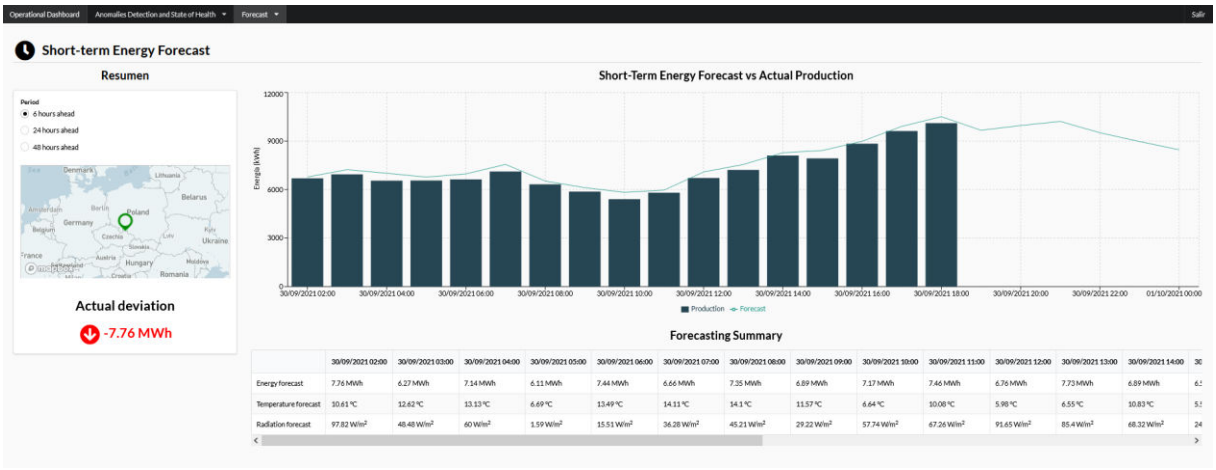

Figure 25: Performance Monitoring/Forecasting and Predictive Maintenance Application - Operational Scheduling Optimiser Short-Term Forecasting

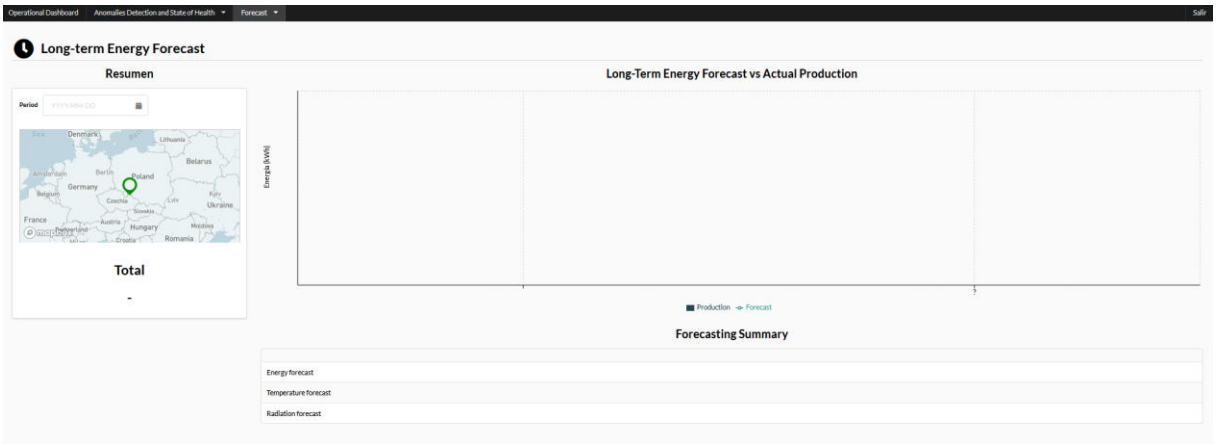

Figure 26: Performance Monitoring/Forecasting and Predictive Maintenance Application - Operational Scheduling Optimiser Long-Term Forecasting

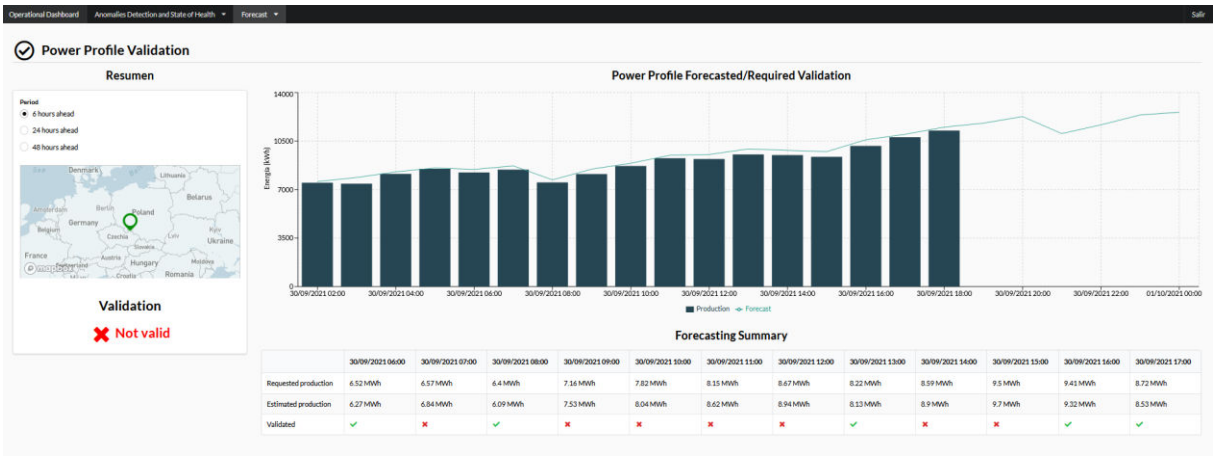

Figure 27: Performance Monitoring/Forecasting and Predictive Maintenance Application - Operational Scheduling Optimiser Generation Profile Validation

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4.3 Technology stack and implementation tools

Table 10: Performance Monitoring/Forecasting and Predictive Maintenance Application - Technology stack and implementation tools

Library	Version	License	Purpose
meteor-base	1.4.0	MIT License	User interface Packages every Meteor app needs to have
mobile-experience	1.1.0	MIT License	User interface. Packages for a great mobile UX
mongo	1.10.1	MIT License	User interface. The database Meteor supports right now
static-html		MIT License	User interface. Define static page content in .html files
reactive-var	1.0.11	MIT License	User interface. Reactive variable for tracker
tracker	1.2.0	MIT License	User interface. Meteor's client-side reactive programming library
session	1.2.0	MIT License	User interface
accounts-password	1.7.0	MIT License	User interface
standard-minifier-js	2.6.0	MIT License	User interface. JS minifier run for production mode
es5-shim	4.8.0	MIT License	User interface. ECMAScript 5 compatibility for older browsers
ecmascript	0.15.0	MIT License	User interface. Enable ECMAScript2015+ syntax in app code
shell-server	0.5.0	MIT License	User interface. Server-side component of the `meteor shell` command
aldeed:collection2	3.0.0	MIT License	User interface
underscore	1.0.10	MIT License	User interface
react-meteor-data		MIT License	User interface
alanning:roles		MIT License	User interface
semantic:ui		MIT License	User interface
jquery		MIT License	User interface
flemay:less-autoprefixer		MIT License	User interface
matb33:collection-hooks		MIT License	User interface
mizzao:user-status		MIT License	User interface

