IANOS

SUSTAINABLE SOLUTIONS
for islands' decarbonisation

D5.3

Ameland's use cases preliminary iVPP integration tests (T5.1)

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Executive Summary

This deliverable, D5.3, describes the preliminary intelligent Virtual Power Plant (iVPP) integration tests and results on Ameland, which represents an important milestone on the route towards a fully operational deployment of the iVPP value chain.

The document first describes the details of the most important components that are involved in the iVPP value chain:

1. The company Repowered which fulfils the aggregator role, and the energy markets it is targeting as the aggregator
2. The Reflex (software) platform which implements the intelligence of the iVPP.
3. The smart energy assets that provide the flexibility. These assets receive instructions from ReFlex..

The interaction between Repowered and the Reflex platform is handled by the Reflex API. This API allows Repowered to set certain targets for the optimization performed by Reflex. For the communication between Reflex and smart assets the European energy flexibility standard (EN50491-12-2), also known as the S2 protocol, is used which allows ReFlex to send instructions to the smart energy assets and by doing so, ReFlex is able to execute its optimized plan.

Scenarios have been defined to test the integration between all of the components mentioned above. These tests had been planned to be conducted in TNO's HESI lab. The results of these tests have also been described in detail in this deliverable.

The main outcome of these tests show the successful integration between the ReFlex platform and Repowered software. The test results also show that ReFlex is able to send instructions to the smart energy asset. Although the tests were performed in a simulation setting, they provide a good indication of physical implementation in the respective use cases later in the project.

This is a very promising result towards a full deployment later in the IANOS project. Next steps are to perform further tests that will include the related asset-managing hardware and to advance the functionality of the individual components themselves.

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Abbreviations

BRP	Balancing Responsible Party
BSP	Balancing Service Provider
CEM	Customer Energy Manager
CoP	Coefficient of Performance
CSP	Capacity Service Provider
DDBC	Demand-driven-based-control
dEF-Pi	Distributed Energy Flexibility Platform & Interface
DSM	Demand Side Management
DSO	Distribution System Operator
EMS	Energy Management System
ETPA	Energy Trading Platform Amsterdam
EV	Electric Vehicle
HBES	Home and Building Electronic System
HVAC	Heating, ventilation and air-conditioning
iVPP	Intelligent Virtual Power Plant
PV	Photovoltaic
SASS	Singe Application Smart System
TSO	Transmission System Operator
VPS	Virtual Private Server

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1 Introduction

1.1 Purpose and Scope

The iVPP is one of the core components of the IANOS project, both on Terceira and on Ameland. That is why it is very important to test the correct functioning of the iVPP in the lab in an early stage to prevent problems during the roll-out in the field later.

This D5.3 deliverable describes the preliminary iVPP testing for Ameland and presents the test results. It not only focuses on the correct functioning of the iVPP itself but also on the correct integration with the other components in the iVPP value chain.

1.2 Relation to other deliverables

There are relations with T5.2 (Deployment Plan and Risk Management), T5.3 (System Integration, Implementation & Commissioning), and T5.4 (Use Case operation, optimization, and performance monitoring). Furthermore, this deliverable connects to the functional requirements defined in WP2 and the preliminary testing of iVPP decision making intelligence from WP4. Finally, there is also an important relation with the D6.3 deliverable for Terceira as it is the Terceira counterpart of these integration tests.

1.3 Structure

The deliverable is structured into two main parts. The first part, which can be found in chapter 2 (Ameland iVPP Value Chain), focuses on the components and interfaces which were tested, linked to the Ameland use cases as defined in the IANOS project. Amongst other things, an overview is provided of GOPACS and the role within energy markets as well as exploring its suitability of connecting to a marketplace that facilitates GOPACS trading. Following are sections on SolarFlex, ReFlex, dEF-Pi and hybrid heat pump (HHP).

The second part is found in chapter 3 (iVPP integration testing) and focuses on test scenarios and results, including an overview of elements that were excluded from testing. The test scenarios that are described show the interaction between the different components of the iVPP value chain in great detail.

This deliverable finishes off with the conclusions and next steps which are presented in chapter 4.

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2 Ameland iVPP Value Chain

2.1 Overview

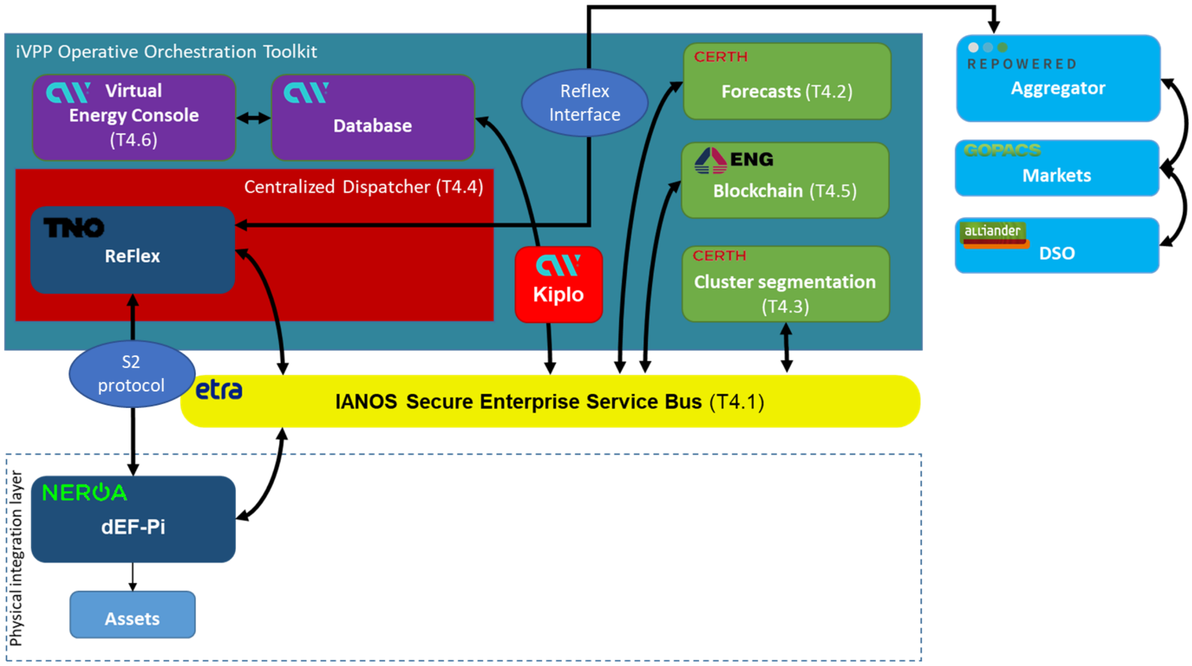

Figure 1: Overview of the complete iVPP value chain on Ameland

Figure 1 shows an overview of the iVPP value chain on Ameland. For the preliminary iVPP integration testing that is the subject of this deliverable the following components are involved:

