IANOS

SUSTAINABLE SOLUTIONS
for islands' decarbonisation

D4.7

The iVPP Centralized Dispatcher (T4.4)

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Disclaimer

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Executive Summary

This deliverable describes the requirements and architecture of the Centralized Dispatcher, based on the IANOS use cases. The Centralized Dispatcher is part of the IANOS iVPP Operative Orchestration Toolkit (iVPP) that contains functionalities to provide energy flexibility services and foster island self-consumption according to each use case specification.

The Centralized Dispatcher (CD) contains the main decision logic to create an optimal dispatch of all the assets that are part of the span of control of the IANOS iVPP. The detailed analysis of the use cases also required an analysis of the devices that are part of the use case, in order to assess their ability to be monitored and/or controlled. This is of great importance because without the ability to control devices there is not much to decide by the Centralized Dispatcher. This analysis will continue in the upcoming months, as more information of the devices in the use cases will become available. This will be reflected in the second version of this deliverable.

For each use case its CD goal is extracted and analysed. In some cases, goals of different use cases can conflict with each other, especially when the same devices belong to different use cases with different goals. In the demonstration work packages (WP5 & WP6) these issues will be addressed further. Choices made there will be reflected in the second version of this deliverable and will feed the Centralized Dispatcher software configuration and decision-making logic.

The CD’s decision-making logic is provided by three controllers. For each pilot a deployment architecture is developed that matches the partners that are active in those pilots. Furthermore, it provides an analysis of the features of the different controllers, such that follower islands can make a well-informed decision what controller to choose in their deployment.

Additionally, this deliverable includes an analysis on how other IANOS modules will provide information to the CD in order to reach its goals as defined by the use cases. This is high level and is input for the tasks on the overall IANOS architecture (T2.5) and the secure Enterprise Service Bus (T4.1) where the interaction will be detailed further.

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1 Introduction

1.1 Purpose and Scope

This document is the first deliverable of T4.4 and accompanies the software developed in this task and describes the iVPP Centralized Dispatcher (CD) tool. This deliverable analyses the use cases with the aim to deliver software that is able to implement the IANOS optimization goals outlined by the use cases.

Furthermore, this deliverable outlines the requirements that the Centralized Dispatcher imposes on the actual energy resources that are controlled. This analysis is required as the ability of reaching the goals of the use cases is heavily dependent on the capabilities of the actual devices that are part of the use cases and the ability to monitor and control them effectively.

This first version of the deliverable will focus on the requirements and architecture of the CD, its role in the IANOS infrastructure and the controllability of the devices that will be optimized by the CD.

The second version will describe the final design of the Centralized Dispatcher as part of the integrated iVPP platform. Because many aspects of the use cases in the pilots at Ameland and Terceira require further detailing, the second version will also refine the use cases based on the developments in WP5 (Ameland) and WP6 (Terceira).

1.2 Structure

This deliverable consists of four main topics. The first topic focusses on the Centralized Dispatcher and the requirements put on it by the nine use cases defined in the IANOS project. The second topic focuses on the architecture of the Centralized Dispatcher, the role of the three different controllers that are provided by the partners, and how they interact with the other modules developed in the IANOS project.

The third topic consists of a description of these three controllers and their associated features, to support follower islands in their selection of a controller for the Centralized Dispatcher.

The fourth topic will link the Centralized Dispatcher to other dependencies, such as the forecasting module, which are developed in other tasks. Each module is described in brief and the interactions are defined at a high level of abstraction. The detailed interactions are part of the deliverables of task T2.5 (Architecture) and T4.1 (Secure Enterprise Service bus).

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1.3 Relation to other deliverables

Four main inputs are used for this deliverable:

- D2.1 Requirements Engineering & Decarbonization Roadmapping (WP2) that describes the high level requirements of the iVPP, based on the use case analysis.
- D2.13 IANOS System Architecture, that describes the interactions between the different modules in the iVPP from a system point of view.
- WP5 activities at Ameland for the refining of the IANOS use cases and the devices that are part of the use cases
- WP6 activities at Terceira for detailing the IANOS use cases and the devices that are part of the use cases.

2 Centralized Dispatcher

2.1 Purpose

In Figure 1 the Centralized Dispatcher is depicted as part of the IANOS iVPP Operative Orchestration Toolkit (iVPP for short). The iVPP contains the functionality to provide flexibility services and foster island self-consumption. The iVPP is expected to spur the deployment of localized RES and storage systems, while improving self-consumption of renewable energy. Several modules support the iVPP in reaching its goal.

The Centralized Dispatcher (CD for short, in dark red in Figure 1) contains the main decision logic to create an optimal dispatch of all the assets that are part of the span of control of the iVPP, such as storage, load, and supply assets.

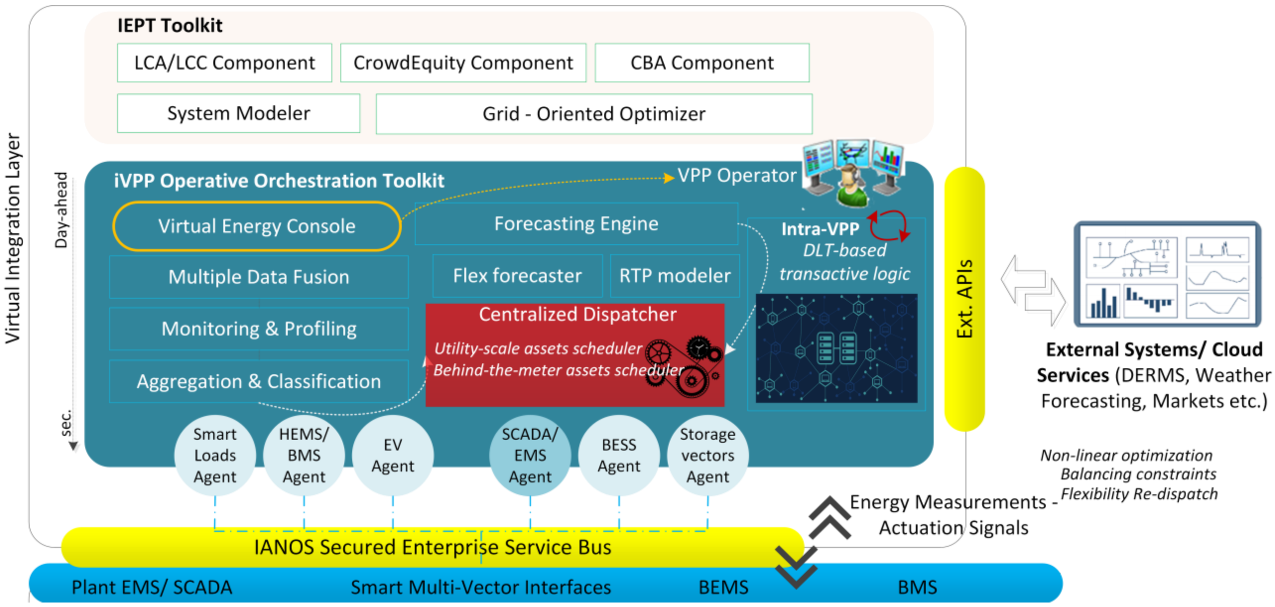

Figure 1: Centralized Dispatcher as part of the IANOS concept, playing a major role in the iVPP. The figure shows the upper part of the IANOS concept.

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The decision making of the CD is based on the use cases. Each use case describes a certain goal to optimize for. For example, self-consumption of local households, or providing balancing services to the grid. It is the task of the CD to realize these goals by creating the optimal dispatch of the devices that are part of that use case.

2.2 Use cases and Requirements

The IANOS proposal defines 9 different technical use cases to show the benefits of the IANOS project. These use cases have been analysed and elaborated upon in IANOS D2.1 - Report on Islands requirements engineering and UCs definitions, developed in task 2.1. This chapter builds upon these requirements and details them further for the Centralized Dispatcher, with the aim to create a common understanding of the goals the centralized dispatcher needs to fulfil in the IANOS project.

This section dives also into the actual devices that are part of the use cases. Since there is (still) no uniform way to unlock the energy flexibility of these devices and additional manual work is required to expose the capabilities of devices to the Centralized Dispatcher (e.g., by using gateways such as FEID-PLUS or Raspberry Pi hardware). Therefore, it is important to analyse in-depth what kind of capabilities these devices have in terms of controllability, what role they play in the specific use case and how they add to reaching the goal(s) of the use case.

2.2.1 Use Case 1: Community demand-side driven self-consumption maximization

Outline

This use case focusses on the optimization of self-consumption of renewable energy produced in the local building, neighbourhood or at the island. The control algorithms will shift demand to periods characterized by renewable generation surplus.

Centralized Dispatcher Goal

There are three goals in this use case:

1. Maximising consumer-level self-consumption of renewable energy sources (RES) such as PV, by controlling local building loads and storage;
2. Maximising self-consumption at the Neighbourhood-level from locally (Terceira) or centrally (Ameland) produced RES energy;
3. Promote self-consumption in neighbourhoods by means of the P2P energy transactive framework. This goal is elaborated upon at the end of this section.

Requirements:

- The RES devices' production must be measured and forecasted;

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- The devices that induce load in this use case can be controlled, while taking the comfort levels into account, for example by taking the timeframes when hot water is needed into account;
- Load forecasting;
- Heat consumption forecasting (in case heat storage is used and the stored heat is used for hot water and/or classic radiators);
- Technical characteristics of Energy Storage Systems (ESS), Thermal Energy Storage Systems (TESS), and PV;
- Measurements for all energy assets.

Analysis

The three mentioned goals might interfere with each other. Local self-consumption maximalization might be efficient from a local perspective but might impact the overall efficiency at the neighbourhood level or island level. The current default behaviour is to optimize for the local situation first, and the global situation second. In collaboration with the stakeholders in WP5 and WP6 circumstances can be defined where one would deviate from this behaviour (e.g., local grid constraints).

Outcome

The expected outcome is that the CD will shift demand to periods where there is excess of renewable energy.

2.2.1.1 Terceira view

Notable aspect specific for Terceira

Devices part of the use case in Terceira

Device	# Assets	Main technical characteristics	Measurable variables	Controllable variables
Household Smart Meters	40	Measure max. 120A, WiFi, 365 days energy history	Voltage, current, active power, reactive power, energy, power factor	No control
Smart Plugs	40	Zig bee home automation communication Current load < 16A	Voltage, current, power, energy, power factor	ON/OFF
Household batteries	16	No data available yet	SoC	Charging and discharging
Heat batteries	24	Electric heating @ 2.8kW (≈75L water heater tank)	Heat battery SoC, readings from 3 temperature sensors	ON/OFF
Water heaters	5	Water capacity of 150L Electric heating element of 1.5kW Comm. via WiFi to the ESB	Readings from 3 temperature sensors Forecast for the next 24 hours (hourly average power value)	ON/OFF and Scheduling
Household PV systems	40	1.5kWp each	PV generation	Connect and disconnect
Smart Energy Router	2	Smart hybrid inverter with 5kWp PV panels and a 0.5kWh storage battery	PV generation, battery SoC	Connect and disconnect, Charging and discharging

Table 1: Overview of devices of Use Case 1 at Terceira and their main technical characteristics, measurable and controllable variables.

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Besides the information in Table 1, which contains the main relevant technical characteristics, measurable and controllable variables of each energy asset, the following specific aspects have to be taken into account:

- **Smart Plugs**
  - Smart Plugs have embedded energy metering capabilities and are controllable (ON/OFF);
  - The consumer will have access to a HEMS from Cleanwatts that will give the consumer information regarding the individual consumption of the plugged appliance, and it will have control on the ON/OFF of the plug.
- **Household batteries**
  - No information yet about the system to be installed, but it will have to comply with the following:
    - Capable of being integrated with Cleanwatts and CERTH gateway, so that it can be measurable and controllable.
- **Heat Batteries**
  - Only ON/OFF operations can be done to the 2.8kW electric heating element.
- **Water heaters:**
  - UNINOVA is going to supply special modified water heater tanks, with embedded temperature sensors and with a smart plug with measurement and controllable capabilities;
  - UNINOVA can provide the forecast for the next 24 hours (hourly average power value) and the power that we can increase or decrease in every hour slot;
  - The iVPP can send the average power hourly and the device performs the necessary calculations to reach the average value sent.
- **Household PV systems**
  - PV panels of 1.5kWp with integrated micro-inverters in each household;
  - It is possible to get metering data and connect/disconnect the system.
- **Smart Energy Router**
  - The equipment is composed by a smart hybrid inverter coupled to PV panels and a small size battery;
  - It has embedded algorithms for self-consumption optimization although it allows to receive controls from the iVPP.

