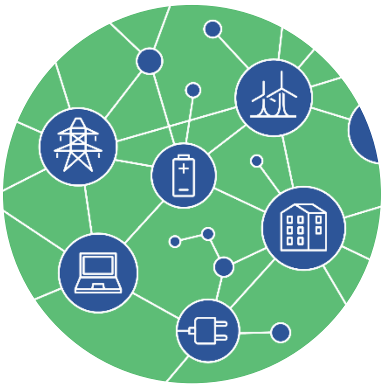
OSMOSE

OPTIMAL SYSTEM-MIX OF FLEXIBILITY SOLUTIONS FOR EUROPEAN ELECTRICITY

Demonstration tests

D6.5



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3 List of acronyms and abbreviations

Table 1: List of acronyms and abbreviations

Acronym	Term
ACE	Area Control Error
aFRR	Automatic Frequency Restoration Reserve
BRP	Balance Responsible Party
BSP	Business Service Provider
CB	Critical Branch
CGM	Common Gird Model
CO	Critical Outage
CRAC	Critical Network Elements, Critical Outages, and Remedial Actions
ECCO SP	ENTSO-E Communication & Connectivity Service Platform
EG	Electrical Grid
EMP	Energy Management Platform for Bidding
EN4M	Electricity Network for Market
FAT	Factory Acceptance Test
FEB	FlexEnergy Bid
FEB-CM	FlexEnergy Bid Calculation Module
FEB-CT	FlexEnergy Creator Tool
FEBPP	FlexEnergy Bid Preprocessing Tool
FEM	FlexEnergy Market (Place)
FEMP, FEDMP	FlexEnergy Market Platform
GA	Grant Agreement
GUI	Graphical User Interface
HPP	Hydro Power Plant
IGM	Individual Grid Model
KPI	Key Performance Indicator
MW	Megawatt
MWh	Megawatt-hour
OPT	RTE Optimization platform/tool, Optimization platform for FEB selection
OTDF	Outage Transfer Distribution Factors
PoC	Proof of Concept
PTDF	Power Transfer Distribution Factors
PU	Production, Power Unit
RAM	Remaining Available Margin
RCC	Regional Control Center
RES	Renewable Energy Source
SAT	Site Acceptance Test
TSO	Transmission System Operator
UC	Use Case
VDT	"*Variazione Dati Tecnici*", a .xlsx file generated by TERNA and containing technical data of generation units.
VTL	Virtual Tie-Line
WP6	Work Package 6

4 Introduction and Summary

This deliverable refers to D6.5 of Grant Agreement 773406 (GA) and is related to Task 6.6 (Demonstration Tests) of the GA. This report contains results of demonstration tests held after the development of the platforms : testing the proof of concept of near real-time cross-border energy market, usability and capability of platforms when operated individually and commonly and potential of this market.

Task 6.6, which presents the framework of the work done for this deliverable, is divided in three subtasks:

- Testing of the platforms individually and commonly, Subtask 6.6.1, where tests were performed in an open loop principle, directed to input/output performance of platforms under tasks 6.2, 6.3 and 6.4.
- Real time control tests on the generation units, that were performed according to the testing protocols developed in task 6.5. Tests were performed from simple to the most complex ones including real time closed loop operation. Aim was to tune the platform parameters under real system conditions and the focus on overall stability of the platforms, task 6.6.2.
- Closed loop tests directed to business proof of concept, where focus was made on market and bidding interest of players, liquidity in real system environment, etc., subtask 6.6.3.

Subtasks listed above form the framework of the document, where chapter 5 provides information on subtask 6.6.1, chapter 6 summarizes subtask 6.6.2 and chapter 7 rounds the proof of concepts demonstration test. In chapter 8, KPIs as defined in D6.5 are calculated based on the performed tests.

This deliverable follows deliverable D6.4 of the project. D6.4 described the workflow, platforms created and FlexEnergy Market. D6.5 is next phase of D6.4 where KPIs are calculated, and market workflow tested in real environment.

Proof of concept was performed successfully on 3.3.2022 at 11:30. All the flexibility providers submitted their bids, calculated and created by FEB-CT and FEB-CM, on FlexEnergy Market Platform (FEMP). In parallel, a model of the grid was created by Electricity Network for Market (EN4M) platform from the grid snapshots provided by TSOs. All this information, FEBs and grid model, were used by Optimization (OPT) platform which created a list of activated bids. That list was imported into the TSOs SCADA and then further sent to FlexEnergy Providers in form on an activation signal. All the flexibility units reacted as expected and sent the measurements back to TSOs. TSOs created new snapshots which were fed into EN4M and the loop was closed.

The successful Proof of Concept test (PoC) shows that such trading, exchanging the flexibilities near-to-real time using a novel approach of available transmission capacities, works.

This significant finding contributes to flexibility markets of the future on a pan-European level. What is important is that transmission capacities can be assessed near-to-real time and not be defined days ahead like today. This enables more exchanges between market participants and a better usage of the transmission grid.

Moreover, the working PoC shows that flexibility providers could automate bidding process, which is a step forward to automatic exchange of the flexibilities. This can result in less imbalances and higher level of use of flexibility sources, which is today limited by intraday gate closure times.

5 Performance of platforms

This chapter provides information about Sub-Task 6.6.1: Open loop tests directed to input/output performance of platforms under tasks 6.2, 6.3 and 6.4. Each of the three pillars (OPT, FEMP, EN4M) were tested and validated separately and commonly. Tests related to FEMP included testing of FEB-CT and FEB-CMs.

Several tests were performed on each side (Italy, Slovenia) and commonly. Open-loop tests started on 18. October 2021. The first session ended on 14. December, while two other sessions were performed from 15. to 31. January 2022 and from 14. to 18. March 2022. These tests could be divided into two groups:

- Jointly performed demos
- Tests performed with the purpose of getting data for KPIs.

Main purpose of jointly performed demos was to test how all components perform together. These demos were performed on predefined timeslots, with the main goal of preparing all the components for the second group of tests, from which the KPIs would be calculated.

All the workflows during the demos are described in chapter 7 of D6.4 where ‘Use cases’ are described. Use cases provided in D6.4 are the basis of all tests – both open and closed-loop tests. Use cases were the foundation for the basics test where performance of each and all platforms together were tested.

5.1 Performance of FEM platform

5.1.1 Bid pre-processing and merge tool and FEB-CT open and closed-loop tests

The FlexEnergy Bid pre-processing and merge tool (FEBPP), developed by ENG, is responsible for performing the quality check of FEBs and merging valid FEBs in one XML file that is one of the inputs of the Optimization platform for FEB selection (OPT). Open and closed-loop tests for FEBPP were defined in D6.4 to check the proper implementation of FEBPP functional requirements and the integration of FEBPP into the ELES IT environment, respectively. Starting from the open loop tests, ENG performed this kind of tests locally (on ENG server) before the official delivery of the tool. After that, tests were conducted on ELES server where the tool was deployed and actually run for the demo purpose. Open loop tests on ELES server were executed in June 2020 and test results demonstrated that the released tool is compliant to the main functionalities defined in D6.2. Indeed, the FEBPP tool properly identifies valid and not valid FEBs and provide a report in case of FEBs not compliant to the format. This report contains the name of FEB file, the BidID and the reason why the quality check failed. The report is a txt file providing information about the file path (it is the local path of ELES server where the tool is running) the name of FEBs file and the reason why the quality check failed such as the inconsistency with the network data since both the GridNode ID and the UnitID are checked. Details on how the quality check is made by the tool are provided in D6.3. An example of the report that was generated by FEBPP in case the quality check failed during the open loop tests is provided as Annex. I.

The Closed loop tests focused on the integration of the FEBPP tool into the ELES IT environments and with the OPT tool. Indeed, the data exchange between these two tools is performed by means of sFTP application server that was configured and hosted by ELES for this purpose. The performed tests demonstrated that the FEBPP tool can properly connect and access to the sFTP folders following the access policy defined by ELES IT Department. This kind of tests was performed in June 2020 upon completion of the deployment activity on ELES server.

After the final delivery of OPT tool on ELES IT environment, ENG performed Closed loop tests aimed to check the overall chain of FEB creation and submission, FEBs quality checks and merging and FEBs optimization. Different test sessions were scheduled with the active participation of FlexEnergy Provider (HSE; ENEL and HDE) responsible for FEBs creation and RTE as responsible for the OPT tool. The performed tests proved that the synchronisation of the overall process worked as expected: only some minor adjustments regarding the format of the exchanged data were needed. It is important to underline that from the beginning of the experimentation about 3.000 FEBs files were created and submitted (each file can contain more bids), approximately 2.286 merged FlexBid files were created and processed by the OPT tool.

During the open loop and closed loop tests, FEBs were created and submitted using the FlexEnergy Creator Tool (FEB-CT). FEB-CT is an application developed by ENG and running on ENG server at https://feb-project-osmose.eng.it/login from August 2020.

5.1.2 Open and closed-loop tests for EN4M tool

The Electricity Network-for-Market (EN4M) software package, developed by EKC, is used for the creation of a regional-common grid model (CGM) through the process of merging individual state estimation snapshots as well as for the creation of the list of relevant network constraints for the FEM optimization.

The first part of the testing was focused on the robustness and timing of the network data preparation process, where it was checked if merged network models and corresponding lists of critical network elements with contingencies are timely and accurately created. EN4M tool consists of four different submodules that are integrated with Transmission Network Analyzer software. Every specific submodule of the tool is tested independently and in a sequence within the open-loop test, as described in D6.4. Open-loop tests were first performed locally with a previously delivered set of input data from ELES, TERNA, and RTE for the testing dates and when the stabilization process was completed, the EN4M tool was installed at the ELES server. When the process of network snapshot model delivery was established by all participating TSOs, the EN4M tool was tested with real-time input data. The network processing tool is up and running at the ELES server since the first half of 2020 and its robustness and quality are tested all the time. During this period, the tool is slightly adjusted to deal with the real quality of network models and their time of delivery.

EN4M tool is tested within closed-loop tests with the highest focus on the following checks:

- Input snapshot data from ELES, TERNA, and RTE state estimators receiving and check
- Creation of valid regional network model for every timestamp
- Creation of a reasonable number of network constraints for every timestamp
- Export of created CGM and CRAC files to the output folder

For purposes of open-loop software tests, it was very important to enable continuous delivery of RTE, TERNA, ELES, and CH snapshots. Anyhow, during the 2-year testing period, delivery procedures of the snapshot network models from state estimators were not continuously running and SN models often weren't received, which caused some problems with quality checks. Even though the content and quality of the final network model are highly dependent on the availability of the received input data from state estimators, the EN4M tool is adjusted to work with the latest available models. It is important to note that the EN4M network creation process requires the ELES SN model for the current timestamp to create the network model and CRAC file for that timestamp. Different timing of delivery, causing delays in receiving of some models imposed the need for software adjustments to enable continuous work. A combination of event-triggered and time-triggered procedures was implemented in the EN4M tool to deal with the timing discrepancies detected during the testing periods.

5.1.3 Open and closed-loop tests for OPT

The optimisation platform (OPT) was mainly developed in Python and used as a “glue code” to perform the data management of the tool. The network conversion from UCT format to a tabular one dedicated for the optimization problem has been performed using the open-source framework developed by RTE and called Powsybl[1]. The model of the problem has been written using the AMPL language.

