Ref. Ares(2021)4907609 - 02/08/2021

VPP4ISLANDS

Virtual Power Plant for Interoperable and Smart isLANDS

VPP4Islands

LC-SC3-ES-4-2020

GA 957852

Deliverable Report

Deliverable ID	D2.6	**Version**	V04
Deliverable name	Technical specification of VPP4Islands		
Lead beneficiary	ALWA: Diego Piserà, Stefano Bianchi		
Contributors	CU: Saif Sami, Yue Zhou and Meysam Qadrdan; SCHN: David Pampliega, Evgeny Prokofyev; BC2050: Ioannis Dontas, Konstantinos Tsiomos, Entrit Metai, CIVI: Martina Di Gallo, Andrea Sacchetto; IDEA: Francisco Mednéz Flores.		
Reviewer	CU, BC2050.		
Due date	31/07/2021		
Date of final version	30/07/2021		
Dissemination level	Public		
Document approval	Seifeddine BEN ELGHALI	**Date**	30/07/2021

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

Acknowledgement: VPP4ISLANDS is a Horizon 2020 project funded by the European Commission under Grant Agreement no. 957852.

REVISION AND HISTORY CHART

Version	Date	Main Author(s)	Summary of changes
V01	28/05/2021	Diego Piserà (ALWA)	ToC, Executive summary
V02	26/07/2021	David Pampliega, Evgeny Prokofyev (SCHN), Francisco Méndez Flores (IDEA), Martina Di Gallo, Andrea Sacchetto (CIVI)	Setup of services, VPP4INode VPP4IPlatform and VPP4IBox tech spec
V03	29/07/2021	Ioannis Dontas, Konstantinos Tsiomos, Entrit Metai (BC2050); David Pampliega, Evgeny Prokofyev (SCHN);	Internal Review of D2.6
V04	30/07/2021	Saif Sami, Yue Zhou and Meysam Qadrdan (CU).	Second internal review of D2.6

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

EXECUTIVE SUMMARY

The present report is a public deliverable (Deliverable D2.6) of the VPP4ISLANDS H2020 funded European project. The VPP4Islands project aims to facilitate the integration of renewable systems, accelerate the transition towards smart and green energy system and help islands to exploit energy efficiency potentials and innovative energy storage approaches. In particular, VPP4Islands project proposes disruptive solutions based on digital twin concept, Virtual Energy Storage Systems (VESS) and Distributed Ledger technology (DLT) to revolutionize the existing Virtual Power Plants (VPP) and build smart Energy Communities (EC).

In this context, the objective of Deliverable D2.6 is to define the Technical specifications of the VPP4Islands in order to provide the necessary level of interoperability for the VPP4Islands components (VPP4IPlatform, VPP4INode and VPP4IBox) and underlying standardized data exchange between VPP4Island's service providers and commercial and technical stakeholders. These technical specifications are used in other Work Packages (WP) of the project, that will design and develop the VPP4Islands components and their functionalities.

Establishing the technical specifications implies the following activities:

- Define the technical specifications for the setup of different proposed services in the expected demonstration pilots.
- Define the resources that the Digital Twin will be able to connect from stakeholder's database to the VPP4Islands components such as real time data, historical data, generation resources and consumption device models, etc.
- Define physical objects to be modelled in the digital mirror of the physical system, within the Digital Twin concept.
- Define the functionalities of the cloud-based services that will be designed and implemented in VPP4Platform.
- Introduce the data management sscheme and protocols that can support scalability, availability, modularity, and usability of VPP4Islands solutions.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

- Propose a technological solution for the VPP4IBox including needed hardware and software.

As results of the activities listed above, D2.6 will specify the design of standardized interfaces, Graphical Users Interfaces (GUI), data management scheme, and optimal data exchange between the different actors involved in the flexibility service provision of VPP4Islands.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

TABLE OF CONTENTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

LIST OF PROJECT PARTNERS

Abbreviation	Meaning
ALWA	AlgoWatt
AMU	Aix-Marseille Université
BC2050	Blockchain2050
BORN	Bornholms Varme A/S
BoZI	Bozcaada Belediye Baskanligi
BUL	Brunel University London
CIVI	CIVIESCO srl
CSIC	Consejo Superior de Investigaciones Científicas
CU	Cardiff University
DAFNI	Network of Sustainable Greek Islands
FORM	Consell Insular de Formentera
FTK	FTK Forschungsinstitut fur Telekommunikation und Kooperation EV
GRADO	Commune di Grado
IDEA	Ingenieria Y Diseno Estructural Avanzado
INAVITAS	INAVITAS Enerji AS
LIS	Laboratoire Informatique des Systèmes
PVM	Protisvalor Méditerranée
RDIUP	RDI'UP
REGENERA	REGENERA LEVANTE
SCHN	Schneider Electric
TROYA	TROYA CEVRE DERNEGI
UEDAS	Uludag Electric Dagitim

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Meaning
AMI	Advanced Metering Infrastructure
BRP	Balance Responsible Party
CHP	Combined Heat and Power
DER	Distributed energy resources
DF	Demand Flexibility
DSO	Distribution System Operator
DT	Digital Twin
DTE	Digital Twin Environment
DTI	Digital Twin Instances
DLT	Digital Ledger Technologies
EC	Energy Community
ESS	Energy Storage System
EV	Electric Vehicles
GHG	Greenhouse gases
GUI	Graphical User Interface
P2P	Peer-2-peer
PV	Photovoltaic
RES	Renewable energy sources
RTU	Remote Terminal Unit
SoC	State of Charge
SRS	Software technical Requirements Specifications
UI	User Interface
VSoC	Virtual State of Charge
VESS	Virtual energy storage systems
VPP	Virtual Power Plant

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

LIST OF FIGURES

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

LIST OF TABLES

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

1. INTRODUCTION

The present report is the public Deliverable D2.6 of the VPP4ISLANS H2020 European project.

1.1. The VPP4Islands Project

The VPP4Islands project aims to facilitate the integration of renewable systems, accelerate the transition towards smart and green energy systems and help Islands to exploit energy efficiency potentials and innovative energy storage approaches, foster the active participation of citizens and become self-sufficient in energy, while reducing costs, GHG emissions and reliance on heavy fuel oil to generate power, and creating new intelligent business and local skilled jobs.

To reach these goals, VPP4Islands project will:

- Revolutionize the existing VPP by integrating many services potentially deliverable by a VPP into a single platform (i.e., the VPP4INode) that will be able to aggregate and coordinate distributed energy resources (DERs).
- Build a Digital Twin (DT) of the energy system at islands involved in the project.
- Implement the concept of Virtual energy storage systems (VESS) to combine the flexibility coming from different assets such as storage and flexible loads.
- Utilise the Distributed Ledger Technology (DLT) to allow peer-2-peer (P2P) energy transaction.
- Build smart energy communities and promote self-consumption.
- Enhance the Demand Response Capability of consumers by understanding their behaviours.
- Validate and evaluate the VPP4ISolutions, with two different real-life use cases, one in Gökçeada (Turkey) and one in Formentera (Spain).
- Replicate the qualified VPP4Islands solutions in three following islands Bozcaada (Turkey), Grado (Italy) and Bornholm (Denmark).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

1.2. VPP4ISLANDS SOLUTIONS OVERVIEW

VPP4Islands solutions is a system composed of three fundamental units. The component of the lowest hierarchical level is the VPP4IBox, it can observe and control plants with different assets (e.g., PV + storage unit + heat pump). The second level is the VPP4INode, it is a tool for managing VPP, so it allows to aggregate and coordinate different power plants with the aim to reach the minimum size to participate in energy and balancing markets. The highest level is the VPP4IPlatform, it is a centralized operational centre that can collect data from different VPP4INode and combine the digital twin technology with Artificial Intelligent (AI) and Machine Learning approaches to generate value from data. The goal of the VPP4Islands solutions is to provide a system that helps islands in the decarbonization process. The overall architecture of VPP4Isolution is shown in Figure 1.

The VPP4IPlatform is both a data and information service provider and a Digital Twin Environment. It collects dynamic data from different VPPs, from the DSO the own the distribution network of the island, from meteorological centres and from energy market. The data collected include weather related such as temperatures, solar radiation and wind, energy demand and production and energy price in day-ahead, intraday, and balancing markets. It could provide this data to VPP to improve their performance. In the VPP4IPlatform will be the Digital Twin Environment (DTE), so it will be cloud base where the DT will take place. The digital twin is composed by many digital twin instances (DTI), them describe a specific corresponding physical asset Digital Twin remains linked to (i.e., mathematical model of distribution network, generators, storages, and flexible load) or the operational states captured from sensors and measurement instruments. The Digital Twin Environment has a predictive and interrogative purpose: it can predict the future behaviour and performance of the physical assets, and it can be interrogated for the current and past histories. The forecasts are carried out by the forecast engine that is able to forecast the whether, energy consumption and energy production.

The VPP4INode is a real Virtual Power Plant (VPP), it is a network of decentralized, medium-scale power generator units such as wind farms, solar parks, and Combined Heat and Power (CHP) units, as well as flexible power consumers and energy storage systems. The interconnected units are coordinated by the VPP4INode but nonetheless remain independent in their operation and ownership. Individual small plants can in general not sell energy or offer

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

services as the balancing reserve in power exchanges as their production or consumption profile varies strongly, they have insufficient availability due to unforeseen outages or they simply do not meet the minimum bid size of the markets. In addition, there are strict requirements regarding the availability and reliability of the flexibility offered in the market. The VPP4INode goal is to aggregate a pool of several small- and medium scale installations, either consuming or producing electricity to overcome these barriers. The combination of several types of flexible production and consumption units, controlled by a central intelligent system, is the core idea behind a VPP. Thanks to aggregation, a VPP can deliver the same service and trade on the same markets as large central power plants or industrial consumers. The owner and manager of a VPP is called Aggregator.

The VPP4IBox is a remote control unit. It allows the system to connect thousands of decentralized electricity producers and active customers to aggregator's central system (VPP4INode) and control them from there. Moreover, each VPP4IBox is able to send to aggregator exactly the data he needs in real-time to market their electricity with quarter-hourly precision. The VPP4IBox can calculate optimal dispatching of schedules for both individual plants and the whole sub-pools. At a signal from VPP4INode, the assets can so start up or shut down individually and as a group at any time.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

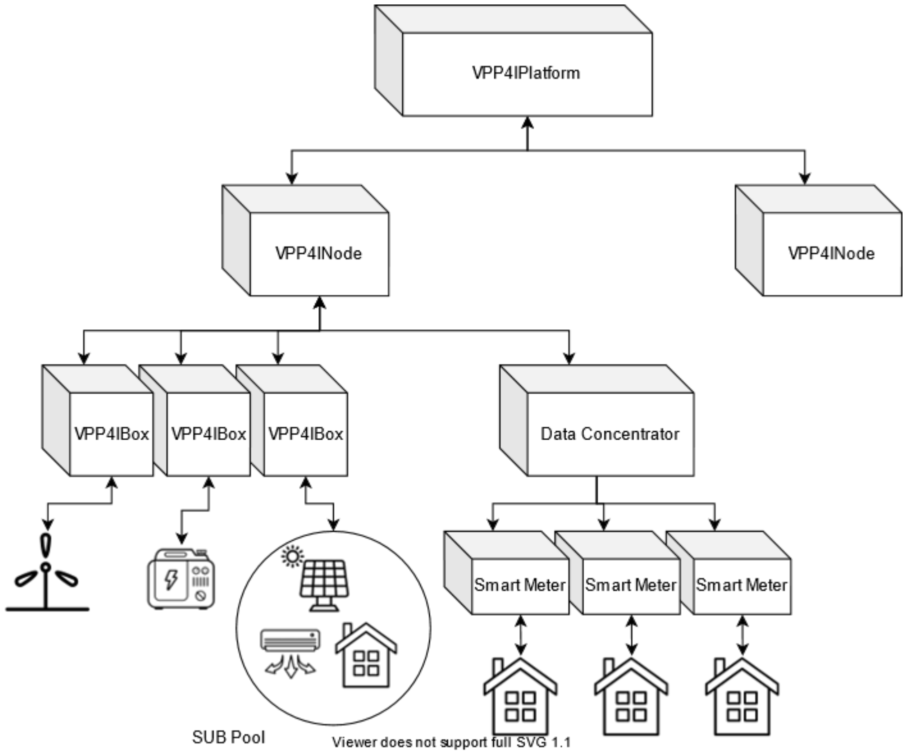


Figure 1: VPP4Islands overview

1.3. Scope and structure of Deliverable D2.6

The objective of Deliverable D2.6 is to define the technical specifications of the three VPP4Islands solutions: the VPP4IBox, the VPP4INode and the VPP4IPlatform. This delivery will be a setup of services in demonstration pilots and a high level simplified business use case for Gökçeada and Formentera. These setup of services and business use cases will be used in D2.8 “Scenarios for studying VPP4Islands concept”, that will define more precise scenario descriptions for each use cases, tailored to islands specific needs.

Defining the technical specifications implies to carring out, for each solution, the following activities:

- Describe the functionalities of the three VPP4Islands solutions.
- Describe the user interface (UI) and the user experience.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

- Describe the communications protocol.
- Describe the software requirements.
- Describe the hardware requirements.

More specifically, Chapter 2 describes the setup of services in demonstration pilots. Chapter 3 is devoted to the identification and characterisation of the high level use cases that will be investigated in the project. Chapters 4, 5 and 6 show the technical specifications of the VPP4IPlatfom, the VPP4INode and the VPP4IBox respectively. To give self-consistency to the technical specifications of the two cloud-based platforms envisaged in the project, the VPP4IPlatform and the VPP4INode, these are reported in appendix A and appendix B of delivery D2.6.

2. SETUP OF SERVICES IN DEMONSTRATION PILOTS

This section describes the setup of the services in the two leading and three follower islands. The setup of the services is obtained starting from the analysis of the needs of the actors involved in the islands and of the existing assets.

2.1. SETUP OF SERVICES IN GÖKÇEADA

Table 1 shows the list of the actors involved in the demonstration pilots. The first column shows the univocal identification code of the actor, this is composed of the initials Ac (i.e., Actor) followed by a number (i.e., the actor's identification number). The second column shows the actor's full name. The third column indicates the role that the actor has (note that an actor can have more than one role, for example it can be both the Distribution System Operator (DSO) and the aggregator of a VPP). The fourth column indicates whether the actor is a member of the VPP4Islands project consortium. Finally, the fifth column lists all the physical assets owned by the actor.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

Table 1: List of actors in Gökçeada

Actors in Gökçeada				
Actor code	**Actor name**	**Roles**	**Consortium member**	**Assets owned**
Ac.1	ULUDAG ELEKTRIK DAGITIM AS (UEDAS)	DSO	Yes	As.1.1 As.1.2 As.1.3 As.1.4 As.1.5 As.1.6
Ac.2	TEİAŞ	TSO	No	
Ac.3	Wind Turbines owner	Producer	No	As.3.1 As.3.2
Ac.4	Photovoltaic (PV) plant owner	Producer	No	As.4.1
Ac.5	Private or Commercial Users	Passive Customer	No	As.5.1
Ac.6	Limak Energy Group	Energy Trader	No	As.6.1

Table 2 indicates the list of physical assets involved in the VPP4Island project. The first column shows the unique identification code of the asset, consisting of the asset abbreviation (i.e., As), a middle number that identifies the owner of the asset and a final number that identifies the physical asset. The second column contains the description of the physical asset.