Some of the households have roof top Solar Thermal water tanks with electric backup and others have gas water heaters. These solutions will keep operating on the households that the Heat Batteries will be installed.

The V2G chargers will not be used on this UC since they are installed in non-residential sector and are to be used as network energy assets in UC 5.

Ameland view

Notable aspect specific for Ameland

Devices part of the use case in Ameland

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Device	# Assets	Existing	Main technical characteristics	S2 type*	Measurable variables	Controllable variables
Solar Farm	1	X	6MWp, read power via backend	PEBC	?	-
Hybrid Heat Pumps	136	X	7 types on the island, of which 4 have been lab-tested. Comm. via Pi.	DDBC		Smart-grid ready: Compressor ON/OFF (for at least 4 types)
Suwotec Battery	1		120kWh, comm. probably via backend	FRBC		?
Fuel Cell CH4	35	X	2kWe each	OMBC	?	
Wind Turbines	2		12kWe each	PEBC	?	
Residential PV	400		Total around 1MW. Could be monitored in 2 ways: From smart meter, or at inverter.	PEBC	M?	
Battery pack, solar panels, µCHP	3		Battery: 3.5 kW	FRBC, PEBC, FRBC	?	?

Table 2: Overview of devices of Use Case 1 at Ameland and their main technical characteristics, measurable and controllable variables.

***** S2 type refers to the control type category as defined by EN 50491-12-2 (better known as *S2* interface as described by the European Reference architecture for Smart Grids, see also Appendix B.

At Ameland this novel S2 interface is utilized to communicate energy flexibility. For each device an analysis is made to which S2 control type the device belongs.

Peer-to-peer energy transactive framework

Additionally, there is a peer-to-peer (P2P) transactive framework in this use case, which aims at promoting self-consumption in neighbourhoods. The integration part of the use case will be detailed in 5.4.

2.2.2 Use Case 2: Community supply-side optimal dispatch and intra-day services provision

Outline

This use case focuses on the potential of the iVPP to perform the day-ahead optimal dispatch and provide intra-day balancing services to the power system (e.g., re-scheduling Battery Energy Storage System dispatch for grid congestion management) using the available energy flexibility on the generation side (at utility-scale, both from dispatchable and non-dispatchable renewable energy units).

Centralized Dispatcher Goal

The goal of this use case is to create an optimal day-ahead dispatch and utilize the batteries available in the use case for the delivery of intra-day balancing services to the grid, ensuring that the remaining capacity of the batteries is sufficient to maximize the penetration of RES.

Requirements

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- PV and wind turbine forecasting;
- Load forecasting;
- Day-ahead dispatch scheduling;
- Energy Storage Systems technical characteristics (SoC, Capacity, C-rates for charging/discharging);
- PV and WT technical characteristics (installed power, inverter nominal powers, power factor).

Analysis

Smart planning of battery capacity is needed to make sure that intermittent production can always be supplied to the grid.

Outcome

Maximize RES penetration

2.2.2.1 Terceira view

Notable aspect specific for Terceira

It will not be possible to perform direct control of the network assets at Terceira. This UC will have to be based on a semi-simulated environment. The iVPP controllers will send the set-point for the large-scale Battery Energy Storage Systems and project partner EDA will follow it or not.

Cleanwatts together with EDA, are attempting to integrate the smart metering of the network assets that compose this UC, although at the time of writing this report some of the network energy assets were not yet installed. This solution will give access to smart metering data with 15 minutes granularity acquired each 30 minutes from the smart metering system. Efforts are being made to integrate the SCADA system that will give data with lower granularity.

Devices part of the use case in Terceira

Device	# Assets	Main technical characteristics	Measurable variables	Controllable variables
BEES	1	To be installed by EDA	Energy (kWh)	-
Geothermal plant	1	4.7Mwe	Energy (kWh)	-
Wind Farms	1	5.4 out of total 9MWe of total installed wind farms on the island	Energy (kWh)	-
Waste incineration power plant	1	2.6Mwe	Energy (kWh)	-
PV farm	1	2MWe PV farm, to be installed	Energy (kWh)	-

Table 3: Overview of devices of Use Case 1 at Terceira and their main technical characteristics, measurable and controllable variables.

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2.2.2.2 Ameland view

Notable aspect specific for Ameland

The 3MWh Battery is used in use case 2, 3 and 4, while the goals of the use cases differ. A solution has to be found to be able to utilize this battery in all use cases at the same time (e.g., by virtually splitting the battery up in three batteries).

In Ameland GOPACS (Grid Operation Platform for Congestion Solutions) will be utilized to deal with congestion management that will be signaled by the DSO through this platform.

Devices part of the use case in Ameland

Device	# Assets	Existing	Main technical characteristics	S2 type*	Measurable variables	Controllable variables
Solar Farm 6 MW	1	X		PEBC	tbd	-
3MWh Battery	1			FRBC	tbd	tbd
Electrolyzer	1			PEBC / OMBC	tdb	tbd

Table 4: Overview of devices of Use Case 2 at Ameland and their main technical characteristics, measurable and controllable variables.

2.2.3 Use Case 3: Island-wide, any-scale storage utilization for fast response ancillary services

Outline

The goal of this use case is to capacitate the power system with distributed storage technologies with capabilities of frequency and voltage control, improving the Power Quality and Continuity of Power Supply. The iVPP will be able to aggregate the various storage energy assets to provide fast services to the grid such as FFR (Firm Frequency Response) and voltage deviations, also ensuring that there is a pre-defined capacity reserved for these services, that can vary according to the status and situation forecast of the power system in a short window of time (e.g., one day).

Analysis

Pre-defined capacity reserve means a fixed amount that does not change over time (e.g., by splitting up the battery in multiple virtual batteries). Alternative is to split it in time (e.g., 1 month one service, 1 month the other), based on the business case behind these markets).

Centralized Dispatcher Goal

Handle FFR requests to mitigate voltage deviations.

Requirements

- A partner with market access (e.g., aFFR or FCR);
- Ability to control and measure battery storage at required time scale and precision;
- Measure battery storage with market operators' approved meters;
- Reservation of battery capacity for a specific market.
- Logical positioning of batteries to support voltage management

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- Sufficient metering of the grid

Outcome

The expected outcome is that the iVPP utilizes storage in the system to handle voltage deviations.

Terceira view

Notable aspect specific for Terceira

The BEES is not yet installed and EDA and Cleanwatts are analysing ways to acquire data from this network energy asset.

The flywheel from Teraloop will be installed on an Industry dairy products facility.

As also mentioned in UC2, there will be no direct control on the network energy assets like the BEES and flywheel. This UC will have to be based on a semi-simulated environment. The iVPP controllers will send the set-point for the large-scale BESS and EDA will follow it or not. As for the household batteries, they can be controlled by integrating the battery inverters into the iVPP.

The flywheel will be used for the improvement of power quality issues in the industrial facility where it is installed.

Devices part of the use case in Terceira

Device	# Assets	Main technical characteristics	Measurable variables	Controllable variables
Household batteries	16	No data yet available	SoC	Charging and discharging
Flywheel	1	3 kWh/100 kWe	No information yet available	-
BEES	1	15MW/10.5MWh	No information yet available	-

Table 5: Overview of devices of Use Case 3 at Terceira and their main technical characteristics, measurable and controllable variables.

Ameland view

Notable aspect specific for Ameland

This will monitor the installation of several storage technologies, including fuel cells, CHPs and battery storage, as well as control algorithms to enable provisioning of fast response ancillary services through distributed storage technologies such as frequency support and voltage regulation within the selected area for demonstration in Ameland Island.

Further analysis of the devices is needed to check if the response times and size of these assets match the regulated requirements for using fast response ancillary services.

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Devices part of the use case in Ameland

Device	# Assets	Existing	Main technical characteristics	S2 type*	Measurable variables	Controllable variables
3MWh battery	1			FRBC		
Private **CHP**s	35	X	2kW	FRBC		
CHP	2		75 KWe/110KWth	FRBC		
Fuel cell	1		600KWe	OMBC		
Heat grid Klein Vaarwater	1	X	Is driven by the CHP on Klein Vaarwater & have some regular HR-boilers as a back-up for the system	?		

Table 6: Overview of devices of Use Case 3 at and their main technical characteristics, measurable and controllable variables.

2.2.4 Use Case 4: DSM and Smart Grid methods to support Power quality and congestion management services

Outline

This use case has two aims. It aims to validate the potential of the iVPP to provide power quality services to the grid using available energy flexibility from demand resources. The other aim is in the context of an increasing penetration of non-dispatchable RES (Wind Turbines, PVs), where Demand Side Flexibility (DSF) is key to reduce RE curtailment.

Analysis

The focus in this use case is on utilising demand side flexibility to help the overall energy system to incorporate more RES production, i.e. not to curtail these sources, as much as possible (e.g., by shifting load).

Furthermore, for the Terceira use case additional hardware is present (Hybrid transformer and Smart Energy Router) to support the power quality of the grid.

Centralized Dispatcher Goal

1. Reduce renewable energy curtailment, by using demand-side flexibility.
2. Improve power quality using demand sources by utilizing the Hybrid transformer and the Smart Energy Router

Requirements

- Load forecasts;
- Production forecasts;
- Controllable load;
- Real-time measurements.

Outcome

This UC would demonstrate that in the case of the optimal dispatch of centralized generation (UC#3), not being enough to maximize the penetration of renewables and ensuring at the same time the stability of the power system, a second stage of the VPP can be enabled, where the Demand Side Flexibility will be activated to increase the penetration of RES.

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Terceira view

Notable aspect specific for Terceira

Devices part of the use case in Terceira

Device	# Assets	Main technical characteristics	Measurable variables	Controllable variables
Hybrid transformer	1	400kVA	Temperatures, humidity, currents, voltage levels on LV and HV side, power	Reference for compensation for each phase or establish the set-point voltage for autonomous regulation
Smart Energy Router	2	Smart hybrid inverter with 5kWp PV panels and a 0.5kWh storage battery	PV generation, battery SoC	Connect and disconnect, Charging and discharging
BEES	1	15MWh/10.5MWe	No information yet available	No direct control is possible

Table 7: Overview of devices of Use Case 4 at Terceira and their main technical characteristics, measurable and controllable variables.

Besides the information in Table 1, which as the main relevant technical characteristics, measurable and controllable variables of each energy asset, the following specific aspects have to be taken into account:

- **Hybrid Transformer**
    - The communication is using the MODBUS but EFACEC will send the information to the ESB;
    - It can be controlled by giving the necessary compensation for each phase or by pre-establishing the setpoint voltage per phase and it will perform the autonomous voltage regulation;
    - It has a continuous onload voltage regulator (DVR) that performs the voltage regulation +/-10% the established setpoint per phase;
    - The reactive power control developments are delayed, but the hybrid transformer will be able to perform it also.
- **Smart Energy Router**
    - The equipment is composed by a smart hybrid inverter coupled to PV panels and a small size battery;
    - It has embedded algorithms for self-consumption optimization although it allows to receive controls from the iVPP.
- **BEES**
    - No information is yet available regarding the information that can be acquired from the BEES to be installed;
    - The direct control will not be possible.

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Ameland view

Notable aspect specific for Ameland

For Ameland, the Grid Operation Platform for Congestion Solutions (GOPACS) will be installed and connected, to handle grid-congestion using the hybrid heat-pumps, fuel cells, CHPs, and battery storage.

Since Ameland is connected to the main land (and thus part of the European synchronous area) frequency control is not a primary concern. Therefore, the Power Quality scope on Ameland will only be on congestion management.

Devices part of the use case in Ameland.

Device	# Assets	Existing	Main technical characteristics	S2 type*	Measurable variables	Controllable variables
3MWh Battery	1			FRBC		
CHP	2	X	75KWe/110KWth	FRBC		
600KWe Fuel cell	1			OMBC		
Hybrid Heat Pumps	136	X	7 types, of which 4 are tested on Smart-Grid-Readyness	DDBC		SGR: Compressor ON/OFF
Suwotec Battery	1		120 kWh	FRBC		

Table 8: Overview of devices of Use Case 4 at Ameland and their main technical characteristics, measurable and controllable variables.

2.2.5 Use Case 5: Decarbonization of transport and the role of electric mobility in stabilizing the energy system

Outline

The aim of this use case is to present the roadmap for decarbonizing Ameland and Terceira transport sectors, using RES production available on the island. This is done by installing EV chargers on the islands and studying their future expansion potential. Offering balancing services to the grid, through V2G/smart charging schemes would be also demonstrated (e.g., voltage support of grid nodes with heavy RES penetration, helping the grid to avoid congestion).