- Aggregator. The aggregator in the case of Ameland is Repowered.
- Reflex interface. The Reflex platform is at the core of the iVPP on Ameland, this interface/API is allowing Repowered to interact with Reflex.
- ReFlex. This is the software that implements the intelligence of the Ameland iVPP.
- S2 protocol. The S2 protocol is being used to communicate with the smart assets that provide energy flexibility.
- dEF-Pi. The dEF-Pi platform unlocks the smart assets and translates proprietary protocols of smart assets into the S2 protocol which allows communications with ReFlex.
- Assets. Ultimately the assets provide the energy flexibility that is exploited throughout the iVPP value chain. In the case of this preliminary test the hybrid heat pump is used to represent the smart assets.

The components that were identified above will be explained in more detail in the following sections.

2.2 Description of components and interfaces

2.2.1 *Aggregator and Markets*

Repowered, within its role as aggregator, integrates the various energy markets and ReFlex allowing the iVPP to optimize the cluster of assets for those markets. In the Ameland case, the first focus is on interaction with the GOPACS congestion market [1] and the EPEX-day-ahead market [2].

The GOPACS market is a relatively new initiative where TSOs and DSOs can mitigate congestion over specific lines by re-dispatching production or consumption from one location to another. To achieve this, market

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parties can place intraday energy bids with a specific location tag. If a TSO or DSO wants to mitigate congestion, it can purchase one of these bids in one area and purchase the opposite order in the other area. This way the overall production and consumption stay the same and the TSO or DSO does not hold a net position. The location of production and consumption has shifted however, and this mitigates congestion over specific points. The GOPACS initiative can be perceived as a specific type of intraday trading. Currently, access to the GOPACS platform is only provided via the ETPA marketplace. However, in 2023, GOPACS trading will also be possible on the EPEX-market place.

Since the GOPACS initiative is quite new, Repowered is exploring the most suitable method of connecting to a marketplace that facilitates GOPACS trading. Repowered currently does its trading on the Nord Pool market with Kinect as an intermediary and will, within the IANOS project, investigate the best alternative marketplace to allow for GOPACS trading.

Repowered can fulfil the roles of Balancing Service Provider (BSP), and can externalize the role of Balancing Responsible Party (BRP) to a partner, like Kinect.
With these official roles, Repowered can operate on the Day-Ahead market, the intraday-market and use the passive balancing system the Netherlands uses, to make last-minute balancing adjustments to the asset portfolio, to balance the grid and obtain revenue for the asset owners. The specific division of roles is being investigated together with the local cooperative, who also want to play a role in the ecosystem, and who have the best connection with the asset owners on the island. Regardless of who takes on the official roles, Repowered will facilitate the technical connection between the markets, the optimal asset dispatch based on market conditions, and the communication with TNO and the ReFlex platform to investigate the capabilities the asset portfolio has to act on the different markets. Repowered will do this either as a facilitator only or as a BSP, CSP or any other suitable market role.

To achieve the optimal dispatch, Repowered has developed in-house algorithms to operate on the Day-Ahead market, the passive imbalance market and different balancing markets. Within IANOS, Repowered will be working with ReFlex to combine these market-based algorithms with the capabilities of the assets. The connection to ReFlex will be performed via the ReFlex API. Repowered will call this API to find out the status of the devices, using a web platform called SolarFlex, based on Python, running in the cloud (with the provider being Digital Ocean). After ingesting the data from ReFlex, Repowered will use its in-house algorithms, together with market data provided by ENTSOE-Transparency Platform, TenneT and the market access provider, which will likely be Kinect, to determine an optimal dispatch strategy that can be carried out physically. It will verify the feasibility by calling the ReFlex API, sending it the developed strategy and analysing the response.

Repowered will store dispatch and trading data for analysis, validation and performance monitoring. For the data storage InfluxDB and PostgreSQL databases will be used.

2.2.2 ReFlex API

The ReFlex API is used by Repowered to send a target to the Reflex platform. This target can take the form of an energy target profile (how much energy should the cluster consume or produce) or a tariff profile (how expensive is energy) that should be optimized on. It is also possible to indicate congestion points within the grid. Reflex will look at the flexible assets in its cluster and calculate a plan that matches the target as closely as possible. This plan is returned to Repowered through the API.

When Repowered is happy with the outcome of the plan they can use the Reflex API to assign it. Once a plan is assigned, Reflex will execute it by sending corresponding instructions to the flexible assets via the S2 protocol.

2.2.3 ReFlex

The iVPP on Ameland will be implemented using the ReFlex technology. The ReFlex platform facilitates the aggregator (which on Ameland is Repowered) in optimizing the value of the flexibility resources in its portfolio. Normally this would involve a lot of (manual) analysis on the side of the aggregator which is automated by ReFlex. ReFlex enables an aggregator to find a suitable plan by allowing the aggregator to test a variety of scenarios during the planning phase and learn how the flexible assets in its portfolio will react in those scenarios.

The flexibility of the ReFlex platform helps to support the variety of use cases that will be demonstrated on Ameland.