Table 2: List of physical assets in Gökçeada

Physical assets in Gökçeada	
Asset code	**Physical assets Description**
As.1.1	Gökçeada electrical distribution network
As.1.2	Diesel generators 4x770kVA (~616kW)
As.1.3	Lithium Battery Energy Storage System (50Kw-100kWh)
As.1.4	Sea cable (120mm2 CS, ~20MW, 50Hz AC, 36kV)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

Physical assets in Gökçeada	
Asset code	**Physical assets Description**
As.1.5	Emulation of flexible loads
As.1.6	Data concentrator and Advanced Metering Infrastructure (AMI) Each secondary substation in Gökçeada is equipped with a data concentrator that can record and send all the data measured in the secondary substations (i.e., currents and voltage) and in the smart meters downstream of the secondary substations, if any.
As.3.1	Wind Turbines 1 (900kW)
As.3.2	Wind Turbines 2 (900kW)
As.4.1	PV plant (210kW)
As.5.1	94 Smart Meters already installed +100 smart meters that will be installed with the resources made available by the VPP4islands project. The smart meters will cover all customers connected downstream of three secondary substations on the island of Gökçeada.
As.6.1	Energy trade platform that allows to access to Turkish electricity market and a legal qualification to participate in the Turkish electricity market.

Table 3 lists the VPP4IBox that are expected to be installed on the island. The first column indicates the unique identification code of the VPP4IBox, the second indicates the owner and finally the third indicates the monitored assets. In order to implement the project in Gökçeada, a maximum of 10 units of VPP4IBox will be available. At the moment, not all the 10 units have been assigned, the table on VPP4IBox will be updated in the subsequent phases of the project if new assets to monitor and control are introduced.

Table 3: List of VPP4Ibox in Gökçeada

VPP4IBox in Gökçeada		
Code	**Owner**	**Assets monitored**
Box.1	UEDAS	As.1.3 - Lithium Battery Energy Storage System (50Kw-100kWh)
Box.2	WT owner	Wind Turbines 1 (900kW)
Box.3	WT owner	Wind Turbines 2 (900kW)
Box.4	PV owner	PV plant (210kW)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

VPP4IBox in Gökçeada		
Code	**Owner**	**Assets monitored**
Box.5	UEDAS	Diesel generators 4x770kVA (~616kW)
Box.6	UEDAS	Emulation of Flexible Load
Box.7		
Box.8		
Box.9		
Box.10		

Table 4 lists the services implemented in the demonstration pilot. The first column indicates the type of service implemented. The second column contains the description of the service. The third column presents the level of implementation in the architecture proposed in the VPP4Islands project. The fourth column lists the actors involved in the service, and finally, the fifth column indicates the assets involved in the service. The description of the services shown is that of the USEF framework, [1].

Table 4: Setup of services in Gökçeada

Setup of services in Gökçeada				
Type of services	**Description**	**Layer**	**Actor Involved**	**Asset Involved**
Day-ahead optimization	Day-ahead optimization aims to shift loads from a high to a low-price time interval on a day-ahead basis or longer. Using DF (Demand Flexibility) for day-ahead optimization enables the BRP to reduce overall electricity sourcing costs. DF can be traded via either a Day-Ahead (DA) exchange or by establishing a bilateral agreement.	VPP4INode	Ac.3 Ac.4 Ac.6	As.3.1 As.3.2 As.4.1 As.5.1 As.6.1
Intraday optimization	Intraday optimization (via Intraday (ID) exchange or by bilateral agreements) closely resembles the day-ahead optimization but the timeframe is constrained after closing of the day-ahead market and, in general, intraday markets can trade products with finer granularity, closer to real-time. BRPs can use DF to repair day-ahead forecast errors of intermittent resources.	VPP4INode	Ac.3 Ac.4 Ac.6	As.3.1 As.3.2 As.4.1 As.5.1 As.6.1

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

2.2. Setup of services in Formentera

An Energy Community (EC) will be built in Formentera. Here all the assets that will be involved in the EC are listed. Based on the assets involved and the need of the EC members, a list of services that will be provided by the EC to the island electrical system will be set.

Table 5 shows the list of the public and private buildings involved in the EC. The first column shows the univocal identification code of the building, this is composed of the initials B (i.e., Building) followed by a number (i.e., the building's identification number). The second column shows the building full name. The third column indicates the assets present in the buildings (e.g., PV plants, energy storage units, air conditioning or in general heat pump).

Table 5: Building involved in the energy community in Formentera

Building in Formentera		
B code	**Building name**	**Assets in the Buildings**
B.01	Collegi Mesre Lluis Andreeu (baix)	9.36 kW rooftop PV plant
B.02	Ed. Escorxador	2.08 kW rooftop PV plant
B.03	Antic Ed. Cultura, Educaciò i Patrimoni.	15.6 kW rooftop PV plant
B.04	Collegi Mesre Lluis Andreeu (dalt)	14.56 kW rooftop PV plant
B.05	Camp de Fútbol	29 kWp PV plant. (Installation of a fuel cell is planned)

Table 6 lists the VPP4IBox that are expected to be installed on the island. The first column indicates the unique identification code of the VPP4IBox, the second column indicates the owner and finally the third column indicates the monitored assets. At the moment, not all 10 units have been assigned, the table on VPP4IBox will be updated in the subsequent phases of the project if new assets to monitor and control become available.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

Table 6: List of VPP4Ibox in Formentera

VPP4IBox in Formentera		
Code	**Owner**	**Assets monitored**
Box.1	Football field	PV, load, fuel cell
Box.2	Collegi Mesre Lluis Andreeu (baix)	PV, load
Box.3	Ed. Escorxador	PV, load
Box.4	Antic Ed. Cultura, Educaciò i Patrimoni.	PV, load
Box.5	Collegi Mesre Lluis Andreeu (dalt).	PV, load
Box.6		
Box.7		
Box.8		
Box.9		
Box.10		

Table 7 lists the services implemented in the demonstration pilot. The first column indicates the type of service implemented. The second column contains the description of the service. The third column is the level of implementation in the architecture proposed architecture of the VPP4Islands project.

Table 7: Setup of services in Formentera

Setup of services in Formentera		
Type of services	**Description**	**Layer**
Optimization of self-consumption	In-home energy self-balancing is typical behavior of Active customers who also generate electricity (e.g., through PV panels or Combined Heat and Power (CHP) systems) and have flexible demand. Value is created through the difference in the prices of energy supplied from the grid (buying) and the energy fed to the grid or through incentives.	VPP4IBox
P2P energy transaction	Peer-to-Peer (P2P) energy trading paradigm appears, where consumers and prosumers can exchange energy without the need for an intermediary.	VPP4IBox
Cloud platform for Energy Community Management	The manager of an energy community needs a cloud platform to monitor the consumption of the community members, the generation from renewables shared between several members, to control shared assets such	VPP4INode

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

Setup of services in Formentera		
Type of services	**Description**	**Layer**
	as energy storage, and to calculate the shares of shared energy and distribute the incentives between the various members with the rules agreed within the community.	

2.3. Setup of services in Bozcaada

Within the VPP4ISLANDS project, the main objective of the island of Bozcaada is to exploit the VPP4Island platform to define all the needed requirements, specifications, and infrastructures of a large electric vehicles integration to reduce emissions from cars with internal combustion engine while ensuring the stability of the electric grid and generate economic benefits.

Table 8 indicates the list of physical assets involved in the VPP4Island project. The first column shows the unique identification code of the asset, consisting of the asset abbreviation (i.e., As), and a number that identifies the physical asset. The second column contains the description of the physical asset.

Table 8: Physical assets in Bozcaada

Physical assets in Bozcaada	
Asset code	**Physical assets Description**
As.01	Bozcaada distribution electrical network
As.02	17 wind turbines (more 10MW of nominal capacity)
As.03	PV Plant (20kW)
As.04	Wind Turbines (30kW)
As.05	Sea cable

The project aims to make mobility totally sustainable through the concept of zero impact mobility (NZEM - Nearly Zero Energy Mobility). Considering the following premises:

- The energy vector, not the vehicle itself, used to start the vehicle is responsible for climate-altering emissions.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

- Emissions from Electric Vehicles (EV) are eliminated only if the energy taken from the grid is powered by renewable energy sources.
- There is a lack of charging stations to power EV.
- One of the main barriers to the diffusion/spread of EV is their recharging time.

The project involves the simulations of the integration of point of charge for the recharging of electric vehicles along the islands, which is able to feed the entire EV fleet on the island. The simulation results will make it possible to understand how to best integrate charging points on the grid and the potential for flexibility of demand to avoid stability problems on the electricity grid and at the same time minimize charging costs for EV.

2.4. Setup of services in Grado

In Grado, a feasibility study will be carried out with the aim of building an Energy Community (EC). Here a list of all the assets that will be involved in the EC. Based on the assets involved and the need of the EC members will be set a list of services that will be provided by the EC to the island electrical system.

In the Italian Regulations [2], the renewable energy community consists of consumers located in the same low voltage electricity grid, i.e., under the same medium/low voltage secondary substation. Participants retain their rights as end customers, including the right to choose their supplier and leave the community when they wish. Participation is open to all users under the same electrical substation, including those belonging to low-income or vulnerable families.

The energy shared within the community is equal to the minimum, in each hourly period, between the electricity produced and fed into the grid by the community plants and the electricity drawn by all the associated members. Energy is considered shared for instant self-consumption also through energy storage systems.

At the current state of the law in Italy, therefore, for the island of Grado it will be necessary to create "n" energy communities which will be as many as there are medium voltage substations on the island (given that it will have to be obtained from the DSO). Hypothetically, the island of Grado will be divided into matrices that will have the medium voltage substation as the centre and

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

all the users connected to it as a cluster. The Municipality has a fundamental role in the definition of the matrices as within the individual matrices.

The municipality of Grado could make its buildings available in order to install PV systems on the surfaces of the roofs that will belong to some of the energy communities that will be formed.

The required technology to create energy communities need to be able to support a network of Smart Homes/Buildings. There are two different levels of applications of these technologies:

1. Home: The fundamental component of the technological architecture is the energy box, that is a home device that allows users to integrate different sensors to facilitate home energy management. It also allows to communicate with the cloud platform aggregator/energy community manager. In this way, the end user has the ability to remotely monitor and control his home.

2. Building / network: The data monitored at the house level by existing the sensors are transmitted, via the energy box, to the aggregation cloud platform, where the acquired data is stored in a database and organized to carry out analyses and subsequent processing, in particular synchronization and diagnostics.

Table 9 shows the list of the public buildings that could be involved in the energy communities. The first column shows the univocal identification code of the public building, this is composed of the initials B (i.e., Building) followed by a number (i.e., the building's identification number). The second column shows the building full name. The third column indicates address of the public buildings. Finally, the fourth column indicates the existing assets in the public buildings (e.g., PV plants, energy storage units, air conditioning or in general heat pump).

Table 9: List of public buildings in Grado

Public building in Grado			
code	**PB name**	**address**	**Assets**
B.01	Kindergartens	Via dell'Operosità, 16 Grado	
B.02	Library	Via Leonardo da Vinci, 20	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

Public building in Grado			
code	**PB name**	**address**	**Assets**
B.03	Retirement Homes “Serena”	Via Papa Giovanni XXIII, 40	PV since 2022
B.04	Town Hall	Piazza B. Marin 4	
B.05	Multipurpose Gym	Piazzale Atleti Azzurri d'Italia, 4	
B.06	Primary School “Dante”	Via dell'Arte, 40	Mono crystalline silicon PV (20 kWp)
B.07	Nursery School Grado	Via dell'Operosità, 14	
B.08	Secondary School	Via Marchesini, 34	
B.09	Town Hall /Technical Office	Via Leopardi 16	
B.10	Charging stations for electric vehicles	Viale del Sole, Riva Giovanni da Ver-razzano, Riva Zaccaria Gregori, Viale Argine Moreri, Viale Argine Moreri	Maximum power 22 kWh

2.5. Setup of services in Bornholm

Table 10 shows the list of the regulated actors, such as TSO and DSO, involved in the demonstration pilot of Bornholm.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

Table 10: List of actors in Bornholm

Actors in Bornholm			
Actor name	**Roles**	**Consortium member**	**Assets owned**
Energinet.dk	TSO	NO	
El-net Øst	DSO	NO	

Table 11 indicates the list of physical assets that could be involved in the VPP4Island project for simulations. The first column shows the unique identification code of the asset, the second column contains the description of the physical asset.

Table 11: List of physical assets in Bornholm

Physical assets in Bornholm	
Asset code	**Physical assets Description**
As.1	Sea cable (Mix: A-Power, Hydro etc.) 60 kV AC cable of 60 MW capacity
As.2	Biogas plant
As.3	PV Plants (Approximately 1000 rooftop-PV systems distributed all over Bornholm, with different capacities from 1- 300 kW, and 2 PV plants each 10 MWp, and 7,5 MW of inverter capacity)
As.4	Wind turbines in Bornholm
As.5	Power Plant (Woodchips)
As.6	Power Plant coal/oil

Bornholm is interested to implement/demonstrate through simulations which services could make it possible to have a better integration of energy production from wind turbines and PV in the islands electric system by coupling the electric system with the district heating system.

A list of interesting services requested by Bornholms Energi & Forsyning (Energy and heat supplier company) are listed below:

- Forecast of the energy production of wind turbines.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

- Forecast of heat consumption.
- Advanced control of the district heating system based on forecasting (In Bornholm, many hot water storages are installed that could be controlled more dynamically to be able to accumulate heat injection generated from electric boilers).
- Simulation of a secondary market mechanism that allow to have P2P trading of electricity directly between PV and Wind plants to hot water storages owners.

Figure 2, Figure 3, Table 12, and Table 13 give an overview of the energy production and consumption on Bornholm in 2020. For the following years, Bornholm authority expects that:

1. the electricity consumption will increase with approximately 50 GWh/y due to conversion to EV's.
2. Electrically based heating and district heating production will gradually replace biomass.