Analysis

Besides roadmapping the decarbonization of transport on the islands, it also contains tasks for the Centralized Dispatcher. It uses decarbonized mobility (such as EVs) to help stabilize the energy grid using their smart charging functionality and/or batteries (V2G is part of the Terceira use case).

Centralized Dispatcher Goal

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Offer balancing services to the grid to avoid grid congestion using the EVs available.

Requirements

- Ability to control the (dis)charging behaviour of the EVs;
- Information on the usage of the EVs, e.g. when are they being charged and for how long;
- Real-time metering in the grid.

Outcome

Smarter smart charging (Ameland) or V2G (Terceira) of EVs help avoid grid congestion

Terceira view

Notable aspect specific for Terceira

The V2G are to be installed in two different locations: one in the city center (EDA building) and another on the geothermal central. The V2G equipment's have an integrated energy meter and will send data to the ESB. For remote operations the V2G equipments have the OCPP protocol available.

The iVPP will be able to control the charging current using the OCPP communication protocol instructions.

There is no information about the overall consumption of the buildings or information about the RES generation. So, the V2G are to be used as a distributed energy assets for the stabilization of the network energy system, and not on the micro-grid optimization perspective (e.g., building level).

Another notable aspect about the control of this equipment is that the components can have access to the SoC of the connected EV, but there is no information regarding the total size of the EV battery connected. This value must be pre-configured based on local information of the EV that is most probably to be connected.

Devices part of the use case in Terceira

Device	# Assets	Main technical characteristics	Measurable variables	Controllable variables
V2G	2	Max charging power: 10kW It has an integrated smart meter OCPP protocol	EV battery SoC, voltage, current, power, energy, errors	Charging current

Table 9: Overview of devices of Use Case 5 at Terceira and their main technical characteristics, measurable and controllable variables.

Ameland view

Notable aspect specific for Ameland

Activities in this subtask include the following:

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1. Connecting 10 public charging points and 3 EVs to a VPP, and the monitoring of the charge points
2. Development, installation, and monitoring of hydrogen fuelled 12-person watertaxis, with hydrogen locally supplied by the electrolyser,
3. Development, installation and validation of a charging infrastructure, supporting decarbonized transportation on Ameland.

There is currently discussion ongoing to incorporate the 6 E-busses of Ameland in this use case.

Devices part of the use case in Ameland

Device	# Assets	Existing	Main technical characteristics	S2 type*	Measurable variables	Controllable variables
Electrolyzer	1			PEBC / OMBC		-
H2 Watertaxi	2			?		-
H2 infrastructure	1			?		-
Charging Station EV	10		Spread across the island, only 1 type of charging station. comm. will be established through backend	PEBC		OCPP/OCPI backend?

Table 10: Overview of devices of Use Case 5 at Ameland and their main technical characteristics, measurable and controllable variables.

2.2.6 Use Case 6: Decarbonizing large industrial continuous loads through electrification and locally induced generation

Outline

This use case is Ameland-only

The Ameland project partners will integrate a large-scale industrial load, available RES (6MWp community owned solar farm) and newly installed RES (3MWp solar farm, a 500kWe tidal-kite, 2*15kWe wind turbines, a 500kWe fuel cell), 2*75kWe CHPs) to a local VPP/EMS to safeguard energy supply, maximize RES utilization and realize a significant reduction of NG usage.

Analysis

This use cases tries to utilize the surplus of RES to power the large-scale industrial load, the NAM gas drilling platform, near the island.

Centralized Dispatcher Goal and associated Requirements

Using local RES to substitute part-of fossil-based power of the large-scale industrial load

Requirements

- Consumption data of the large industrial load to identify fluctuations in consumption.

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Outcome

Significant reduction of emissions of the large-scale industrial load by using local RES production.

Ameland view

Notable aspect specific for Ameland

Devices part of the use case in Ameland

Device	# Assets	Existing	Main technical characteristics	S2 type*	Measurable variables	Controllable variables
Solar Farm 6MW	1	X		PEBC		
Solar Farm 3MW	1			PEBC		
500kW Tidal Kite	1		Communication will be done via backed.	PPBC / PEBC		
NAM Platform	1	X	Monitoring will be done via backend.	-		-
Mainland connection	1	X		-		-
Fuel Cell	1	X	500kWe	OMBC		
Wind Turbines 12KWe	2			PEBC		
CHP	2		75kWe/110KWth	FRBC		

Table 11: Overview of devices of Use Case 6 at Ameland and their main technical characteristics, measurable and controllable variables.

2.2.7 Use Case 7: Circular economy, utilization of waste streams and gas grid decarbonization

Outline

This use case is Ameland-only

This will further decarbonize the island by re-using waste streams on a local level. To this effect, BAREAU will develop, install and commission a small-scale auto-generative High-Pressure Digester (110.000 Nm3 green gas, injected in the existing NG network), perform an inventory of available biomass streams and assess suitable processing technologies for biomass to investigate the potential and possibilities of an efficient use of the remaining waste streams.

Analysis

There is no involvement of the Centralized dispatcher in this use case

Centralized Dispatcher Goal and associated Requirements

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None

Outcome

No Centralized Dispatcher related outcome

Ameland view

Devices part of the use case in Ameland

Device	# Assets	Existing	Main technical characteristics	S2 type*	Measurable variables	Controllable variables
Electrolyzer	1			-		-
Digester	1			PEBC / OMBC		

Table 12: Overview of devices of Use Case 7 at Ameland and their main technical characteristics, measurable and controllable variables.

2.2.8 Use Case 8: Decarbonisation of heating network

Outline

This use case is Ameland-only

This will monitor the installation of four decarbonized heating solutions including the connection of existing residential heat-pumps and their integration with the iVPP. It considers the integration of fuel cell, H2 storage and additional heat pump for peak demand and expand the current heat grid. It will, assess and determine the technical approach for phasing out of natural gas in a heating grid and the installation and piloting of an innovative heating grid infrastructure (heat pumps, battery storage, PVth panels, heat buffer, iVPP-platform).

Analysis

The goal is to use more green energy to feed the heat demand at Ameland. Some of the plans are still conceptual and need further detailing.

Centralized Dispatcher Goal

Manage electricity demand for heat production facilities (e.g. heat pumps) such that RES electricity is used as much as possible.

Requirements

- Ability to control heat production facilities for the mentioned heat networks.
- Load profiles of demand in heat networks

Outcome

Use local RES electricity for powering the heat pumps.

Ameland view

This use case is still being developed at the time of writing. The next version of this deliverable will provide more detail on this.

Devices part of the use case in Ameland

Device	# Assets	Existing	Main technical characteristics	S2 type*	Measurable variables	Controllable variables
Fuel Cell	1		500KWe	OMBC		
Heat Grid Nes	1		Planned to be driven by heat pumps to exploit energy from surface water in 40 households	?		-
Heat Grid Klein Vaarwater	1	X	Is driven by the CHP on Klein Vaarwater & have some regular HR-boilers as a back-up for the system	?		-
Suwotec Battery	1		120kWh	FRBC		
Hydrogen Storage	1		Dimensions of this storage are to be researched			
Hybrid Heat Pumps	136	X	7 types, of which 4 are tested on Smart-Grid-Readiness	DDBC		SGR: Compressor ON/OFF

Table 13: Overview of devices of Use Case 8 at Ameland and their main technical characteristics, measurable and controllable variables.

2.2.9 Use Case 9: Active Citizen and LEC Engagement into Decarbonization Transition

Outline

This includes all activities that raise citizen's awareness and promote their participation to DSM programs. To achieve this, initiatives will be implemented to increase and utilize local generation (PV, wind) by members of the cooperative, LEC members will be connected to the local DSM-platform, and capacity building and training will be for local home-owners and children.

Analysis

This use case is not related to the Centralized Dispatcher, but focuses on community engagement. Therefore, no requirements for the CD are present.

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3 Centralized Dispatcher architecture

3.1 Common architecture, different controllers

Due to the fact that not all IANOS partners are participating in the different demonstration pilots, while at the same time multiple partners provide similar technology for the Centralized Dispatcher, a deployment architecture was developed for each of the demonstration pilots that matches both the IANOS high-level architecture, the use cases at the pilot islands and the partners' participation in the demonstration work packages.

TNO, Cleanwatts and CERTH provide similar controller functionality required for the Centralized Dispatcher (CD) in the IANOS project. TNO provides this functionality in WP5 and both Cleanwatts and CERTH are providing this in WP6. To avoid multiple controllers interfering with each other, the decision was made to keep the high-level IANOS architecture generic (there is a single centralized dispatcher) while the technology used to realize this architecture in the demonstrations on the islands can be different. This is elaborated in more detail below.

TNO provides the Centralized Dispatcher functionality for WP5 (Ameland). Similarly, Cleanwatts and CERTH provide the Centralized Dispatcher functionality for WP6 (Terceira). This matches the planned effort for each of the partners in the respective demonstration work packages.

Furthermore, the follower islands can choose which of the Centralized Dispatcher implementations would fit their use case best. All three technologies create an optimal dispatch for assets, but they differ in the approach and applicability in use cases. This also means that only one partner and/or CD technology needs be involved in the replication, reducing the complexity of replication.

Since the architecture is kept generic, it is important to define clear interfaces on the boundaries of the Centralized Dispatcher. The IANOS Secure Enterprise Service Bus leverages this approach, reducing the integration effort required.

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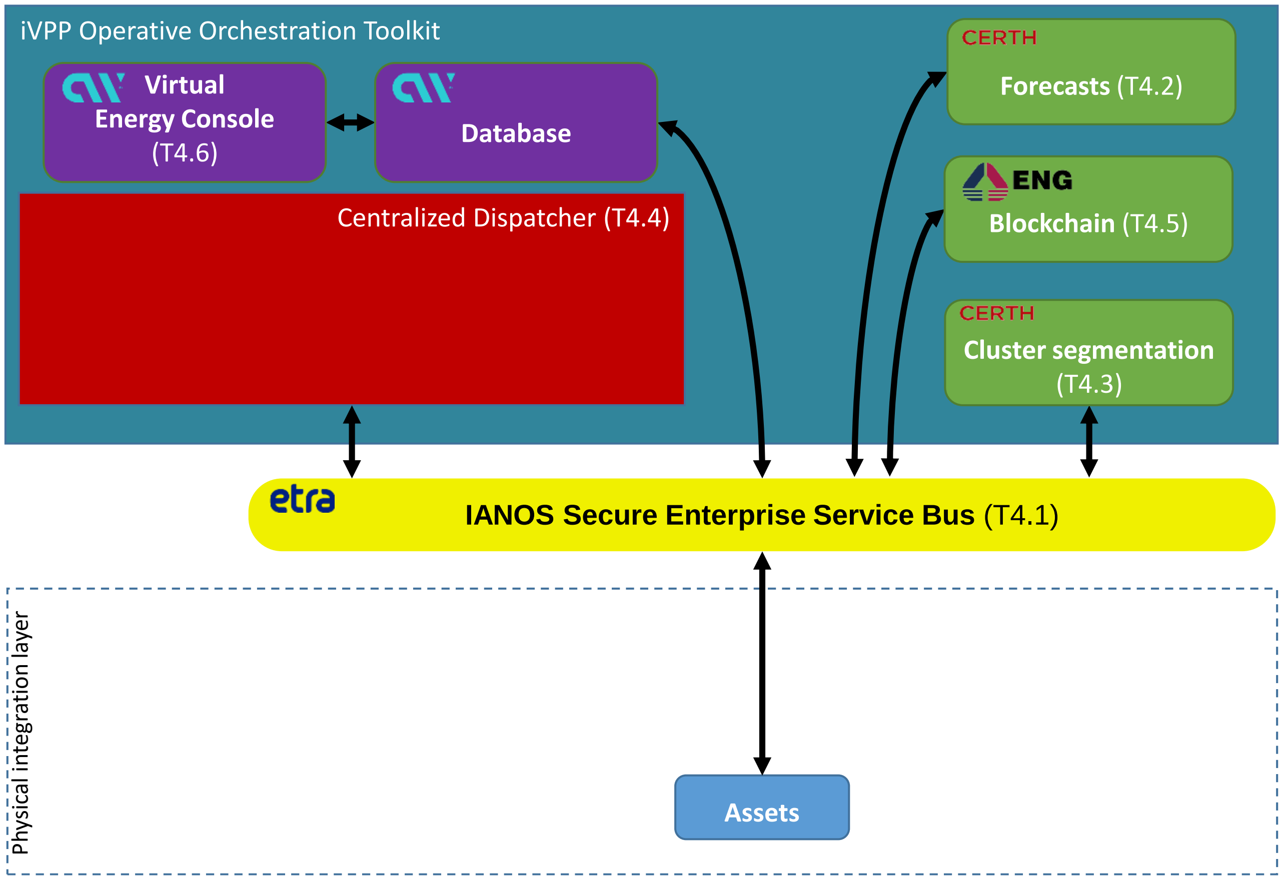

Figure 2: IANOS general architecture (based on Proposal figure)

3.2 Pilot deployment views

3.2.1 Terceira deployment view

The figure below describes the deployment architecture for the Terceira demonstration. The Centralized Dispatcher functionality is in this case provided by two technologies from respectively Cleanwatts and CERTH. Both Cleanwatts and CERTH provide technology to connect assets to the IANOS infrastructure and provide their own Centralized Dispatcher functionality for these assets.