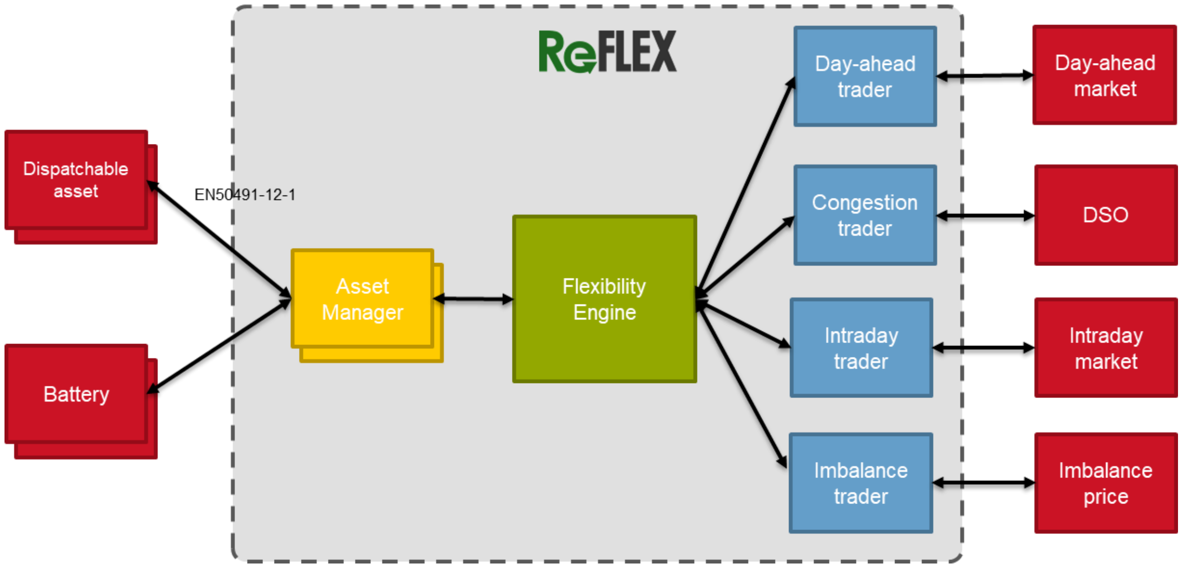

Figure 2: Overview of the Reflex platform

The ReFlex platform is depicted in Figure 2 and consists of the following components: Asset Managers, the Flexibility Engine and Traders.

- The Asset Managers receive the flexibility information from all connected flexible assets in the portfolio of the aggregator, such as batteries, EV's, heat pumps, etc. The protocol that is being used to communicate the flexibility information is S2 which is defined in the European prEN50491-12-2 standard. There is no specific requirement for the frequency with which the flexibility information is exchanged. It is up to the flexible asset to decide when updated information will be sent to the asset manager.
- The Flexibility Engine is used to determine the behaviour of the entire cluster. It is able to consider a wide range of scenarios in order to determine the most optimal one for a given optimization objective or a combination of multiple objectives. It uses the flexibility of the assets as input, but also the constraints of different markets that might take advantage of the available flexibility.

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- The traders communicate their optimization objective/constraints to the Flexibility Engine so that it can take these into account while trying to find the most optimal solution. There is a different trader within Reflex for each market that the aggregator is active on.

2.2.4 S2 Protocol (EN50491-12-2)

The EN 50491-12-2 [3] architecture focuses on the premises side of the smart grid and is mainly concerned with the communication between smart devices and the Customer Energy Manager (CEM). Figure 3 provides a logical view of the components that can be found at the premises side.

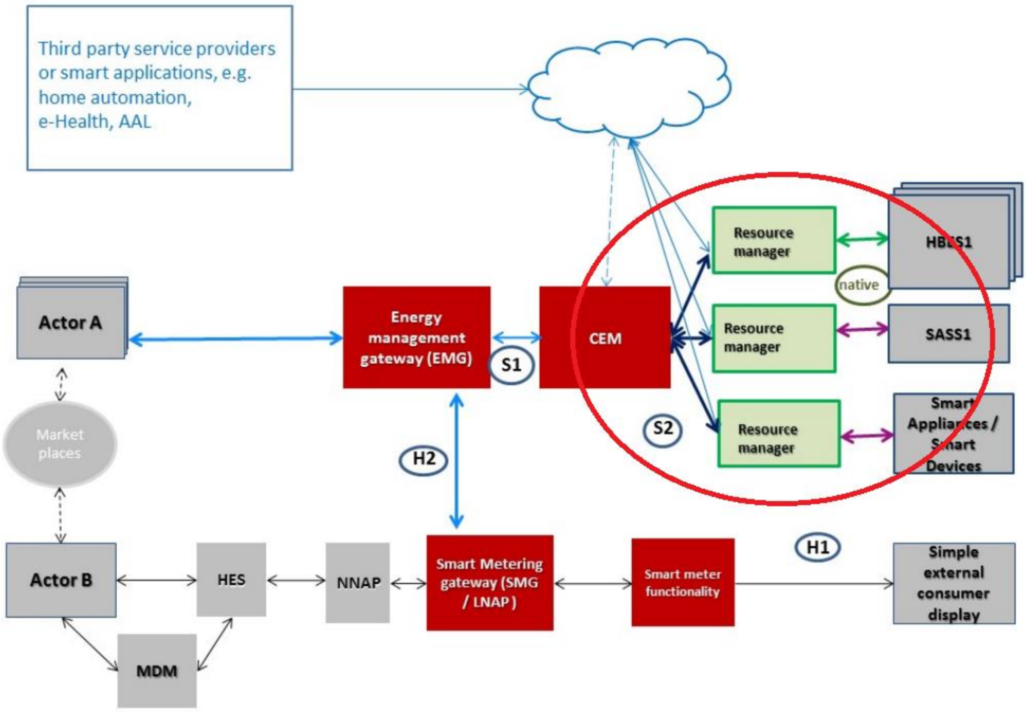

Figure 3: Logical view of a premises smart grid system

The logical view shows all the relevant smart grid systems on the premises, the red circle outlines the scope of CEN-CENELEC's 50491-12 standard series. Within this standard series the so called S2 interface is being specified.

The S2 interface is used to communicate the energy flexibility of smart devices to the Customer Energy Manager (CEM). The CEM also uses S2 to send instructions to smart devices to exploit their flexibility in a specific way. The components involved in the S2 communication are described below.