Moreover, a 2 GW wind power plant offshore Bornholm is planned to be connected to the island through an HVDC-transformer station on Bornholm in 2030. The energy produced by the wind power plant will be exported via sea cables to the mainland.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

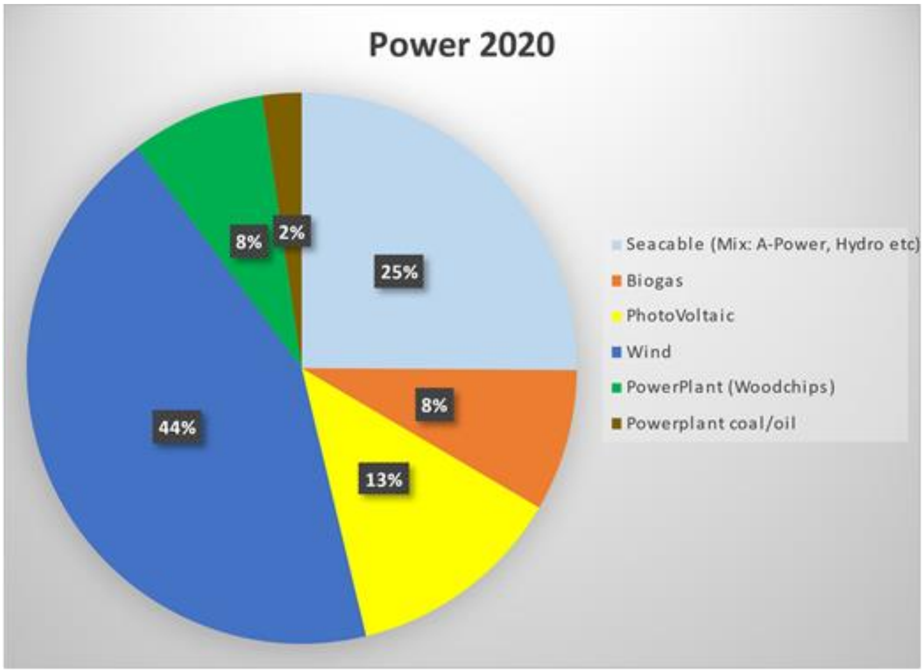


Figure 2: Electrical energy mix in Bornholms during 2020

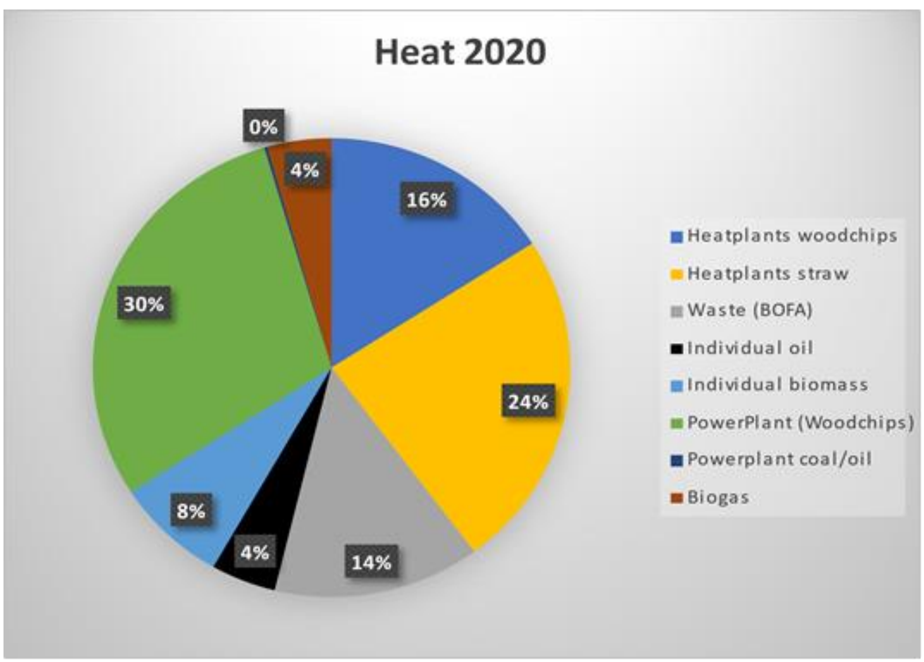


Figure 3: Heat mix in Bornholms during 2020

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

Table 12:Energy sources in Bornholms during 2020

Power Source	Power 2020	2020 [kWh]
Seacable (Mix: A-Pow	25%	59,742,200
Biogas	8%	19,829,479
PhotoVoltaic	13%	30,442,370
Wind	44%	103,575,948
PowerPlant (Woodchi	8%	18,831,995
Powerplant coal/oil	2%	5,514,960
Ialt	1	237,936,952

Table 13: Heat sources in Bornholms during 2020

Heat Source	Heat 2020	2020 [kWh]
Heatplants woodchip	16%	54,087,000
Heatplants straw	24%	81,306,000
Waste (BOFA)	14%	47,733,611
Individual oil	4%	15,000,000
Individual biomass	8%	26,000,000
PowerPlant (Woodchi	30%	100,513,527
Powerplant coal/oil	0%	765,028
Biogas	4%	14,733,000
Ialt	1	340,138,166

3. USE CASES

3.1. OPTIMIZATION IN SPOT MARKET (GÖKÇEADA)

The case study in Gokceada foresees the optimization of profits from exchanges in the energy market. Limak, in the role of energy trader, will have in its portfolio of generators the two wind turbines, the photovoltaic system, the energy storage and the emulated flexible load described in the Table 1.

Limak will use the data sent by the VPP4INode that will be installed on the island of Gökçeada to obtain the generation forecasts of the renewable plants, the forecast of prices on the energy markets and the consumption or input set points of the flexible load. Furthermore, it will be able to have access to the data coming from the UEDAS Advanced Metering Infrastructure and from the Forecast Engine of the VPP4INode to have accurate estimates of energy consumption.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

Limak will be able to share the live data coming from the generators in its portfolio with the DSO via the VPP4IPlatform, which will be managed by the local DSO UEDAS. The VPP4IPlatform through power flow analysis and other simulations will be able to predict if there will be technical problems in the island's distribution network such as voltages out of the admissible range or over currents.

3.2. Energy communities (Formentera)

An energy community will be set up in Formentera. All buildings participating in the energy community will be equipped with a VPP4IBox. The VPP4IBox, in buildings that have photovoltaic systems and flexible loads and/ or energy storage units, will be able to maximize the amount of self-consumed energy in order to reduce CO2 emissions and use the submarine cable that connects Formentera to the national grid.

Buildings equipped with VPP4IBox which, however, are not equipped with photovoltaic generation systems or energy storage units will still benefit from the energy community through the exchange of energy with other buildings that have a surplus of production compared to their consumption. In fact, the VPP4IBox will allow the implementation of P2P energy trading through smart contracts. Smart Contracts will allow to validate this transaction without the supervision of third parties.

3.3. Balancing Services Provision (FLEXIS)

Located in Wales, the FLEXIS Demonstration Area spans 50 square kilometres of Neath Port Talbot, a region characterised by its industrial heritage and the UK's largest point source of CO2 emissions. In the demonstration area includes private and industrial customers, wind turbines generators, universities, and industrial research centres.

VPP4Islands project will use FLEXIS demonstration area to validate the functionality of balancing service provision implemented in the VPP4INode.

4. VPP4IPLATFORM TECHNICAL SPECIFICATIONS

The VPP4IPlatform will be a cloud-based platform. To better write the technical specifications of the VPP4IPlatform, it was decided to use IEEE guide to software requirements specifications (IEEE Standard 830-1984) [3].

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

Attached to this delivery, in Appendix A, the first version of the software technical specifications (SRS) of the VPP4IPlatform is presented. The SRS are the result of various brainstorming and meetings that took place among work package 2.

5. VPP4INODE TECHNICAL SPECIFICATIONS

The VPP4INode will be a cloud-based platform. For the VPP4INode, It was decided to use IEEE guide to software requirements specifications (IEEE Standard 830-1984), [3].

Attached to this delivery, in Appendix B, the first version of the SRS of the VPP4INode is available.

6. VPP4IBOX TECHNICAL SPECIFICATIONS

The goal of the VPP4IBox is to provide solutions for the control of DERs and smart appliances for flexibility provision and energy trading. The VPP4IBox is a hardware platform which features embedded software components. Consequently, it provides the communication of information between the energy system of each monitored facility at the demonstration sites and the flexibility aggregators, the VPP4INodes.

This section describes the main specifications of the VPP4IBox, based on the current information available to date in the VPP4Island project. As the project moves forward and the demonstration sites in the islands are defined in a more precise way, some of these specifications could be affected, in order to be adapted to the real needs of the demonstration sites. A more detailed information of the VPP4IBox will be included in in Task 6.2, which is focused on the development of the VPP4IBox.

6.1. VPP4IBox FUNCTIONALITIES

To implement the services described in Section 2, it is necessary to establish the functionalities of the VPP4IBox. These functionalities are based on the VPP4Island Concept Design Architecture that was introduced in Deliverable D2.2 and on specifications provided by the host of the demonstration sites.

The main areas in which the VPP4IBox will participate are the ones consisting of Monitoring, Model Predictive Control, Scheduling and Demand Response (DR) automation. Based on that,

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

the VPP4IBox functional diagram can be divided in to 4 main blocks: Energy Management Commitment Engine, Smart Contracts, Virtual energy storage systems (VESS) module and Distributed Energy Resources (DER) communication interface. Figure 4 illustrates how the main VPP4IBox functionalities interact with each other.

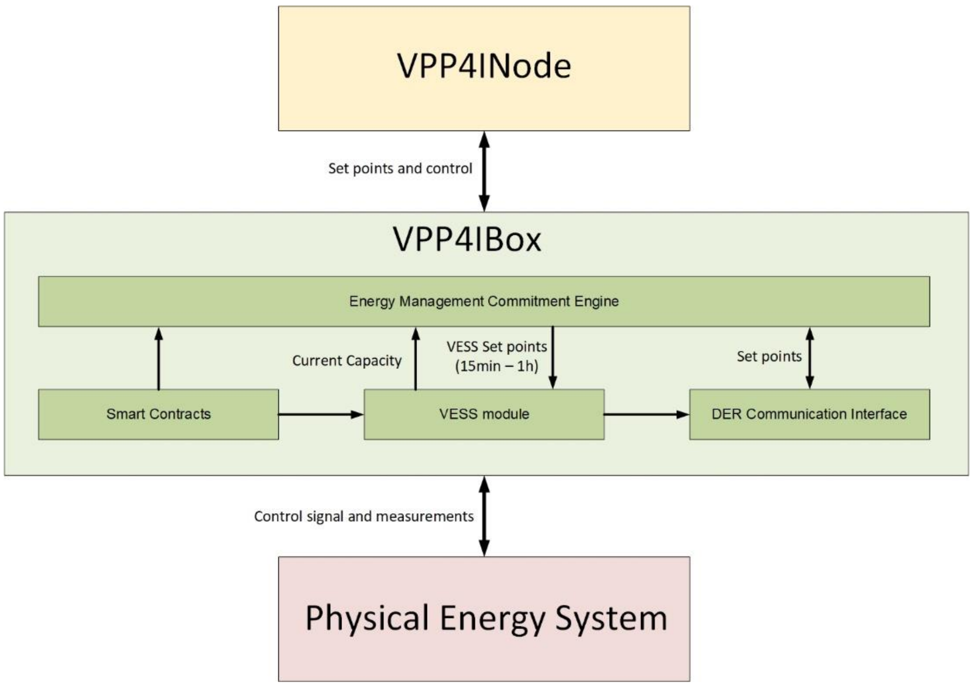


Figure 4: VPP4IBox functionalities

- The Energy Management Commitment Engine is in charge of communications with the VPP4INodes and data harmonization between the two elements.
- The Smart Contracts will run on the Ethereum blockchain in order to implement a Peer-2-Peer Trading Engine.
- The VESS module will estimate the Flexibility Capacity and provide a set point to the Energy Management Commitment Engine.
- The DER communication interface will be connected to the primary energy sources such as PV, wind generators or energy storage units.

Those functionalities in the VPP4IBox will be provided by two main elements, a Remote Terminal Unit (RTU), and a Raspberry Pi. The RTU would be in charge of communicating with the DER

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

and energy storage units, harmonizing the data and then sending it to the VPP4INode. Then, the Raspberry Pi would implement the VESS and smart contracts modules and would also exchange information with the VPP4INode.

6.2. Hardware Requirements

As mentioned previously, the VPP4IBox main hardware will be based on a Remote Terminal Unit (RTU), and a Raspberry Pi.

The RTU will be provided by Schneider Electric, featuring a large stack of communication protocols (Modbus, IEC 870-5-101/104, IEC 61850-based protocols), web-based interface and enhanced cyber security model imposed by IEC 62443 standard.

Figure 5: Example of a RTU platform

Figure 6: Raspberry Pi module

Each VPP4IBox will also be equipped with an 8GB Raspberry Pi 4 Model B Go module. These modules cover all recommended hardware requirements, so all the developed Smart Contracts and VESS algorithms will run and operate directly from them in an efficient and seamless manner. Regarding free disk space, 20GB should be considered the minimum required size, while 32GB is the recommended one.

Another important requirement that the VPP4IBox should have is a stable and independent communication interface with the elements of the VPP4IPlatform, so it will be necessary to include a 3G/4G modem in each VPP4IBox.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

6.3. Software Requirements

The software requirements have been separated by each of the software blocks presented in Figure 4.

6.3.1. Energy management commitment engine and DER communication interface

These modules will be mainly performed by the RTU. As such, the specifications applied to the RTU would be the following ones:

- Implementation of an internal web server, to be able to connect in real-time to the RTU to check the main operation parameters and perform some troubleshooting actions.
- Support of cyber security features, to provide protection against possible cyber-attacks.
- Possibility to configure the RTU remotely, to minimize the need of travelling on site to upgrade the RTU configuration.
- Possibility to log information and store it locally at the RTU, for maintenance and troubleshooting purposes.
- Support of real-time operations and communications through standard telecontrol protocols, to ensure the information is properly managed and transferred to the right elements of the VPP4Island solution.
- Capability to implement some calculations over real-time data.

It is important to mention as some of those requirements have been included with the aim of obtaining an improved operability and maintainability of the system based on the RTU.

6.3.2. VESS Module

A Virtual Energy Storage System (VESS) is an aggregation of flexible demand units and small capacity energy storage units to form a single entity that act similarly to a large conventional energy storage system. A frequency control scheme of the VESS that provides low, high and continuous frequency response services was introduced. Additionally, a voltage control scheme of the VESS that supports the voltage control of the distribution network was established.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

As mentioned in 6.1, the VESS module estimates the flexible demand capacity and provides a set point to the energy management commitment engine. There are two services that are implemented by the VESS, frequency and voltage support.

The frequency control scheme of the VESS is implemented as follows:

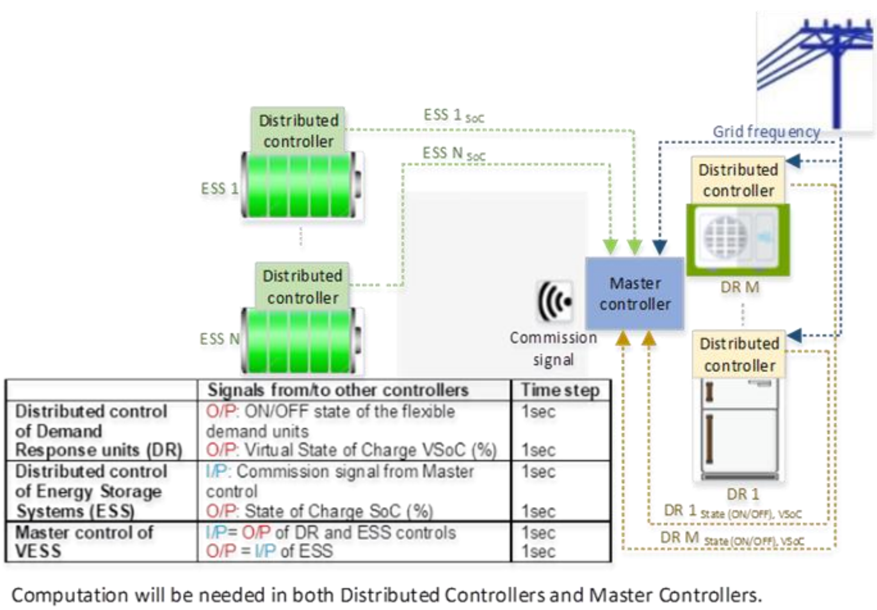
1. When a large frequency deviation takes place, the distributed controllers switch ON/OFF DR units to stop the frequency deviation. Then, these controllers compute the units' VSoC and send it with the units' ON/OFF states to the master controller.