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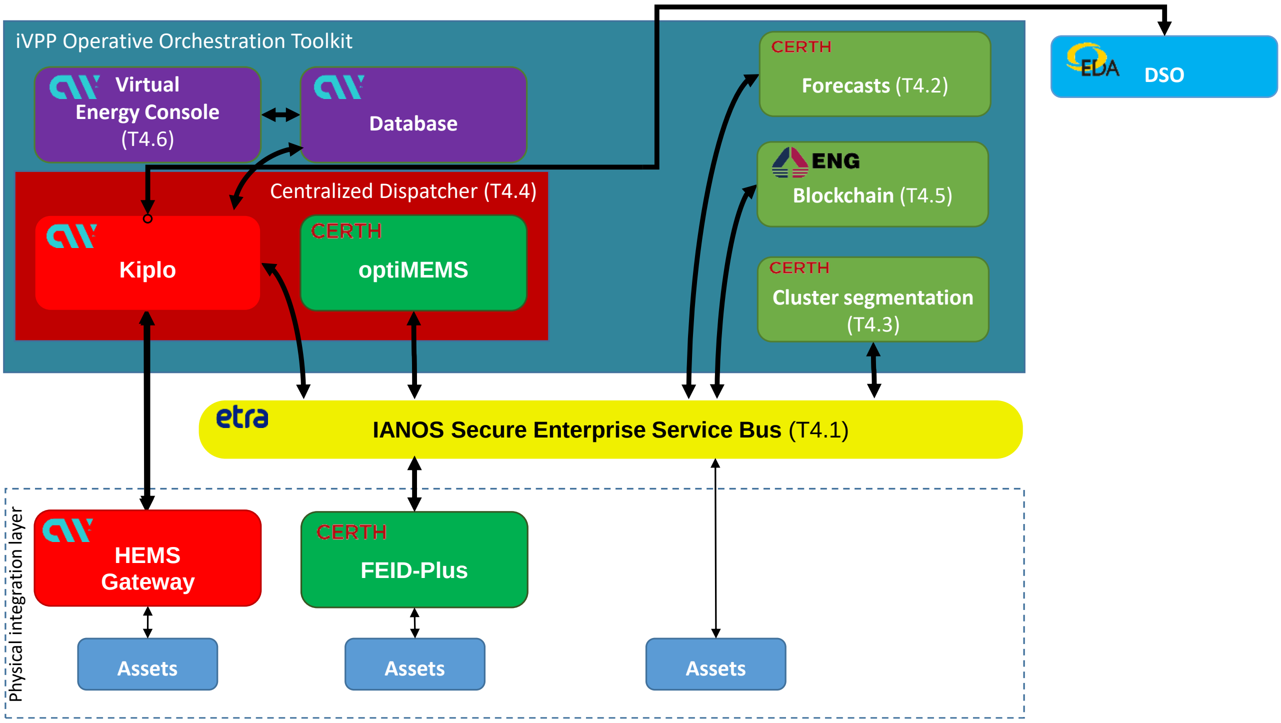

Figure 3: Deployment view for Terceira demonstration (WP6)

Assets are generally made accessible and unlocked by gateway technologies of partners such as the HEMS gateway (CleanWatts) and FEID-Plus (CERTH). Some assets are already unlocked and can be connected to the ESB directly.

3.2.2 Ameland deployment view

The figure below describes the deployment architecture for the Ameland demonstration. The Centralized Dispatcher functionality is provided by the ReFlex technology of TNO with support from dEF-Pi communication infrastructure from Neroa.

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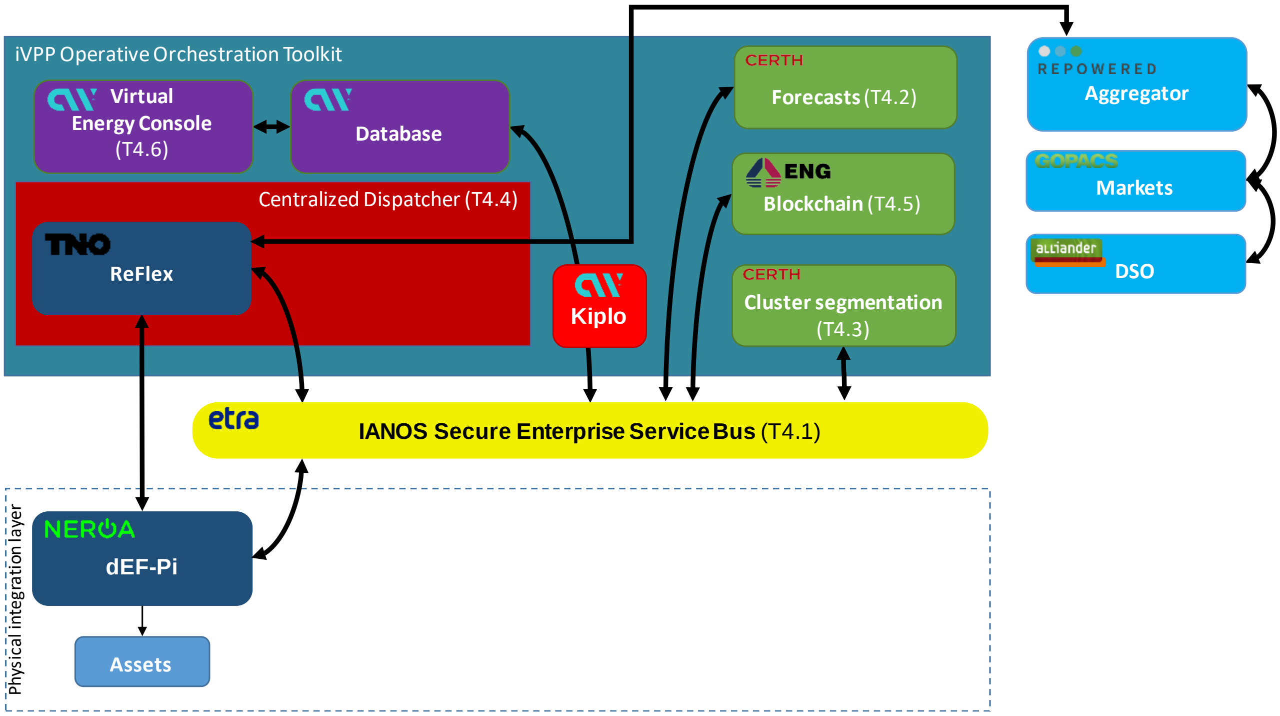

Figure 4: Deployment view for Ameland demonstration (WP5)

Within the IANOS architecture, monitoring and performance data are stored in a database, and visualized in the Virtual Energy Console. Kiplo dedicated internal modules provide this functionality for both deployments, but is not part of the Centralized Dispatcher in the Ameland Deployment view, as ReFlex contains the decision-making logic. Therefore, the Kiplo functionality is placed outside the Centralized Dispatcher block, as it is used for the integration of the ESB with the Database.

4 Centralized dispatcher: controllers

4.1 Differentiation of controllers

As described in the architecture, this project contains multiple controllers. This chapter focusses on the features of these controllers, to help follower islands to choose which of the controllers suit their specific use cases best. The chapter starts with a description of the controllers and ends with a feature comparison.

4.1.1 TNO ReFlex

Description

ReFlex is a software solution that empowers aggregators to create a powerful Virtual Power Plant (VPP). This VPP can utilize the flexibility of large quantities of (small) devices effectively for multiple purposes. Enabling the flexibility of DER assets, such as: electric

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cars, batteries and solar panels, to be utilized in both energy markets and ancillary service markets. In this way the value of flexibility can be stacked, and the profits of utilizing flexibility increased.

In order to optimize the utilization of flexibility, it needs to be known what the flexibility of the cluster is. Since there are typically too many devices of different types, it is not possible to consider each device individually. Instead, the aggregated flexibility of the cluster needs to be considered. The owner of a VPP typically wants to know how much it can ramp up or down at a certain point in time, and what the consequences are of dispatching up or down (since there can be a rebound effect for certain types of flexibility). ReFlex provides that insight.

ReFlex works with a moving planning window. Typically, ReFlex plans the energy production and consumption for every device for the coming 48 hours with a precision of 15 minute intervals (sometimes referred to as PTU’s or ISP’s). Each interval has a fixed start and end time, and the first one of the day always starts at midnight. In order to plan the energy consumption and production of each device, ReFlex needs to have knowledge about the future behavior of the devices. This typically requires forecasts of the behavior of the devices to be made.

ReFlex always has a target for the sum of the energy consumption and production of all the devices in the cluster for each interval. The flexibility of the devices can be utilized by changing the target. When the target changes, ReFlex will try to adjust the behavior of devices in cluster in such a way, that the sum of energy comes as close as possible to the target. Changing the target can also be simulated. This way, the rebound effect of dispatching flexibility (by changing the target) can be made explicit.

In addition to changing the target for the sum of energy of all devices, it is also possible to put in energy constraints for intervals for a subset of the cluster. This way, it is possible to take (local) grid congestion constraints into consideration. By placing a constraint on a subset of devices, ReFlex will do anything in its power to respect those constraints.

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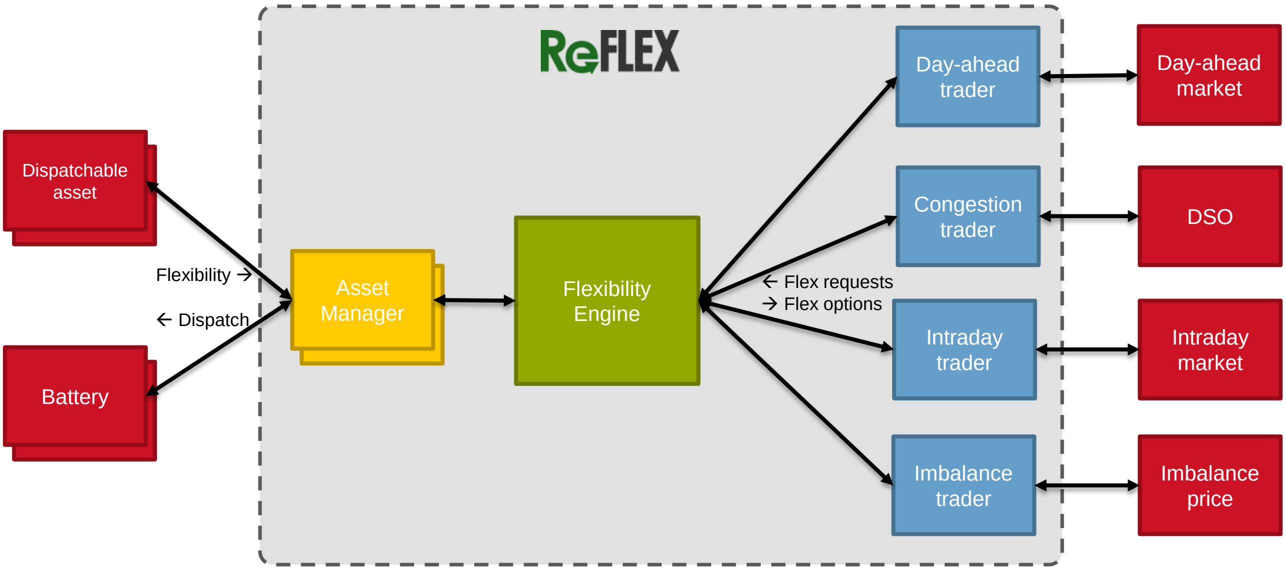

Figure 5: ReFlex high-level architecture.