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Library	Version	License	Purpose
etraid:accounts-openid		MIT License	User interface
@babel/runtime	^7.12.5	MIT License	User interface
@popperjs/core	^2.6.0	MIT License	User interface
bcrypt	^5.0.0	MIT License	User interface
etra-forms	^1.0.4	Proprietary	User interface
etra-ui-components	^2.0.0	Proprietary	User interface
etraid_formats	^1.0.16	Proprietary	User interface
html-react-parser	^1.2.4	MIT License	User interface
i18next	^20.1.0	MIT License	User interface
i18next-browser-languagedetector	^6.1.0	MIT License	User interface
i18next-http-backend	^1.2.0	MIT License	User interface
jquery	^3.4.1	MIT License	User interface
lodash	^4.17.15	MIT License	User interface
luxon	^1.26.0	MIT License	User interface
meteor-node-stubs	^1.0.0	MIT License	User interface
moment-timezone	^0.5.33	MIT License	User interface
popper.js	^1.16.1	MIT License	User interface
prop-types	^15.7.2	MIT License	User interface
react	^16.14.0	MIT License	User interface
react-dom	^16.14.0	MIT License	User interface
react-i18next	^11.8.11	MIT License	User interface
react-icons	^4.2.0	MIT License	User interface
react-live-clock	^5.0.16	MIT License	User interface
react-moment	^1.1.1	MIT License	User interface
react-month-picker	^2.2.0	MIT License	User interface
react-router-dom	^5.2.0	MIT License	User interface
react-semantic-ui-datepickers	^2.13.0	MIT License	User interface
recharts	^2.0.9	MIT License	User interface
recompose	^0.30.0	MIT License	User interface
semantic-ui-react	^1.1.1	MIT License	User interface
simpl-schema	^1.10.2	MIT License	User interface

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Library	Version	License	Purpose
styled-components	^5.2.1	MIT License	User interface
tensorflow	2.4.0	BSD 3-Clause "New" or "Revised" License	Business logic
pandas	1.3.3	BSD 3-Clause "New" or "Revised" License	Business logic
requests	2.26.0	BSD 3-Clause "New" or "Revised" License	Business logic
numpy	1.19.5	BSD 3-Clause "New" or "Revised" License	Business logic
scikit-learn	0.24.2	BSD 3-Clause "New" or "Revised" License	Business logic
statsmodel	0.12.1	BSD 3-Clause "New" or "Revised" License	Business logic

4.4 API documentation

The majority of the analytics required by the application have been configured as *analytic workflows* that are executed by the SYNERGY Platform. In order to access to the results of such analytics, different *data retrieval queries* have been configured, all of them exposing specific REST endpoints. Authentication mechanisms are implemented within the SYNERGY Platform in order to ensure that only authorized parties (components of the *Performance Monitoring/Forecasting and Predictive Maintenance Application*) are granted access.

Table 11: Performance Monitoring/Forecasting and Predictive Maintenance Application - Integration with SYNERGY platform via REST API

Data Retrieval Query	Type	Implementer	Purpose
[DEV-WP5] SCADA data	HTTP GET	SYNERGY Platform	PV Plant historical values from SCADA system

4.5 Installation instructions

All the components of the application have been packaged as a set of docker images. These docker images are available from a private repository at docker hub. This kind of packages facilitate the deployment in any platform supporting this technology (e.g. Kubernetes). Due to the nature of the software, being offered in the form of SaaS, no installation procedure is required by final users.

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Table 12: Performance Monitoring/Forecasting and Predicitive Maintenance Application - Docker hub images

Image	Tag	Purpose
etraid / synergy_performancemonitoringui	0.0.8	Application frontend.

4.6 Assumptions and restrictions

The architecture of the *Performance Monitoring/Forecasting and Predictive Maintenance Application* relies on the services provided by the SYNERGY Platform, specifically in the features related to data ingestion and data analytics.

In order to be able to use the application, following configuration steps need to be taken for every new RES Operator that wishes to integrate with the application:

- RES Operators are required to be registered as users of the SYNERGY Platform
- RES Operators are required to configure the necessary data check-in jobs, so required datasets get accessible through the platform
- RES Operators are required to grant access to application manager to the required datasets, so those can be incorporated to the application workflows, by signing the appropriate contracts within the SYNERGY Platform
- Application manager configures the preprocessing steps – which ensure that existing datasets from any RES Operators are transformed from the SYNERGY CIM (as documented in the SYNERGY Deliverable D3.1) to meet the data model required by the application during the execution of the analytics services.

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Table 13: Performance Monitoring/Forecasting and Predictive Maintenance Application – Assumptions and restrictions

Dataset	Content	Description
Performance Monitoring	SCADA data	Operational and weather data of different monitoring equipment deployed in the plant
Predictive Maintenance	Customer id Plant id Current Sensor1_value … Current SensorX_value	Operational and weather data of different monitoring equipment deployed in the plant
Forecasting	Plant id Latitude Longitude Altitude Plant information	Definition of the plant location and characteristics

4.7 Licensing and access

Table 14: Performance Monitoring/Forecasting and Predictive Maintenance Application - Licensing and access

Component	Licensing details
Enhanced Performance Monitoring	COBRA is the owner of all intellectual property rights of this component. All rights are reserved. ETRA I+D is the owner of the UI and backend.
Fault Occurrence Inspector and Maintenance Optimiser	COBRA and CIRCE ARE the owners of all intellectual property rights of this component. All rights are reserved. ETRA I+D is the owner of the UI and backend.
Operational Scheduling Optimiser	COBRA is the owner of all intellectual property rights of this component. All rights are reserved. ETRA I+D is the owner of the UI and backend.

A demo version of the application is accessible at https://performancemonitoring.synergy-bigdata.eu/[5].

[5] Test credentials can be made available upon request.

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4.8 Planned features for next release

For the next release, more sophisticated solutions for each algorithm described in section 4.2 will be developed with the goal of obtaining improved results. These solutions will include algorithms testing, new data to the initial datasets for better training and also other optimizers and loss functions.

All strategies will be compared in order to keep an integrate the approaches providing best results.

Finally, obtained results by the synergy analytics platform will be integrated with our implemented user interface.

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5 Asset Management Optimization Application

5.1 Overview

The *Asset Management Optimization for Power Grids Application* implements different features that target the maintenance responsible operators of DSOs and TSOs, with the objective of providing different models that optimize the maintenance management by enriching the available data with the results of a number of analytics and forecasts. Any interested actors, such as the DSO and the TSO will be able to access the application upon being authenticated by the SYNERGY Platform.

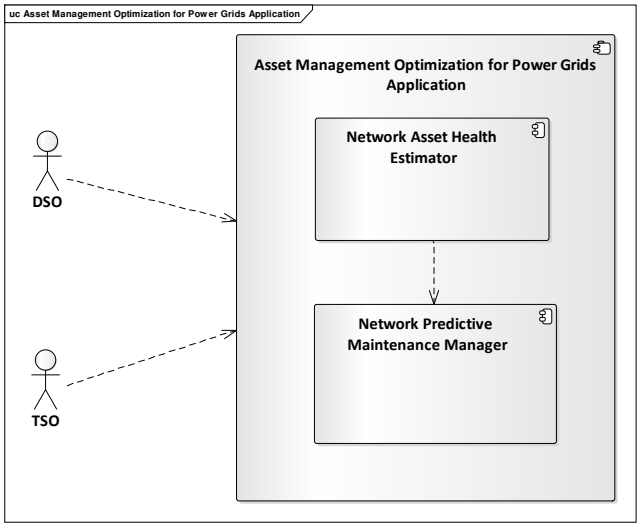

Figure 15: Asset Management Optimization Application

The *Network Asset Health Estimator* component will, based on the different measurements available for a given asset type, model the overall health score of each asset instance under maintenance, providing automated assistance in the evaluation of asset status by maintenance staff, and an additional indicator to properly prioritize the scheduled maintenance operations.