The tool has been delivered in his final form during the autumn 2021. OPT is at the core of the tool because it receives data from the network through the EN4M tool and the bids from FEMP and finally send the results to the ELES’ SCADA for real activation. No optimisation can take place if any error occurs in the precedent processes.

So, three sequences of open-loop test were performed to assess:

- The correct delivery of network
- The correct delivery of bids
- The correct delivery for the SCADA

Each of the three tests mainly lead to minor adjustments regarding the format of the data which were solved. We also encountered more deeper problems regarding the time delivery of data each quarter hour which concerned at the maximum one third of the timestamps. We didn’t treat this issue because those procedure were linked to national data delivery of snapshots.

From the last release of the tool the 18th of November 2021, the tool worked on 14,882 timestamps which is a bit more than 70% of the total time. The main unavailability of the tool, at the beginning of January 2022, is linked to the expiration date of one license. The other unavailabilities of the tool were linked to errors in connection with the sFTP protocols to other components and some remain without a firm explanation.

[1] https://www.powsybl.org/

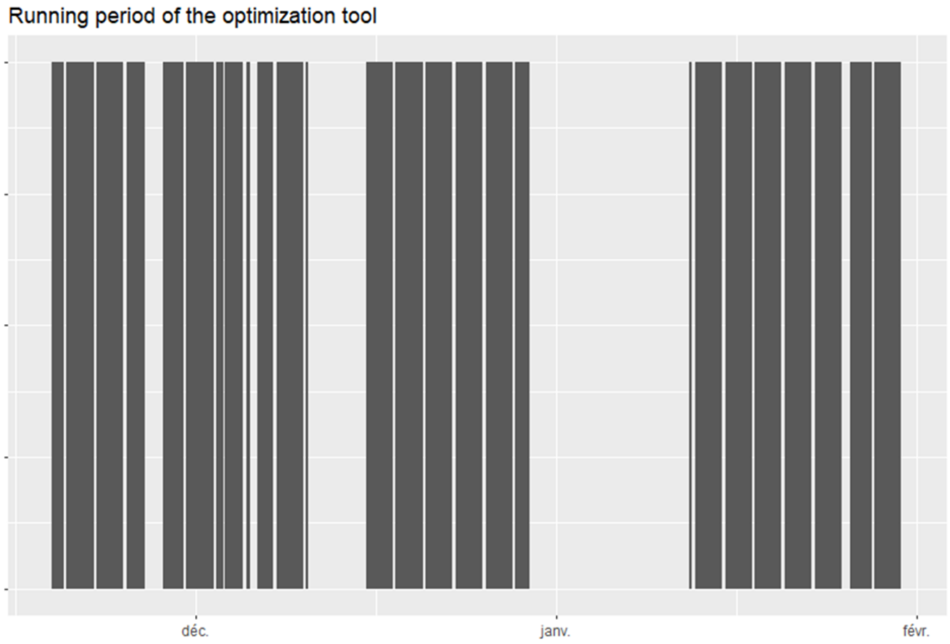


Figure 1: Periods of OPT run

When available, the tool performed mainly as expected as less than 2% of the instances crashed during execution. The major cause of failure was linked to data issue of the networks associated with delivery issues from the TSO.

The test period also made possible to observe that bids were described in a quarter of hour manner. This choice comes from the producers and from business perspective as they are not limited by the algorithms. This leads to the fact that the command for each bid was 0 at the end of each quarter to close to bid.

5.1.4 FlexEnergy providers' tools testing in open and closed loop incorporating current market regulations

5.1.4.1 FEB-CM for unused flexibility from the market

FEB-CM developed by HSE was tested continuously from the very beginning. There were more than 13.000 bids calculated since HSE also automated the process. Of course, not all the bids had prices that would reflect the real value of the flexibility, but the tool showed that flexibility could be auto assessed.

Three fifteen-minute intervals are crucial for the bidding. If we bid for time interval T+1, FEB-CM calculated FEB during time interval T with the values from SCADA from time interval T-1. In other words, for, let's say, time interval from 13:00 to 13:15, the FEB was calculated between 12:45 and 13:00 with the values from the end of the time interval 12:30 – 12:45. This resulted in the reconfiguration of FEB-CM in a way that it always calculated for two time intervals ahead: T and T+1, while only the bid for T+1 was used, and values for T were used to estimate the current operating states of the flexibility units.

After the before mentioned reconfiguration of the tool, FEB-CM performed as expected.

5.1.4.2 FEB-CM for integration of non-dispatchable renewable energy sources

At the time of writing, the Italian market is still not allowing portfolio management of power plants; thus, the tests of this FEB-CM were conducted in open-loop configuration. This means that FEBs were not submitted to FEMP. However, the FEB-CM is only responsible for calculating the quantity that can be offered and for generating the bid file; once the bid is created, all the rest of the workflow is the same for all CMs. Given that a closed loop test (with power plant activation) was already demonstrated with the FEB-CM for unused ancillary services, for this CM an open loop test was considered sufficient.

The test of this FEB-CM consisted of a relatively prolonged operation of the FEB-CM itself, which allowed to record its behavior and results. FEBs were not processed by the Market Platform because of the aforementioned reason; moreover, the prolonged duration of this test would have required an excessive workload on the other partners for producing bids from their side. On the other hand, a prolonged test was the only reliable way to assess the performance of the FEB-CM's "brain", the nowcasting model. So, the FEB-CM was run for three months, from 3. January 2022 to 31. March, being executed in HDE's internal IT environment. The inputs described in Deliverable 6.3 were fed to the FEB-CM, and the results of the nowcasting were stored. The performance was then calculated, in terms of accuracy and execution time. The execution time is obtained from the sum of the time needed by the FEB-CM to gather all input data and of the one needed by the nowcasting model to run. The resulting execution time was usually one minute, but, in some occasions, it was significantly greater and the FEBs couldn't be generated in time for the (potential) submission. This was always due to delays in gathering the input data, while the model run time remained constant. More in detail, it is worth mentioning that the problems occurred in the external data sources (in this case, the water gauge, not operated by HDE), which delivered the data in delay.

The accuracy was calculated by means of RMSE and confirmed the good results obtained during the training of the machine learning nowcasting model (described in detail in Annex 9.7 of D6.3).

5.1.4.3 FEB-CM for unused aFRR

ENG, as responsible for the development of this FEB-CM, performed functional and performance tests to verify that the released tool worked as expected. This kind of tests were performed on ENG development environment before the official release of the tool. Moreover, after the deployment of the tool on ENG server, extensive tests were done by ENEL and HDE as FlexEnergy Providers directly involved in the Italian scenario. The performed tests demonstrated that the FEB-CM for the integration of unselected aFRR is compliant to the information provided in D6.3, since it determines the time periods and the maximum power that can be offered in the FEM. As explained in D6.3, the generation of FEB involves the active participation of FlexEnergy providers that, using the FEB Creator tool (FEB-CT), can review the outcome of FEB-CM and can decide the quantity to bid, the price and the timeslot for bidding. Several tests were done with the collaboration of both ENEL and HDE that, accessing to the FEB-CT, had the opportunity to create and submit FEBs. These were also processed by the OPT during open loop and closed loop tests. During the testing activity, a specific pricing strategy was adopted by FlexEnergy providers:

i. Bids made to make a guarantee match with other operators, for functional tests.
ii. Bids made by simulating real market behaviour and then entering real market prices without the guarantee of having a match, for economic performance tests.

The inputs to identify the calculated quantities were chosen following the same strategy:

i. inputs that generate quantities that guarantee a safe match with other operators, for functional tests.
ii. real inputs that do not guarantee they have quantities to offer, for economic performance tests.

Summarising, the testing activity demonstrated that both FEB-CM and FEB-CT worked as expected; the satisfies the FlexEnergy providers' expectation.

5.2 Common performance

Each component worked as planned, within the capabilities of the chosen technologies. Main difficulties arose from the coordination of the different components, from the network delivery and bid processing until the SCADA signal to the power units. Those tests were complex to operate because they took place in the real business environment of TSOs and flexibility providers. The major difficulties encountered are the following:

- Real power units had to be reserved for the tests and removed from the standard trading environment with a notification of several days.
- Due to the almost real-time coordination process, all the data delivery had to be closely synchronized.
- The workflow of the tests relied on standard process of partners; e.g. the network snapshots creation of each TSO came from a production tool, external from demo.

Due to those limitations, only three real activation tests were conducted. Two of them lead to real activation of units, on the 23 December 2021, 19th January 2022 and 3rd March 2022. First two tests were not perfect as only one producer (HSE) managed to perform the full activation procedure, due to technical issue with the SCADA signal at the border between Italia and Slovenia. After further development and debugging on TSOs SCADA side, the third test was satisfying since the whole process worked as expected.

As a conclusion, we demonstrated the technical capacity to perform this kind of close-loop tests; the third full test was successful and served also as a proof of concept.

6 Tuning of platform parameters under real system conditions

This chapter provides information about "Sub-Task 6.6.2: Closed loop tests", directed to tuning of platform parameters under real system conditions and to focus on overall stability of the platforms. Real time control tests on the generation units are performed according to the testing protocols developed in Task 6.5. Tests are performed from simple configurations to the most complex ones, including real time closed loop operation of individual storage units.

Not just the development test but also real operation of individuals parts and of the platform were performed in-line with D6.4 (chapter 6). Chapter 6 of D6.4 is divided to four chapters, FEB-CT, EN4M, RTE and FlexEnergy providers test. To reflect a real market operation and our work we reshaped the chapters from four to three, but the content remained as foreseen in D6.4.

6.1 Tuning of activation mechanism for flexibility units

On Italian side, each producer performed an individual activation test with TERNA. For HDE, it occurred on 11. March 2021. One of the 70 MW production groups of HPP S. Massenza hydropower plant was excluded from its ordinary service and dedicated to the test. First, the proper reception of the activation signal was verified. Then, the remote control was enabled; over half an hour, TERNA sent a stepped ramp of setpoints, ranging from 0% to 100%. As already explained in D6.3, 50% means "no activation", i.e. the activation signal has no effect on production, while 0% means full activation in downward direction (decrease of power) and 100% full activation in upward direction (increase of power on the production group) Figure 2 reports the relevant measures recorded during the test, showing its successful outcome. The red line is the active power produced (in MW), as measured from the plant's transducers. The blue line is the power request, in MW, calculated by plant's automation from OSMOSE signal (in %), half-band (in Italian "semibanda") value and current production schedule. The green line, in % and on the secondary y-axis, is the OSMOSE setpoint as received by the plant from TERNA. All performance parameters met the requirements and the test was successful.