- Smart Devices. Smart Devices and Smart Appliances can offer energy flexibility by deviating from their normal consumption/production pattern. These devices can be controlled externally so that they can be integrated into the premises smart grid system. These devices are very diverse and perform a wide range of functions within a home or a building, including whitegoods, PV and HVAC. In Figure 3 this is reflected by terms SASS, Smart Appliances, Smart Devices and HBES all referring to various types of smart devices and appliences. To elaborate, the Home and Building Electronic System (HBES) are systems that are used in home or building automation and perform functions such as switching, open and closed loop control. Single Application Smart System (SASS) are systems that are composed of a group of devices that work together for a single application. Think of a HVAC system that is composed of components such as fans, chillers, radiators etc. Controlling a single component within such a system for flexibility purpose might disrupt the correct functioning of the complete system. Therefore, the entire system with all of its components should be treated as a single source of flexibility.

As is apparent these devices are very diverse in their functionality. This also goes for the protocols that are used to control these devices externally. Examples of such (IoT) protocols are KNX, EEBUS/SPINE, ModBus, Zigbee, Bluetooth, WiFi, Z-Wave, but also proprietary protocols. The same holds for the data models/parameters that are used. It is virtually impossible for a Customer Energy Manager to be aware of and support all possible permutations of functionality, protocols and data models. This is where the Resource Manager and the S2 interface come in.

- Resource Manager. The Resource Manager is an intermediary logical component that on one side communicates with the smart devices using its native protocol and data model and understands the functionality that the device performs. On the other side it communicates the flexibility options of the devices to the Customer Energy Manager (CEM). The CEM is only interested in the energy flexibility that the device has to offer. It is not interested in all available detailed device parameters and protocols as such detailed information is unnecessary for the purposes of utilizing the flexibility.

  The Resource Manager translates the low-level device information into more high-level information on the energy flexibility that is offered to the CEM via the S2 interface. This is not a straightforward mapping; information that is not relevant for energy flexibility needs to be filtered out while other information needs to be enriched to make it relevant for energy flexibility. Take a thermal buffer for example; a Resource Manager will have to understand what the capacity of that buffer is and how fast it can be heated. It will send this flexibility information in the form of an S2 message to the CEM. The Resource Manager will also receive instructions over S2 from the CEM to use the flexibility in a particular way.

  In providing flexibility to the CEM, the Resource Manager will also take user comfort as well as the operational boundaries/safety margins of the device into account. These aspects will also be checked if the Resource Manager receives an instruction from the CEM. If user comfort or the operational boundaries/safety margins are compromised by executing a CEM instruction it is the responsibility of the Resource Manager to reject that instruction.

- Customer Energy Manager. The CEM takes into account the flexibility that is being provided by all Resource Managers on the premises. Based on its optimization objectives and additional external information/incentives, it will decide how to use that flexibility so that its objectives will be met as closely as possible. Examples of CEM objectives could be to optimize on dynamic energy tariffs, promote self-consumption as much as possible or to help the DSO alleviate congestion. After the CEM decided on how to use the flexibility, it will send an instruction to the Resource Managers over S2.

  By utilizing S2 the innerworkings of the devices are hidden from the CEM by the Resource Manager and the CEM can focus on its core business of managing energy flexibility. This enables the CEM to connect to a wide variety of devices with little effort thus promoting interoperability.

In the Ameland iVPP integration test the following roles are assumed:

- Customer Energy Manager (CEM): ReFlex
- Resource Manager: dEF-Pi
- Smart Device: A single hybrid heat pump representing an arbitrary smart device. At Ameland the controlled asset consist mainly of hybrid heat pumps which makes this a prime choice for the integration test.

2.2.5 dEF-Pi

The Distributed Energy Flexibility Platform & Interface (dEF-Pi) aims to create an interoperable platform that is able to connect to a variety of appliances/assets and support a host of Demand Side Management (DSM) approaches. As it is so interoperable it decouples the energy management system (EMS) hardware from the service that controls it dEF-Pi allows the owner of the asset and EMS to switch to another service without

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changing both the hardware and the software except for configuring the platform to use the new service. This decoupling has the other effect of making it easier for service providers to introduce new services, as they do not have to provide service-specific EMS hardware to their customers.

The goal of dEF-Pi is to provide a runtime environment that makes it possible to quickly design and implement services dealing with energy management. Therefore a number of (non)functional requirements are important:

- Scalability on both the number of appliances / assets controlled and energy management services that communicate with dEF-Pi to instruct the assets.
- Robustness so unresponsive assets are handled correctly and errors are isolated so they do not crash other assets or components of the dEF-Pi platform.
- Security so assets or the platform are not hacked by malicious actors.

In this particular setup dEF-Pi is used to host the Resource Manager for the hybrid heat pump and will facilitate the communication to ReFlex.

2.2.6 Hybrid heat pump

Figure 4: The hybrid heat pump setup in the HESI lab (Elga heat pump on the left and gas boiler on the right)

The hybrid heat pump is a combination of a heat pump and a conventional gas boiler. The default behaviour of the hybrid heat pump is to use the heat pump as much as possible to fulfil the heat demand of a house. The gas boiler will only be switched on to support the heat pump when the heat demand exceeds the maximum thermal power that can be delivered by the heat pump alone. Another reason to switch to the gas boiler would be that the outside temperature is too low to efficiently operate the heat pump. In that case the Coefficient of Performance (CoP) of the heat pump is so low that is too costly to run in heat pump compared to the gas boiler.

The ability to switch from the heat pump to the gas boiler can also be exploited for flexibility reasons. This is particularly useful for congestion management in the electricity distribution grid. A heat pump uses a significant amount of electricity while the gas boiler only uses gas. Peaks in the electricity distribution grid

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can be alleviated by temporarily switching the hybrid heat pumps to gas boiler only operation. This can be achieved by using the Smart Grid Ready Protocol [4] which is supported by the Elga heat pump.

2.2.7 Hybrid heat pump mock

The intention for this preliminary iVPP integration test was to implement the dEF-Pi software on a local gateway device capable of also supporting the Smart Grid Ready Protocol to control the physical hybrid heat pump in the lab. Unfortunately, project partner NEROA was confronted with availability issues for the hardware they normally use for local gateways: the Raspberry Pi. Alternative hardware has been selected, but this required too many adaptations to be ready in time for this iVPP integration test.