The *Network Predictive Maintenance Manager* component will provide models to forecast failures of assets, based on the flows of data monitored from those assets and by considering also the effect of cascading effects (i.e. how an asset can be indirectly affected by failures detected on other assets of the grid).

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5.2 Implemented functionalities

The following table summarizes the current status of all the features to be provided by the application.

Table 16: Asset Management Optimization Application - Implemented functionalities

Feature	Status	Notes
NCHE_1 Picture Based Indicators	Implemented	A pretrained neural network has been used to solve this problem. The neural network is called YOLO (You-Only-Look-Once) and it has been previously trained to detect 80 classes, but we used this knowledge previously acquired to re-train the neural network but only with 3 new classes: Persons, Fire and Smoke. This new system has been deployed in a fast API and it has been served using a dockerized container. In the next the model will be trained with a new set of data adding new classes.
NCHE_2 Metrics Visualization	Partially Implemented	All metrics are calculated and in the next release we will provide appropriate graph visualizations.
NCHE_3 Asset Health Score Calculation Regression	Implemented	A custom deep neural network has been used to solve this problem. It consists of an input layer, two hidden layers where the first one is a LSTM (Long-Short Term Memory) layer with 100 neurons and a dropout with 0.2 threshold and the other has the same architecture but with 50 neurons. Finally, it has an output layer with 1 neuron, with a mean-squared-error as a loss function and a linear activation function. The optimized used for the training has been the Adam optimizer. The neural network has been dockerized, scheduled to request the data to synergy-analytics platform each "x" instance of time, train the neural network and post the forecasted results to the synergy-analytics platform again. In the next release new topologies, optimizers and loss functions will be tested.
NCHE_4 AR System	Partially Implemented	The AR front-end is a separate mobile application serving as an additional front-end to AR application, and relying on visual codes to identify the object at hand. In this phase the API integration with ETRA application and the selection of code technologies have been solved. The development of the app is in progress. The analysis and selection of QR code as marker technology is delivered. Furthermore, as the app is supposed to be used in the field, UX designers have been working on the refinement of the app compared to the mockup in D5.1, to have a more consistent user flow. Xamarin-based demo version of the application has been developed albeit with a rudimentary GUI in order to test the mobile app integration with the APIs and code detection. The next steps include the full implementation of the mobile GUI and completion of the app front end, and upgrading of the security which is currently based on a preshared api key.
NPM1	Implemented	A custom deep neural network has been used to solve this problem. It consists of an input layer, two hidden layers where the first one is a

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Feature	Status	Notes
Asset Health Score Calculation Classification		LSTM (Long-Short Term Memory) layer with 100 neurons and a dropout with 0.2 threshold and the other has the same architecture but with 50 neurons. Finally, it has an output layer with 2 neurons (number of classes: error before 30 cycles and error after 30 cycles), with a categorical-crossentropy as a loss function and a softmax activation function. The optimized used for the training has been the Adam optimizer. The neural network has been dockerized, scheduled to request the data from the SYNERGY platform each "x" instance of time, train the neural network and post the forecasted results to the SYNERGY platform again. In the next release new topologies and optimizers will be tested.
NPM2 Prioritization of maintenance tasks	Partially implemented	All necessary inputs are available and the strategy implementation will be developed in the next release.
SNPM3 Event Correlations	Partially implemented	A correlation matrix of all occurrences between each alert will be used to calculate the probability to occur an alert given a previous one. The data will be analysed by the process to obtain all possible pair of events, but the process will be improved in the future to allow it to manage more than one previous alert to predict the new one. In the next release, a new way to solve this problem will be tested. The new point of view will be redirected to use deep neural networks to try to forecast alerts instead of use a correlation matrix.

5.2.1 Login

The user interface will be provided in the form of a web application. . Login is implemented as an integration with the SYNERGY Platform's Security, Authentication and Authorization mechanisms through Keycloak, an open-source identity service provider implementing a set of well-known authentication and authorization protocols.

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Figure 28: Asset Management Optimization Application - Login

The access to the application will be provided by using the same credentials as the maintenance operators use in the SYNERGY Platform.

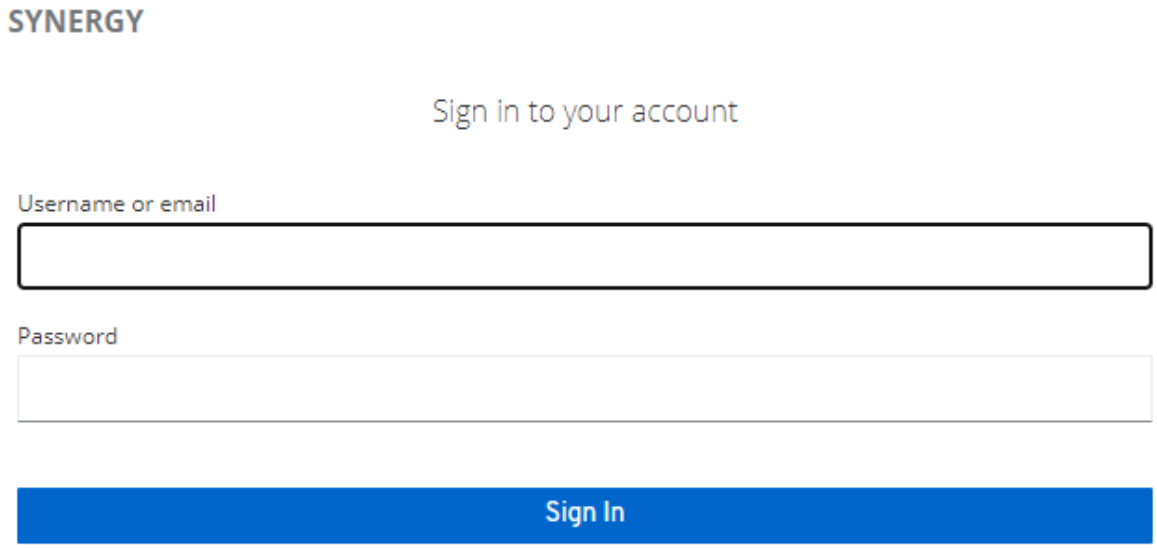

Figure 29 : Asset Management Optimization Application – Login (ii)

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5.2.2 Assets Health Status

The Health status menu will provide the visualization of all assets under maintenance details. The first site will display a summary table with the assets, their health status and the timestamp this status refers to.

On the right hand side a map displays the geolocation of the elements shown in the table. By clicking on those elements (both in the table and in the map), the user gets redirected to the *Asset Details* site.