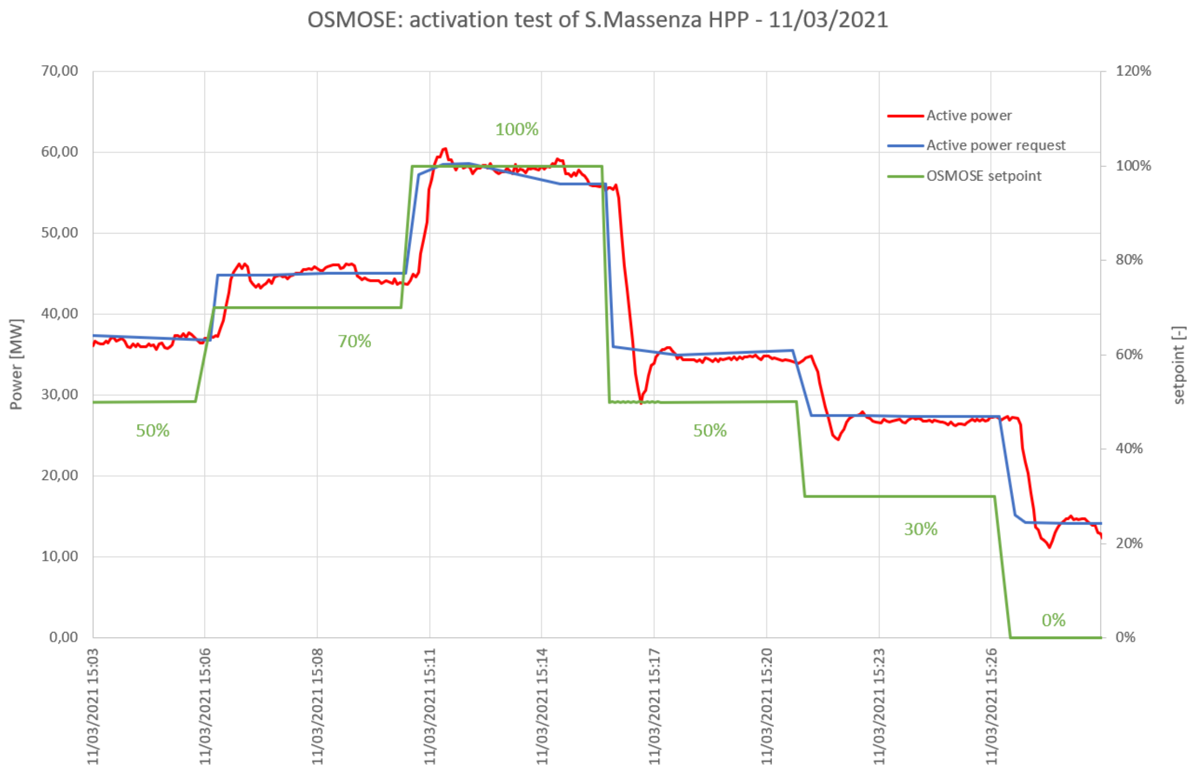


Figure 2: HDE activation test. Active power measured and requested are plotted toghether with the OSMOSE setpoint signal (on secondary axis) received by the HPP.

On Enel side, the first activation signal was on 21 April 2021. The test followed the usual verification sequence that Terna carries out for secondary regulation activation, aFRR: a sinusoidal waveform that starts from the center of the band (50% of the activation signal - no activation), reaches the maximum upward band (100 % of the level signal - maximum activation upward), goes down to the maximum downward band (0% of the level signal - maximum activation downward) and returns to the starting point.

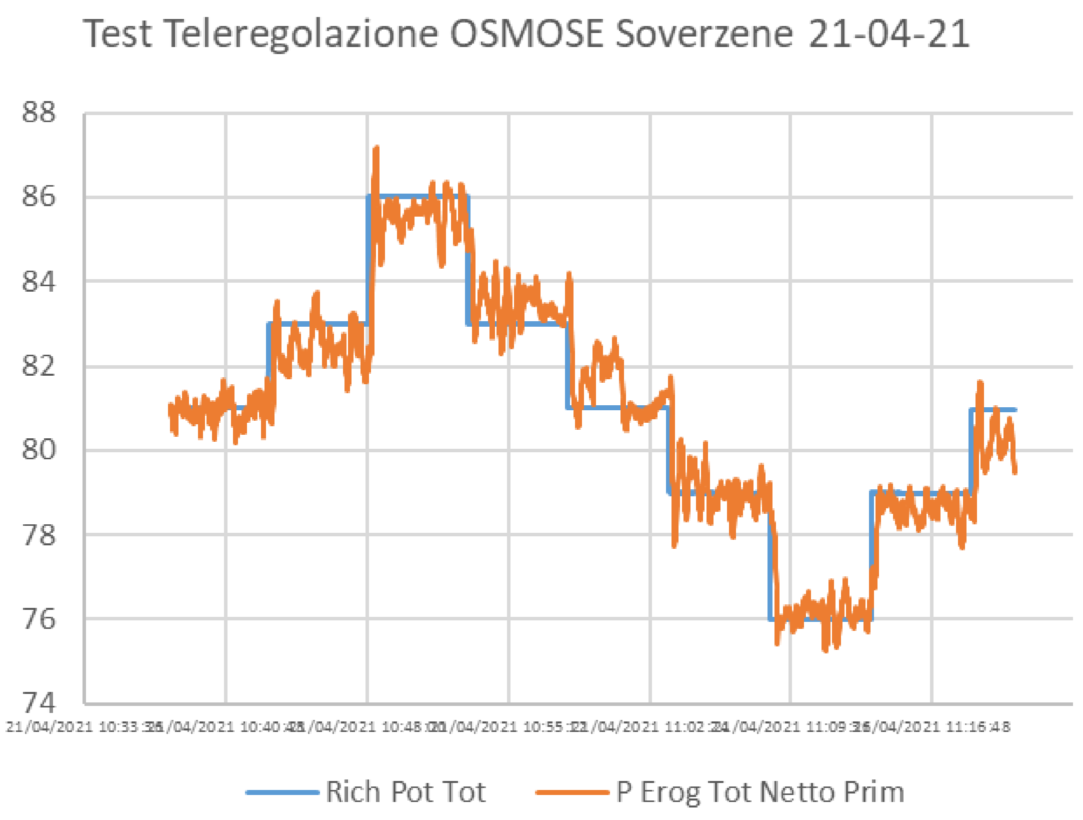


Figure 3: ENEL Activation test. Total requested power ("Rich. Pot. Tot.") from OSMOSE and total generated power ("P Erog. Tot. Netto Prim. ")

In this case, the verification test has been calibrated to remain at fixed values for 5 minutes; the 5 minutes are relative to the activation time of FEB. In Figure 3 it is possible to see in blue the activation signal received (*Rich Pot Tot*) and in orange (*P Erog Tot Netto Prim*) the active power generated by groups of the HPP Soverzene production plant.

On Slovenian side, the first successful test of activation signal from ELES to HSE was on 14 September 2021. On Figure 4 it can be observed the activation and response signal of the activated unit inside the HSE portfolio. The signal was fully routed to HPP Vuzenica, one of the powerplants in group of DEM. The test started with a signal that increased the power for 3 MW. After a few minutes ELES changed the activation request to -3 MW which meant a change of 6 MW. The unit performed as expected and the test was successful. After the test there were two main observations:

- From the moment when the activation is requested it takes several seconds for the signal to be visible on the unit.
- Each unit's power controller has some dead-zone. When the unit received a request for a change of 3 MW only 2,6 MW were realized.

The activation signal was created from a group of "measurement" signals. This approach was used since 1) it was not possible to use a production and testing aFRR channel at the same time and 2) creating a new setpoint for testing purposes in the production environment of TSO is not a feasible option due to the security of the power transmission system.

A recommendation for a real market would be to create a new set-point signal for wholesale market activities, which in the case of this project is FlexEnergy Market. Regarding the power regulator dead-zone, little can be done since it's a technical property of the flexibility units.

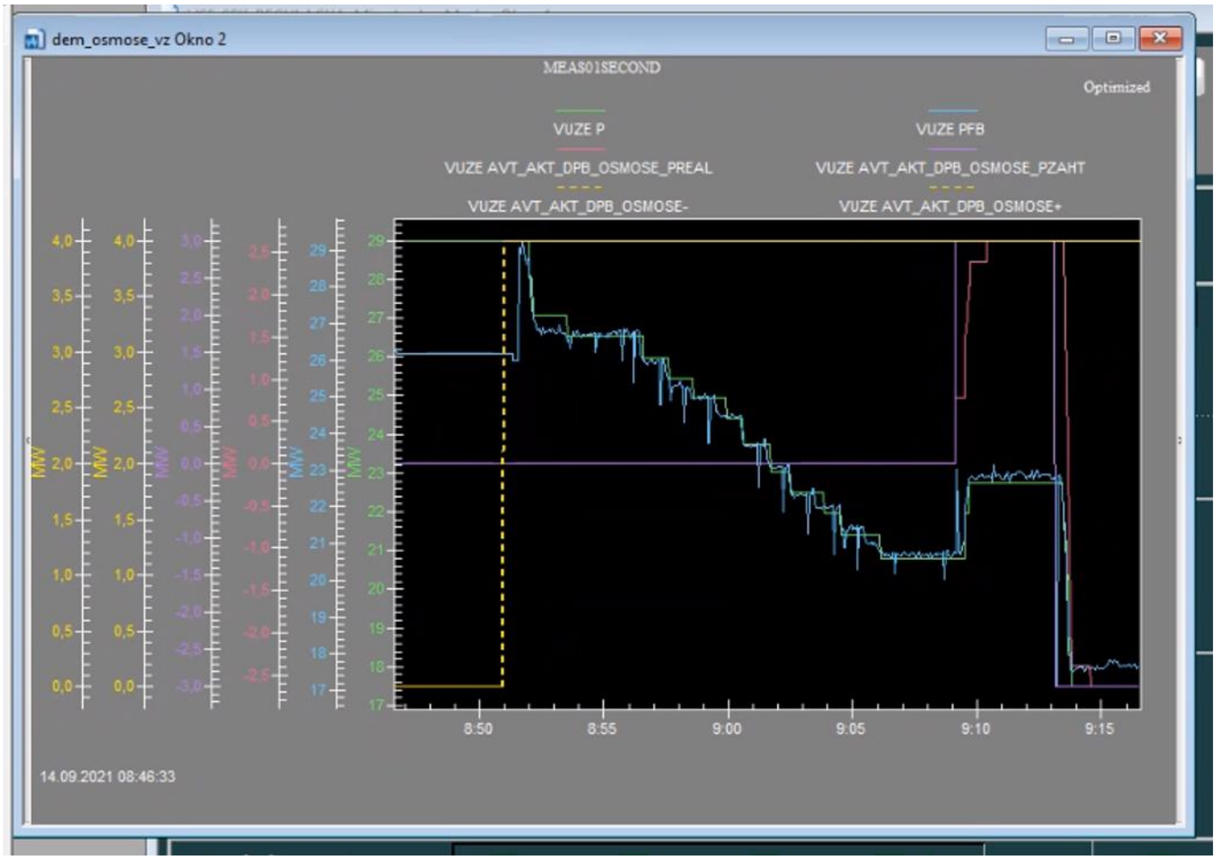


Figure 4: First successful activation of flexibility on Slovenian side

On the part of FEB-CT, there was no need to further tune the calculation tool used by HSE, since the FEB calculated were feasible.

6.2 Tuning of EN4M, FEM and OPT

As anticipated in section 5.1.1, open loop and closed loop tests of FEBPP and FEB-CT didn't bring out relevant issues since both the software components were compliant to the expected functional requirements. Focusing on the integration with other components like the OPT, it was necessary some small adjustment on RTE side (e.g. the provision of a new file for each OPT run and the adoption of ZULU format) in order to allow the FEB-CT to properly read the OPT output and to show it in the Graphical User Interface (GUI).