2. The master controller calculates the required power output from the VESS and send a commission signal to all distributed controllers of ESSs.

3. The distributed controllers of ESSs compute the required power output and instruct ESSs to deliver it. Then, these distributed controllers send ESSs' SoC to the master controller.

4. The steps 1-3 above are implemented consecutively every second until the frequency deviations return to normal values.

Figure 7 illustrates the Frequency Control strategy implemented by the VESS.



	Signals from/to other controllers	Time step
Distributed control of Demand Response units (DR)	O/P: ON/OFF state of the flexible demand units O/P: Virtual State of Charge VSoC (%)	1sec 1sec
Distributed control of Energy Storage Systems (ESS)	I/P: Commission signal from Master control O/P: State of Charge SoC (%)	1sec 1sec
Master control of VESS	I/P= O/P of DR and ESS controls O/P = I/P of ESS	1sec 1sec

Figure 7: Frequency Control of VESS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

The voltage control scheme of the VESS is implemented as follows:

1. When a large voltage deviation takes place, the distributed controllers switch ON/OFF DR units. No communication is required between these controllers.
2. The distributed controllers of ESSs rely on the remote voltage measuring devices (e.g., voltmeters) to send them the voltage measurements of vulnerable busbars. Based on the voltage measurements, the distributed controllers of ESSs compute the required power output from ESSs and instruct ESSs to deliver it. Hence, ESSs are expected to eliminate any voltage violations following the response of DR units.
3. The steps 1-2 above are implemented consecutively every minute until the voltage deviations return to the normal.

Figure 8 illustrates the voltage control strategy implemented by the VESS.

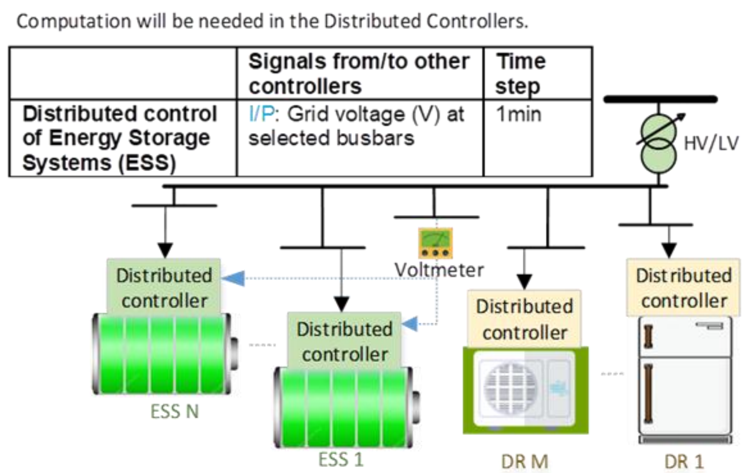


Figure 8: Voltage Control of VESS

6.3.3. Smart Contracts

For the Smart Contracts that will run and operate from the Raspberry Pi 4 Model B Go module, it is required to have installed any Linux 20.04 LTS version. Past versions are also acceptable but should be no earlier than 18.04. A proper OS setup requires some ports open so that Smart Contracts' related infrastructure communicate with the Infura API and subsequently with the permissioned-based Ethereum blockchain environment.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

6.4. COMMUNICATIONS PROTOCOLS

The VPP4IBoxes will be integrated in the existing architecture available at the demonstration sites. Below, a high-level description of the leading islands demonstration sites is provided, with respect to the interaction with the VPP4IBoxes.

Gökçeada demonstrator

The VPP4IBox should communicate with energy analysers that provide measurements and statuses of circuit breakers of some wind turbines. Similar information will also be gathered from a solar power plant, an Energy Storage System (ESS) and several diesel generators.

Formentera demonstrator

In the Formentera case the information will be gathered from public buildings which are equipped with PV installations. The VPP4IBox could get information from a monitoring system already in place, or it could be necessary to deploy another monitoring system to obtain the needed information for the use cases defined in the project.

Most of the communications of the VPP4IBox will be handled by the RTU. The RTU should be able to use standard communication protocols for exchanging information with other devices deployed at the demonstration sites (like protective devices deployed at the DER or energy storage units for instance, as introduced above). Based on the available information of the existing equipment at the demonstrations sites, the protocols that would need to be included by the RTU would be the following ones:

- Modbus TCP/RTU protocols.
- IEC 870-5-101/104 protocols.
- Protocols included in IEC 61850 standard, like MMS or GOOSE.

On the other hand, the Raspberry Pi will have the Smart Contracts communicating with the Infura API and with the Ethereum blockchain environment. Furthermore, for the additional verification layer, some extra ports will need to be open for the TestNet POST and GET functions to work, so the corresponding data transactions can be verified on LTO Network. Raspberry Pi should also

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

support some of the already mentioned communication protocols of the RTU, in order to exchange information between the VESS module and the Energy Management Commitment engine.

A general architecture proposed to be implemented in a VPP4IBox is illustrated in Figure 9.

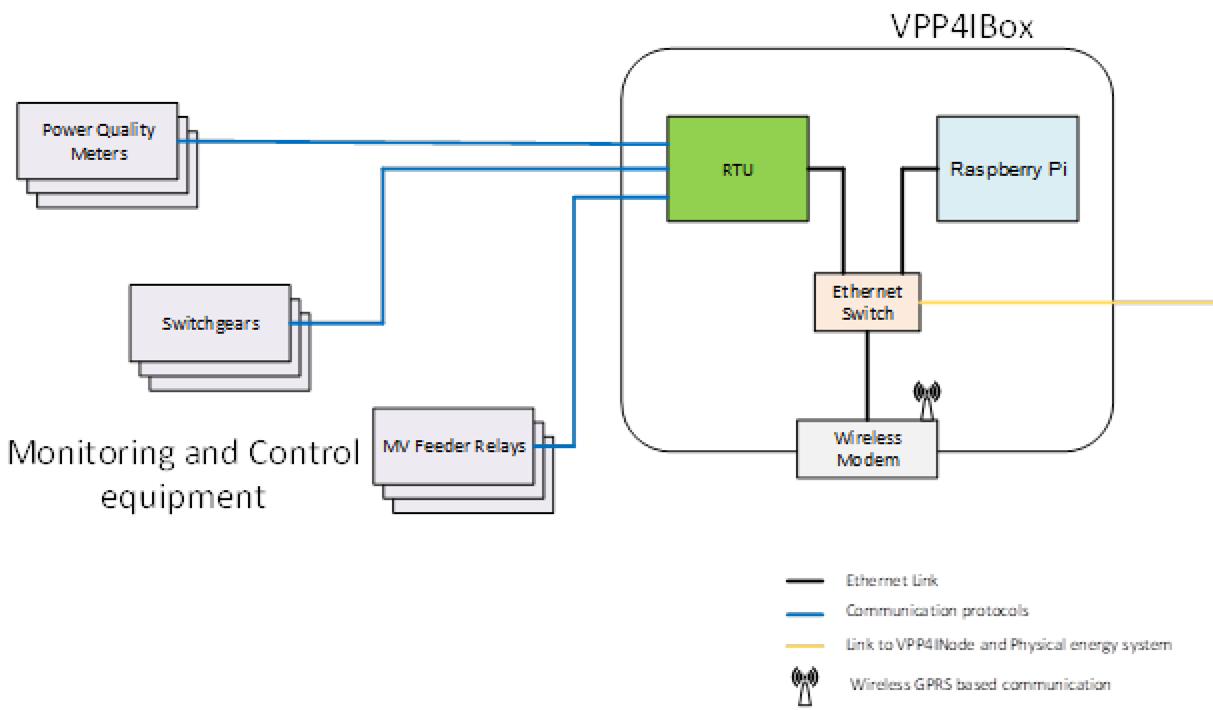


Figure 9: VPP4IBox architecture example

The communication links can be divided into 4 groups:

- The first group include the Ethernet link between the RTU and the Raspberry Pi. This link will provide the necessary setpoints gathered by the RTU that will send the necessary inputs for the VESS functionality implemented by the Raspberry Pi.
- The second group connects the RTU to the Metering and Control hardware available at the demonstrations sites. This includes devices such as Switchgears, Energy Analysers or Feeder Relays. This communication link will be implemented by automation protocols, depending on the hardware installed at the demonstration sites.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

- The third group connects the VPP4IBox with the rest of the VPP4IPlatform. This includes an TCP/IP link with the VPP4INode which could implement a MQTT or HTTP connection.
- Finally, the fourth group will be provided by a Wireless Modem which incorporates a 3G/4G connection for remote access. The modem would allow the VPP4IBox devices to communicate with other elements of the infrastructure. Having a 3G/4G connection the VPP4IBox does not have to depend on Internet communications that may or may not be available at each site.

7. BIBLIOGRAPHY

[1] Usef Design Team, "FRAMEWORK," 2021. [Online]. Available: https://www.usef.energy/download-the-framework/#.

[2] Ministero dello sviluppo economico, "DECRETO 16 settembre 2020," *Gazz. Uff. della Repubb. Ital.*, 2020.

[3] IEEE, "Recommended Practice for Software Requirements Specification, IEEE Std 830-1993, IEEE Computer Society," *Software Engineering Standard Comminttee of the IEEE Std Computer Society*, vol. Revision o. p. 32, 1998.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n°957852

Technical Specification

for

VPP4IPlatform

Version 0.2.2

Prepared by Francisco Méndez
IDEA Ingeniería

DATE 30/07/2020

Table of Contents

Revision History

Name	Date	Reason For Changes	Version
Francisco Méndez	16/7/2021	Initial submit	0.1
Diego Piserà	26/7/2021	Review of initial submission	0.2
Ioannis Dontas Konstantinos Tsiomos Entrit Metai	28/7/2021	Peer review of v0.2 by BC2050	0.2.1
Saif Sami, Yue Zhou and Meysam Qadrdan	30/7/2021	Peer review of v0.2.1 by CU	0.2.2

1. Introduction

1.1 Project Scope

The VPP4Islands Cloud Platform project is a part of a larger system that will provide the functionality and features to clients and users to consume and process the data provided by different sources.

This system will provide the ability to execute and consume data in several processes or subsystems. Based on the taxonomy described at the earlier stages of the project, this system will hold the global forecasting engine, the digital twin and the smart planning and decision support system, all of them aligned with the shared knowledge base.

1.2 Terms, Definitions, and Acronyms

- Knowledge Base (KB).
- Digital Twin (DT).
- Global Forecasting Engine (GFE)
- VPP4Islands. The project in which this system will be developed and deployed.
- VPP4Islands Cloud Platform (VCP) or VPP4IPlatform. The system described in this document.

1.3 References

The information referenced in this document is listed below

- Taxonomy

2. Overall Description

2.1 Product Perspective

The VPP4Islands Cloud Platform project is a part of a larger system that will provide the functionality and features to clients and users to consume and process the data provided by different sources.

The system will consume data from the observations, which provide information used by the system to run the simulations and forecasting. This data will be stored and transformed to be ready to execute the forecasting engine and the digital twin to:

- Optimize energy usage
- Optimize CO_2 emissions
- Make decisions about control signals and setpoints into the VPP4INode system.

2.2 Product Features

The system will provide the next listed features

- Cloud native design
- Cloud provider independent
- Collect and route data from different data sources
- Store and persist different data models and formats
- Retrieve and expose data to third party services
- Run the global forecasting engine to provide and transform data to be used in the simulations
- Run the digital twin engine to provide simulation data to third party services
- Run the energy and CO_2 emissions saving system
- Run the smart planning tools and decision support system
- Manage and route data from and into the shared knowledge base

2.3 User Classes and Characteristics

The final user of this system is meant to be an experienced and digital native person whose expertise must fall into the electrical / scientific scope.

On top of that the users must be experienced with REST APIs and how the HTTP or https protocol works.

2.4 Operating Environment

The system will be operating in a private or public cloud, related to the dependent systems. That could be, data sources that could not be exposed and must remain in private networks.

This system will run in single or multiple locations depending on the requirements of the stakeholders and will be running continuously with the highest availability possible.

2.5 Design and Implementation Constraints

The system will be designed to run as a cloud native solution, and it will be independent of the provider.

The system will run in a Kubernetes environment so the deployment of the solution will be as abstracted as possible using images (containers) of the services that run within the platform.

The final infrastructure requirements of the system will be defined later, but one could take as temporary the minimum requirements for a production Kubernetes environment.

Hardware Requirements

One or more machines running one of:

- Ubuntu 16.04+
- Debian 9
- CentOS 7

- RHEL 7
- Fedora 25/26 (best-effort)
- HypriotOS v1.0.1+
- Container Linux (tested with 1800.6.0)

Minimal required memory & CPU (cores)

- Master node's minimal required memory is 2GB and the worker node needs minimum is 1GB
- The master node needs at least 1.5 cores and the worker node need at least 0.7 cores.

2.6 Assumptions and Dependencies

This system will use internet to access external dependent services, such as market prices or weather information.
The system depends on other subsystems that carry other responsibilities and should be available to successfully complete the project.
Those systems are:

- Global forecasting engine
- Digital twin
- Energy and CO_2 emissions savings
- Smart planning tools and decision support system
- Shared knowledge base

3. System Features

The system will provide the abilities listed below.

From the **Observations** point of view, the system will provide the listed functionality:

- Ability to insert data in json format
- Ability to securely make authentication and authorization

From the **VPP4INode** point of view, the system will provide the listed functionality:

- Ability to setup the setpoint for generator and flexible loads and manage data event.
- Ability to consume information from the shared knowledge base

From the **services** point of view, the system will provide the listed functionality:

- Ability to consume information from the subsystems within the core system (VPP4IPlatform)

From the **administrator** point of view, the system will provide the listed functionality:

- Ability to configure how the system interacts with other subsystems.

As for the **general** functionality, the system will have:

- Ability to run simulation triggering the digital twin system
- Ability to run forecasting triggering the forecasting engine
- Store different data models:
  - Document and object based
  - Timeseries based
- Provide a documented REST API to interact with the main system and its subsystems within:
  - Using the OpenAPI v3 standard
  - Using the Swagger UI

4. External Interface Requirements

4.1 User Interfaces

The graphical user interface for the VPP4IPlatform has not yet been discussed. This will be defined according to the needs of the DSO who will be the user of the tool. The discussion and implementation of the graphical interface will take place within WP6, in particular in task T6.1.2.

4.2 Hardware Interfaces

Non applicable.

4.3 Software Interfaces

The system will have an advanced http or https rest API documented by the standard OpenAPI v3 and providing all the documentation needed to interact with the system.
That will be the inputs coming from the observations and the VPP4INode system and the outputs needed by the dependent services that consume the data, documented by the stakeholders.