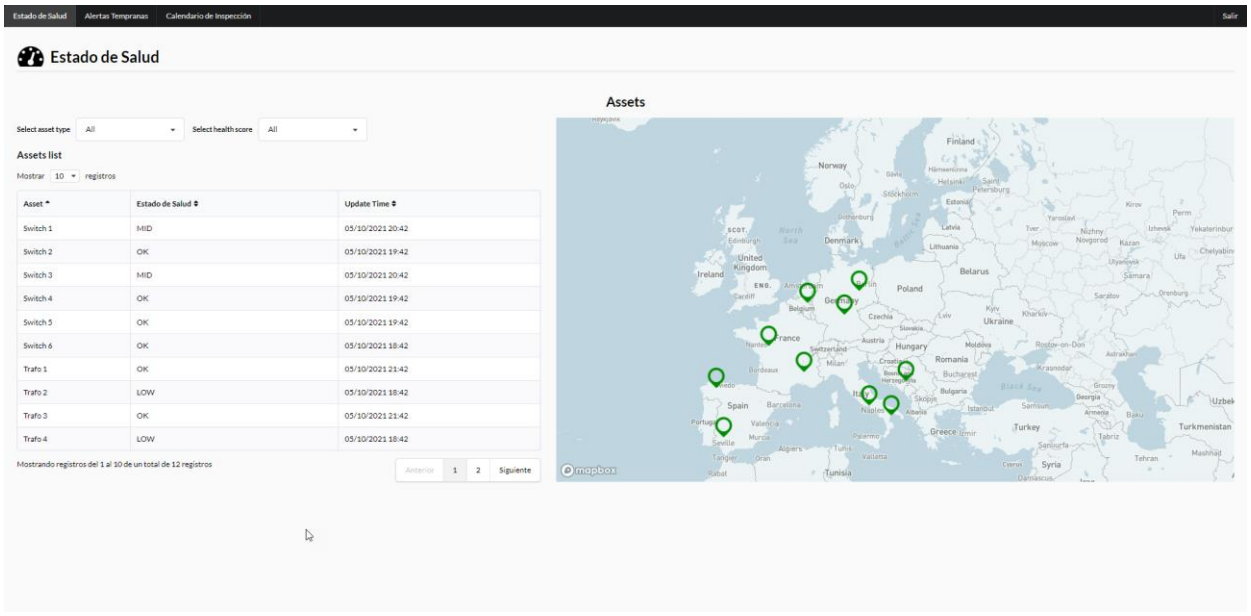

Figure 30: Asset Management Optimization Application – Assets Health Status

The *Asset Details* site gives access to all the details considered by the application for each one of the assets.

The left-hand side presents the list of elements under maintenance in a tree view, to facilitate the navigation and search of the assets.

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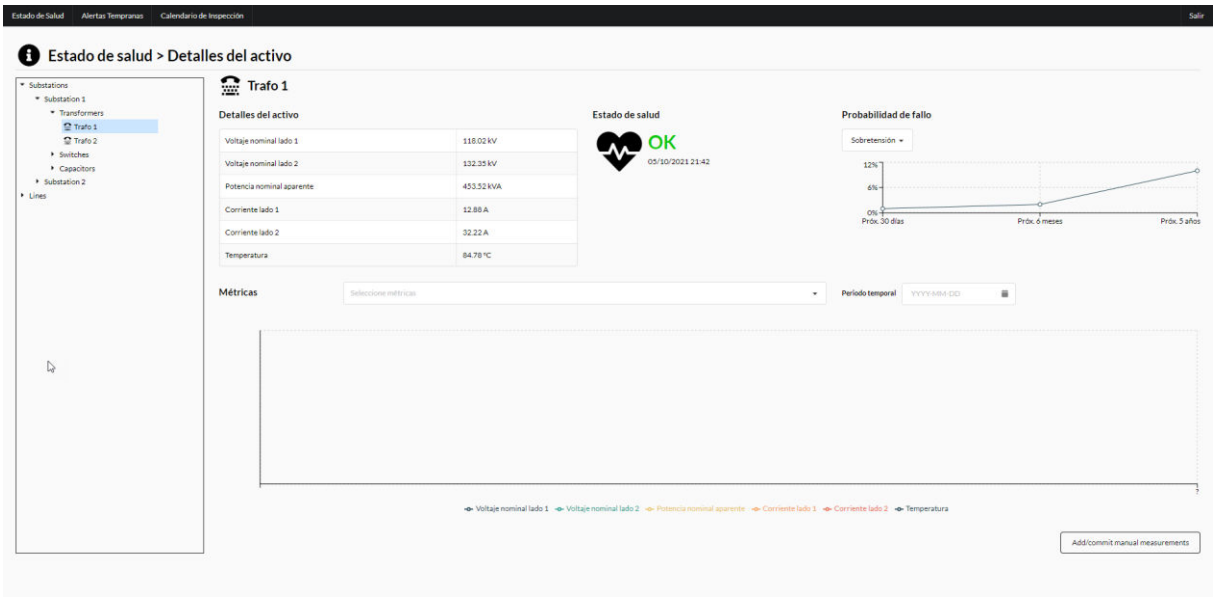

Figure 31 : Asset Management Optimization Application – Assets Health Status Detailed

The *Asset details* site will also offer the possibility to manually upload related measurements to the platform, which may be obtained during physical inspections of assets that may not be telemetered.

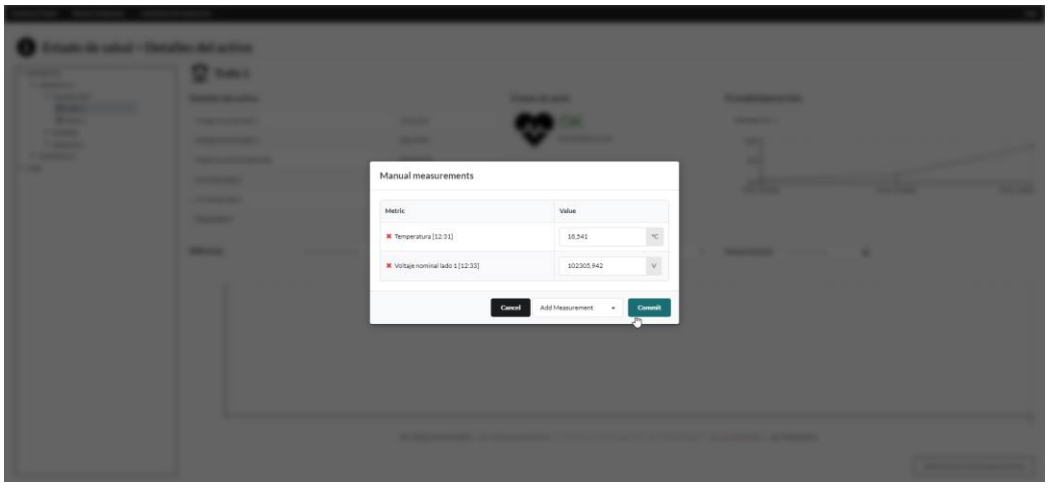

Figure 32 : Asset Management Optimization Application – Manually Upload

5.2.3 Early Alerts

The *Early alerts* site displays an alert log of the monitored systems, which is enriched with the outputs of the *Network Predictive Maintenance Management* component.

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The main part of the site will display a table with the relevant details of the alerts that are read from the SCADA and other systems of the DSO/TSO that are integrated in the SYNERGY Platform.