The communication between the different components belonging to the FEM platform like the FEBPP and the OPT was performed by means of sFTP protocol. An sFTP server was set up in the ELES' business environment as single point for data exchange; this has allowed to perform a smooth integration process between the different software components. However, the performed tests demonstrated that the selected protocol is not always performing and it could be replaced by the usage of event-store and stream-processing platform like Apache Kafka. Moreover, the adoption of ECCo SP Service platform is recommended to enhance security and reliable data delivery.

On ELES side a business communication channel was established. ELES created an ICT service design and risk assessment which is crucial for testing in production environment. They provided 3 logical servers with Windows 2019 servers as operating system on virtual machines (VM). For all three VM they made available 10 CPUs, 56 GB of RAM and 800 GB of disk space.

Regarding the security there was an sFTP configuration (user accounts, folder structure and access rights), LAN/VLAN configuration where some users had to be whitelisted to be able to access the VM through VPN which also had to be configured.

Activation files that are created by OPT every 5 minutes are automatically placed to predefined folder on ELES sFTP server. Files appear between 1 minute 30 seconds and 1 minute 50 seconds after round 5-minute interval (e.g., at hh:01:30, hh:06:35, hh:11:40, hh:16:45, …). Exactly 2 minutes after round 5-minute interval, Automize process checks for new files and copies them to predefined folder on NAS to which ELES SCADA system has access. Files on sFTP server are not deleted automatically, so after some time when there are many files, the process can take up to 20 seconds or even more. SCADA built-in functionality DCI (Data Communication Interface) checks exactly 2 minutes 30 seconds after round 5-minute interval for latest activation file and imports it to corresponding data points in SCADA RDB (Real Time Database). These data points are mapped to ICCP data exchange between ELES and HSE for Slovenian activation and between ELES and TERNA for Italian activation. When activation file is imported to SCADA it takes up to 10 seconds before it is transmitted via ICCP to partners (HSE, TERNA). This is because data points are configured as measurands and belong to dataset that is cyclically transmitted each 10 seconds to partners.

In worst case scenario, HSE and TERNA are activated 2 minutes 40 seconds after round 5-minute interval for which results of OPT are calculated. To put the market into real environment this delay should be minimized. Automize process could be tuned to check for new files more often (e.g., few seconds) and move (instead of copy) them to NAS. Similarly, SCADA DCI could be tuned to check for new files more often (e.g., few seconds) and import them. Data points for activation could be defined as Set Points in ICCP, so they are transmitted to partner immediately after a change.

6.3 Tuning of FEB-CM

FEB-CMs, when computing FlexEnergy from imbalances of RoR HPP or as unused flexibility, requires some real-time data.

In both cases, real-time data from SCADA needs to be acquired. Connections to SCADA are always delicate since these are production systems and vital for the business. In case of HSE, the connection to SCADA was not done directly but rather via the SCADA archive. Data in the archive is one-minute old, which was enough for the project. A benefit of reading the data from SCADA archive is also that the production system was not loaded with the requests from FEB-CT. In any case, additional configuration of system firewall and user accounts needed to be done to enable the read-only access for FEB-CT to be able to acquire near-to-real time measurements, which were used to calculate FEBs.

HDE had a similar situation, but they were able to connect to the production SCADA environment. Because of security measurements, IT permission changes needed to be done to all involved systems.

For both producers, connections were established in the developing phase and no major adaptations were required in later stages of the project.

In case of calculating the bids from RoR HPP, an additional input is needed: Adige river’s flow rate. This required to develop a web scraper to read water flows from public sites. Such tools, web scrapers, are prone to changes of the websites: changes in the web page structure could result in data unavailability for the tool. It would be better if such public services would have other options to gather data from them.

Beyond some minor bug-fixing, both the FEB-CM for unused ancillary services and the FEB-CM for integration of non-dispatchable RES didn't require any change, since the performed tests demonstrated that they worked as expected. They are aligned with the design and development activity in Task 6.4.

7 Proof of concept tests

This chapter provides information Sub-Task 6.6.3: Closed loop tests directed to business proof of concept. Here the focus is made on market and bidding interest of players, liquidity in real system environment, etc. Proof of concept includes a successfully performed closed-loop test.

First attempts of closed-loop test were performed in December 2021. The first partially successful closed-loop test was performed on 23. December 2021. FEBs submitted on FEMP were pre-agreed in a way, that FEBs would economically match. In this way a bid match was guaranteed. On the other side, the circumstances in the power grid allowed such exchange in near-to-real time so OPT generated an activation signal which was sent to ELES. ELES then forwarded the activation signal further to HSE and TERNA. HSE activated their portfolio while on TERNA side the signal stopped. The signal was stopped due to misconfiguration of the signal but since the test between TERNA and ENEL and HDE was already completed this test was understood as the first successful full closed-loop test.

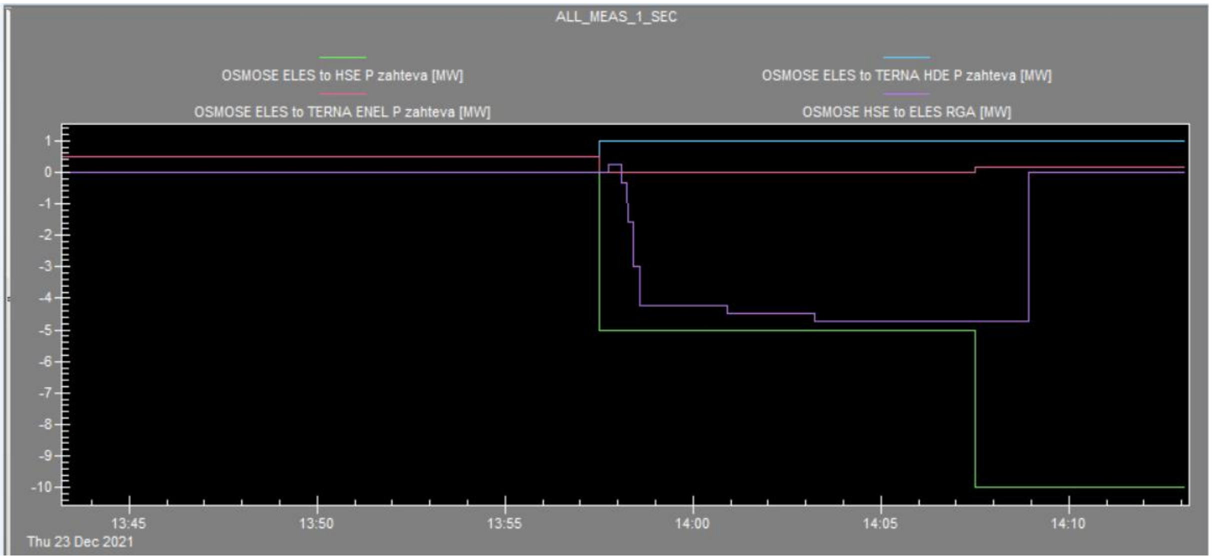


Figure 5: Closed-loop test on 23.12.2021 on ELES side

The last full closed-loop test which served also as the proof-of-concept test was on 3. March 2022 between 11:30 and 12:30. For PoC flexibility providers agreed upon prices of the bids. HSE created FEB for buying 5 MW between 11:30 and 12:00 and selling from 12:00 to 12:30. On the other side HDE created FEBs where it was buying during 11:30 and 12:00 5MW (same as HSE) and ENEL was in the opposite position: buying 10 MW from 11:30 to 12:00 and selling 10 MW from 12:00 until 12:30.

All of the bids matched and all of the snapshots were provided. Delivery by EN4M and OPT worked without issues. OPT provided an activation list which was imported to ELES SCADA from where activation signals were sent to flexibility providers.

All flexibility providers responded to the activation signal as expected. First part of the PoC was successful (11:30 till 12:00). After 12:00 the hydrologic circumstances on Drava River prevented further execution of PoC so the test was stopped at 12:07 because of low levels in HPP basins.

In Table 2 values from ENTSO-E Transparency Platform are presented. Columns under “Available transfer capacities” are from “Forecasted Day-ahead Transfer Capacities [11.1]” ENTSO-E timeseries, while “Scheduled flows” are from “Total Commercial Schedules [12.1.F]” timeseries for 3rd March 2022.

Table 2: ENTSO-E transmission flows on 3.3.2022 for IT-SI border

	Available transmission capacities / MW		Scheduled flows / MW	
	IT->SI	SI->IT	IT->SI	SI->IT
H12	660	735	0	735
H13	660	729	25	754

From the values in Table 2 it can be observed that there was a commercial congestion between Italy and Slovenia in direction from Slovenia to Italy during the proof-of-concept test. For the delivery hour block H13 (12:00 – 13:00) there was even more exchange (754 MW) than available transmission (729 MW). This was possible due to the reason that there was an exchange of 25 MW in the opposite direction (IT to SI) which resulted in a net flow of 729 MW from Slovenia to Italy which is equal to the available transmission capacity.

Regardless the commercial congestion during the proof-of-concept demo, we were able to activate the exchange from Slovenia to Italy (HSE was selling from Slovenian market, HDE was selling in Italian market and ENEL was buying in Italian market) between 12:00 and 12:30. This shows that OPT identified an opportunity to exchange flexibility based on the transmission snapshot that reflect a near-to-real time network status.

Due to the low hydrology on Drava River the activation had to be stopped at 12:07 but until then we were able to transfer FlexEnergy even on commercial congested direction.

This shows that it is possible to exchange FlexEnergy regardless commercial congestions using near-to-real time grid snapshots and near-to-real time bidding.