4.4 Communication Interfaces

The system will make use of TCP/IP communication sockets along the HTTP or https protocol (Figure 1).

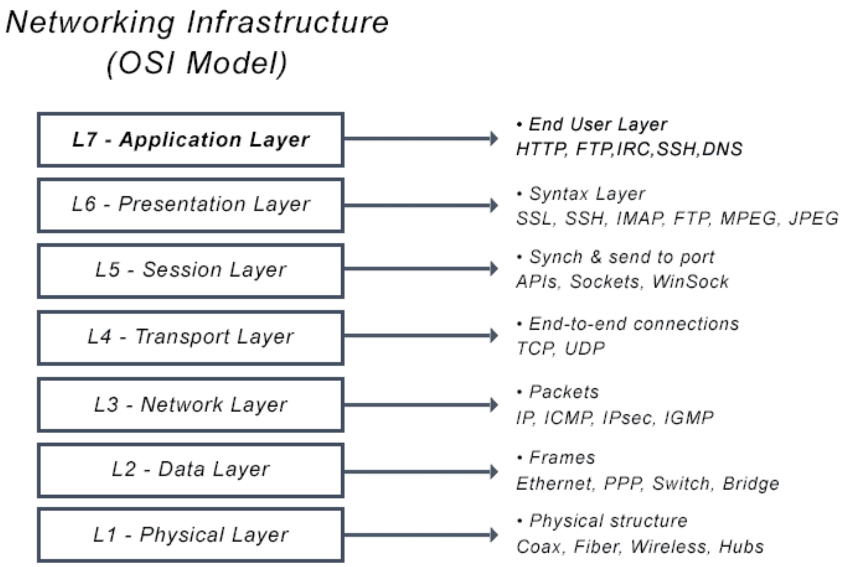


Figure 1:Networking Infrastructure (OSI Model)

5. Detailed Use Cases

5.1 Use case 1. Inserting data from observations

The platform design should only be thought of as a data consumer and not as a data requester. That is, the external information should only be inserted by external clients and not requested by the platform.

This design asserts that the subsystems in the platform are consuming the information available internally and thus making it more secure.

The system will provide a feature to register a client that securely inserts the data information regarding this client into the platform shared knowledge base.

To securely insert the data, the client will need to provide a token or key to accept the incoming request by the client to post the data.

This data will be evaluated to assert that it conforms a schema previously accepted by both parts, client, and platform.

5.2 Use case 2. Consuming information from services and the VPP4INode

External services will have the ability to consume information from the shared knowledge base using a rest API provided by the platform.

These endpoints will serve the data requested by the third-party services and node as a resource.

The REST API will be secured by industry standards such as OAuth2 and OpenID, thus providing an easy way to interact with the API and integrate it in a quick a secure manner.

The API will conform OpenAPI v3 to make sure integrations honour the interface. As for the developer, the system will provide an endpoint for a fully documented API using SwaggerUI to try it out.

The resources will be defined by the data inserted in the use case 1 and the generated by the forecasting and digital twin engines.

5.3 Use case 3. Executing data forecasting using the global forecasting engine

The system will have a forecasting engine to provide the platform with future-trends information about external inputs using a model.

This engine will make use of the information available from the use case 1. When requested, the engine will provide a forecasting result using the historical data stored in the shared knowledge base and storing the result back to it.

The forecasting engine will be triggered by a background job with a frequency set by the system administrator. That is, the information from this engine will be available as the system keeps executing the tasks in background.

The task will save and store periodically forecasting data regarding the information needed to run the digital twin or other subsystems that require this data.

The subsystems which need this information, will request the latest available stored data in the shared knowledge base by the last task if no other query options are needed.

5.4 Use case 4. Executing simulations using digital twin engine

The system will have a digital twin engine which will run the simulation models regarding the electrical grid and the environmental model. The DT will use the information from the forecasting engine combined with the static data containing information about the electrical grid and other physical assets (such as load and generators) to run simulations. The results of simulations will be stored in the KB.

The system will have two main ways of executing the digital twin engine.

- This system will be triggered by a background job with a frequency set by the system administrator. That is, the information from this engine will be available as the system keeps executing the tasks in background.
- The external service will need a specific simulation using other parameters not set in the default environment. That is, providing a way to execute a simulation on demand, but in an asynchronous way to create a queue of executions that will not lead to overload the system. When the system finishes the simulation, the results will be stored in the shared knowledge base to be consumed by the client who requested it.
- The system will provide a way to let the client know that the task has been finished by webhook or by polling the status.

5.5 Use case 5. Providing a setpoint to VPP4INode

This use case describes how the platforms set the events for the VPP4INode setpoints. The VPPI4Platform will have an automated background job which will be running in the stablished period at the required frequency.

This job will execute the simulation needed to provide a setpoint to the VPP4INodes as an event.

This event will live in a queue which the Nodes will subscribe to access to these events.

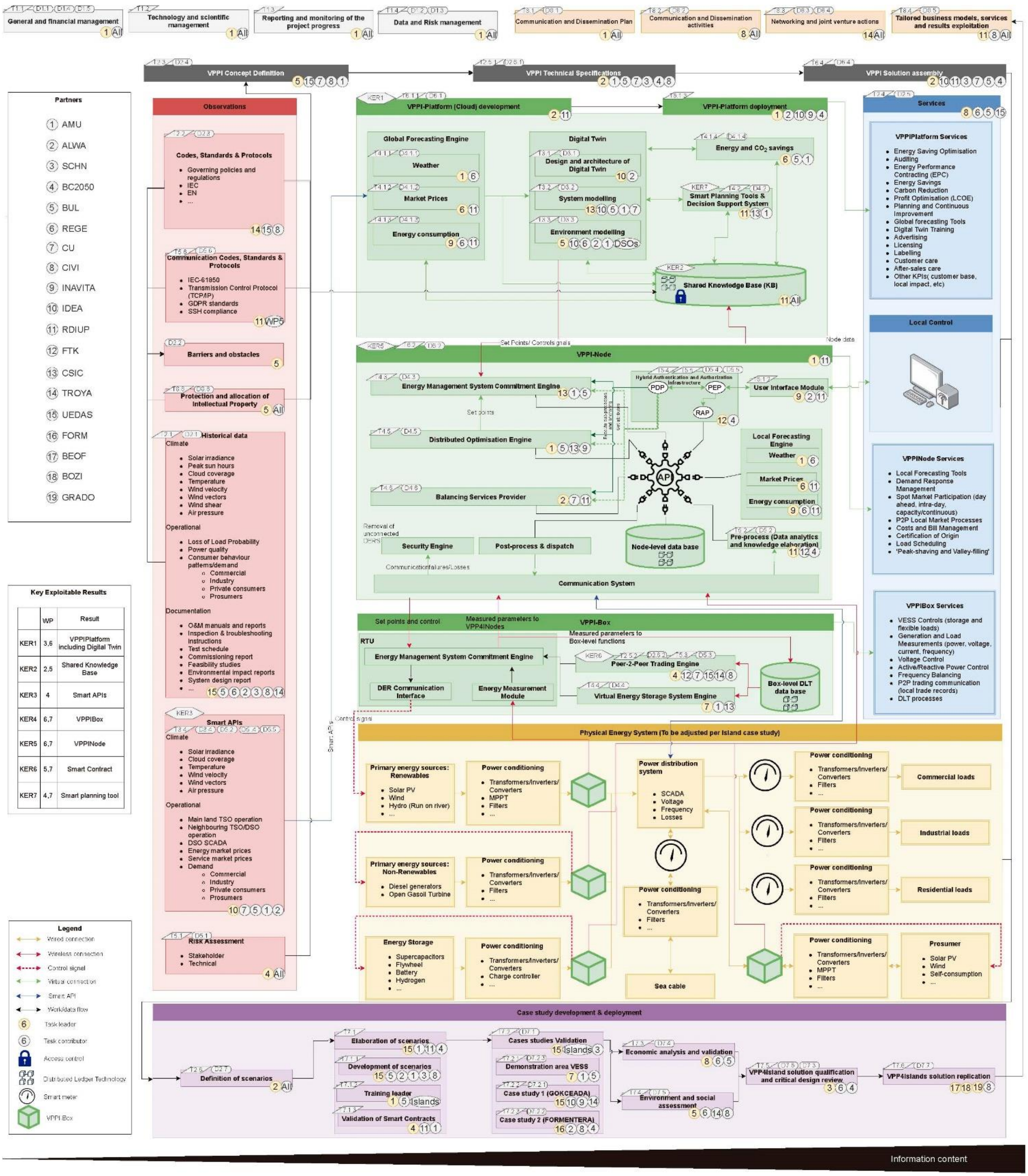
At the time the event is received the node will process and acknowledge it to make sure it has been processed.

- Administrator will set a frequency in which the digital twin engine should be triggered.
- The task will run in background and resolve as a setpoint of the node.
- The task will publish the event so that the node will process it as soon as the task has finished.

Using this event-driven pattern, the node just needs to listen to the published event.

6. Appendix

6.1 Taxonomy



General and financial management
Technology and scientific management
Reporting and monitoring of the project progress
Data and Risk management
Communication and Dissemination Plan
Communication and Dissemination activities
Networking and joint venture actions
Tailored business models, services and results exploitation
VPPI Concept Definition
VPPI Technical Specifications
VPPI Solution assembly
Partners
AMU
ALWA
SCHN
BC2050
BUL
REGE
CU
CIVI
INAVITA
IDEA
RDIUP
FTK
CSIC
TROYA
UEDAS
FORM
BEOF
BOZI
GRADO
Observations
Codes, Standards & Protocols
Communication Codes, Standards & Protocols
Barriers and obstacles
Protection and allocation of Intellectual Property
Historical data
Smart APIs
Risk Assessment
VPPI-Platform (Cloud) development
VPPI-Platform deployment
Global Forecasting Engine
Weather
Market Prices
Energy consumption
Digital Twin
Design and architecture of Digital Twin
System modelling
Environment modelling
Energy and CO2 savings
Smart Planning Tools & Decision Support System
Shared Knowledge Base (KB)
Services
VPPIPlatform Services
Local Control
VPPI-Node
Energy Management System Commitment Engine
Distributed Optimisation Engine
Balancing Services Provider
Security Engine
Post-process & dispatch
Node-level data base
Pre-process (Data analytics and knowledge elaboration)
Communication System
User Interface Module
Local Forecasting Engine
VPPINode Services
VPPI-Box
Peer-2-Peer Trading Engine
Virtual Energy Storage System Engine
DER Communication Interface
Energy Measurement Module
Box-level DLT data base
VPPIBox Services
Physical Energy System (To be adjusted per Island case study)
Primary energy sources: Renewables
Primary energy sources: Non-Renewables
Energy Storage
Power conditioning
Power distribution system
Sea cable
Commercial loads
Industrial loads
Residential loads
Prosumer
Case study development & deployment
Definition of scenarios
Elaboration of scenarios
Development of scenarios
Training leader
Validation of Smart Contracts
Cases studies Validation
Demonstration area VESS
Case study 1 (GOKCEADA)
Case study 2 (FORMENTERA)
Economic analysis and validation
Environment and social assessment
VPP4Island solution qualification and critical design review
VPP4Islands solution replication
Key Exploitable Results
KER1 3,6 VPPIPlatform including Digital Twin
KER2 2,5 Shared Knowledge Base
KER3 4 Smart APIs
KER4 6,7 VPPIBox
KER5 6,7 VPPINode
KER6 5,7 Smart Contract
KER7 4,7 Smart planning tool
Legend
Information content

Technical Specification

for

VPP4INode

Version 0.1.2

Prepared by Diego Piserà (ALWA)

30/Jul/2021

Table of Contents

Revision History

Name	Date	Reason For Changes	Version
Diego Piserà	22/7/2021		V0.1
Ioannis Dontas Konstantinos Tsiomos Entrit Metai	28/7/2021	Peer review of v0.1.0 by BC2050	V0.1.1
Saif Sami, Yue Zhou and Meysam Qadrdan	30/7/2021	Peer review of v0.1.1 by CU	V0.1.2

1. Introduction

The Virtual Power Plant (VPP) is a key technology for solving the tasks of an aggregator in the new distributed energy paradigm. The VPP4ISLANDS allows aggregating thousands of electricity producers, consumers, and energy storage units. It also enables offering their power and flexibility into different markets by intelligently controlling their power injection and consumption.

VPP4INode is a VPP software solution for various business cases. It supports aggregators in energy trading (Day-ahead and Intraday Market), in Balancing Services Provision (Balancing Market) and in the management of Energy Communities. It has an intelligent module for load managements & demand response that enables the aggregator to observe and control flexible loads, energy storage units and generators on price signals from the power market.

1.1 Purpose and Intended Audience

The purpose of this technical specification is to define what will be implemented in VPP4INode tool. It provides a means of communication between the software designers of the different partners of the VPP4Islands consortium.

1.2 Project Scope

VPP4INode is a part of a larger system called VPP4Islands. The larger system is made up of three basic units: VPP4IPlatform, VPP4INode and VPP4IBox.

VPP4Islands aims to facilitate the integration of renewable systems, accelerate the transition towards smart and green energy and help Islands to exploit energy efficiency potential and innovative energy storage approaches, foster the active participation of citizens and become self-sufficient in energy, while reducing costs, GHG emissions and reliance on heavy fuel oil to generate power, and creating new intelligent business, growth, and local skilled jobs.

To reach these goals, VPP4Islands project proposes disruptive solutions based on digital twin concept, Virtual Energy Storage Systems (VESS) and Distributed Ledger Technology (DLT) to revolutionize the existing VPP and build smart Energy Communities. Based on aggregation and smart management of distributed energy resources (DERs), VPP4Islands increases the flexibility and profitability of energy systems while providing novel services. VPP4Island will also enhance the Demand Response Capability of consumers by understating their behaviours and promoting self-consumption.

VPP4INode will be a Software as a Service (SaaS) aimed at aggregators. It is composed by application software and database running on cloud infrastructure. The cloud provider installs and operate application software in the cloud and cloud users access the software from cloud clients. Since the aggregator can cover different roles in the electricity market with different business models, the VPP4INode will provide to aggregators different software that will be able to assist them in different tasks. The VPP4INode will be composed off:

1. An algorithm that will be able to assists the aggregator in selling energy on the day-ahead and intraday markets.
2. A software that will be able to assist the aggregator in the balancing services provision.
3. A software that will be able to assist the aggregator in the management of Energy Communities.
4. A forecasting Engine that will be able to forecast the weather temperature, the wind speed, the solar irradiation, the electricity demand, the generation from renewable sources and the market price.
5. A data exchange system: The data exchange with other systems on the side of the VPP operator - such as VPP4IPlatform, SAP databases, trading platforms or accounting systems – will takes place via an API.
6. A communication system with the asset on the field (i.e., energy storage, power generators and loads) able to receive and filter data on real time.

The VPP4INode will NOT have:

1. A trading platform that is able to access to the energy market, instead the VPP4INode will be able to communicate with the energy trade platform via API.
2. A Technical Virtual Power Plan that will be able to perform power flow analysis. The results of analysis will be used to assess the technical feasibility for the distribution grid of the of the generation/consumption plan scheduled.