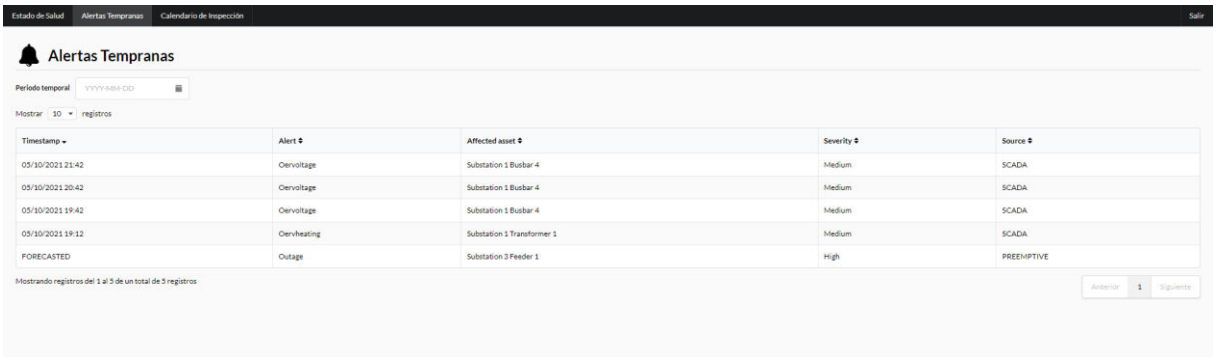

Figure 33 : Asset Management Optimization Application – Early Alerts

5.2.4 Inspection Scheduling

The *Inspection scheduling* site displays a proposal for asset inspection. Based on the health score, short-term probability of failure (for the different considered issues) and impact level, the application will compose a ranked list of the assets that can be used to schedule the inspection visits by the maintenance staff, prioritizing those assets that accordingly to the data available and the results of the different analytics need more attention.

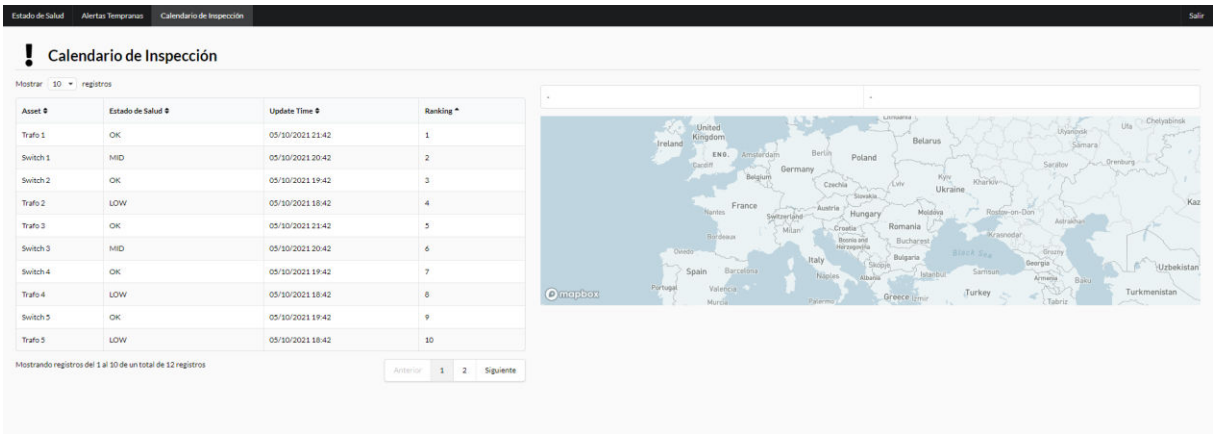

Figure 34 : Asset Management Optimization Application – Inspection Scheduling

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5.2.5 AR Visualization – Investigation of the most suitable marker technology

For the purposes of augmented reality (AR)-based mobile application, an investigation and analysis of suitability of different visual marker types for the AR front end application has been prepared in this phase of algorithm development. This chapter provides the rationale for selection of the QR code as the data carrying marker for the AR application. The key takeaways of marker investigation are:

- The role of markers is to trigger application-specific behaviour, including but not limited to presenting 3D or 2D graphics, or performing some business action
- There are two types of AR markers: data-carrying and shape-based
- Data-carrying markers can be more easily generated on the fly and there can be an infinite number of them
- Shape-based markers more easily support virtual 3D space anchoring
- There are Open-source implementations for both types of markers

The decisions in AR modelling of the SYNERGY mobile application have been decided given the business context of the application – it is an „in the field“ application where the user flow is the most important, and it is decidedly not a mobile game. There are several options to trigger the AR actions: by using the touch screen, by analysing the accelerometer sensors and gyroscope data, by using locational data from GPS and compass, and by analysing the camera feed to detect the visual markers.

All of the selected have particular drawbacks in our context: touch screen requires the user to interact with the phone which is often difficult outdoors and is not well suited for a field worker; GPS and compass data is often of quite poor quality, and accelerometer and gyroscope based actions are also not optimal for this context. This leaves the visual markers as the best suitable technology.

The visual markers are graphical elements in the real world, recognized by the AR apps which analyse the feed from camera and used to initiate some kind of action. The markers can either be classified by visual appearance as geometric markers or natural feature markers, or by mode of use as data-carrying markers and natural image recognition markers. The most common marker formats of this types are given in the following table.

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Table 17 : AR frontend to Asset Management Application: Data carrying AR marker formats

1D (linear) marker formats	2D marker formats
UPC-A, UPC-E EAN-8, EAN-13 UPC/EAN Extension 2/5 Code 39 Code 93 Code 128 Codabar ITF GS1 DataBar	QR Code Data Matrix Aztec PDF417 MaxiCode RSS-14 VuMark (Vuforia Marker)

Bar-code markers (also called linear codes) typically only carry a numerical value, usually formatted for a specific purpose, like product identification. These are not commonly used for AR, but their robustness and ubiquity can be a factor.

QR codes are the most popular 2D markers. The standard defines multiple marker sizes (called "versions") and levels of data correction. QR codes can contain almost any kind of alphanumeric data. QR code "versions" go from 1 to 40, and refer to the literal marker size in the number of squares on each side, given by the equation (4 * version + 17). Any version can be combined with any level of data correction, which are referred to with a letter, as described in the following table.

Table 18 : AR frontend to Asset Management Application: QR code data correction levels

Data correction Level	Letter	% of data which can be restored
Low	L	7%
Medium	M	15%
Quartile	Q	25%
High	H	30%

There are several symbol encodings documented for QR codes, ranging from 3.5 bit-per-symbol numeric-only encodings, to 5.5 bit-per-symbol alphanumeric encoding, to 8 bit-per-symbol byte encoding and some specialised encodings. The available data capacity follows from the marker size and data correction level used while creating the code. For example, a "40-L" code can contain 4296

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alphanumeric symbols (at 5.5 bits-per-symbol) or 2953 8-bit bytes. QR codes are very commonly used and well supported by a very wide range of devices. The most recent Android devices (versions 10 and newer) include the QR code detection in the basic camera functionality directly.

Data matrix is a code visually similar to QR, commonly used in hardware industry to identify parts of the equipment. The Aztec Code has the sometimes-useful property that it doesn't require a clear zone around the code, as it is read from the center outwards.