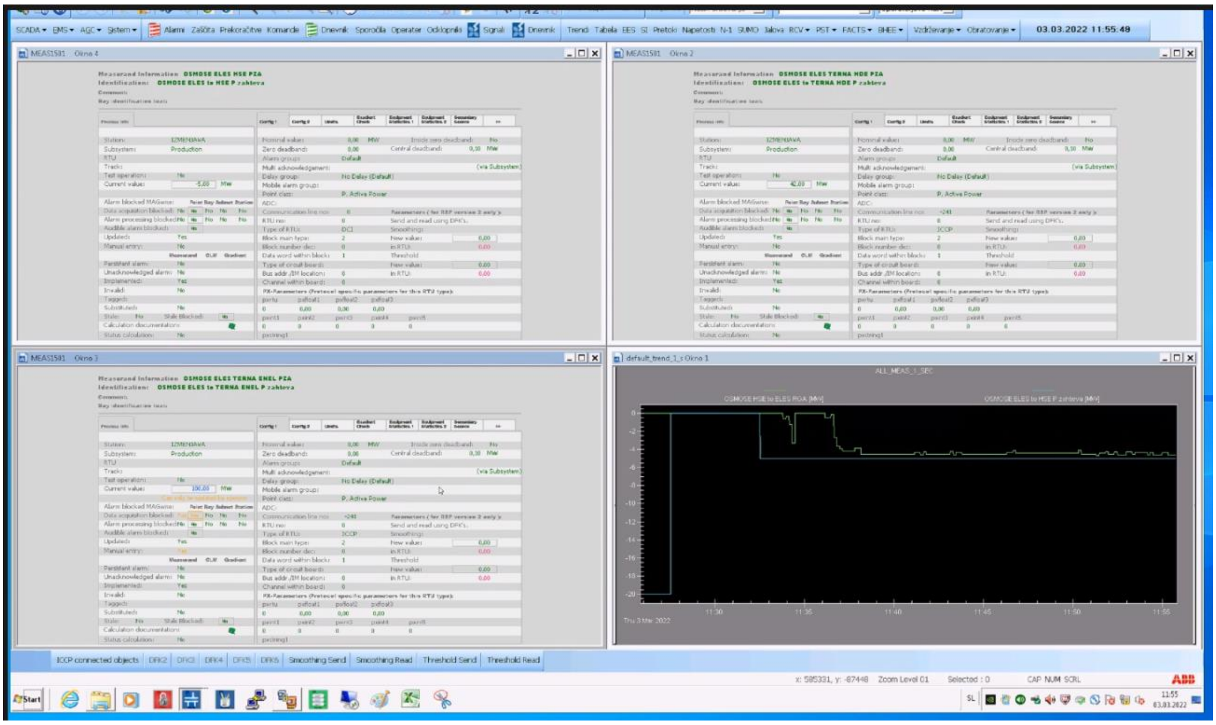


Figure 6: PoC screenshot on TSOs side

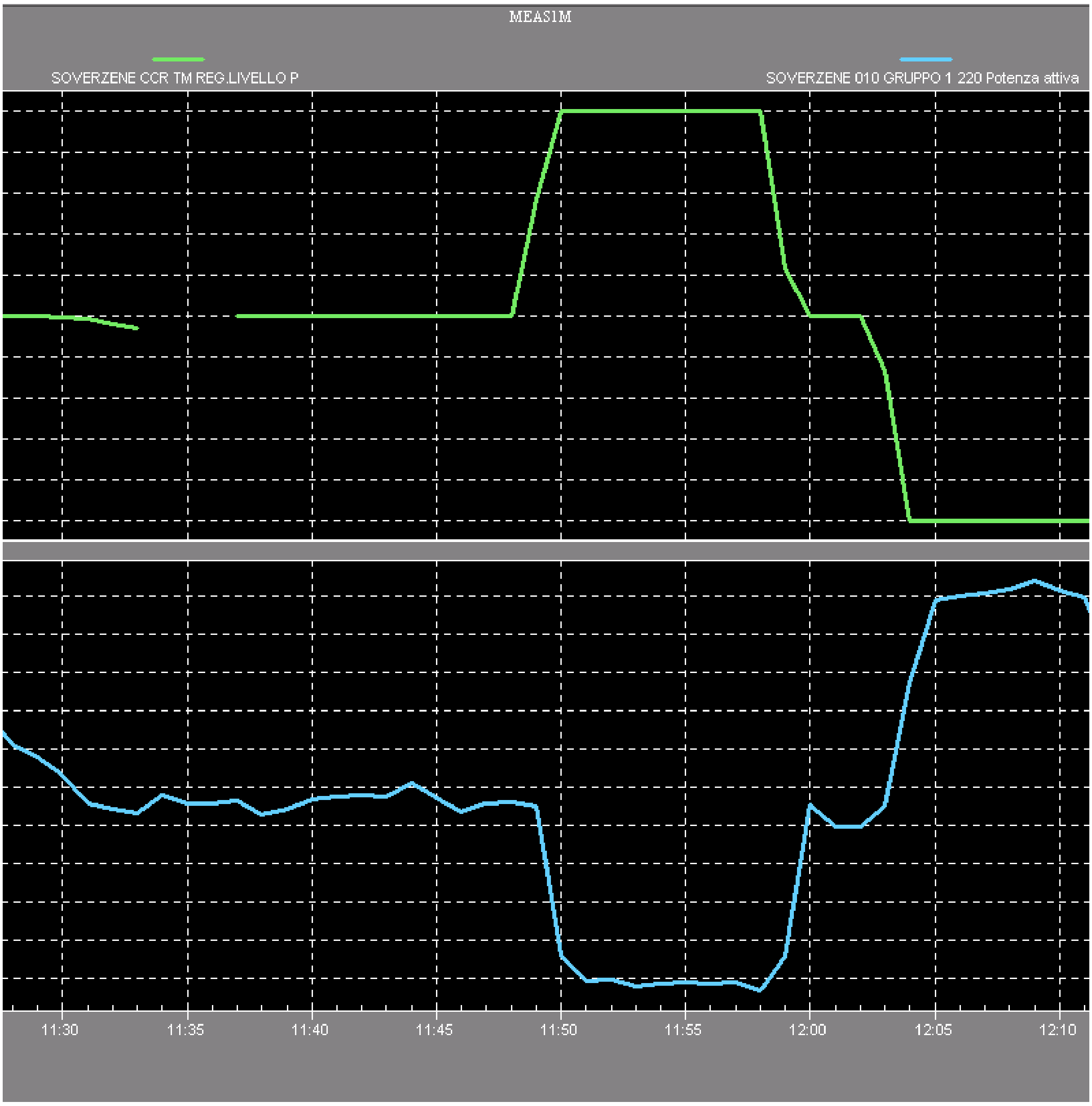


Figure 7: PoC on ENEL side

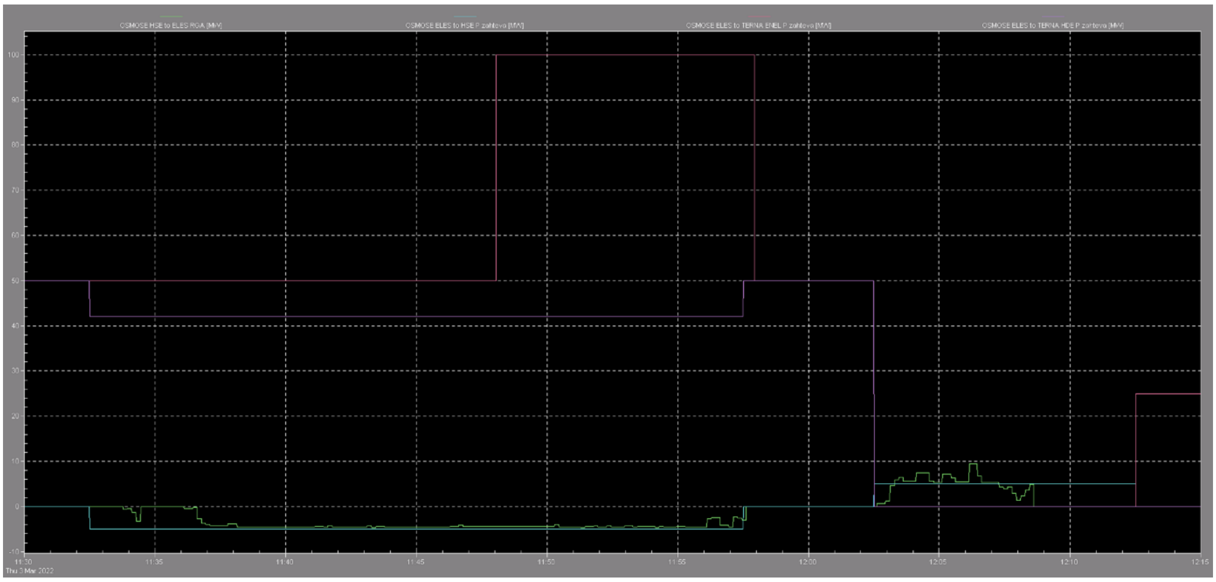


Figure 8: PoC on TSOs side (as trendlines)

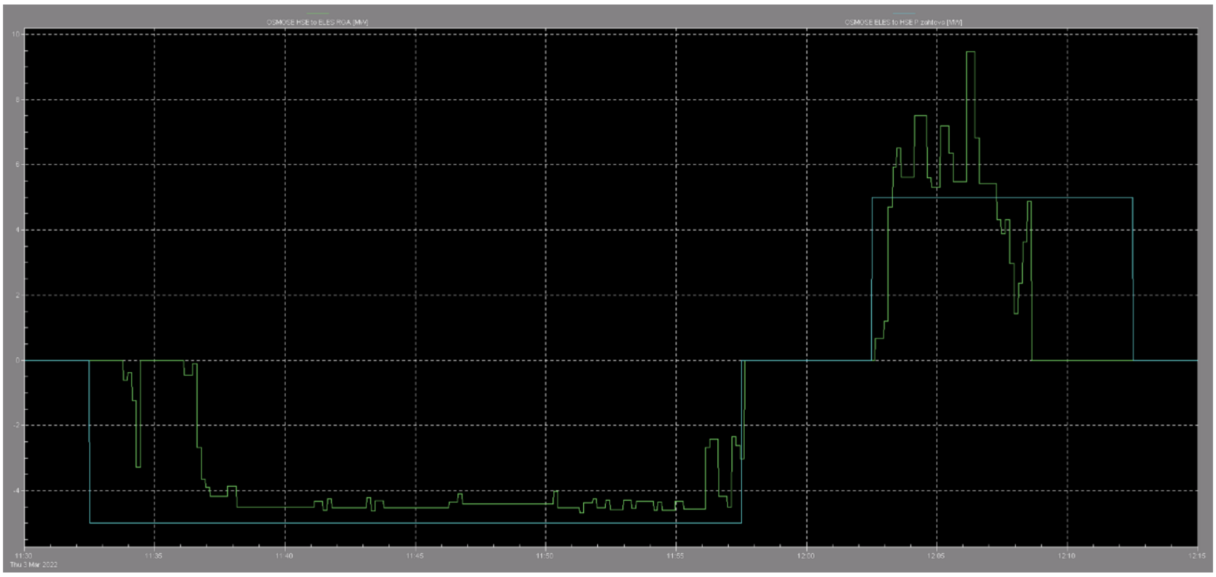


Figure 9: PoC on HSE side

8 KPI Calculation Results

Calculated KPIs are an important part of each project. They provide an additional dimension of the outcomes, where the potential of the project can be assessed. Even if proof of concepts is successful, KPIs may show that the proposed market works but it lacks opportunities. KPIs in this chapter are calculated as proposed in D6.4, chapter 8, retaining the same structure of subchapters; so, it is easier to check and compare the contents. Calculated KPIs also provide a proof that the components and the market were tested and measured.

Technical and software KPIs show that such market can operate and is functional. KPIs with lower scores show which components would need further development for a real operation.

Economic KPIs shows that the potential of proposed market in small compared to existing power markets. One of main economic indicators is presented in 8.1.1.

8.1 Economic KPIs

To estimate the economic performance of proposed FEM, two test sessions were conducted:

- First one from the 15th to the 31st of January 2022.
- Second one from the 14th to the 17th of March 2022.

Those sessions were real bidding sessions, meaning that flexibility providers (in the case of our project, producers) were free to determine their prices and volumes to assess the economic potential of the project. To allow such relatively long sessions, the tests were conducted in open-loop configuration. This means that every part of the trading process was real, except for the activation signals, which were blocked by FEMP and did not reach the flexibility units. These were therefore freely available for normal operation and not affected by the test. Given that the total power of the plants participating on the demo is small with respect to the inter and intra-area power flows, it is assumed that no activation due to FEM could significantly change the boundary conditions of the market (e.g. transmission capacities, marginal prices). In other words, the assessment of the FEM's real economic performance should not be altered by the lack of activation.

To test FEM in various market conditions, the two sessions were planned in different months. In fact, the electricity prices vary over the year due to many factors, e.g. the trend of the consumption and of the RES production. One of the relevant seasonal variables is water availability, which is pivotal for HPPs. In fact, in January, prices are usually high and water availability is low. On the contrary, in March, prices are generally lower and water availability is higher than during winter. In 2022, however, prices were extremely high and a severe drought affected southern Europe. These considerations are addressed more in detail in subsection 8.1.1.3.