Figure 5 shows the high-level architecture of ReFlex. On the right side different trader modules (blue) focussing on different markets (red) can ask the Flexibility Engine (in green) for flexibility in the cluster. ReFlex provides these trader modules with flexibility options from which the trader can decide which options matches its market best.

The Flexibility Engine is able to calculate these options through aggregating and planning the flexibility provided by the assets (such as batteries, on the left side of the figure). When an option is chosen by the trader, ReFlex incorporates this option in its plan for the next 48 hours. Based on that plan the assets are dispatched.

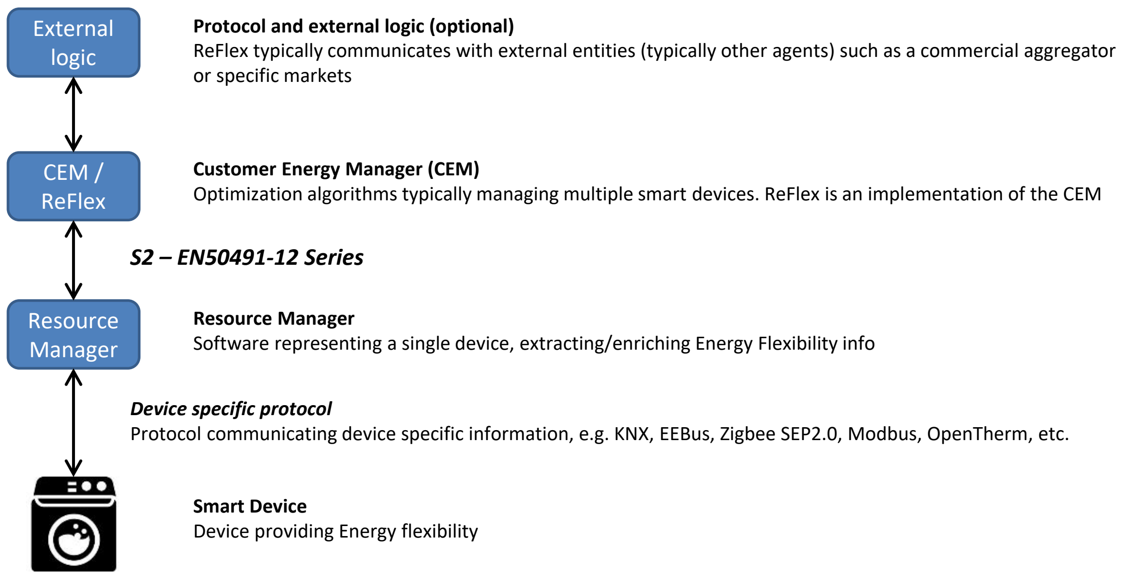

Figure 6: Integration of ReFlex with smart devices using S2 according to the European Smart Grid architecture.

The flexibility of all the assets is provided by utilizing the upcoming S2 (EN 50491-12-2) standard. That standard defines five distinctive ways to model energy flexibility for a myriad

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of assets, and is part of the European Smart Grid architecture (see Figure 6 and Appendix B). This means that, according to the S2 architecture, each device is accompanied by a Resource Manager that is able to translate low-level data (such as power or temperature measurements and setpoints) to flexibility information in S2. This means that ReFlex utilizes a standard and generic way to manage any flexible asset as long as it supports S2, without any additional effort. This allows the system to scale easily.

4.1.2 CWD Kiplo Core Platform

Description

Kiplo Core Platform is integrated into the Cleanwatts (CWD) platforms being developed with the main purposed of helping utilities, aggregators and users in the management of their energy assets and associated flexibility. By monitoring and managing accurate real-time data from demand and supply side, it allows the optimization of available energy resources using Demand Response activities, flexibility management, connection with upstream markets and the possibility to enable P2P energy markets. Kiplo Core Platform its constantly updating the inputs to dynamically optimise the global operation of the Virtual Power Plant (VPP).

At the current state of development, it can connect to a wide range of sensors and actuators (IoT devices), utilising several communication protocols, and allowing seamless third-party integration through API and web services. Kiplo Core Platform is equipped with an API that makes it possible to easily integrate external advanced services (load and RES forecasting, clustering, and storage optimization) and manage novel types of equipment (e.g., V2X chargers, heat storage). It is integrated within a global design with a tiered and service-oriented architecture, allowing an easy expansion and integration (adding new modules or services) and interoperability (upgrading or replacing some modules).

At the Terceira pilot, Kiplo Core Platform will perform the data collection and store it at the overall database, for visualization in the Virtual Energy Console. It will also serve has a communication exchange platform between the ESB and the EDA Dispatch Center, the SUNAMP heat batteries and the Cleanwatts HEMS. Using embedded Artificial Inteligent algorithms, it will also perform analysis and processing of some of the data on the use cases of Terceira Pilot. At the Centralized Dispatcher (CD) component level, besides the inputs from external components, IoT devices and energy assets, it will also have the inputs from the “Aggregation and Classification”, “Forecasting engine”, and “OptiMEMS” to consolidate the dispatching setpoints.

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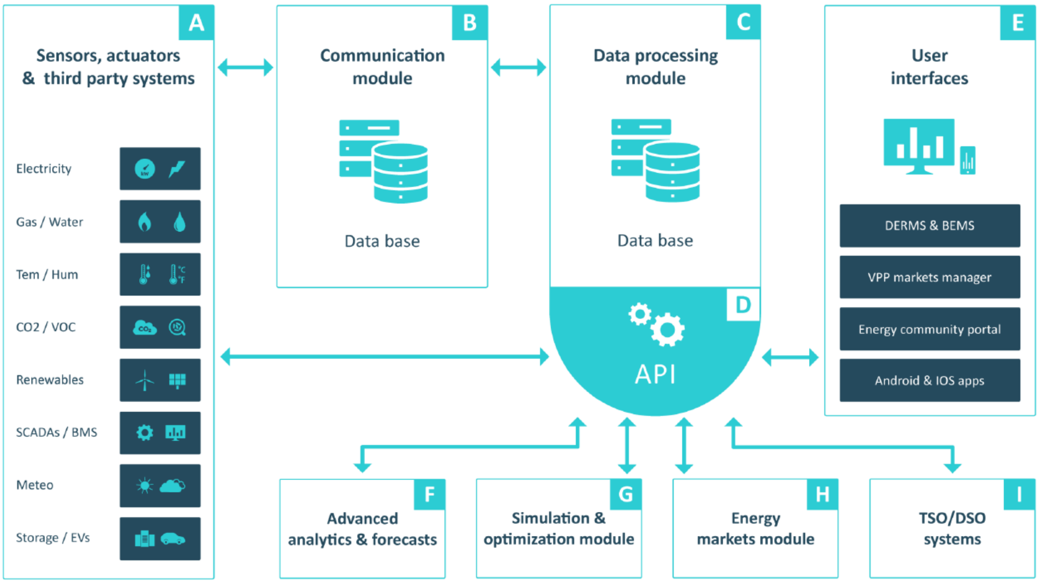
At the Ameland pilot, the Kiplo Core Platform will perform the data collection (using the ESB) and store it at the overall database, for visualization in the Virtual Energy Console.

The general platform architecture for the CWD platforms is shown on the diagram below. Kiplo Core Platform is integrated within this architecture.



4.1.3 CERTH OptiMEMS

Description

Aiming towards creating a realistic optimal scheduler, an Optimized Energy Management System (OptiMEMS) has been developed and tested for microgrids and VPPs, that includes four main components: a MILP-based optimization engine to produce day-ahead microgrid (MG) schedules, a real-time supervising tool that validates the schedule application, a machine-learning-based forecasting tool for load consumption and, a hybrid deterministic/stochastic forecasting tool for PV generation (Figure 7) [1]. The optimized scheduler solves a modified Unit Commitment (UC) problem, tailored for MGs and VPPs operating either in grid-connected or islanded mode, while its objectives can vary based on the desired use cases, i.e., from minimizing costs to maximizing reliability or resilience. Finally, a customised module is responsible for applying the optimized schedule, when allowed and for triggering its recalculation, in case of significant divergence between real load consumption, RES generation and the forecasted ones. OptiMEMS has been successfully applied upon a plethora of applications, namely microgrids (CERTH/ITI's DIH SmartHome [2], EV-based VPPs [3], distributed ESS-based residential VPPs [4] and OpenADR-compliant dynamic small and medium scale VPPs including prosumers and consumers [5].

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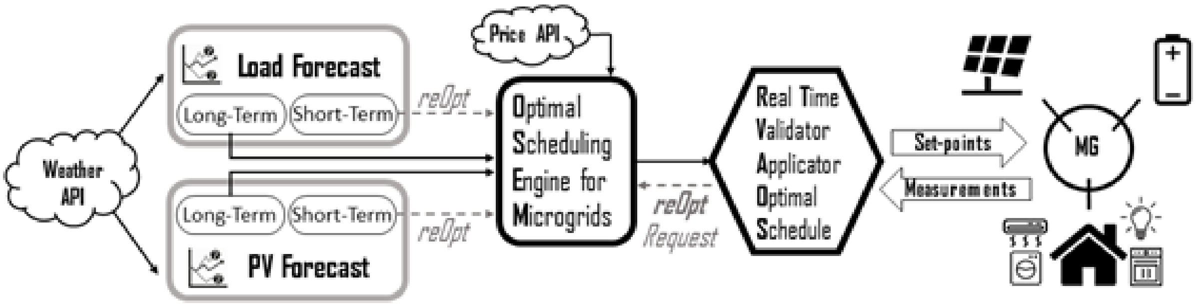

Figure 7: OptiMEMS System Architecture

In the context of OptiMEMS, one of the two critical components is the optimization module which is responsible for solving an adjusted UC problem, tailored to MG and VPP needs. The general UC is the problem of determining the optimal scheduling of electricity generation units within a power system subject to operating constraints. The basis of the proposed adjusted UC problem lies in a new concept called the Virtual Distributed Energy Resources (vDERs). Using the Passive Sign Convention, a vDER can be a power source (provider: negative power) or a power load (consumer: positive power). The accumulated output of all vDERs must satisfy the load demand in each time slot.

The formulation of vDERs follows the principles of a) splitting DERs that exhibit bidirectional energy flow into two complementary virtual ones and b) keeping unidirectional units as one vDER. Seeing the Point of Common Coupling (PCC) as a bidirectional DER and assuming a MG solemnly based on RES, ESSs (assigned index S in short) and a PCC (assigned index G for Grid), the formed vDERs that provide power are ESS Discharge and Grid Import, and the vDERs consuming power are ESS Charge and Grid Export. Regarding RES, since it is generally desired to maximize their contribution during grid-connected operation, RES can be modelled as negative loads, meaning that the forecasted RES production is subtracted (time-slot-wise) from the forecasted consumption, leading to a new artificial curve of "Actual Demand". Alternatively, if PV curtailment is desired, PVs are modelled as an additional vDER (negative power).

The optimization problem is formed as a MILP problem since all optimization expressions are linear and the optimization variables are either continuous or binary. This is considered an asset because LP/MILP problems are solved much faster than their non-linear equivalents and thus, re-running the optimization algorithm can be achieved quickly.

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4.2 Feature comparison

In the following table the features of the different controllers are compared.

Centralized Dispatcher Feature	ReFlex	Kiplo	OptiMems
Congestion management	Y	D	-
Device planning based on forecast	Y	Y	Y
Self-consumption maximization	Y	Y	Y
Day-ahead plan optimization	Y	Y	Y
Intra-day plan optimization	Y	D	Y
Market integration			
Day-ahead	D	D	Y
Intra-day	D	D	Y
DSO Congestion Management	Y	D	-
aFFR / FCR	D	D	-
Passive imbalance	-	D	-
Power quality optimization	-	-	-

Table 14: Feature comparison of the three controllers used in the iVPP in IANOS.

Y – Yes

N – Not possible now

D – Under development

The table shows that all controllers support self-consumption optimization and plan optimization, but that much of the market integration still has to be developed in IANOS.

5 Integration with IANOS modules

This chapter describes the integration of the Centralized Dispatcher with the other modules developed in WP4. At the time of writing this document the integration procedures are still work in progress and will be updated in the next version of this deliverable (M32).