1.3 Terms, Definitions, and Acronyms

A list with the definition of the actors and role in the electricity market framework, such as Balance Responsible Party, Aggregators, etc, can be found in D2.5 – "VPP4Islands Services".

1.4 References

These technical specifications are the results of various meetings between the partners of VPP4Islands project, the minutes of this meetings are available for project 's partners on the LIS platform.

The information referenced in this document are listed below:

- Taxonomy

2. Overall Description

2.1 Product Perspective

In this section an overview of the VPP4INode solutions is provided.

2.1.1 **VPP4INode a VPP software solution for various business case.**

The VPP4INode will provide a VPP software solution for various business case. The VPP4INode not only will allow aggregating thousands of electricity producers, consumers, and storage units. It will enable offering their power and flexibility into different markets by intelligently controlling their feed-in and consumption.

Energy Trading: with VPP4INode, the aggregator can bundle a great amount of different energy sources and thus achieve the necessary size to participate in power energy markets. Thanks to the live data transmitted from each technical unit to the VPP, the aggregator will be equipped for trading renewable energies.

Dispatch: VPP4INode will be equipped with a dispatching software for scheduling flexible assets, such as diesel generators and energy storage, based on the current market prices. A price oriented steering can significantly increase the revenues.

Balancing services: VPP4INode enables the aggregator to increase or reduce the electricity production of controllable assets, such as energy storage units or diesel generators, at short notice. Thus, the aggregator can ensure the grid stability and achieve additional revenues on the balancing energy markets.

Load management & demand response: Commercial and Industrial consumers can also be aggregated and controlled via the Virtual Power Plant. This enables the aggregator to control install and operate application software in the cloud able to monitor and control consumer's assets. The aggregator will be able to send consumption set point to flexible loads based with the aim to get advantage on market price.

Energy Communities: Commercial and industrial consumers, prosumers and small energy producer that are located in a restricted area (e.g., in the same feeder) can be aggregated in an Energy Community. This enables the aggregator to monitor and control assets shared between various members of the energy community (for example energy storage).

2.2 Product Features

In this section is provided a summary of the features that the VPP4INode will possess.

2.2.1 **Features of VPP4INode, a VPP Software as a Service.**

VPP4INode will be a modular designed software as a service solution (SaaS) that enables the owner of the VPP to connect, monitor, and control distributed power producers, consumers, and energy storage systems. Thereby, it will offer a wide range of business fields to Renewable Energy Sources portfolio operators, aggregators, utilities, grid operators and energy traders.

Aggregation: A standard interface will assist the aggregator to connect different renewable energy assets such as wind, solar, or hydro power plants and controllable loads into the VPP and steer them remotely.

Monitoring: The control system will display and records real-time information on current capacity, storage levels, and standby status of the connected assets. The aggregator will be able to see the exact amount of available capacity.

Data Visualization: The control system of VPP4INode will provide several interfaces. For example, the owner of the VPP will be able to filter the information provided by the interface by technology type, customer groups, or location.

High-Performance Data Processing: Price signals from the energy markets and control signals from the system operator are processed in seconds and converted to operational commands for the assets.

Optimized Asset Operation: Based on data of the networked assets in addition to market and weather data, the aggregator will be able to execute schedules for peak-load operation and implement demand response solutions.

Individual Control: The central control system remotely manages each asset and ensures the predetermined schedule is executed respecting individual restrictions such as technical constraints. Schedule changes are possible on short notice.

2.3 User Classes and Characteristics

Here are listed potential users of VPP4INode:

1. **Technical team of an aggregator**: this user has in-depth knowledge of electricity markets and its mechanism.
2. **VPP members**: they are the energy managers of power plants or flexible loads; these users have in-depth knowledge of electricity markets and its mechanism. It is expected that this kind of users have an excellent knowledge of power plant or of flexible load that they manage.
3. **Energy Community Members**: They are the members that participate in the creation of the energy community. They are expected to have no technical knowledge of the electricity market or operation. The dashboards aimed at them will highlight the costs in the electricity bill and the savings in both economic and environmental terms.
4. **Energy Community Manager**: This user is expected to have a fair technical knowledge of renewable generation, energy storage and incentive mechanisms for energy communities. Therefore, this type of users will be provided with a dashboard with detailed technical information on consumption and electricity generation of members belonging to the community.

2.4 Operating Environment

The VPP4INode will be accessed by users using a thin client (i.e., a simple low performance computer) via a web application. The thin client will be able to establish a remote connection with a server-based computing environment. The server launch software programs, performing calculation, and storing data.

2.5 Design and Implementation Constraints

No implementation constraints have been identified at the moment.

2.6 Assumptions and Dependencies

No dependencies have been identified at the moment.

3. System Features

3.1 Power Trading: Trading Services

The VPP4ISolutions will provides a decision support for those actors as Balance responsible party or energy traders that have access to energy market. This includes support for maximising the revenue in day-ahead and intraday markets.

3.1.1 Support for energy trading

VPP4INode will provides services to those actors that have market access to power exchanges for example EPEX, EUROPEX and Enerji Piyasaları İşletme A.Ş. (EPİAŞ). This includes decision support for day-ahead and intraday markets. VPP4INode will provide a 24/7 trading decision support for power trading. The tools that make up the trading services are listed and described below:

Live Data: The VPP4INode will have access to live feed-in data from connected assets, including weather-dependent sources such as wind and solar. The data will be stored in the VPP4IPlatform to train the forecasting engine, because the more data is used, the more precise is the forecasting.

Accurate Forecasts: Weather data will be continually updated from meteorological analysis made in the forecasting engine. New data will be continuously compared against historical values for a steady reduction in forecasting errors.

Intelligent Dispatch: Whether an aggregator is selling the power of an individual asset through VPP or managing a portfolio, our detailed forecasting allows for balancing out any excess or shortfall quantity and help the aggregator to sell the power to the best possible price.

3.1.2 Portfolio & BRP Management

The VPP4INode will help the BRP in their role. This includes all communication with the responsible market partners such as the DSO and TSO and the accounting for customers' assets.
The VPP4INode will help the BRP to manage the risks regarding the portfolio management. The BRP services include schedule optimization of all the generators in their portfolio.

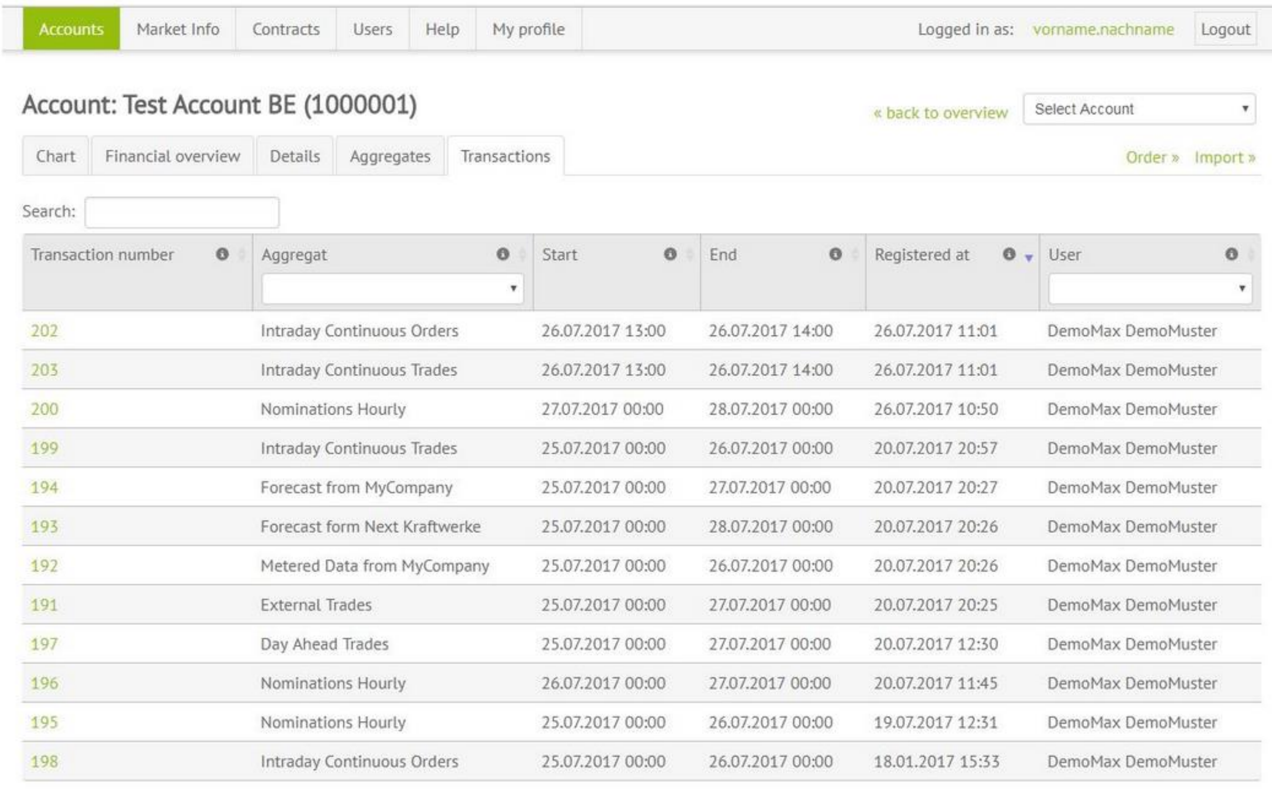
Energy Data and Schedule Management: As part of the balancing group management, VPP4INode will provide support for energy data management. VPP4INode will allow the user to monitor in real time the power injection/absorption of each system, the state of charge of the energy storages, and the power injection/absorption plans scheduled for plants, storages, and flexible load for the day ahead.

Communications with DSO: This includes forecasting and plausibility checks for generation and consumption. Moreover, it will provide an interface between BRP/energy trader and the DSO/TSO, it will prepare balancing group schedules and transmit them in time – schedule optimization included.

Portfolio Management and Residual Profile: VPP4INode will offer a wide range of solutions from short-term trading at day-ahead and intraday markets. It will implement the optimal strategy to cover the residual profile (i.e., the difference between the energy produced by RES and power consumption) with storage and flexible loads.

3.1.3 Communications with Trading Platform

VPP4INode will be able to communicate with the trading platform for an easy access to power markets for various participants. VPP4INode will enables utilities, balancing responsible parties or consumers (commercial & industrial) to manage their assets themselves. The possibilities range from trading excess or shortfall quantities, balancing a portfolio or directly procuring the energy that the customer needs for consumption. Also, aggregators and large-scale power producers can also manage their assets through VPP4INode. An easy to use interface gives customers all the information they need in terms of forecasting, trading, and analytics. Figure 1 depict the interface of a Trading Platform. The VPP4INode will be able to communicate directly with trading platform through API.



Transaction number	Aggregat	Start	End	Registered at	User
202	Intraday Continuous Orders	26.07.2017 13:00	26.07.2017 14:00	26.07.2017 11:01	DemoMax DemoMuster
203	Intraday Continuous Trades	26.07.2017 13:00	26.07.2017 14:00	26.07.2017 11:01	DemoMax DemoMuster
200	Nominations Hourly	27.07.2017 00:00	28.07.2017 00:00	26.07.2017 10:50	DemoMax DemoMuster
199	Intraday Continuous Trades	25.07.2017 00:00	26.07.2017 00:00	20.07.2017 20:57	DemoMax DemoMuster
194	Forecast from MyCompany	25.07.2017 00:00	27.07.2017 00:00	20.07.2017 20:27	DemoMax DemoMuster
193	Forecast form Next Kraftwerke	25.07.2017 00:00	28.07.2017 00:00	20.07.2017 20:26	DemoMax DemoMuster
192	Metered Data from MyCompany	25.07.2017 00:00	26.07.2017 00:00	20.07.2017 20:26	DemoMax DemoMuster
191	External Trades	25.07.2017 00:00	27.07.2017 00:00	20.07.2017 20:25	DemoMax DemoMuster
197	Day Ahead Trades	25.07.2017 00:00	27.07.2017 00:00	20.07.2017 12:30	DemoMax DemoMuster
196	Nominations Hourly	26.07.2017 00:00	27.07.2017 00:00	20.07.2017 11:45	DemoMax DemoMuster
195	Nominations Hourly	25.07.2017 00:00	26.07.2017 00:00	19.07.2017 12:31	DemoMax DemoMuster
198	Intraday Continuous Orders	25.07.2017 00:00	26.07.2017 00:00	18.01.2017 15:33	DemoMax DemoMuster

Figure 1: Trading Platform

3.2 Power Scheduling: Flexibility for Higher Revenues

The VPP4INode will aim to help Energy Traders and BRP to manage their portfolio as well as to help a single active customer and energy producer to maximise their profit when aggregated each other.

With an optimal power scheduling it is possible to generate higher revenues for flexible assets (i.e., energy storage) or reduce energy costs of a company by strategically planning the consumption processes. The optimal power scheduling will allow Energy Productor and active customers with flexible loads to achieve the best price in the day-ahead and intraday markets.

3.2.1 Schedule Optimization for Generators

The price for power changes 24 times a day at the day-ahead markets and 96 times a day at the intraday market of the EPEX SPOT. The price differences may exceed 50 Euro per MWh. An owner of a power generator can get advantage from this volatility and produce power when the price for it is high and let asset rest when the price is low. The VPP4INode will be able to perform the schedule optimization of flexible assets such as biogas, CHP, or hydropower plants.

Optimizing the production of a distributed asset through a VPP can result in a significant revenue growth. Depending on the asset type and the market various different options for optimization are possible. Based on the need of the owner of the asset the distributed optimization engine algorithms will develop a schedule that will allows the owner to take advantage of price spreads at the short-term power exchange. This can range from a weekly schedule, a daily optimization or a peak-load operation that is based on the quarter of an hour of the spot market. The power producer will decide according to the parameters of the asset, how much to optimize the operation of each single asset.

Below are the three main characteristics that the power scheduling system for generators will have:

1. **Individual schedules for each asset:** all the asset specific parameters will be considered to model the generator in the formulation of the optimization problem. The specific requirements of the asset (as minimum power production, energy constraints, etc.).
2. **Full control:** The power producer will be able to decide which functions can be controlled by VPP4iNode control system. This includes the maximum number of start & stop, power limits for steering the asset.

3. **Secure Machine2Machine communication:** All the data exchanged by the asset and the control system will be established via an encrypted connection.

Figure 2**Error! Reference source not found.** depicts an example of a controllable power unit which follows the price development on the electricity market.