8.1.1 Generated social welfare

To assess in detail the potential social welfare generated by the proposed FEM in different boundary conditions, the two test sessions are addressed separately.

8.1.1.1 First test session

On the 1,600 quarters tested, producers proposed a bit less than 50 % of the time mainly due to work schedule of trading teams (no bidding during night hours and weekends) and to availability of power plants.

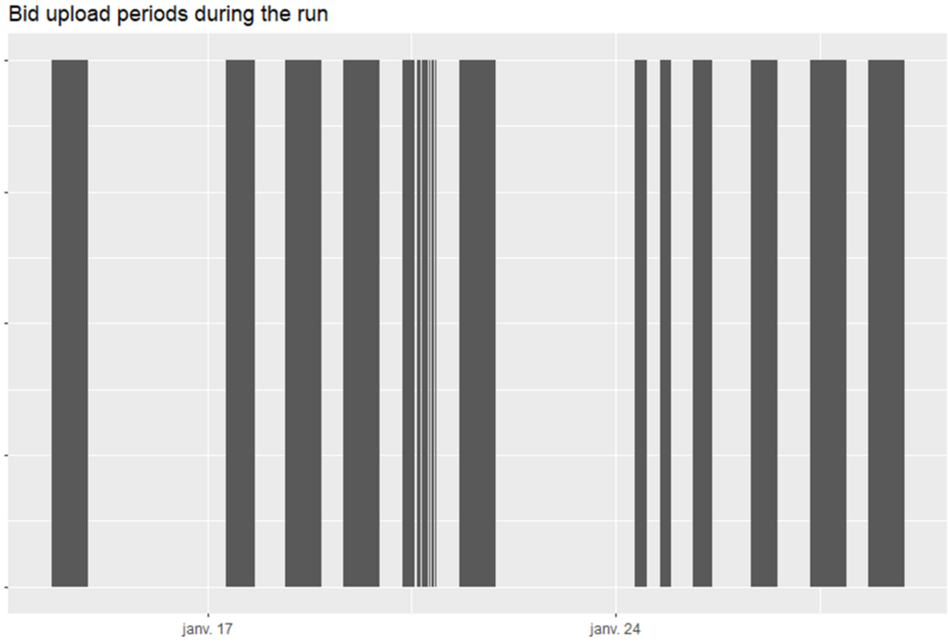


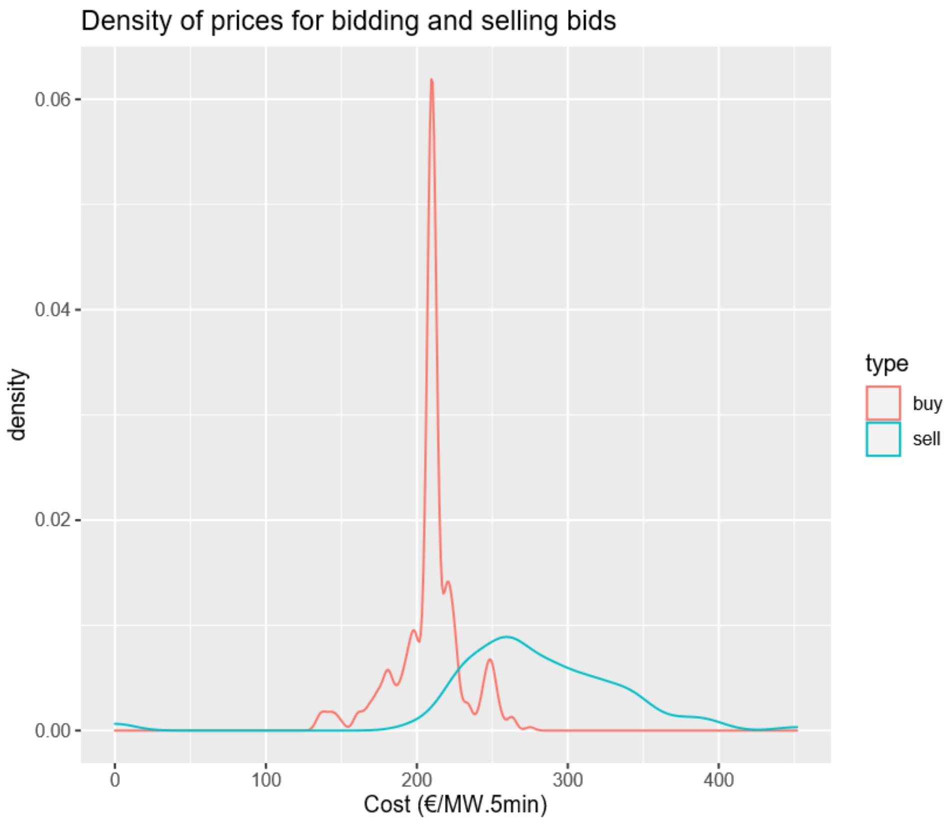
Figure 10: bid upload periods during the run of the first test session.

The maximum power proposed downward (buying) was 35 MW and upward (selling) was 20 MW. The gradient of one bid was mostly limiting with a 5 MW/5 min value.

The maximum price proposed downward was 275 € and upward 451 €. These prices are extreme and reflect the tension on the power market during the winter 2021-2022.

During this test, only one match took place on 19th of January at 13:55 for a volume of 0.417 MWh, which is very small. The total social welfare associated with this exchange was of 100 € for the whole period, which is extremely low. If we could generalize this value to the size of the power systems in Italy and Slovenia, then the associated economic welfare would be of 1 M€ annually as an order of magnitude, which is extremely low compared to the value associated with other power markets. The net value of such a market could even be negative if we consider the cost of development and maintenance of such tools, especially due to the fact that real-time procedures need careful attention.

The following plot shows the distribution of prices during this test period. Although we observe some overlap between selling and buying bids, they didn’t occur during the same time period and didn’t lead to economic exchanges.



We also observed that buying bids were in general associated with more volume than selling bids, which were in the vast majority around 20 MW.

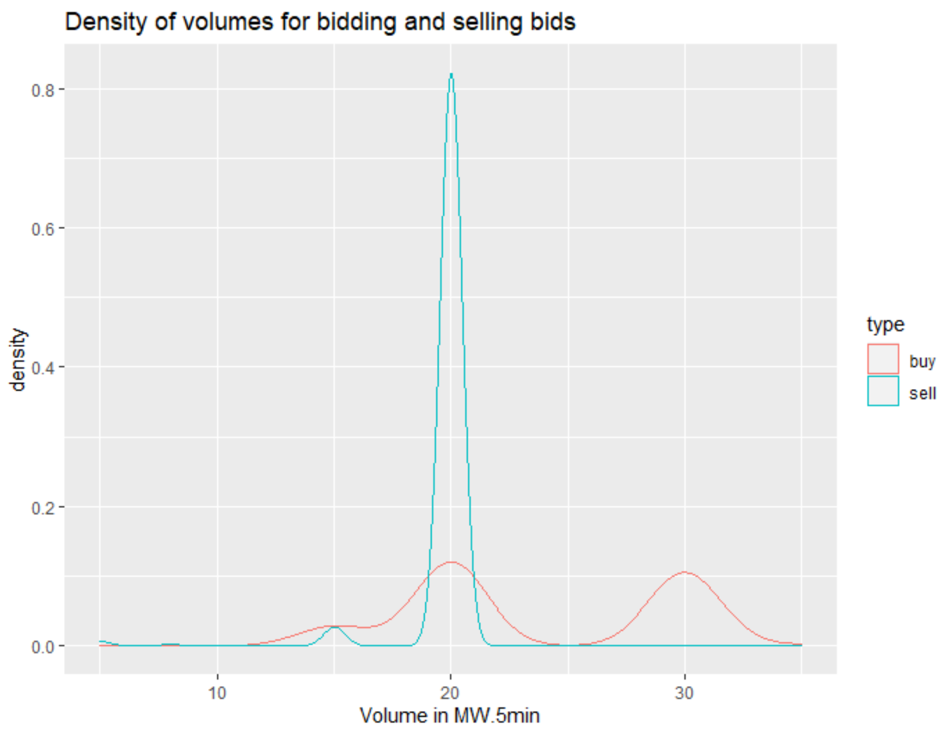


Figure 11: Density of volumes for bidding and selling FEBs

HSE was the producer who offered most of the volume on the platform but was often limited by the gradient of the bids which was 5 MW/5 min.

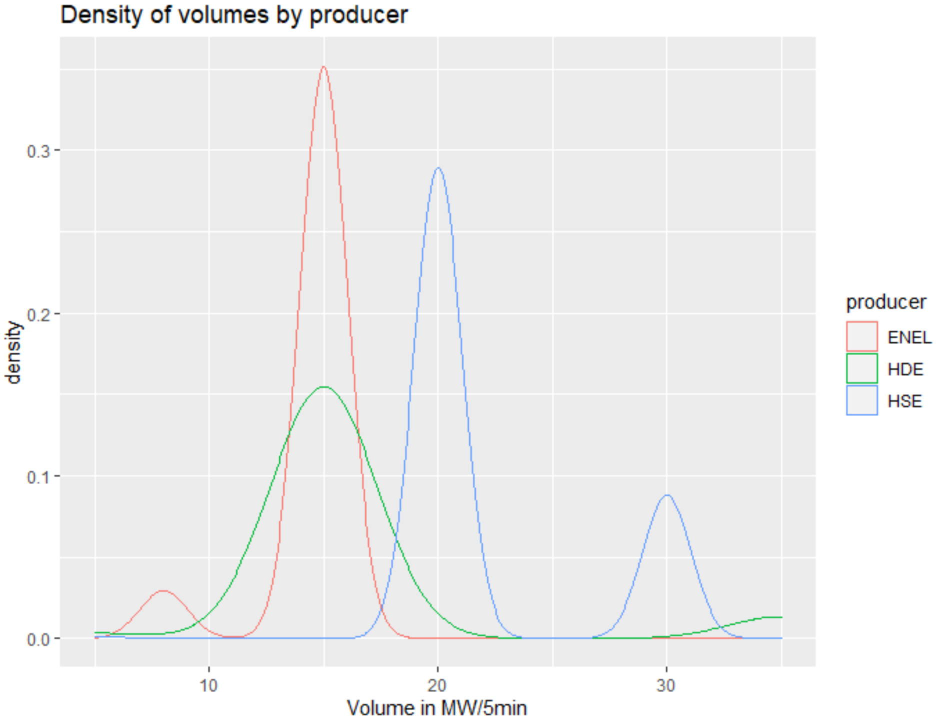


Figure 12: Density of volumes by FlexEnergy provider

8.1.1.2 Second test session

During the second test session, we observed better matching between buy and sell bids. It leads to a slightly higher creation of value.