To still be able to test the iVPP integration a hybrid heat pump mock has been used instead which replaces the physical hybrid heat pump and the resource manager which was to use the dEF-Pi platform. It acts as a proper S2 endpoint (Resource Manager side) so that a full iVPP integration test can be conducted up to the hybrid heat pump. Once the dEF-Pi platform is successfully deployed on the local gateway the integration test will be repeated with the physical hybrid heat pump.

The consequence of using a mock consist of not testing the resource manager which is to control the physical hybrid heat pump but it still allows us to test up to the S2 communication between ReFlex and the mocked resource manager of the hybrid heat pump. In other words, we can confirm that the instructions from ReFlex are send at the right time using the expected protocol but we cannot validate that the resource manager is able to successfully control the hybrid heat pump yet.

3 iVPP integration testing

This chapter is divided into two main sections. The first section describes the scenario that was used to conduct the iVPP integration tests, while the second section describes the test results.

3.1 Test scenario

3.1.1 Overview

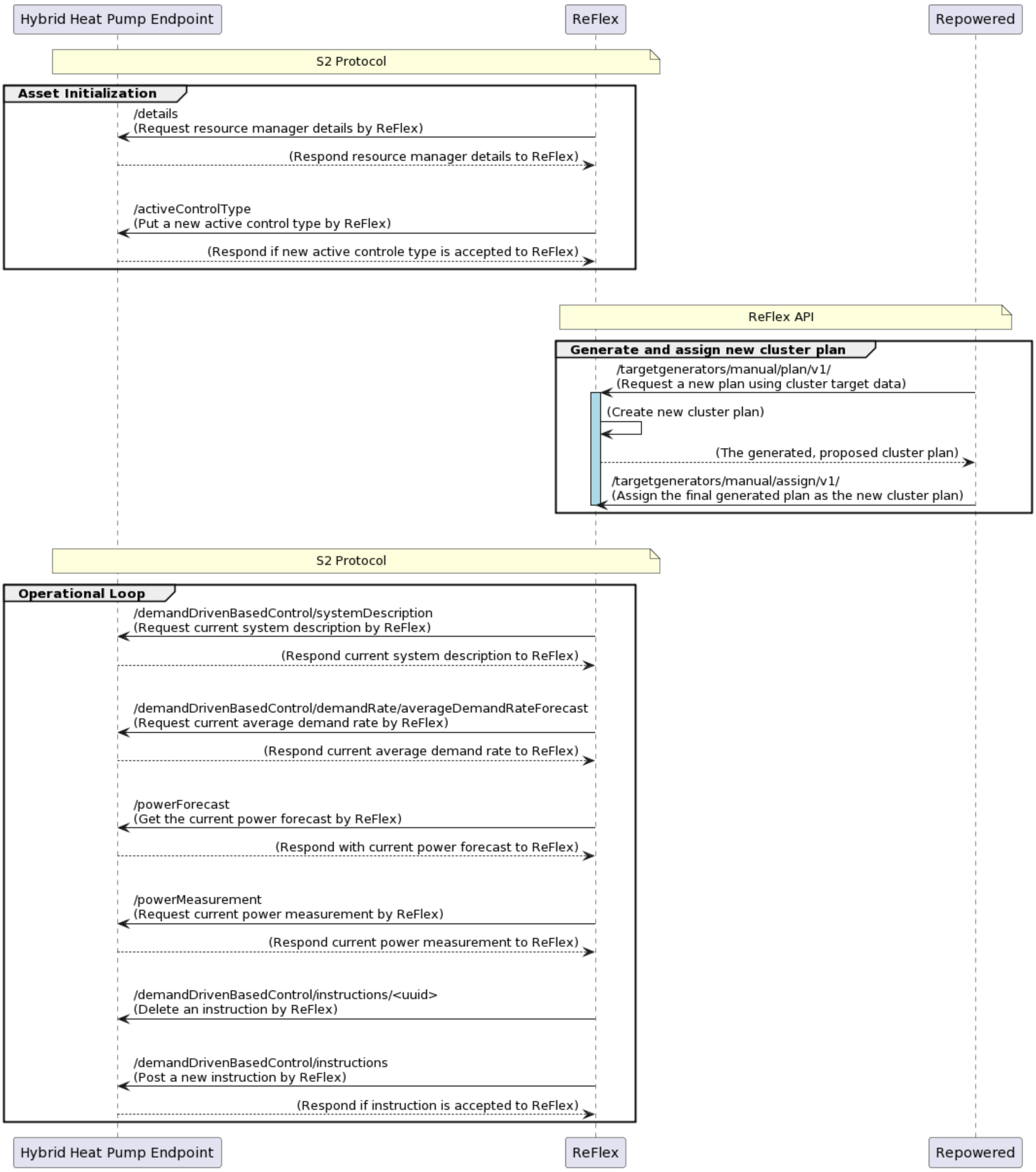

Figure 5 Sequence diagram detailing the expected communication between Repowered, REflex and the hybrid heat pump during the integration test.

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The integration test includes 3 components:

1) A script created by Repowered that represents the Solarflex platform.
2) The ReFlex tool
3) A mock implementation representing the resource manager of the hybrid heat pump and the hybrid heat pump itself.

Figure 5 shows the various REST API calls between the components. The diagram is split into 3 different blocks: 1) Asset initialization, 2) Generate and assign new cluster plan and 3) Operational Loop. These blocks are explained in more detail in the next paragraphs including the expected result from the integration test.

Blocks 1 and 3 detail communication between the hybrid heat pump and ReFlex and the S2 REST protocol is used. The REST implementation for S2 details a number of REST endpoints that should be implemented and the JSON data structures that are communicated across the REST endpoints.

Block 2 details the communication between ReFlex and the script from Repowered. Here a ReFlex-specific API is used which is also implemented using REST / JSON.

3.1.1.1 Asset Initialization

The hybrid heat pump asset implements a REST API according to the S2 protocol. ReFlex initializes this component by first requesting the asset details using the /details API endpoint followed by setting the S2 control type using the /activeControlType API endpoint. These asset details specify which S2 flexibility control types the asset can communicate as which are, in other words, the modes in which the flexibility of the asset may be expressed and utilized.