5.1 IANOS Secure Enterprise Service Bus (ESB)

5.1.1 *Introduction*

The iVPP Secured Enterprise Service Bus (ESB) will be the component that will play the data transfer role, with a special focus on cyber-security aspects. The IANOS iVPP framework functionalities and energy services require the exchange and appropriate handling of data and control commands among the different system components and field devices. This number of field-level heterogeneous data flows will be intake in the iVPP by

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means of an Enterprise Service Bus. The field devices will be interfaced by means of drivers in the ESB, featuring the required communication protocols and transforming data to the common information model in the ESB. On the other hand, the different components in the VPP orchestration toolkit connects to the iVPP ESB by using gateways that adapts from the specific data model and the common information model. This model will allow IANOS to be extended and support multiple field device types, and at the same time, the intelligent agents and applications in the VPP will be able to work without worrying about the details (connectivity, data models, etc.) of the specific field devices in each pilot or scenario.

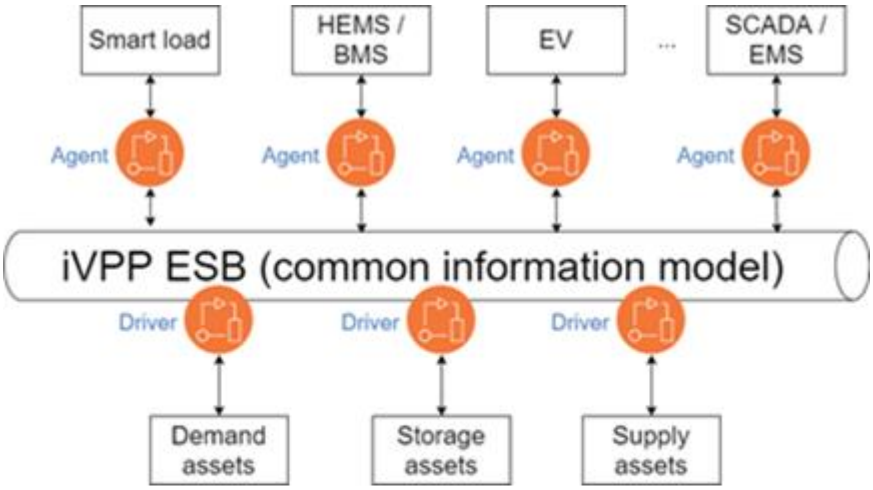

Figure 8: Common data exchange format interoperability

iVPP ESB will be based on the CITRIC smart city platform that follows the RIVER © architecture created by ETRA. RIVER is a Reactive, Interoperable, Visible, Elastic and Resilient architecture oriented to microservices and events. It is an open architecture with capacity to grow its service network, reactive because it is event-driven, interoperable because it is supported by standard protocols and agnostic models of data, visible because it is monitored in its operation, elastic because it can be scaled out and independently in each of its services and resilient because it is orchestrated and monitored to be fault tolerant. CITRIC's microservices distribution fully complies with UNE178104:2017 in its orientation towards functional layer. All microservices are scaled out using replicas and load balancers based on the needs of each installation.

CITRIC is composed of a plethora of services and modules that interact among each other and provide services. All of them are containerized, making it possible to deploy and update any architecture component in just a few minutes. Different processes can be applied to the ingested data (this is configurable):

- **Transformation:** Process to normalize the data before entering it into the platform. Transformation schemas are pre-configured for each source in the configuration

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database and are particular to each platform deployment as they must be tailored to particular data sources and how they are stored in the storage service and then served to the higher layers.

- **Security:** Every ingestion process is authenticated and authorized by a layer of security in each microservice. Each credential per token or user/password has an authorization scheme to access a subset of platform data at three levels of security: read, write, and only public attributes.
- **Storage:** If data persistence is needed, this microservice handles the storage of data when it is injected or modified. It manages the real-time database supported by an ElasticSearch Cluster.
- **Message brokering:** the information received is routed to pre-configured endpoints, allowing for a scalable architecture.

The CITRIC architecture is adapted and extended to support the functionalities required in IANOS. CITRIC platform plus the required additions will compose the iVPP ESB.

5.1.2 Required data exchange with Centralized Dispatcher

The iVPP Secured Enterprise Service Bus (ESB) will manage the data transfer role, taking into account cyber-security aspects. The IANOS iVPP framework functionalities and energy services require the exchange and appropriate handling of data and control commands among the different system components and field devices.

5.2 Forecasting

5.2.1 Introduction

IANOS iVPP Forecasting Engine is responsible for providing the necessary forecasts for all the uncertainties, namely load, PV and Wind generation and energy market, in every time horizon and spatial distribution. The component will utilize both data-driven and physical models in order to provide accurate forecasts in each case. It is separated into different submodules depending on the forecasting variable.

The methodology followed by the forecasting engine can be separated into four main steps, as seen in Figure 9. The first step consists of the acquisition of the data. The forecasting component will acquire historical consumption and generation data using the ESB, together with the necessary numerical weather predictions, also stored in the database. Additionally, Energy market data, namely day-ahead price, intra-day price, imbalance price and Frequency Containment Reserve (FCR) are retrieved from an external API. Lastly, for the load forecasting subtask, the component will receive cluster labels data from the Intelligent VPP Clusters' Segmentation module.

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The next step concerns pre-processing and cleaning of the available data. This is a vital step in most forecasting tasks in order to provide more accurate results. More specifically, the component is responsible to detect the missing values and clean or drop the possible outliers, as well as normalize the data when it is necessary.

The third step of the methodology is the training phase. Firstly, feature engineering techniques are applied to extract the necessary features for the optimal training of the models. The final features used for the training of the algorithms vary from past historical values, numerical weather predictions and temporal features to capture the season periodicity. In addition to the latter, in energy market forecasting developed for Ameland pilot island, forecasts for the aggregated load and generation for Netherlands are utilized. After the model training, the most common evaluation metrics are used to evaluate their performance. Thus, the most accurate models are found and saved, to predicted the future values.

The last step of the methodology is the real time forecasting, where the historic values of the data and the pre-trained model are loaded in order to get real time predictions.

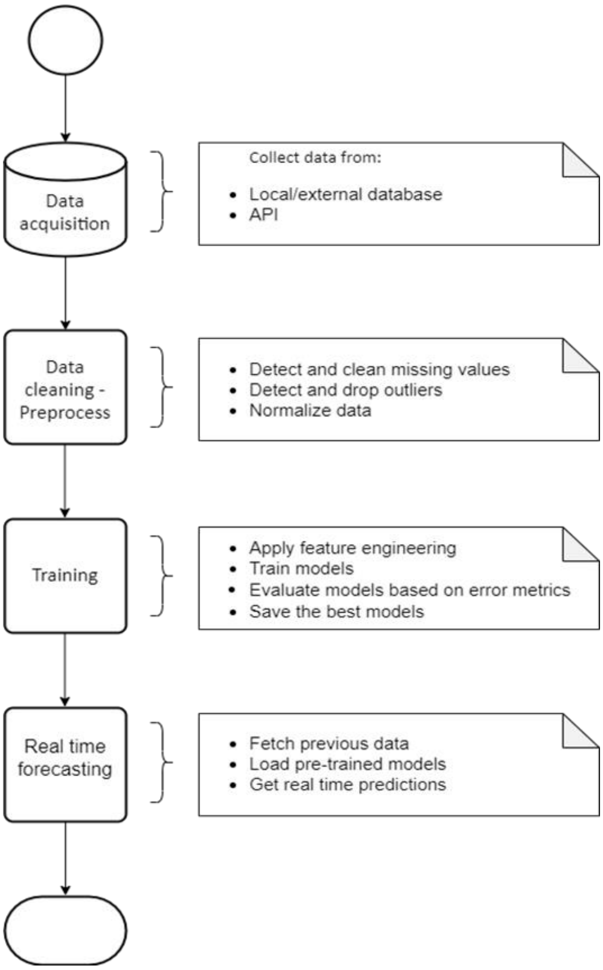

Figure 9: IANOS iVPP Forecasting Engine Methodology

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In the development of the forecasting engine the focus is set to providing accurate, fast and lightweight forecasting agents that predict the consumption, generation and price of electrical energy in the two pilot islands. Based on the analysis of IANOS project's different scenarios, two main time horizons of forecasting have been found. In the day-ahead forecast, in the start of each day, the values of the whole next day are forecasted. In the short-term forecasting the horizon, as its name suggests, corresponds to the forecasting of the next timestep.

5.2.2 Required data exchange with Centralized Dispatcher

As described previously, IANOS iVPP Forecasting Engine will receive data from the ESB, external APIs for energy market data and Aggregation and Classification module for cluster labels.

The forecasts are retrieved by the Centralized Dispatcher to optimally dispatching field-level IANOS elements and the DLT-based Transactive Logic in order to facilitate direct energy transactions in the community. The following figure presents the allocation of the Forecasting Engine into IANOS architecture component and its interaction with other modules. The allocation of the forecasting component into the IANOS project's architecture is depicted in the following diagram.

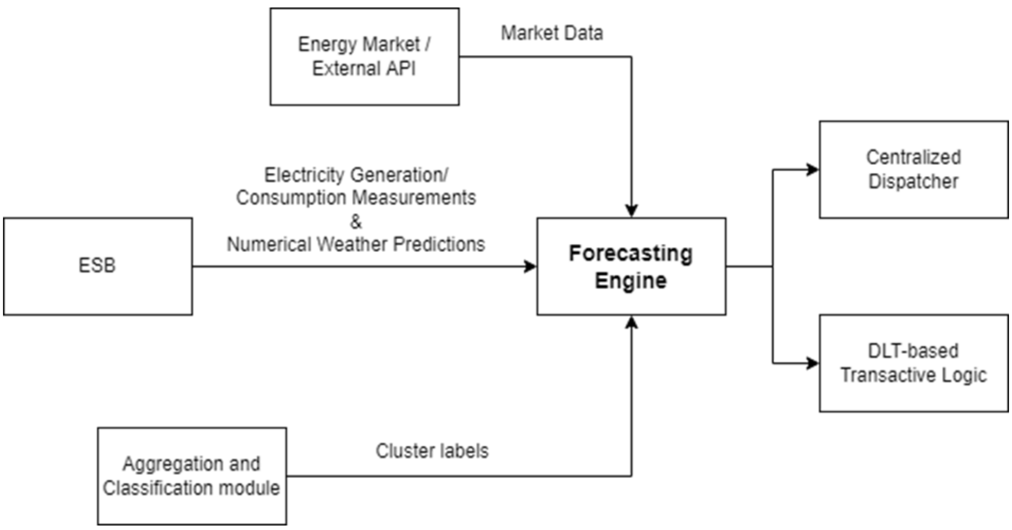

Figure 10: Allocation of the forecasting component into the IANOS project's architecture

5.3 Intelligent VPP Clusters' Segmentation

5.3.1 Introduction

The Intelligent VPP Clusters Segmentation component will be responsible for the segmentation of the stakeholder's portfolio according to certain objectives. Two main modules will be included in this module: The classification module and the clustering

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module. The clustering module will utilize data-driven methods to segment unlabelled data and create clusters based on objectives defined by the aggregator or system operator. The classification module will be used to classify new assets based on their contractual characteristics and assign them to previously extracted labels. The process that will be followed until the clustering is described in the following figure:

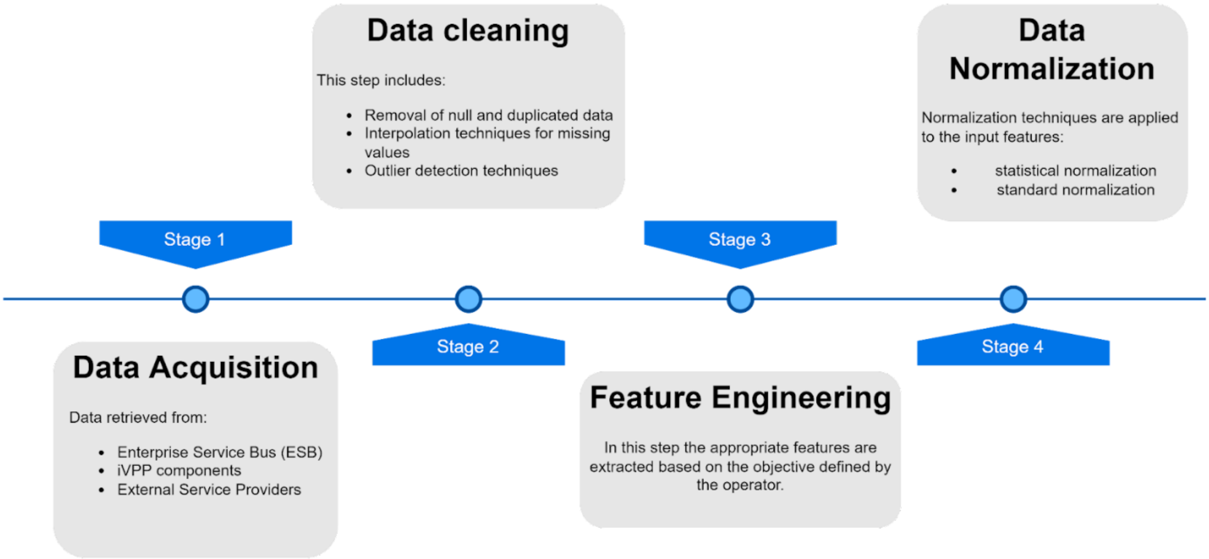

Figure 11: Clustering process.