VuMarks are a proprietary marker format developed for the Vuforia multi-platform AR framework, and it can both carry encoded data and be used for AR tracking. They offer unmatched design freedom, with the specification allowing different shapes and sizes of individual marker elements. VuMarks are, though, a non-free standard which requires licensed software which imposes some limitations based on the license type and there are no independent implementations of VuMarks. The only automated service for generating VuMarks is offered by the authors of Vuforia. Not surprisingly, these markers are quite often used in AR industry, as Vuforia has a streamlined workflow for using VuMarks, especially for tracking their position and orientation. In fact, KONČAR's own RTGo technology utilizes VuMarks in its current production version. However, as the technology implies that the application must be developed in Unity framework, and that the Vuforia licensing fees could be prohibitive for an asset heavy activity, we have decided this approach is not suitable for the AR frontend to this application.

The AR applications can also detect natural features from images. Here, the images which are being searched for are usually pre-processed by software which extracts "features", i.e. parts of a mathematical model, from the image. However, this is a poor choice for detection of visually almost identical devices such as transformers that are the subject of asset management application. Furthermore, even locational filtering can't improve the detection of the assets: not only due to relatively low reliability of positional filtering, but since it is quite common to have two or more assets of the same type (e.g. transformers in a transformer substation) practically at the same location.

The above analysis implies a data carrying marker should be used, as has been assumed previously. The characteristics of available codes and the characteristics of the desired workflow, including the fact the assets and codes are subject to environmental impacts, QR markers have been selected as the most suitable marker technology.

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5.2.6 AR Visualization – Current implementation status

As the application will be used in the field, the ease of use and simplicity of GUI is of principal importance. For this reason, the application will have slightly different specifications to the ones presented in the mockup in D5.1 – namely there will not only be a functionality to search by code but also an option to select the asset manually, e.g. if AR recognition fails due to damaged or obscured code. This selection will be geographically filtered so that only assets nearby will be offered for the user to select. The current application version does not feature the full GUI.

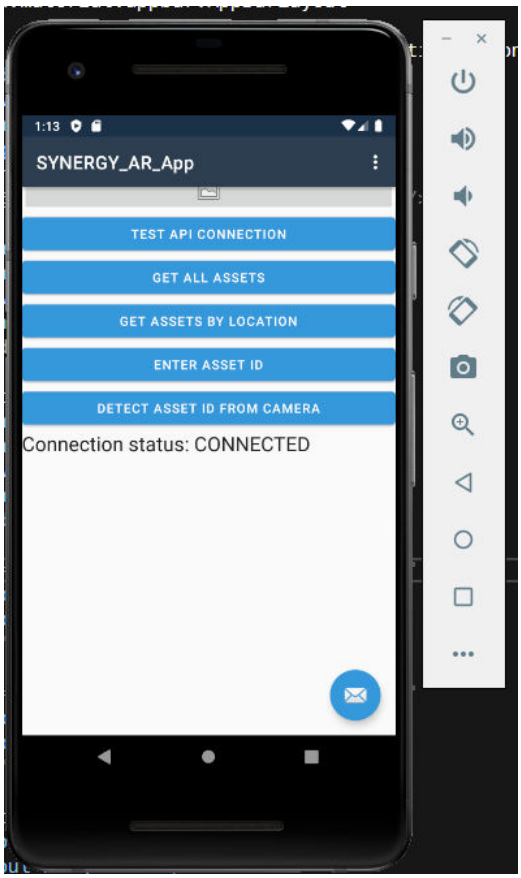

Figure 35 : Asset Management Optimization Application – Main screen of mobile app in Android emulator

Tapping on "Test API connection" tests the connection with the ETRA server. The Get ALL assets button retrieves and shows the list of all assets, and can show the assets on the map. The Get assets by location shows a certain number of closest assets. Enter asset ID allows manual entering of asset ID to get the properties, and finally Detect asset IT from camera deduces the asset ID from the QR code visible on camera.

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Once the asset has been identified the application can shows the retrieved asset details in the lower part of the screen.

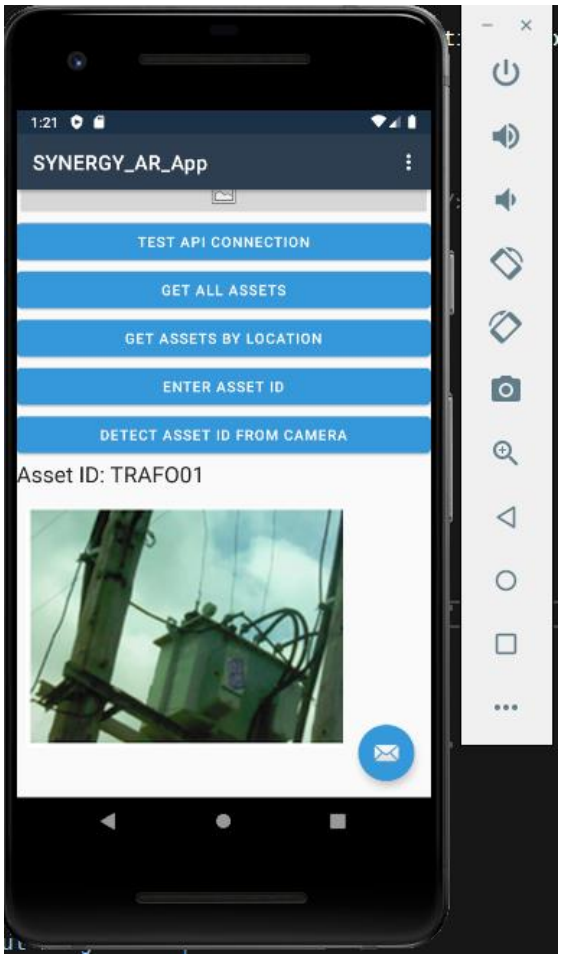

Figure 36 : Asset Management Optimization Application – Asset details shown in mobile app

The current version of the mobile application above has a quite rudimentary GUI, but demonstrates most of the functionalities and practically serves for the purpose of integration testing – the full mobile GUI workflow will be presented in the next release. To ease the debugging of API integration with ETRA application, the Insomnia desktop tool debugging the requests and responses is also used.

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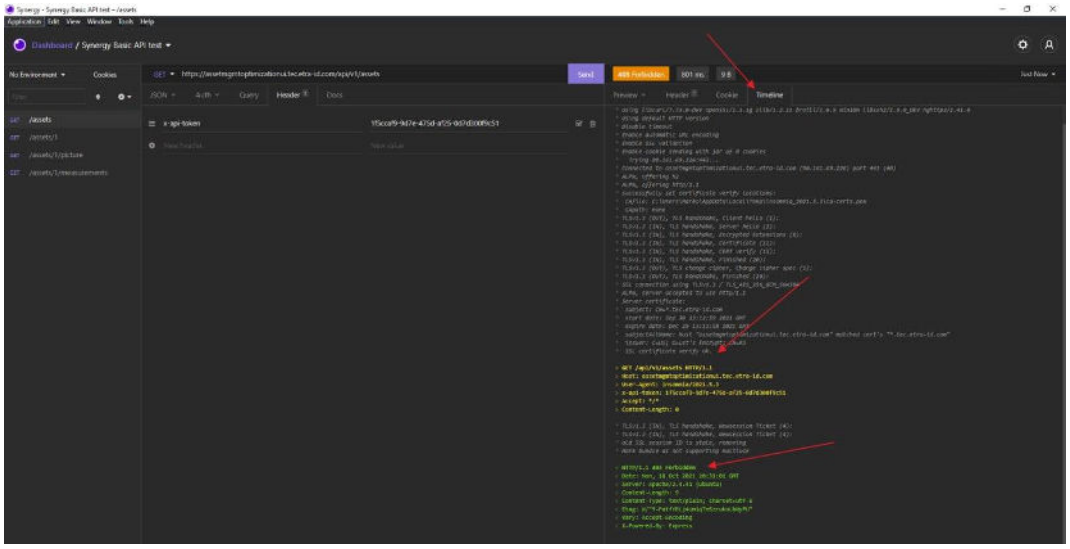