For this test, we have modelled the heat pump as the S2 'Demand-driven-based-control` (DDBC) control type which expresses energy flexibility in terms of multiple actuators that will have to satisfy a demand. For this integration test, the demand is the heat that has to be generated and the actuators consist of the gas boiler and the heatpump which use respectively gas and electricity to produce the required heat. ReFlex is able to optimize which actuator to use and at which utilization so the total energy used to satisfy the heat demand matches the optimization target.

After collecting the asset details, ReFlex will determine that only the DDBC control type is available for the hybrid heat pump asset and it will configure the asset to use this control type through the /activeControlType REST API call.

3.1.1.2 Generate and assign new cluster plan

ReFlex exposes an API through which a new plan may be generated and assigned to the cluster of assets. In the block 'Generate and assign new cluster plan' the script made by Repowered uses this API to generate a new plan for the cluster and then assign it to the cluster. The plan proposed by ReFlex consists of the forecasted joule usages for each separate device and for the various congestion points. To generate a new plan through the API endpoint /targetgenerators/manual/plan/v1/, the script from Repowered supplies a target profile consisting of expected electricity prices using the Day-Ahead market price information. ReFlex

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creates a new plan and responds with the proposed cluster plan. Finally, the script made by Repowered requests ReFlex to assign the new cluster plan using the /targetgenerators/manual/assign/v1/.
ReFlex reacts by assigning each of the assets new instructions that will implement the newly-assigned plan.

During these steps ReFlex will have to satisfy multiple constraints. First, it will solve congestion constraints always as much as it can. Then, it will find the 'cheapest' plan while satisfying the congestion constraints and the targets of each asset. In scope of the integration test the target of the asset is the amount of heat that needs to be generated in each timestep.

3.1.1.3 Operational Loop

During operation ReFlex will call a number of S2 REST endpoints at the hybrid heat pump for various operation goals:

- /powerMeasurement: REflex will retrieve the current power reading periodically to determine the actual actions of the asset regardless of the instructions send to the asset.
- /powerForecast: REflex will retrieve the expected power usage periodically and uses this information when generating a new plan.
- /demandDrivenBasedControl/systemDescription: REflex will retrieve a description detailing the various operation modes the asset may be instructed to, how much power each operation mode uses and the current operation mode the asset is in.
- /demandDrivenBasedControl/demandRate/averageDemandRateForecast: ReFlex will retrieve a forecast periodically which details how much demand the asset will have to satisfy in the future. A demand-driven-based-control asset satisfies a certain demand by using commodities like gas and electricity. For example, the hybrid heat pump uses gas and electricity to satisfy a heating demand for the building. Each operation mode in the system descriptions details how much demand it can satisfy. This forecast will therefore help REflex determine which operation modes should be planned in the (near) future.

3.1.2 ReFlex API

In this test the connection between the ReFlex tool and Repowered will be tested. To perform the test, Repowered has created a script to communicate with Reflex which enacts a test scenario. Repowered will retrieve the Day-Ahead price information for the next day, and request ReFlex to optimize its assets based on these prices. Repowered will also mock a congestion bid, by restraining a congestion point within the ReFlex platform to a production of 0.

This dispatch strategy will be sent to ReFlex, and the feasibility of the strategy will be returned.
Based on this, the strategy will be affirmed by the Repowered script, allowing ReFlex to carry out the strategy.

Repowered does not yet have access to a GOPACS trading platform, so to mock the congestion activation, Repowered has assumed the activation has come with minimal notice, meaning it should be carried out immediately. This will test the flexibility in the system to sudden changes in dispatch strategy.

3.1.3 Hybrid Heat Pump Endpoint

For this test an implementation for the hybrid heat pump using dEF-Pi by NEROA was not used. Instead, a mock implementation of this endpoint was created and used for the purposes of this integration test. The mock implementation implements the necessary S2 REST API endpoints using static data. Reflex will retrieve this data during the integration test and use the mock as if it is a real hybrid heat pump.

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3.1.4 Excluded from Testing

The following items were excluded from testing.

- Physical hybrid heat pump and dEF-Pi. As described earlier in this document these are not yet part of the current integration tests. They will be integrated once the gateway that runs dEF-Pi is available so that this be tested in the lab before it will be deployed in the field.
- Forecasts service. The interaction with the Forecasts service could not be tested as the Forecasts services was not fully available yet. This will also be integrated into the lab test once the forecasts service is available.
- Use cases. Specific Ameland use cases have not been tested as part of this preliminary integration test. The focus is on the generic integration of the iVPP components and not on its finetuning for individual use cases.

3.2 Test results

This section will show the result of the integration as detailed in chapter 3.1. The test has been performed by TNO and Repowered on Tuesday 12th of July 2022.

3.2.1 Deployment

An instance of ReFlex and the hybrid heat pump mock were both deployed on a VPS instance in the TNO HESI lab. A VPN connection was setup between the HESI lab network and the Repowered network. The script made by Repowered was triggered manually while the ReFlex instance and the hybrid heat pump mock were setup as a continuous available service.

3.2.2 Test result between ReFlex and Repowered interfaces

The test was performed by triggering the Repowered script manually. We have validated the working of ReFlex through a number of steps. Figure 6 shows the logging of ReFlex which shows a new cluster plan was generated and assigned.

```
09:27:50.136 INFO  n.t.r.p.CongestionPointPlanner       - CP '': Selected best controller 'battery1' with
improvement of 0.0.
09:27:50.175 INFO  n.t.r.p.CongestionPointPlanner       - CP 'aa45d9ed-2a06-4734-8b9d-7ff3aeca74af':
Selected best controller 'battery2' with improvement of 0.0.
09:27:50.236 INFO  n.t.r.p.CongestionPointPlanner       - CP '0ee4b149-9e83-47bf-a4ff-2d36c9f74028':
Selected best controller 'heatpump1' with improvement of 0.0.
09:27:50.237 INFO  n.t.r.p.PlanningServiceImpl          - Generated new plan in 258 ms
09:27:54.524 INFO  n.t.r.r.c.ClusterControllerImpl      - Accepted new cluster plan, reason: Manually
generated plan by user
09:27:54.524 INFO  n.t.r.r.c.ClusterControllerImpl      - Scheduled replanning in 295455 ms
09:27:54.524 INFO  .e.i.c.EfiInflexibleDeviceController - EfiInflexible device pv1 received plan without
curtailment instruction
09:27:54.524 INFO  n.t.r.rest.ClusterControllerResource - Assigned new manually generated plan
```

Figure 6 ReFlex logging detailing when the manual plan was generated and assigned by Repowered script

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Figure 7 shows the cluster plan before the cluster plan is assigned by the script made by Repowered while Figure 8 shows the cluster plan after assigning the cluster plan that is generated by ReFlex by the script made by Repowered. The main addition is the green line that represents the energy prices for those time slots. These energy prices are sent by the script made by Repowered when the cluster plan is first generated. In the graphs the black bars represent the electricity usage by the hybrid heat pump. Considering the test data, we expected alternating usage of energy each time slot. Unfortunately, this is not the case which shows there is an error in the planning algorithm. However, even though the plan is faulty, currently a plan may be generated. Therefore, we consider the integration test result for interfacing between the Repowered script and the ReFlex component to be successful.