This component will implement five basic functionalities:

- Clustering loads to assist the design of Demand Response Programs
- Clustering loads to produce insights for the portfolio of the aggregator or system operator
- Clustering loads according to their peaks
- Clustering to assist the forecasting engine
- Classification of new assets to existing labels

During clustering various machine learning methods for unsupervised learning are used and are evaluated based on their scores according to various metrics. The best scoring algorithms are selected and the final clusters are created, which are then relayed to the user and to the other VPP components.

5.3.2 Required data exchange with Centralized Dispatcher

In terms of data exchange, the intelligent VPP cluster's segmentation will not have direct communication with the centralized dispatcher. It will use the enterprise service bus (ESB) to retrieve raw data and provide the resulting clusters as labels to the forecasting engine and virtual energy console. The formed clusters will be used to train the forecasting models, and the forecasted results will be delivered to the centralized dispatcher. The

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interconnections between the intelligent VPP cluster segmentation components, the forecasting engine, and the virtual energy console are depicted in the figure below.

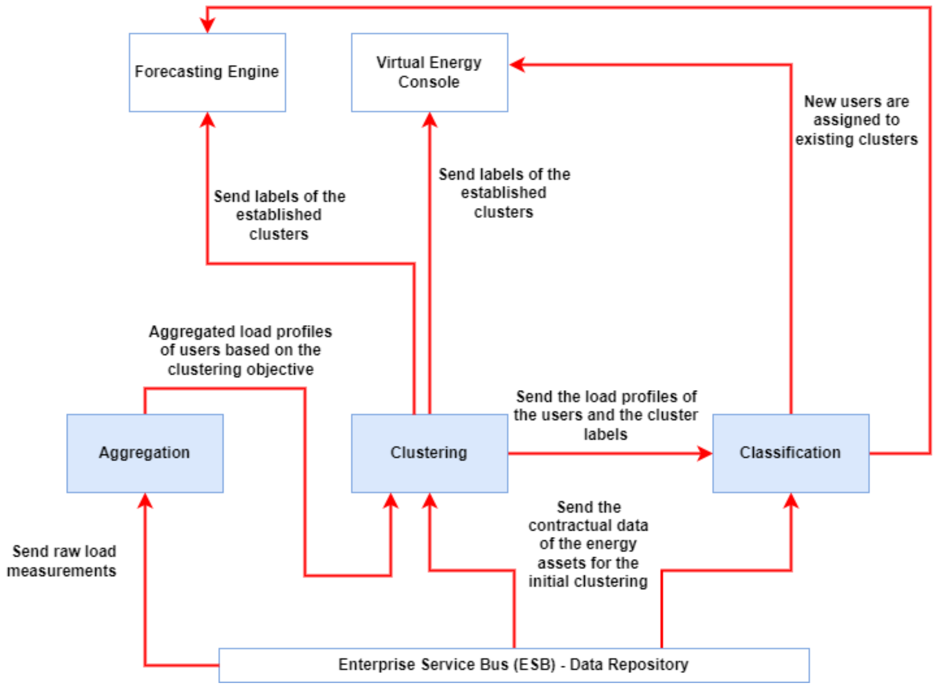

Figure 12. Interconnections between intelligent VPP cluster segmentation components and other iVPPs components.

5.4 Distributed energy transactive framework within VPP Energy Coalitions

5.4.1 *Introduction*

The Distributed energy transactive framework within VPP Energy Coalitions component is responsible for validating a P2P marketplace using blockchain and smart contracts. To avoid high costs, which would be impossible to bear, a private blockchain is used. The P2P market is divided into market time-windows, in each of them, prosumers, based on their energy production/consumption, can insert offers to sell/purchase energy. Once the market time-window is closed a market clearing price mechanism fixes the price of the energy and all the transactions, once validated, are written in blockchain by the smart contract. An example of a market window life cycle is shown in Figure 8. To enable the user to use the platform, a dashboard is provided where historical consumption/production data, all past market windows and all transactions between prosumers can be displayed and energy sell/purchase offers can be added.

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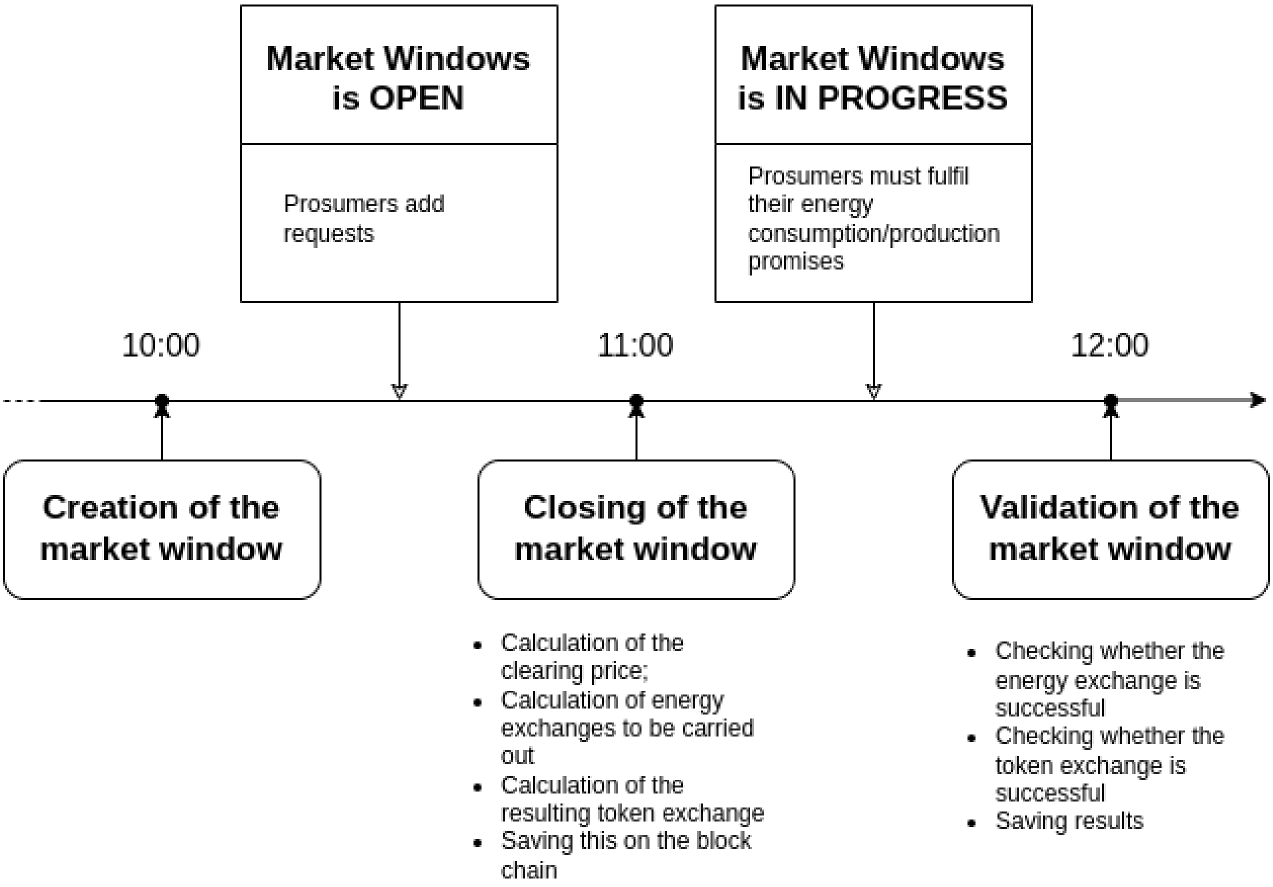

Figure 8: Life cycle of a market time-window

5.4.2 Required data exchange with Centralized Dispatcher

Regarding data exchange, Distributed energy transactive framework within VPP Energy Coalitions have not direct communication with the centralized dispatcher, but it uses the enterprise service bus (ESB) to retrieve actual consumption/production data transmitted by the smart meters and forecast data. Forecast data assists the user in identify her energy consumption/production profile and placing bids in the first phase of the market window lifecycle, when the market window is open (Figure 8). In particular, if an excess production is foreseen for the user it is convenient to add an offer of sale of energy, while if it is foreseen an excess of consumption the user should insert an offer of purchase of energy. Instead, the data transmitted by the smart meters are used in the last phase of the market window lifecycle (i.e., during validation). Whether the prosumer complies with the sales/consumption offers entered previously in the open market window step is checked in this phase. For example, if a prosumer enters an offer to sell 1kWh, it is expected that he will have an overproduction of at least 1kWh to give to the buyer. If not, the transaction cannot take

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place. In case of positive validation of the energy transaction the related value transaction is triggered.

5.5 Virtual Energy Console

5.5.1 Introduction

The Virtual Energy Console is an interoperable user-friendly monitoring console (UI - User Interface) to effectively assess energy flows for VPP operator properly manage, visualize and dispatch their energy assets. It will provide the market with a complete and innovative dashboard that will be tested and validated in real world conditions during IANOS implementation.

The Virtual Energy Console will be specially designed with the requirements of IANOS project. The dashboard will allow the VPP operator to easily access different dataset and important information in line with IANOS KPIs such as generation mix of the VPP portfolio, penetration of RES in the system and historical data. It is based on the existing CWD Kiplo platform User Interfaces (UI) that will be expanded to include the necessary functionalities associated with the intelligent VPP operations including:

- Multiple Data Fusion;
- Monitoring and Profiling;
- Aggregation and Classification.

In relation with them the Virtual Energy Console will be designed to embrace relevant advances in relation with the various services to be offered. It will use innovative visualization and visual analytics methods and tools, to provide the operator an intuitive environment, where it can quantitatively assess both the current operational capacity and running VPP operations.

The Virtual Energy Console will include necessary innovations on visual and data analytics, enabling the dynamic connection of different datasets with several types of visualization, so that user selection in one visualization feature can have a direct impact on the others. Indicative information of-value, to be visualized through this component will entail

- composition summary (mix) of VPP portfolio of units;
- monitoring of dispatchable vs vRES installed capacity;
- actuation of energy assets;
- a diagnostics history.

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5.5.2 Required data exchange with Centralized Dispatcher

In terms of data exchange and communication with the Centralized Dispatcher, the Virtual Energy Console will exchange information and setpoints using the Kiplo Core Platform that will use the ESB interface.

The Virtual Energy Console will mainly be a User Interface for visualization purposes that will feed from the Kiplo Database, that in turn will have to collect and store data from the different CD components, like for example:

i) Forecasting Engine: to show the forecasting data in graphs;
ii) Aggregation and Classification: aggregation/classification data, clustering;
iii) optiMEMS: setpoints for the device operation;
iv) Kilo Core Platform database: monitoring data from all energy assets

6 Conclusions and next steps

This deliverable has described the requirements and architecture of the Centralized Dispatcher, based on the IANOS use cases. The Centralized Dispatcher is part of the IANOS iVPP Operative Orchestration Toolkit (iVPP) that contains functionality to provide energy flexibility services and foster island self-consumption.

The Centralized Dispatcher (CD) contains the main decision logic to create an optimal dispatch of all the assets that are part of the span of control of the IANOS iVPP. This first version of the deliverable is not complete yet. The detailed analysis of the use cases also required an analysis of the devices that are part of the use case, in order to assess their ability to be monitored and/or controlled.

This is of great importance because without the ability to control devices there is not much to decide by the Centralized Dispatcher. This analysis will continue the upcoming months, as more information of the devices in the use cases will become available and will be reflected in the second version of this deliverable.

For each use case its CD goal is extracted and analysed. In some cases, goals of different use cases can conflict with each other, especially when the same devices belong to different use cases with different goals. In the demonstration work packages (WP5 & WP6) these issues will be addressed further and choices made there will also be reflected in the second version of this deliverable.

The CD's decision-making logic is provided by three controllers. For each pilot a deployment architecture is developed that matches the partners that are active in those pilots.