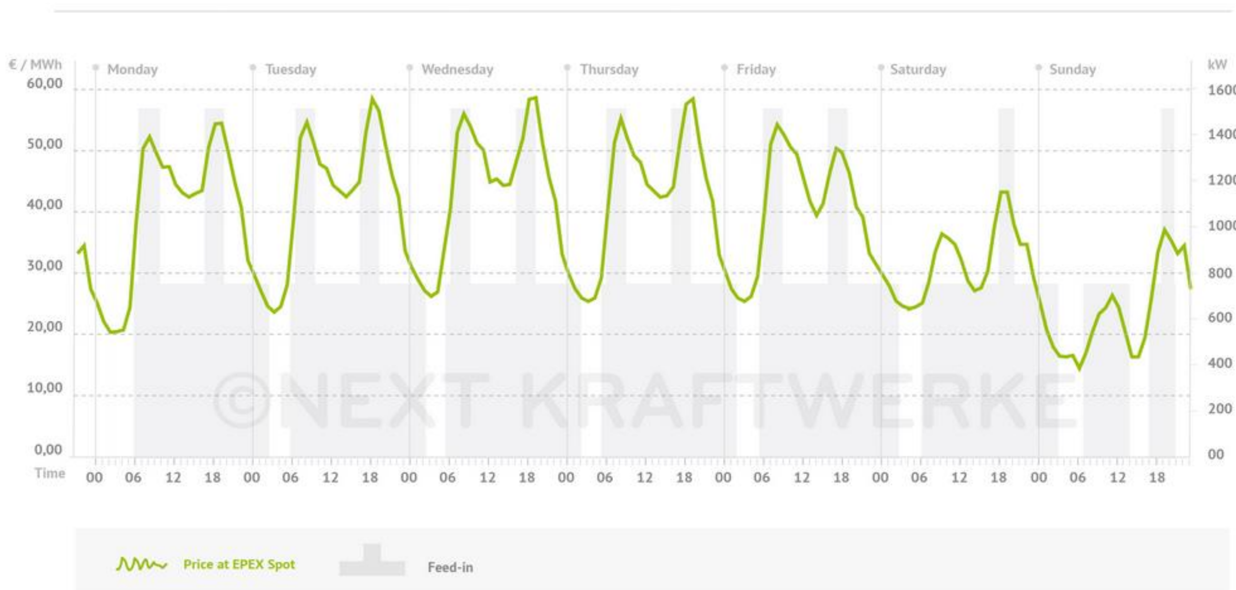


Figure 2: Optimal scheduling for a controllable power generator

3.2.2 **Schedule Optimization for Flexible Loads**

In many European countries electric loads can only offer flexibility with a peak and off-peak price in terms of pricing. For example, peak/off-peak tariffs generally apply for 2 periods of time whereas Real Time Pricing can have higher granularity e.g., hourly prices for day-ahead market and 96 times per day in intra-day market.

The VPP4INode will be able to take advantage of the granularity of the market with a continuous optimization that will be updated several times in a day.

Depending on how flexibly client processes can be implemented, He will be able to choose between different power rates (i.e., discrete level of power consumption). The VPP4INode will guarantee to customers a fixed upper price limit, under no circumstances the client will pay more than in a standard rate.

Customized time zones: With Customized time zones the VPP4Inode offers a power rate with different levels of flexibility. The customer can choose between different fixed times zones with variable pricing, for example for 6, 12 or 24 time zones per day.

Best of 96: With Best of 96, the power rate is optimized against the price fluctuations of the intraday market. Each quarter of an hour gets continuously optimized for the best possible power rate, all within the customer's restrictions. A price cap guarantees that the energy cost does not exceed a defined maximum.

Figure 3 represents the requirements for flexible loads that will be eligible to benefit from the load scheduling above described. The requirements are:

a) Load with a continuous power consumption
b) Load can be temporarily reduced
c) Load with a power consumption

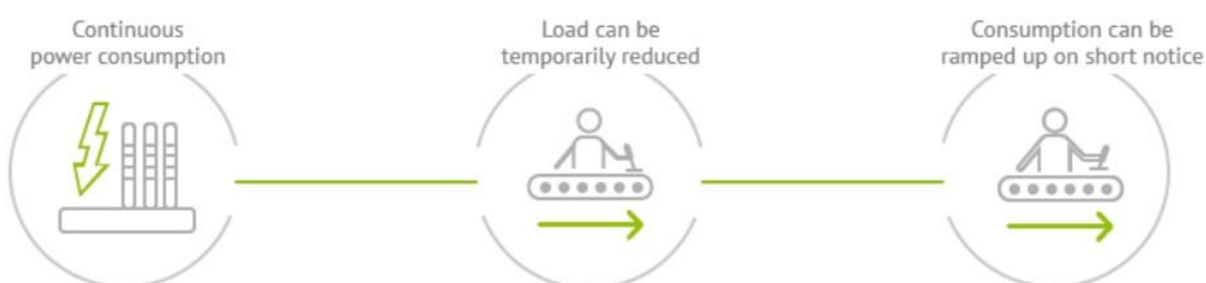


Figure 3: Flexible load requirements

3.3 Balancing Energy: Distributed Resources to Stabilise the Grid

The increased volatile feed-in of renewable energies brought a challenge to managing power grids: a stronger fluctuating grid frequency. These fluctuations need to be minimized in order to keep the grid stable. Aggregated in a Virtual Power Plant (VPP), distributed assets can play a vital role in levelling out these fluctuations. The VPP4INode networks small-scale producers, storage units and Commercial and Industrial (C&I) consumers in its VPP and thereby provides access to profitable balancing energy markets.

3.3.1 Balancing Energy from Distributed Assets

Today, not only large power plants can provide balancing energy. Aggregated in a Virtual Power Plant, flexible assets like biogas plants, hydropower units, CHP plants, batteries and even emergency generators can help stabilizing the grid and thereby generate additional revenues. Smaller units often have a shorter reaction time and combined in a VPP they offer a higher granularity in catching fluctuations. VPP4Islands will assist the Balancing Services Provider in providing ancillary services.

Requirements for the Provision of Balancing Services thought dispatchable sources: Different countries have varying balancing service products and requirements. But generally speaking, if a power productor can operate an asset that has the capability of ramping up or down its power production, he can provide balancing energy through a VPP. Once that an asset is prequalified (technically and functionally checked for complying with the electric system code), the unit will be part of the VPP4INode providing balancing energy. In case of a frequency imbalance, the VPP4INode will be able to receive an order from the TSO requesting a certain amount of power in order to balance out frequency deviations.

The assets able to provide balancing services need to have the following features:

1. Continuous power production
2. Possibility for remote control
3. Fast reaction time of asset's power production (the reaction time will be different based on which kind of balancing services will be provided)

3.3.2 Balancing Energy from Demand Response

Power consumption processes of C&I consumers can play an important role in providing balancing energy and help owners to generate additional profit. In this way, companies can generate revenues where they normally only have costs. The provision of flexibility does not interfere with the main purpose of the industrial purpose. The operator or factory owner sets the restrictions in which the process can provide flexibility. The actual call for flexibility only uses a fraction of the entire consumption process.

Requirements for providing balancing energy through Demand Response: Many consumption processes are suitable for providing balancing energy. The following aspect are indicators that a process might be able to provide demand response services:

1. Continuous power consumption
2. Possibility to ramp up the consumption on short notice
3. Existence of a slack component as a batteries or storage tanks
4. Automated consumption control via process control technology
5. Existence of own power production on the companies' premises (CHP, emergency generators, etc.)

3.3.3 Balancing Service Provision Platform

The VPP4INode will be equipped with a Balancing Services Provision Cloud Platform. The platform will provide:

1. Graphical User Interface for the aggregator and for the energy manager of the plants involved in the VPP.
2. A system for receiving the baseline (i.e., the scheduled active power injection) and the potential flexibility from each plant involved in the VPP.
3. A system for aggregate the baselines and the flexibility ranges of all power plant, as the result of the aggregation will be available a baseline and a flexibility range of the whole VPP.
4. A system for receiving flexibility request from the local TSO.
5. An algorithm to calculate the optimal power injection of each single plant to fulfil the TSO's request for flexibility.
6. A database to store all the information regarding the real time measurement of power production.

7. An algorithm to calculate how to share revenues from balancing market between real plants.

Figure 4 show the dashboard of a Commercial Virtual Power Plant design to enable Balancing Services Provider to aggregate multiple assets.

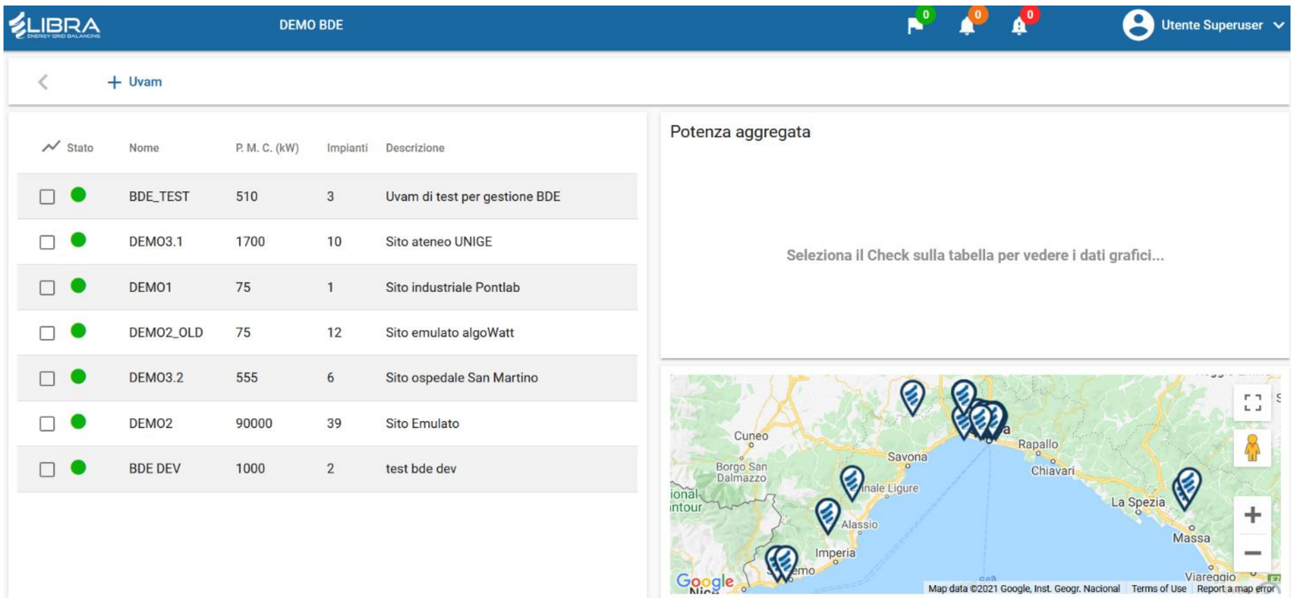


Figure 4: Example of dashboard for BSP

3.4 Energy Community Management

In this subsection is presented an overview on the concept of energy community, on the Italian regulation on energy community and the technologies required to implement them. Finally, is presented the tech spec on energy community platform that will be implemented on the VPP4INode.

3.4.1 **Overview on Energy Community concept**

In 2019, the European Union concluded the approval of the legislative package "Clean energy for all Europeans "(CEP - Clean Energy Package)*.* Of particular interest for the realization of energy communities there are two directives of the CEP:

1. the Renewable Energy Directive (EU Directive 2018/2001), which contains the definitions of collective self-consumption and of **Community of Renewable Energy (CER)**,
2. the Directive on the internal electricity market (EU Directive 2019/944) which defines the Citizens' Energy Community (CEC).

Article 21 of the Renewable Energy Directive (2018/2001) defines ***collective self-consumption*** achieved within a building, thanks to a system that provides electricity to more than one consumer ("one to many"). The classic example is that of a multi-unit building with a system in the common area, able to meet the energy needs for both condominium users and those of the units autonomous. When collective self-consumption transcends the scope of a single building or condominium, we are faced with an ***energy community***.

The Directives, although they have different definitions, both define the energy community as a "legal entity" based on "open and voluntary participation", whose primary purpose
it is not the generation of financial profits, but the achievement of environmental, economic, and social benefits for its members or partners or to the territory in which it operates.
To ensure the non-profit nature of the energy communities, participation in
quality of community members is not allowed for energy companies (e.g., suppliers and ESCos) who can, instead, provide energy supply and infrastructure/digital services.

The main differences between CERs and CECs are:

a) the CER is based on the principle of autonomy among the members and on the need for proximity with generation plants. The CER can manage energy in different forms (electricity, heat, gas) provided that they are generated from a renewable source.
b) The CEC does not provide for the principles of autonomy and proximity and can only manage the electricity produced both from renewable and fossil sources.

In this document we will always refer to CERs by referring to them as simply energy communities from here on out.

3.4.2 Requirements for Energy Communities: the Italian Regulation

The Italian regulation on collective self-consumption and energy communities
renewable consists of Article 42-bis, inserted in the Milleproroghe Decree (converted into law no. 8/2020 to 29 February 2020).

Collective self-consumption: In accordance with the provisions of the Milleproroghe Decree, collective self-consumption is made up of a plurality of consumers located inside a building where there is one or more powered systems exclusively from renewable sources. The plants can be owned by third parties (such as ESCo) and take advantage of specific benefits, such as tax deductions.

Energy Communities: The provision relating to energy communities provides that those participating must produce energy for its own consumption with plants powered by renewable power sources total not exceeding 200 kW. To share the energy produced, users can use the existing distribution networks and use forms of virtual self-consumption.
The renewable energy community must consist of consumers located in the electricity grid of low voltage, under the same medium/low voltage secondary substation. The participants retain their rights as end customers, including the right to choose their supplier and exit from the community when they wish. Participation is open to all users under the same secondary substation, including those belonging to low-income or vulnerable households.

The energy shared within the community is equal to the minimum, in each hourly period, between the electricity produced and fed into the grid by the community plants and the electricity consumption by all the associated members. Energy is considered shared for instant self-consumption also through storage systems. An example on energy shared within the community is depicted in Figure 5.

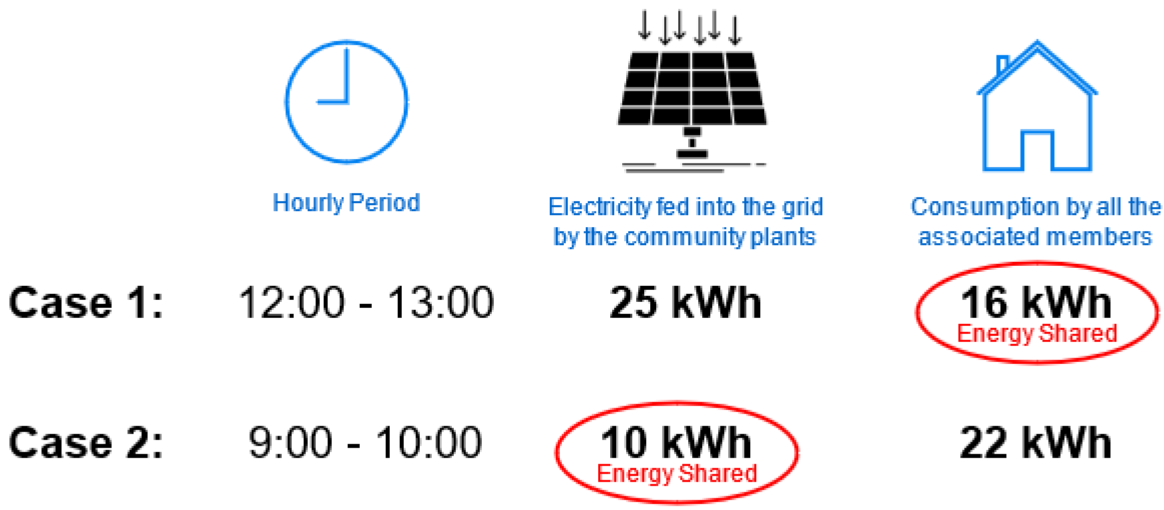


Figure 5: Shared Energy in Energy Communities

To promote the use of storage systems and the coincidence between production and consumption, it was established an incentive rate, to remunerate self-consumed energy instantly. To access to incentives, the system must be new, that is, installed after 1 March 2020. The incentive rate it will be cumulative with tax deductions, where available, and will be established in different values, accordingly to the type below:

a) Shared energy as part of collective self-consumption (same building or condominium): 100 €/MWh.
b) Shared energy within the renewable energy communities (same electrical secondary substation as medium/low voltage): 110 €/MWh.