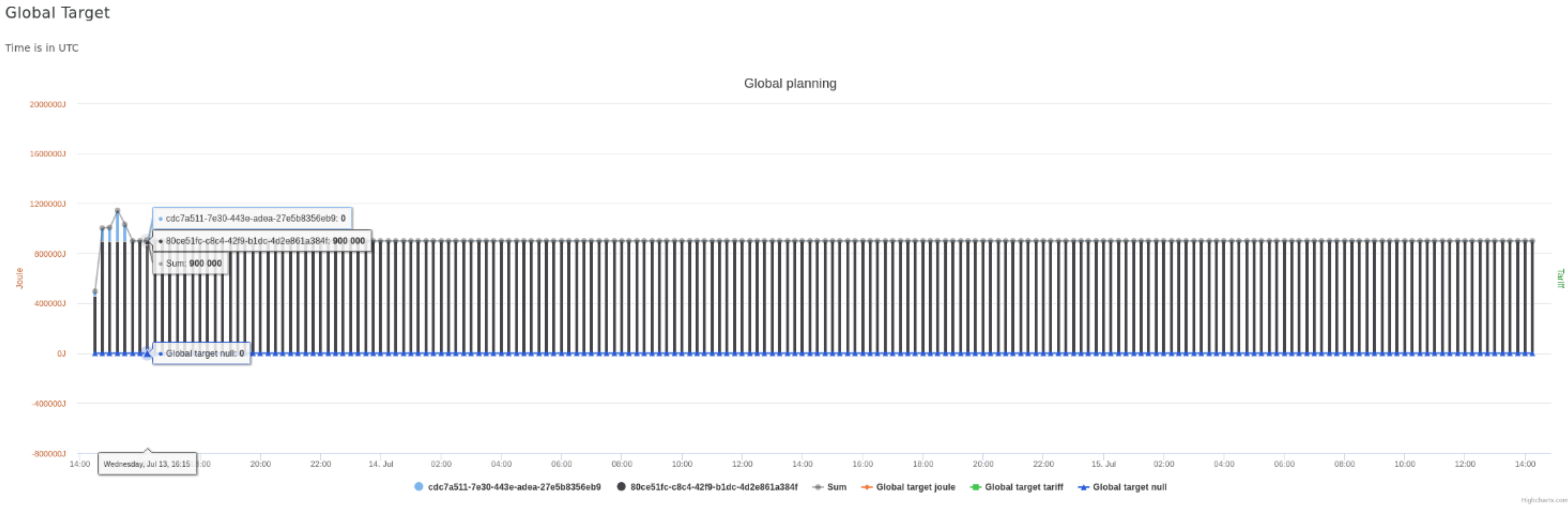

Figure 7 Cluster plan in ReFlex ui before assigning plan through Repowered script.
Black bars represent electrical energy usage by hybrid heat pump and blue line are time slots without a target.

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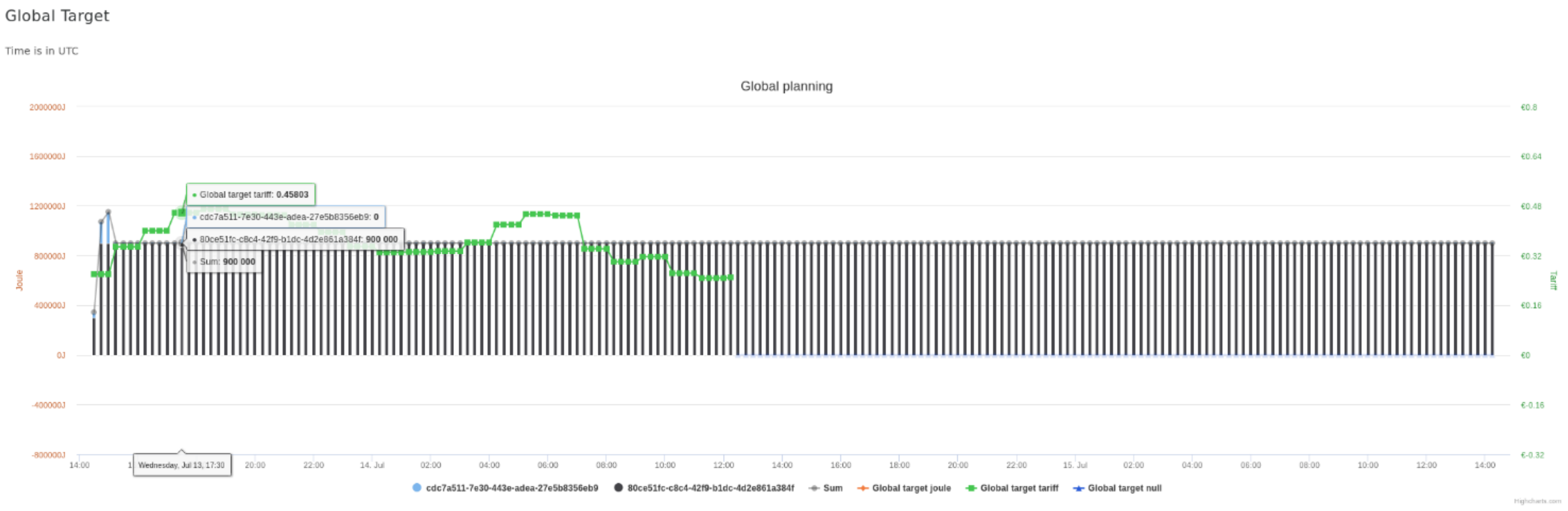

Figure 8 Cluster plan in ReFlex ui after assigning plan through Repowered script.Black bars represent electrical energy usage by hybrid heat pump, green line are the energy prices and blue line are time slots without a target.