Furthermore, it provides an analysis of the features of the different controllers, such that follower islands can make a concise decision what controller to choose in their deployment. This overview will be further detailed in the next version by mapping the features on the use cases.

Additionally, this deliverable includes an analysis on how other IANOS modules will provide information to the CD in order to reach its goals as defined by the use cases. This is still high level and is input for the tasks on the overall IANOS architecture (T2.5) and the secure Enterprise Service Bus (T4.1).

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Appendix A: S2 interface (EN 50491-12-2)

This appendix gives an overview of the S2 interface that is utilized at Ameland to communicate energy flexibility of devices.

This S2 interface follows the European Smart-Grid architecture, as defined during Mandate M/490 and EN 50491-12-2. This is depicted in the figure below:

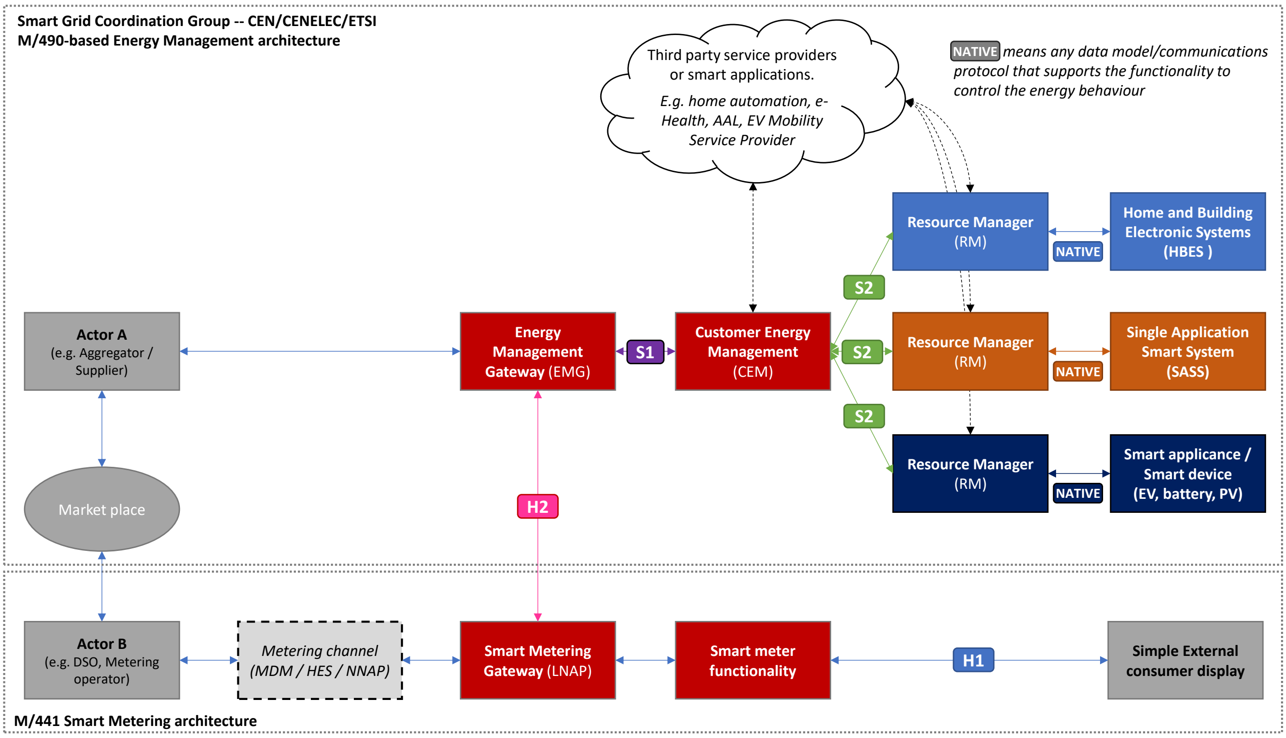

Figure 9: Smart-Grid Coordination Group architecture, which depicts the role of the S2 interface (in green), between the CEM and the Resource Manager.

A.1 Design philosophy

The design philosophy of the S2 interface is to divide the energy management responsibilities between the CEM and the resource manager. The Resource Manager describes the 'technical' flexibility capabilities and constraints, whereas the CEM focuses on how to utilize the value of that flexibility by considering incentive schemes for example.

It is not possible to create an exhaustive list of all possible smart devices and all possible CEM strategies for the expected lifetime of the S2 specification, let alone all possible combinations of devices and CEMs. For this reason, the S2 interface supports a clear separation of concerns between devices and CEMs by focusing on a generic description of energy flexibility. The flexibility capabilities that smart devices provide can be mapped onto this generic description of flexibility, while it also does not impose any limitations on CEM algorithms to exploit this flexibility in a specific way.

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A.2 S2 data models

There are five control types that can be used by the Resource Manager to describe the energy flexibility that a device has to offer. These control types are chosen in such a way that they cover all the flexibility options that can be found in smart devices.

Control Type	Description	Example
Power Envelope Based Control	is used for devices that can be influenced to use a minimum and/or maximum amount of power over time. So the CEM cannot control the amount of power produced or consumed by the device directly, but it can dictate power limits, which can change over time.	PV panels, EV (charge only)
Power Profile Based Control	typical for devices that perform a task (with a clear start and end) with a corresponding power profile that is known or can be predicted. Their main flexibility comes from the ability to change the start time of that power profile. Flexibility can also come from pausing the power profile or providing a small number of alternative power profiles for the CEM to choose from.	White goods (Washing machine, dryer)
Operation Mode Based Control	has the possibility to control the amount of power they produce or consume, without significant effects on their future flexibility options. These devices are modelled as a state machine, where each state (referred to as an operation mode) has an energy production or consumption associated with it.	Diesel generators, Variable electric resistors
Fill-Rate Based Control	can be used for devices that have the ability to store or buffer energy. How energy is stored or buffered does not matter, as long as there is a means to measure how full the storage or buffer is.	Storage, Battery, Water buffer, EV (IEC 15118)
Demand Driven Based Control	can be used for systems that are flexible in the type of energy carrier they use but are not capable of buffering or storing energy (in that case Fill Rate Based Control should be used).	Hybrid Heat pump

A Resource Manager may support multiple control types. Charging of an EV for instance, may be controlled by Power Profile-Based Control or Fill Rate-Based Control. In this case, the CEM decides which one to use. It is not allowed to mix different control types at the same time, but different control types may be used sequentially. A Resource Manager will only be controlled by one CEM at a time.

Power Profile-based control (PPBC)

The power profile-based control type is typical for devices that perform a function with a corresponding power profile that is known or can be predicted beforehand.

Their main flexibility comes from the ability to change the start time of that power profile.

White goods, such as a washing machine with a delayed start option, are good examples of this category.

A consumer fills the washing machine with dirty clothes, selects a program and chooses the final time by which this program should be finished.

The CEM can then decide what the best possible start time is, giving its optimization objectives.

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Power Envelope-based control (PEBC)

The power envelope-based control is used for devices that can be influenced to use a minimum and/or maximum amount of power over time. So the CEM cannot control the amount of power produced or consumed by the device directly, but it can dictate power limits, which can change over time.

A typical example is curtailing solar panels. The amount of power produced by the inverter of a solar panel cannot be controlled; this directly depends on the amount of solar irradiation. However, in some cases it might be desirable for the inverter to produce less electricity (e.g., due to congestion in the power grid). In this case the CEM can provide a PowerEnvelope, which for different time blocks provides a minimum

and a maximum amount of power the inverter is allowed to produce.

Another example is charging electric vehicle. Although the control type *Fill Rate Based Control* is much more desirable for charging electric vehicles (since it gives the CEM more information, so it can do better optimizations with more value to the power grid and the owner of the electric vehicle, e.g. using IEC 15118), in some cases there is not enough information available (e.g. charging with IEC 61851 misses SoC information) and the Power Envelope Based Control provides an alternative.

Operation Mode-based control (OMBC)

Devices that fall within this control type have the possibility to control the amount of power they produce or consume, without significant effects on their future flexibility options.

Typical examples for this control type are diesel generators and variable electric resistors. Such devices are often useful for balancing microgrids.

Operation mode devices offer a lot of flexibility; they can assume a range of power levels at almost arbitrary moments in time. When this type of flexibility would be modelled with power profiles, as used for power profile-based control, the number of possible permutations would rapidly grow beyond practical limits.

To avoid such issues, the operation mode control type is modelled as a state machine. A resource manager can declare multiple operation modes for a device. An operation mode is a mode/state that a device can find itself in, that is associated with a specific power value. For example, a diesel generator can have three operation modes: one for being off, one for running at reduced power and one for running at full power. The \`off\` operation mode has a power value of 0 W associated with it, the \`reduced power\` operation mode has a power value of −1 800 W (a negative value denotes production), and the \`full power\` operation mode has a power value of −3 000 W.

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Fill rate-based control (FRBC)

The fill rate-based control type can be used for devices that have the ability to store or buffer energy.

How energy is stored or buffered does not matter, as long as there is a means to measure how full the storage or buffer is.

There are many examples of devices that can store or buffer energy. Stationary batteries and electric vehicles are examples of devices that store energy in batteries. Heating devices such as CHPs, (hybrid) heat pumps or boilers can buffer energy in a dedicated heat buffer (typically a thermally insulated water tank), but a room with an allowable bandwidth for the temperature can also be used as a buffer.

Finally, there are also devices that produce cold, like air conditioners, fridges and freezers. Just like heat, cold can be buffered. There are even more ways to buffer or store energy imaginable, such as storing energy in the form of hydrogen, air pressure, water pressure or angular momentum.

The main component of this control type is the storage itself. A device shall be able to inform the CEM about its fill level, a measure of how full the storage is, and the lower and upper boundaries that the fill level should remain within. Although the fill level typically has a physical unit associated with it, it is not relevant for energy management algorithms to know which unit is being used.

For a thermal buffer that stores hot tap water for example, the fill level could be the temperature of the water expressed in degrees Celsius. The acceptable boundaries in that case would be a lower boundary of 15 °C and upper boundary of 85 °C.

There can be several processes that have an influence on the fill level; these processes can be modelled in this control type. First of all, a storage can leak; a process that typically reduces the fill level. For a thermal buffer, dissipation of heat gradually reduces the temperature. Since the rate of leakage typically depends on the fill level (a thermal buffer might leak faster if the water has a temperature of 75 °C than when the water has a temperature of 45 °C), the rate of leakage can be expressed in the form of a function of the fill level.

There are also processes that could consume energy from the storage. For example, when hot tap water is consumed, the fill level in the storage will become lower.

When a Resource Manager is capable of forecasting this, it is able to provide the CEM with a forecast of the usage of the storage. Finally, some storage devices might have a target for the fill level for a certain point in time. This can for example be the room temperature in

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the morning, or a target state of charge for a charging electric vehicle that should be reached just before the daily commute to work. By providing this target to the CEM, the CEM is able to figure out the most optimal path towards this target.

Besides the storage itself, there are also actuators that influence the fill level of the storage. For example, an electric boiler has an actuator that consumes electricity, and increases the fill level of the storage. Storage devices can also have multiple actuators associated with them. For example, a hybrid heat pump typically has an actuator that consumes electricity to increase the fill level, but also an actuator which consumes natural gas to increase the fill level.

Demand driven-based control (DDBD)

Demand Driven Based Control can be used for systems that are flexible in the type of energy carrier they use but are not capable of buffering or storing energy (in that case Fill Rate Based Control should be used). A typical example is a hybrid heat pump, that generates heat using either electricity (using a heat pump)

or natural gas (using a gas boiler), but doesn't have a thermal buffer. The hybrid heat pump shall deliver a given amount of heat, but can still decide whether to generate this heat using electricity or natural gas. Typically, such systems favour the heat pump, but use the gas boiler in case the heat demand cannot be

fulfilled by the heat pump alone or when there is a shortage of capacity in the electricity grid. Similar to the Fill Rate Based Control, Demand Driven Based Control has the concept of multiple actuators that contain Operation Model, Transitions and Timers.

In addition, the Resource Manager informs the CEM of the present rate of demand. This is a number that indicates what needs to be produced (in the previous example this was heat), but what exactly needs to be produced is not made explicit to the CEM.

When capable, the Resource Manager can also provide a forecast of the average rate of demand in the near future; this is expressed as single value and not as a range.

A.3 More information

For more information, read the specification document of EN 50491-12-2 available through your national standardisation body. The architecture is described in more detail in EN 50491-12-1.

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