Figure 37 : Asset Management Optimization Application – Testing of API using Insomnia desktop tool

5.3 Technology stack and implementation tools

Table 19 : Asset Management Optimization Application – Technology stack and implementation tools

Library	Version	License	Purpose
meteor-base	1.4.0	MIT License	User interface Packages every Meteor app needs to have
mobile-experience	1.1.0	MIT License	User interface. Packages for a great mobile UX
mongo	1.10.1	MIT License	User interface. The database Meteor supports right now
static-html		MIT License	User interface. Define static page content in .html files
reactive-var	1.0.11	MIT License	User interface. Reactive variable for tracker
tracker	1.2.0	MIT License	User interface. Meteor's client-side reactive programming library
session	1.2.0	MIT License	User interface
accounts-password	1.7.0	MIT License	User interface
standard-minifier-js	2.6.0	MIT License	User interface. JS minifier run for production mode
es5-shim	4.8.0	MIT License	User interface. ECMAScript 5 compatibility for older browsers

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Library	Version	License	Purpose
ecmascript	0.15.0	MIT License	User interface. Enable ECMAScript2015+ syntax in app code
shell-server	0.5.0	MIT License	User interface. Server-side component of the `meteor shell` command
aldeed:collection2	3.0.0	MIT License	User interface
underscore	1.0.10	MIT License	User interface
react-meteor-data		MIT License	User interface
alanning:roles		MIT License	User interface
semantic:ui		MIT License	User interface
jquery		MIT License	User interface
flemay:less-autoprefixer		MIT License	User interface
matb33:collection-hooks		MIT License	User interface
mizzao:user-status		MIT License	User interface
etraid:accounts-openid		Proprietary	User interface
@babel/runtime	^7.12.5	MIT License	User interface
@popperjs/core	^2.6.0	MIT License	User interface
bcrypt	^5.0.0	MIT License	User interface
etra-forms	^1.0.4	Proprietary	User interface
etra-ui-components	^2.0.0	Proprietary	User interface
etraid_formats	^1.0.16	Proprietary	User interface
html-react-parser	^1.2.4	MIT License	User interface
i18next	^20.1.0	MIT License	User interface
i18next-browser-languagedetector	^6.1.0	MIT License	User interface
i18next-http-backend	^1.2.0	MIT License	User interface
jquery	^3.4.1	MIT License	User interface
lodash	^4.17.15	MIT License	User interface
luxon	^1.26.0	MIT License	User interface
meteor-node-stubs	^1.0.0	MIT License	User interface
moment-timezone	^0.5.33	MIT License	User interface
popper.js	^1.16.1	MIT License	User interface
prop-types	^15.7.2	MIT License	User interface

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Library	Version	License	Purpose
react	^16.14.0	MIT License	User interface
react-dom	^16.14.0	MIT License	User interface
react-i18next	^11.8.11	MIT License	User interface
react-icons	^4.2.0	MIT License	User interface
react-live-clock	^5.0.16	MIT License	User interface
react-moment	^1.1.1	MIT License	User interface
react-month-picker	^2.2.0	MIT License	User interface
react-router-dom	^5.2.0	MIT License	User interface
react-semantic-ui-datepickers	^2.13.0	MIT License	User interface
recharts	^2.0.9	MIT License	User interface
recompose	^0.30.0	MIT License	User interface
semantic-ui-react	^1.1.1	MIT License	User interface
simpl-schema	^1.10.2	MIT License	User interface
styled-components	^5.2.1	MIT License	User interface
tensorflow	2.4.0	Apache License 2.0	Business logic
pandas	1.3.3	BSD License	Business logic
requests	2.26.0	Apache License 2.0	Business logic
numpy	1.19.5	BSD License	Business logic
scikit-learn	0.24.2	BSD License	Business logic
Xamarin		Propietary	Cross platform technology for mobile app (user interface and business logic)

5.4 API documentation

5.4.1 Integration with SYNERGY Platform via REST API

The majority of the analytics required by the application have been configured as *analytic workflows* that are executed by the SYNERGY Platform. In order to access to the results of such analytics, different *data retrieval queries* have been configured, all of them exposing specific REST endpoints. Authentication mechanisms are implemented within the SYNERGY Platform in order to ensure that

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only authorized parties (components of the *Asset Management Optimization Application*) are granted access.

Table 20 : Asset Management Optimization Application – Integration with SYNERGY platform via REST API

Data Retrieval Query	Type	Implementer	Purpose
[DEV-WP5] Predictive Maintenance Data	HTTP GET	SYNERGY Platform	Asset health cyclic data ready to be classified or used for regression.
[DEV-WP5] SCADA data	HTTP GET	SYNERGY Platform	SCADA data ready to predict probable occurrence of future events/alerts.
[DEV–WP5] Picture Based Indicators Data	HTTP GET	SYNERGY Platform	Set of images ready to be analysed by the yolo neural network.

5.4.2 Integration with AR Mobile App

The *Asset Management Optimization Application* delivers two different user interfaces targeting different end-users (one specific to maintenance operators, another specific to field personnel). The user interface targeting field personnel is developed in the form of a mobile app, which interacts with the main backend using a REST API.

This interface is defined using the openapi 3.0.0 specification. Currently it defines 4 methods and 8 schemas, as well as API token-based authentication.

At the time of development, the token is a fixed secret token shared between KONČAR and ETRA in order to proceed with app development. QR code located on an asset carries the asset identifier and can be entered manually in case the visual code detection fails.

The interaction includes:

- Getting a list of assets
- Getting detailed info of an asset
- Getting an asset picture from the database
- Uploading a new set of measurements
- Uploading files (e.g. images or video recordings) of an asset
- Getting a list of assets filtered by locational proximity: this is utilized for ease of selection of an asset when the QR code detection fails.