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3.2.3 Test result between hybrid heat pump mock and ReFlex interfaces

We have also validated the interface between the hybrid heat pump mock and the ReFlex instances. Figure 9 shows the sequence diagram as captured by the hybrid heat pump mock. We can validate that all expected S2 REST API calls have been performed. Also, all existing instructions were deleted before new instructions were sent. This was also expected.

In total 384 instructions are sent at a time. This is as there are 192 time slots to be planned and in total there are 2 actuators within the hybrid heat pump: a gas boiler actuator and a heat pump actuator. Each actuator receives a separate instruction.

Based on these results, we can conclude that also the interface between the hybrid heat pump mock and the ReFlex instances are considered integrated.

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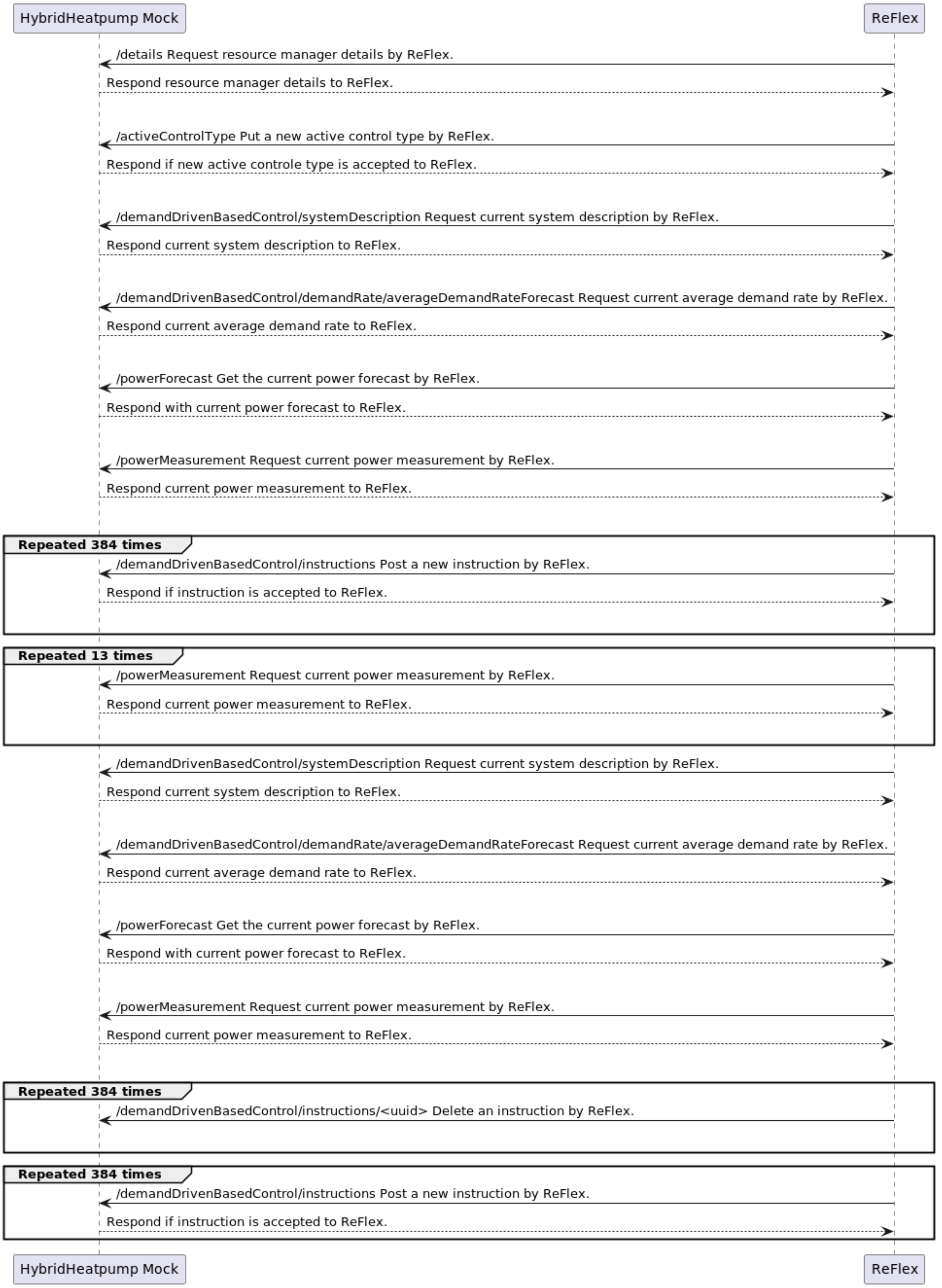
Figure 9 Sequence diagram captured at hybrid heat pump during integration test



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4 Conclusions and next steps

4.1 Conclusions

This deliverable is an important milestone on the route towards a fully operational deployment of the iVPP value chain on Ameland.

The following conclusions can be drawn from the preliminary iVPP testing on Ameland.

- A (partial) testing environment has been put in place that can be re-used for more advanced testing scenarios to build up towards an operational roll-out of the iVPP value chain.
- The integration between the different components, developed by different project partners (Repowered and TNO), has been successfully tested according to the agreed test scenario. There were no major issues that occurred during the tests, the few minor issues that popped up were swiftly dealt with.
- The European energy flexibility standard EN50491-12-2 (the S2 protocol) was successfully leveraged for the communication between smart assets and the Reflex platform.

4.2 Next steps

The outcome of the testing also led to the identification of the following next steps which will benefit the further development of the iVPP value chain.

- Unfortunately for reasons explained in section 2.2.7, it was not possible to test with physical hybrid heat pump yet. In the near future, the iVPP test scenarios will be repeated with the physical hybrid heat pump also integrated once project partner Neroa has solved the hardware availability issues.
- Although the interaction between the components was successful, the functionality of the individual components themselves needs to be advanced further.

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5 References

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