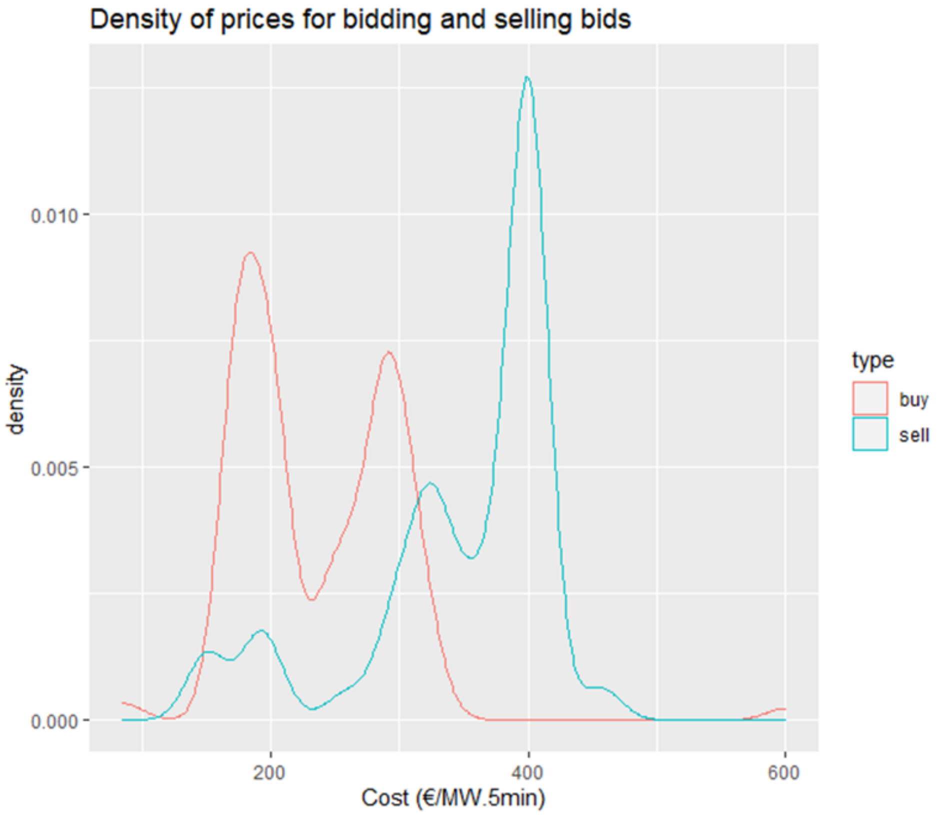


Figure 13: Density of volumes by FlexEnergy provider for the second test

During the 16th and 17th of March buy bid prices were above the sell prices, making 14 matches during as many optimization periods. Maximum buying price was 600 €/MWh and the minimum selling price was 400 €/MWh.

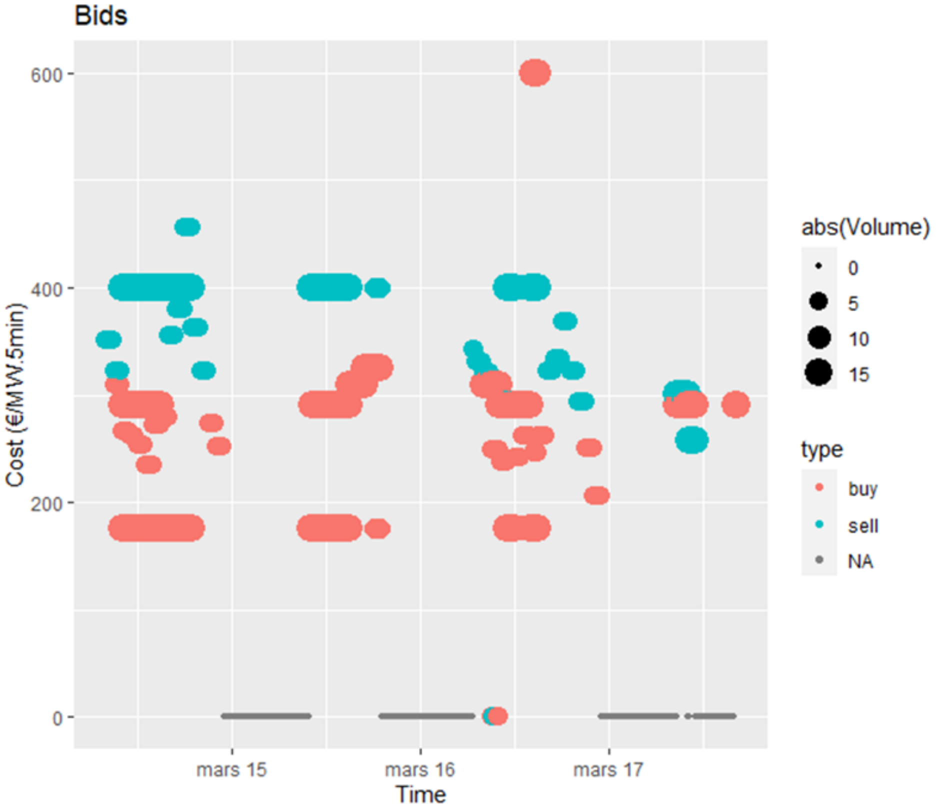


Figure 14: Buy and sell bids for the second test

Those matches were able to create a possible 20 k€ of welfare during those 14 optimization steps. The maximum exchange was about 10 MW for 10 min between Italia and Slovenia.

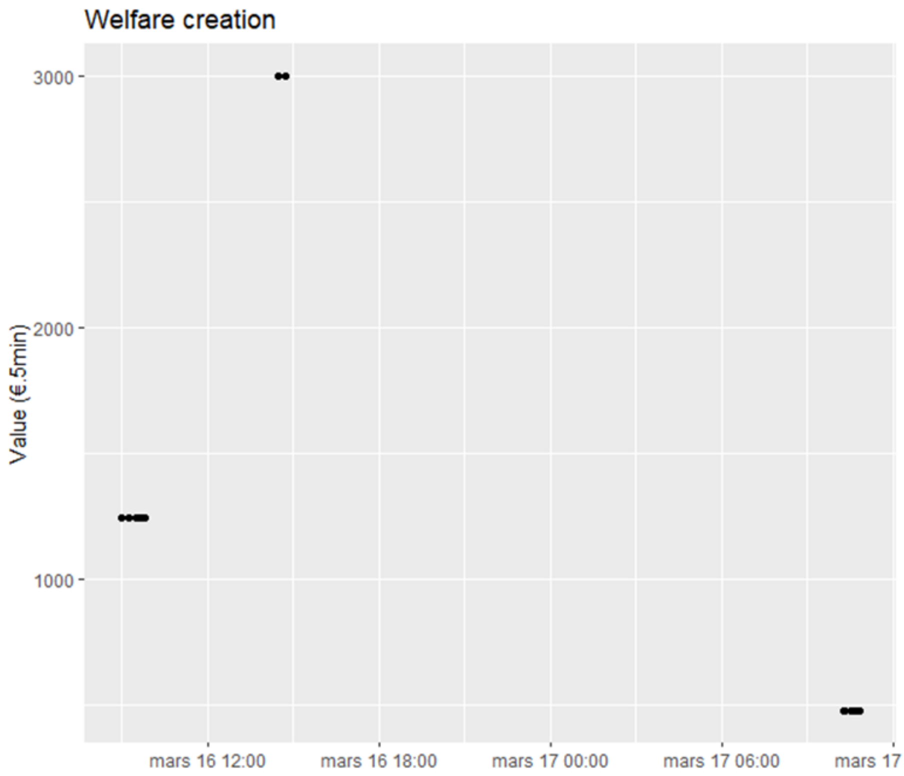


Figure 15: Value creation for the second test session

We were able to observe more matches during this second test session of one week. An extrapolation of the order of magnitude of the value created over one year is again around 1 million euros per year.

8.1.1.3 Conclusions

The order of magnitude of the generated social welfare extrapolated from the bidding test sessions is small. We may suppose several explanations. The first one could be linked to the situation of the winter 2021-2022 with extreme prices on power exchanges and very low hydrology (due to a large and severe drought affecting the western Euro-Mediterranean region and southern Europe). Please note that all power plants involved in the demo are hydropower plants, whose production depends on water availability. Its scarcity could also cause the higher volumes of buy bids with respect to sell bids.

Another explanation to the low value of the market could be the relatively short period of observation of three weeks, compared to what could happen during a whole year. Also, the small number of participants may have proved insufficient to generate significative trading opportunities (the test involved three actors, with a total of two HPPs in Italy and one HPPs portfolio in Slovenia).

A further explanation could be that for those timeframes so close to real-time, the economic potential is low. It could also be possible that producers, having no history of the matches and price forecast, didn't succeed to optimize their bidding process for the new FEM.

Finally, as the FlexEnergy Market is conceived as a pay-as-cleared market, in which operator's demand is supposed to match operator's offer, it might be that during such a short period of test operator's trading strategies did not match. This scenario is even more likely considering that HDE, ENEL and HSE power plants involved in FlexEnergy Market share the same 'market initial condition', i.e. the Day-Ahead Market price. As already highlighted, running FlexEnergy

Market between two countries with different DA Market prices, such as Italy and France, could increase significantly the frequency of matched bids.

As a conclusion, the assessed economic potential for such a market is quite small today and then shouldn't be prioritized compared to other evolutions of power markets. However, the penetration of renewable capacities in power systems, leading to more uncertainty in real-time, may increase the economic value of those markets in the coming decades.

8.1.2 Improvement of power system carbon footprint

As explained in chapter 8.1.2.1 of D6.4, the improvement of power system carbon footprint is achieved thanks to a reduction of imbalances from non-dispatchable RES power plants. In fact, using a FEB-CM as INDRES to reduce the discrepancies between scheduled and actual power production leads to less volumes of frequency restoration reserve activated by TSO, to which fossil fuel plants (like Combined Cycle Gas Turbine) provide a significant contribution.

As explained in 5.1.4, the portfolio management of power plants (a requisite for employing INDRES) was not allowed yet in the Italian power market.

In addition, it is necessary to note that the Italian market setting is changed since the start of OSMOSE, because XBID market was launched in September 2021. This means that potential imbalances might be corrected by operators trading on either XBID and FlexEnergy Market. However, a quantitative assessment of how much imbalance reduction could take place on XBID rather than FlexEnergy Market is challenging because of lack of historical dataset and of operator's experience as well.

Unfortunately, it was not possible to integrate the FEM bidding process with the XBID one. In fact, the latter became operational few months before the start of OSMOSE demo tests and attempts to develop an integration were slowed by delays of the Italian TSO.

As a consequence, FEBs from INDRES could not be used for the economic performance evaluation tests and this KPI could not be calculated.

8.1.3 Additional potential for the exchange of flexibility and its level of utilization

Regarding the level of exchange that we measured during the open-loop session tests, the maximum exchange flow was about to 10 MW for 10 minutes, from Slovenia to Italy. This level is extremely low and in accordance with the economic results.

8.1.4 Amount of energy that is extra exchanged between two markets

As mentioned in 8.1.38.1.4, only 10 MW were accepted for 10 minutes which indicates 1.7 MWh of exchanged energy.

8.1.5 Improvement of the utilization of flexibility resources

Despite the limited volume exchanged as resulted from the tests, FlexEnergy Market shows the potential for interesting trading opportunities. As example, HPP S. Massenza, managed by HDE, has two reservoirs, with seasonal and daily/weekly management respectively. Of course, the hydraulic constraints dominate the trading strategy when it comes to set up the production planning of the smaller reservoir. FlexEnergy Market, because of its close-to-delivery gate closure might offer the possibility to correct potential overproduction as well as underproduction taking advantage of the last available water inflow forecast. Moreover, FlexEnergy Market allows the trading operator to bid a specific volume in specific hours, rather than a flat bidding like MSD markets. This might open interesting trading opportunities even in small reservoirs such as the one used in this project thanks to more control by the operator on the quantity that might be activated.