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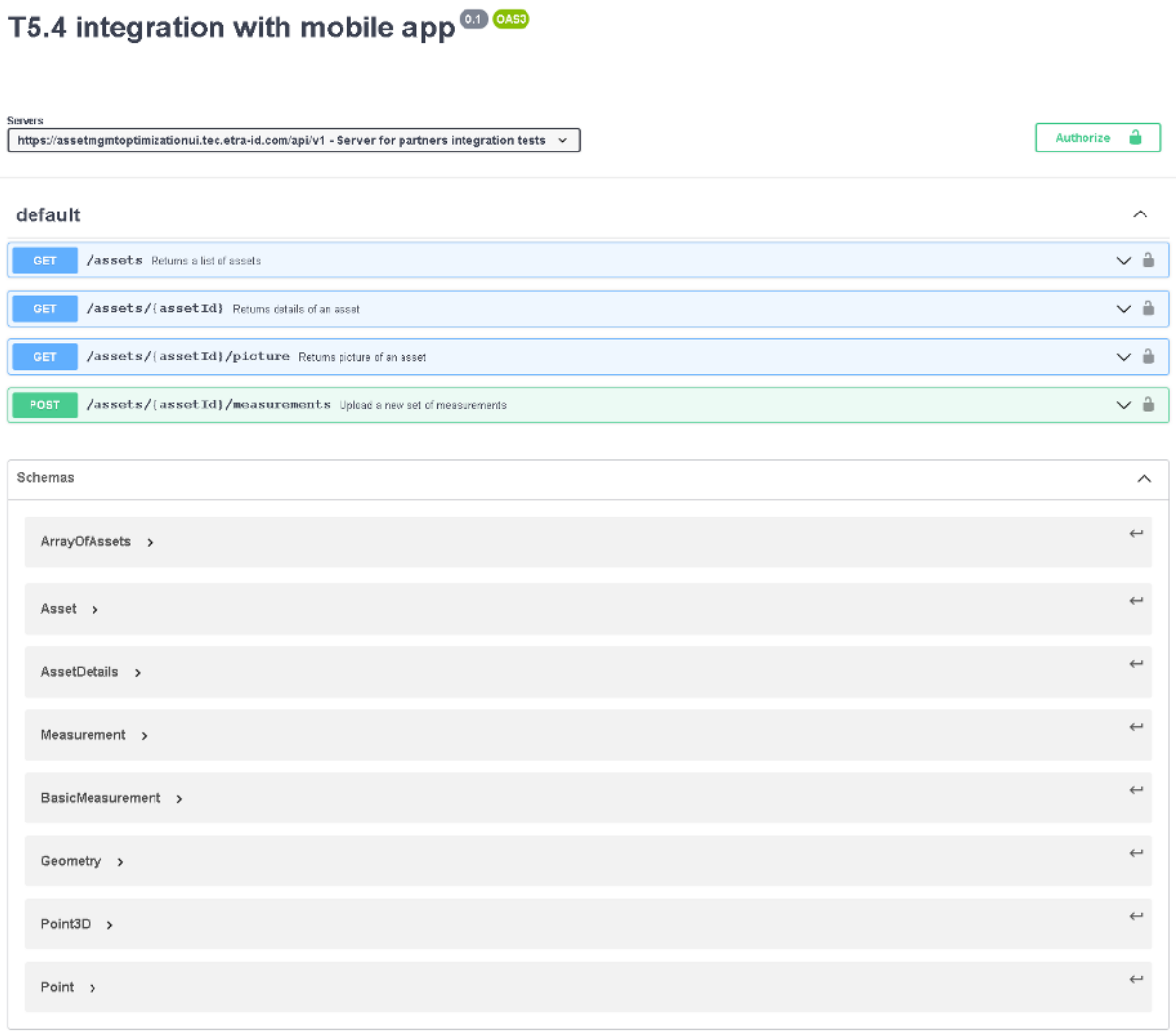

Figure 38: Asset Management Optimization Application – Integration with mobile app

All the components of the application have been packaged as a set of docker images. These docker images are available from a private repository at docker hub. This kind of packages facilitate the deployment in any platform supporting this technology (e.g. Kubernetes). Due to the nature of the software, being offered in the form of SaaS, no installation procedure is required by final users.

Table 21: Asset Management Optimization Application – docker hub images

Image	Tag	Purpose
etraid/synergy_assetmanagementui	0.0.9	Application main backend and frontend.
etraid/synergy_picturebasedindicators	0.0.8	Picture Based Indicators YOLO API.
etraid/synergy_predictivemaintenance	0.0.7	Predictive maintenance service.
etraid/synergy_eventcorrelations	0.0.1	Event correlations service.

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To follow a properly installation, it will be necessary to configure each docker image with a docker stack which will contain all the configuration parameters. The *etraid/synergy_predictivemaintenance* image will be used to solve the problem of asset health score calculation of classification and regression, depending of the used stack.

The mobile application is, at this point, not submitted to any of the mobile app stores and is available as an apk file to be installed manually on the Android (10.0 or newer) device, either directly on the device or by using adb installation tool from the Android toolkit.

5.5 Assumptions and restrictions

The architecture of the *Asset Management Optimization Application* relies on the services provided by the SYNERGY Platform, specifically in the features related to data ingestion and data analytics.

In order to be able to use the application, following configuration steps need to be taken for every new DSO/TSO that wishes to integrate with the application:

- DSO and TSO are required to be registered as users of the SYNERGY Platform
- DSO and TSO are required to configure the necessary data check-in jobs, so required datasets get accessible through the platform

Table 22 : Asset Management Optimization Application – Assumptions and restrictions

Dataset	Content	Description
Predictive Maintenance	Customer id Asset id Cycle id Sensor1_value … SensorX_value	Cyclic health data of different assets
SCADA data	Asset id Time Event/Alert id Event/Alert description	SCADA data of a set of assets.

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Dataset	Content	Description
Picture Based Indicators	.JPEG Images	A set of .jpeg images containing possible alerts in some of these images.

- DSO and TSO are required to grant access to application manager to the required datasets, so those can be incorporated to the application workflows, by signing the appropriate contracts within the SYNERGY Platform
- Application manager configures the preprocessing step – which ensures that existing datasets from any DSO and TSO are transformed to meet a common data model required for the execution of the analytics services.

5.6 Licensing and access

Table 23 : Asset Management Optimization Application – Licensing and access

Component	Licensing details
Asset Management UI	ETRA I+D is the owner of all intellectual property rights of this component. All rights are reserved.
Picture Based Indicators Component	ETRA I+D is the owner of all intellectual property rights of this component. All rights are reserved.
Predictive Maintenance Component	ETRA I+D is the owner of all intellectual property rights of this component. All rights are reserved.
Event Correlations Component	ETRA I+D is the owner of all intellectual property rights of this component. All rights are reserved.
AR Mobile App	KONČAR is the owner of all intellectual property rights of this component. Note: this application functionality is tied to ETRA-developed components above, so the license will be adjusted accordingly through a bilateral agreement between KONČAR and ETRA. All rights are reserved.

A demo version of the application is accessible at https://assetmanagement.synergy-bigdata.eu/[6].

[6] Test credentials can be made available upon request.

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5.7 Planned features for next release

For the next release, more sophisticated solutions for each algorithm described in section 5.2 will be developed with the goal of obtaining improved results. These solutions will include new neural network topologies, new data to the initial datasets for better training and also other optimizers and loss functions.

All strategies will be compared in order to keep and integrate the approaches providing best results.

Finally, obtained results by the SYNERGY platform will be integrated with our implemented user interface.

Considering the mobile application, the current rudimentary GUI will be designed in line with the rest of SYNERGY platform, and the mobile app finalized and tested.

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6 Conclusions

Deliverable D5.2 “1st Version of the Asset Management Tool Suite for Network and RES plant Operators” reports the produced results and developed functionalities of all four applications composing the Asset Management Tool Suite.

All WP5 applications are developed according to the specifications given in the 1st deliverable of WP5, D5.1, and also according to the SYNERGY use cases and the overall architecture of the SYNERGY platform. The deliverable presents the prototype version of each of the applications and documents the implemented functionalities and services. Additionally, the technology stack and implementation tools, API documentation, assumptions and restrictions and access are provided for the four applications.

For each of the applications, the status of the proposed functionalities is presented being either implemented or partially implemented. All the expected functionalities will be fully implemented before the start of the 1st demo run. More enhancements and refinements are expected to be delivered during the demonstration phase. The final version of the Asset Management Tool Suite will be released in M42 with D5.3 documenting the final release of the energy applications, taking into consideration the feedback, findings and any new requirements that emerge from the demonstration phase in WP8.

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