The rule also provides for the return of some items in the bill: The energy shared in energy communities allow to minimize the exploitation of the national transmission network that ARERA (Italian Regulator) quantifies at 10 €/MWh for Collective Self-consumption and 8 €/MWh for CERs on shared energy. For up the remuneration of the energy fed into the grid at an Hourly Zone Price, which, according to RSE (Italian research institute on the electrical system) "could assume approximately 50 €/MWh". So, the sum of all the benefits would amount to about 150-160 €/MWh.

3.4.3 Technology for Energy Communities

Among the smart technological devices, there are smart homes and smart buildings. Within an energy community, a network of Smart Homes can be created which can provide for three different levels of application:

1. home,
2. building,
3. community.

The fundamental component of the technological architecture in home and buildings is the energy box (VPP4IBox in our solution)*,* that is a home device that allows the prosumer to remotely monitor and control his home with the same local interface, making the overall system more scalable. The energy box as also the function to communicate all the power measurement to the energy community manager in order to calculate the Energy Shared (e.g., Through an internet connection) and to control the controllable assets as the energy storage.

The data monitored at the home level by the sensors present are transmitted, via the energy box, to the aggregation cloud platform, where the acquired data are stored in a database and organized to perform subsequent analyses and processing, in particular synchronization and diagnostics.

At the platform level, two interfaces are available for the visualization of the acquired data useful to provide different feedback depending on the type of recipient:

a) Interface for the end user to which feedback is provided to motivate him and direct him towards an energetically more efficient behaviour,
b) Interface for the aggregator to allow a general view of the system and comparison among the users involved in the experimentation.

3.4.4 Energy Communities Management platform

The VPP4INode will be equipped with a platform that has all functionalities of an aggregation cloud platform for energy communities. This platform will provide WEB APP with a standard interface for the member of the energy community a standard interface for the aggregator that play the role of energy manager of the community. An example of a dashboard for an Energy Community Manager is depicted in Figure 6.

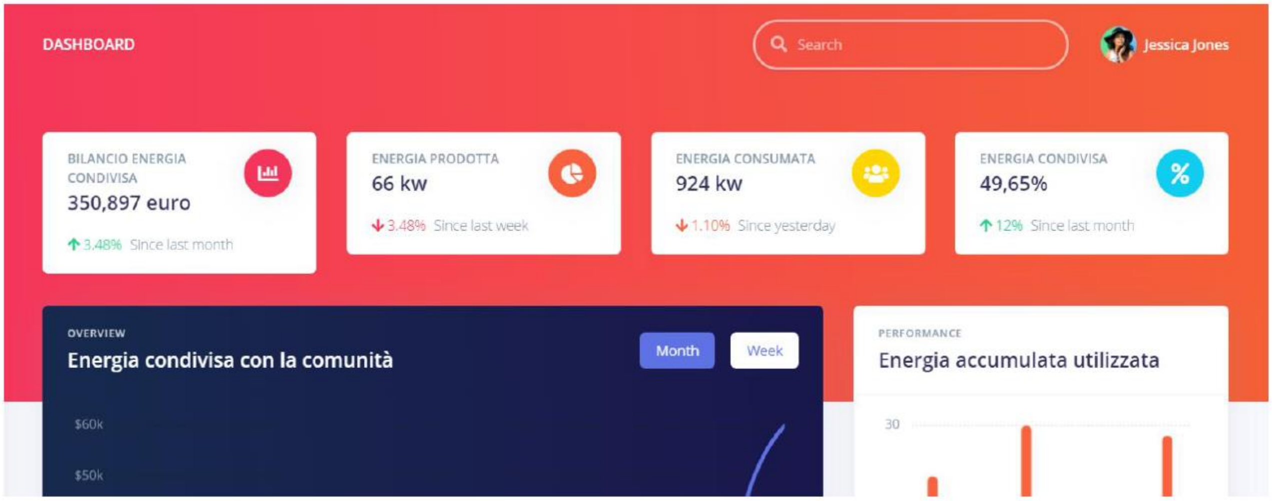


Figure 6: Example of a dashboard for Energy Community Manager

The Energy Community Platform in the VPP4INode will have the following features:

a) login form to the system through credentials for Energy Community member and for Energy Community Manager.
b) Dashboard for EC members.
c) Dashboard for EC Manager.
d) Reception of consumption and generation data by the DSO for each delivery point registered in the energy community.
e) Algorithm able to optimize the storage scheduling for maximise the energy share in the community.
f) Algorithm able to calculate how to share the revenues coming from energy production and energy shared incentives between energy community members.
g) A Database where are stored bill for electricity consumption and incentives for shared energy of each member.

4. Non-Functional Requirements

There is no information available at the moment about Non-Functional Requirements

5. External Interface Requirements

5.1 User Interfaces

The VPP4INode will provide 2 different User environments. The first one is related to the balancing service provision platform, the second is for energy community management platform.

The **balancing service provision platform** will have a user interface that will allow to monitor all the plants connected to the VPP. Following is listed the values that will be displayed in the user interface:

1. The active power injection scheduled during the day ahead (i.e., baseline) for each component (i.e., single generator or single storage), for each plant (i.e., sub pool of components connected at the same point of the grid) and for the whole VPP (i.e., sum of baselines of each power plant).
2. Live measurements of each component.
3. Bids placed on the balancing market by the Aggregator of the VPP.
4. Bids accepted by the TSO.

The aggregator will have the possibility to have a dashboard that contains the data of all the components and all the plants active in the VPP, meanwhile the single member will have the possibility to have data only on their own plant.

The **Energy Communities manager Platform** will have a user interface that will allow to monitor the consumption and the generation of all members in the community. In particular the platform will have a dashboard for members that will resume their consumption, their behaviours in terms of energy shared (i.e., amount of energy consumed during the hours in which renewables are active) and their electricity bill of the previous months where will be highlighted the revenues from energy shared with other members. The platform will also have a dashboard for the energy community manager where will be possible have the information of all members plus the technical information on the shared assets (e.g., PV and storge).

5.2 Hardware Interfaces

Not applicable.

5.3 Software Interfaces

The system will have an advanced http rest API documented by the standard OpenAPI v3 and providing all the documentation needed to interact with the system.
That will be the inputs coming from the observations and the VPP4IPlatform system and the outputs needed by the dependent services that consume the data, documented by the stakeholders.

5.4 Communication Interfaces

The Distributed Optimisation Engine will be the technological core of the VPP4INode. Here, all the information from each asset comes together in real time using machine 2 machine communications. It will provide a precise snapshot of the Virtual Power Plant's available capacity at all the times. Market, network, and weather data is also processed in the Distributed Optimisation Engine and converted to individual operational commands. This allows flexible assets to be, for example, powered up or down as needed. VPP4Islands is based on standard interfaces and is therefore scalable and open to all types of technologies. Importing and exporting data to and from other systems such as VPP4IPlatform will be easy with the API. The system will make use of TCP/IP communication sockets along the HTTP protocol to communicate with VPP4IPlatform and external data (e.g., for communications with TSO) and MQTT or HTTP to communicate with the resources in the field equipped with the VPP4IBox (MQTT protocol could be useful for balancing service provision since could be required by the TSO to have the live measurement of active power with a time step shorter than a minute). Figure 7 show an example of communications interface between the VPP4INode and other data sources.

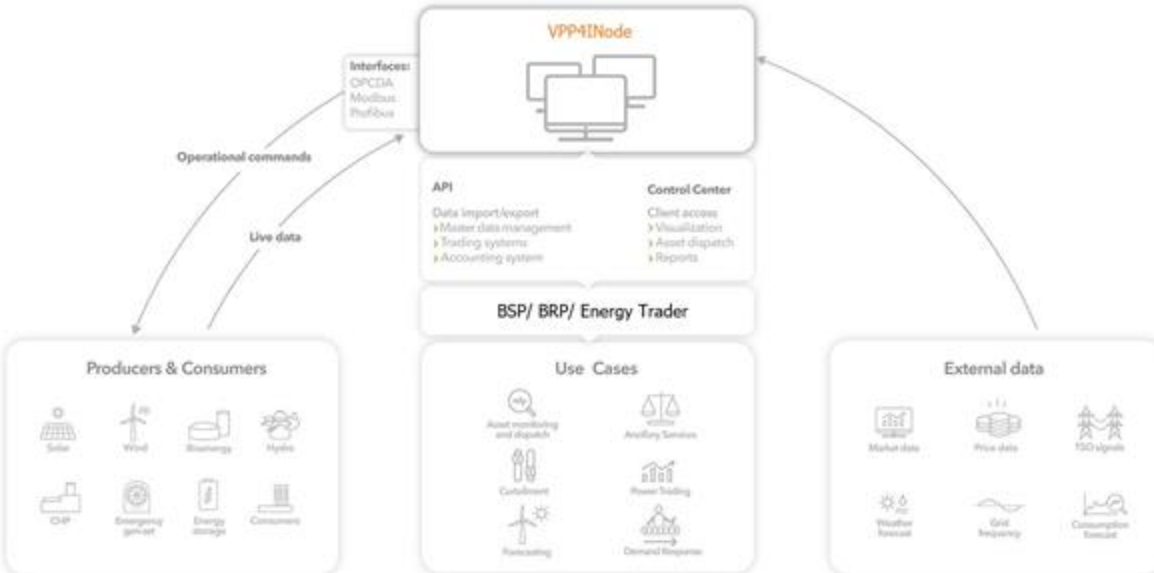


Figure 7: VPP4INode communication interfaces

6. Detailed Use Cases

6.1 USE CASE 1: Trading on Day-ahead and Intraday Markets

In many countries, deviations between forecasted and actual feed-in can be compensated by trading on short-term energy markets (i.e., intra-day market). This is exactly what many companies do as a certified power trader with a large portfolio of PV and WT. First, They trade the assets on the day-ahead market based on forecasts. On the day of the actual feed-in, deviations from the day-ahead forecast occur. If this deviation persisted, it would have to be eliminated by balancing energy. In order to minimize the need for costly balancing energy, traders continuously try to close the gap between day-ahead forecasts and actual feed-in in the intra-day market. Live data from assets is essential for this nowcasting process, as it brings the forecast closer to real generation. Figure 8 shows a PV active power injection forecasted at the beginning of the day (light green) vs the active power feed-in by the PV during the day.

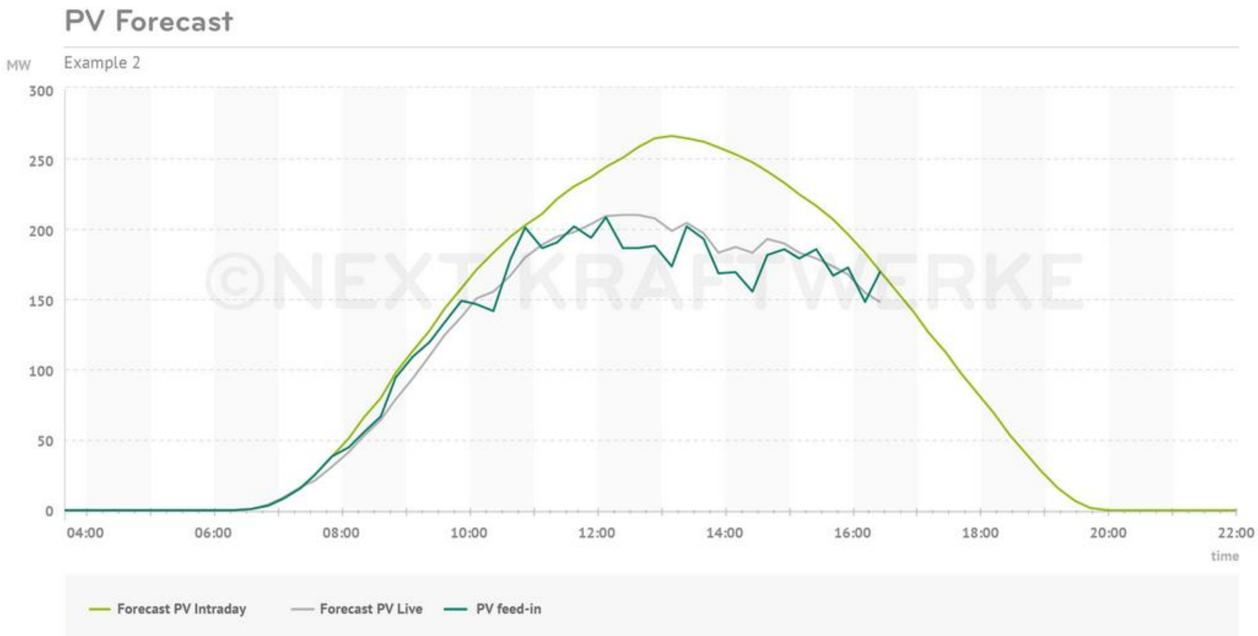


Figure 8: Example of a PV power generation forecast

In this Use case we will use the VPP4Inode to try to close the gap between power generation forecast (and sold) in the day ahead and actual feed-in the intra-day market.

6.2 USE CASE 2: Provide services on Balancing Markets (BSP)

An operator of VPP can provide balancing services in seven European TSO areas at the moment. With a pool of prequalified assets (qualification made by TSO), It is possible to participate in the auctions of the TSOs. In case of frequency imbalance, the aggregator the manage the VPP receive an order from the system operator requesting a certain amount of control reserve. The algorithm of the VPP decides which asset provides how much control reserve, based on individual restrictions of the assets. The respective units then are ramped up or down at short notice. The providers receive additional revenue for this service. In addition, they effectively support the energy transition by protecting the grid against the fluctuations associated with volatile energy sources. In Figure 9 is depicted the dashboard of a flexible asset that we will be implemented in the VPP for BSP.

Figure 9: baseline scheduled, active and reactive power fed-in of a flexible load

In this Use case we will use the VPP4INode to sell energy balancing market through the aggregation of multiple plants that can sell flexibility.

6.3 USE CASE 3: Price-Based Control of Networked Assets

In the course of one day, the electricity price changes 24 times on the day-ahead market and even 96 times in intraday trading. The difference between quarter-hours can be more than 50 euros per megawatt hour. To benefit from these price differences, flexible members of pool as flexible load and storage produce or consume electricity when it is most economically viable. For this purpose, the VPP4INode will continuously optimize the schedules and feed them into the control system. The execution will run fully automatically.

In this use case we will use the VPP4INode for maximise the revenue of dispatchable power generators from day ahead and intra-day markets.

6.4 USE CASE 4: Management of an Energy Community

In this User case we will use VPP4INode to manage an Energy Community.