However, such potential further use of RES flexibility (dispatchable or not) must be supported by a significantly higher market volume exchange. In the context of Flex Market, i.e. a pay-as-cleared market, a possible idea would be to set up a similar market coupling two countries with a different day ahead price, such as Italy and France. This might increase the volume exchanged since the clearing price would tend to set between the day ahead market prices.

This KPIs, as defined in D6.4 8.1.5.1 relates to activated energy compared to last known commercial schedule. For each MTU it's value is 1 in case there is no activation while it is the ratio between the change of schedule and the last known schedule. During the demo there was little energy activated due to few participating units and low market liquidity.

In case we would assume that every bid would be activated, an indicative value of KPI could be 1,0046. This means that during 8,256 hour-intervals the commercial defined schedule would have been changed for maximum 0.46%.

8.1.6 Bid granularity

The KPI discussed in this Section aims to quantify the additional usage of flexibility by means the ratio between the quantity fully activated and the quantity accepted on FEM. The KPI ranges between 0 and 1, meaning that a value equal to 1 represent a full activation of the accepted quantity, while 0 means no activation, e.g. because of grid congestion. The KPI is provided as the average of such ration over the Market Time Unit.

The KPI estimated for HDE, HSE and ENEL results as follows:

- HDE = 0,88
- ENEL = 0,86
- HSE = 0,75

For the sake of clarity, it is specified that a KPI equal to 0,88 means that, on average, 88% of the power bid is then activated.

The resulted KPI shows that most of the quantity accepted on FEM is ultimately activated. This can be considered as a good result because it proves that no major constraints occur at grid level and the market opportunities can translate into effective activation.

Moreover, from the point of view of power unit management this result is promising too. A frequent full activation means that the resulting unit schedule follows a "regular" program, with little probability of having intermediate power unit values as result of partial activation of the bids.

8.1.7 Number of accepted bids

During the open loop test HDE, HSE and ENEL submitted bids on FEM following an independent trading strategy. The KPI here described aims to estimate the fraction of accepted bids with respect to the submitted ones. Of course, the KPI extremes are 0 (no accepted bids) and 100% (every bid is accepted).

The results are summarized for each producer:

- HDE: 4%
- HSE: 2%
- ENEL: 2%

The frequency of acceptance is very low, confirming what has been already highlight in this Deliverable in terms of low exchanged volumes on FEM.

It is worth to remind that FEM is conceived as a pay-as-clear market, where demand and offer from different producers should match leading to an exchanged volume of energy. Moreover, the power unit in order to be eligible on FEM has to be up and running. These two conditions are somehow hard to meet. The first one because of the limited number of producers involved in the open loop test. Besides, those producers share the same the day ahead market price most of the time, which is the most common benchmark price used to build the trading strategy. Starting from the same 'initial condition' it might be difficult having frequent bid matching between two producers.

The second condition is stressed because of the current extreme drought occurring in the Alps, leads to a very low hydropower production and therefore the power unit are off most of the time.

Finally, it is worth saying that the extreme market volatility everyone is experiencing at moment of writing complicates further the picture.

However, the mechanism conceived in FEM is still promising since it allows nearly real-time unit schedule updates with interesting market opportunities. Perhaps different producers from different market zones (e.g. France) might be involved in future case studies to test if the exchanged volumes might increase.

8.1.8 Sell-buy bid spread

This KPI identifies the difference between the minimum sell bid price and the maximum buy bid price at every Market Time Unit. When the KPI is lower than zero, it means that at least one buy bid price is greater than one sell bid price and thus a matching is potentially feasible, if no technical constraints occur.

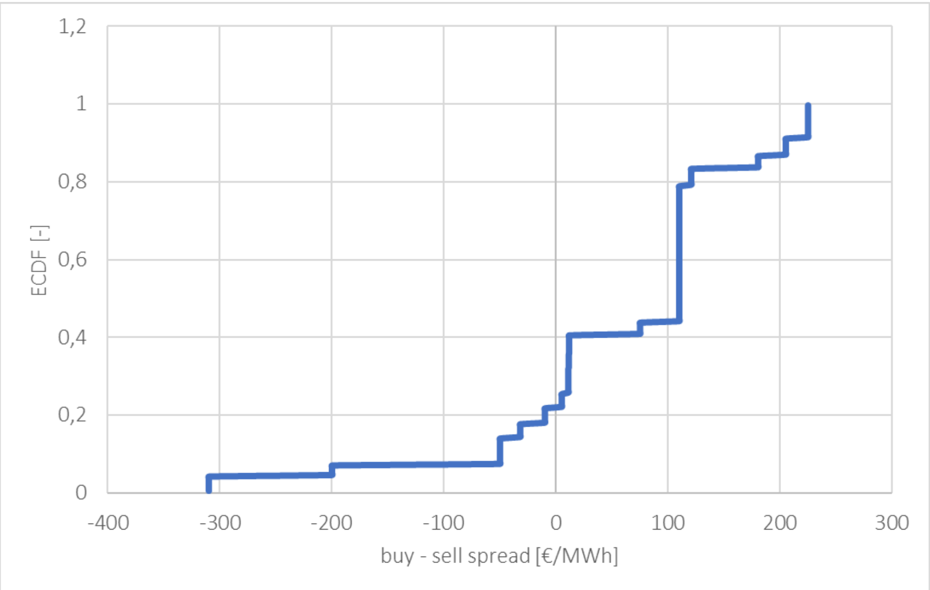


Figure 16: empirical cumulative distribution function of buy-sell bid price spread [€/MWh].

Figure 16 shows the cumulative distribution of the estimated KPI. It shows that around 20% of the bids have negative sell-buy bid spread, i.e. potentially a matching can occur. The other 80% of the times the producers bid do not lead to any matching because there is no possibility of clearing price formation. Such distribution was estimated considering only Market Time Units where at least two producers bid some volumes.

This is coherent with what has been already highlighted before: the FEM should involve producers operating on markets with different structures to ease the matching of buy-sell bids.

Finally, a massive buy-sell bid spread came out from the open loop test. This is expected because of the current large volatility of market prices.

During the test there were also some events of “internal” matching where one flexibility provider uploaded one buy and one sell bid which were matched between each other, resulting in an exchange without physical consequences.

8.1.9 Profit of non-dispatchable PU provider

This KPI could not be calculated because the Italian market, at the time of writing, did not allowed portfolio management yet. Without portfolio management of power plants, the imbalances detected by the nowcasting algorithm cannot be valorized as FEBs.

8.2 Technical KPIs

8.2.1 DC power mismatch

The quality of the network model depends on input SN models delivered by each TSO. If some model is not delivered, it will be replaced by the latest available, but this may cause divergence of the AC load flow. In that case, a fallback procedure with DC load flow is applied and files for optimization are anyhow exported. As described in 11.3.1, the Swiss model is always in discrepancy with the rest of the network, and this causes divergence of AC load flow calculation in most of the cases. This is the reason why this KPI couldn’t be calculated in the way it was defined.

8.2.2 Accuracy of power imbalance nowcasting algorithm

The KPI formula, exposed in D6.4 paragraph 8.2.2.1, is shown below. It describes the Mean Absolute Percentage Error (MAPE) of the power imbalance nowcasting algorithm, although the KPI description in D6.4 mistakenly reports “Mean Absolute Error” instead.

$$KPI_i = mean(|e_{t-T}|)/P_n \,,$$
$$with \;\; e_{t-T} = y_t - \hat{y}_{t-T}$$

- $\boldsymbol{y_t}$ – observed value of power imbalance in generation of non-dispatchable PU at time *t*
- $\boldsymbol{\hat{y}_{t-T}}$ – nowcasted value of power imbalance in generation of non-dispatchable PU at time t based on forecasted performed at time *t-T*
- $\boldsymbol{e_{t-T}}$ – forecasted error
- $\boldsymbol{P_n}$ – rated active power of non-dispatchable unit

Referring to the above notation, *T* is the advance of time at which the forecast $\hat{y}_{t-T}$ is available. It must be considered a variable as well, as it is an additional dimension in which to calculate the KPI. Therefore, as it can be seen in Figure 17, this KPI is estimated for the entire range of *T*, from +1 to +16 TS (Time Steps). In fact, the nowcasting algorithm developed for the project features a forecast horizon of 4 hours (TS ranges from 0 to 15 in the plot, because it represents the array of the forecasted time series).

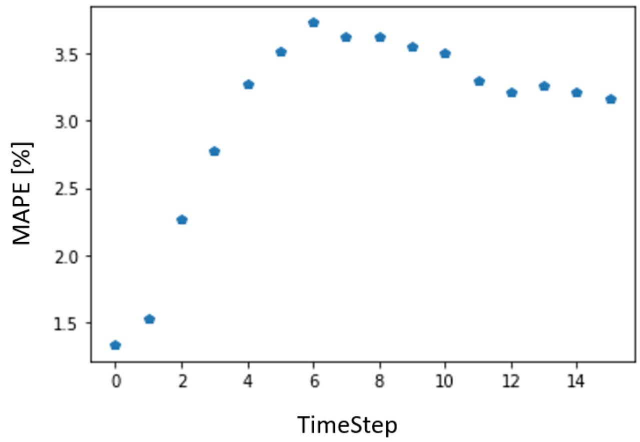


Figure 17: Mean Absolute Percentage Error (MAPE) of the power imbalance nowcasting algorithm over different forecast advances

In conclusion, MAPE ranges from 1.33% of Time Step “+1” to 3.72% of Time Step “+7” (i.e. + 1 hour and 45 minutes). Curiously, MAPE decreases after Time Step “+8”; this odd behavior is possibly related to the concentration time.

8.2.3 Size of initial CRAC list

The CRAC file leads to around 30 critical branches/critical outages pairs to monitor at each time stamp to keep the network safe. For the optimization problems, it means that more than 30 hypothetical network states are monitored at the same time. This is quite a small number compared to what is used for more standard capacity calculations.

8.2.4 Number of presolved constrains

In the process of preparation of the list of constraints for the FEM optimization, the initial CNEC list is created using the EN4M function and filtered considering thresholds of nodal PTDF (for CNEs) and OTDF (for COs). This initial CNEC list is consisted of 435 CNECs, considering 93 critical network elements and 56 different topologies. After the creation of CGM for every timestamp, the size of this list is reduced by applying 2 presolve algorithms in the EN4M tool. In the majority of the cases tested during the demonstration period, the size of the initial CNEC list is reduced to 70-80% of the number of predefined CNECs.

8.2.5 Number of filtered CB/CO pairs

The number of invalid CNECs during the demonstration period is negligible and limited to the number of the CNECs with different statuses or potentially busbar systems. If the status of the critical network element is switched off, this CNEC wouldn’t impact capacity calculation and should not be considered in the list.

8.2.6 Number of filtered bids

This KPI counts the number of valid bids relative to the initial submitted bids. It was defined in D6.4 as follows:

$$KPI \quad = \frac{\text{Number of valid bids}}{\text{Number of submitted bids}_i}$$

The numerator indicates the number of FEBs xml files that passed the quality check performed by the FEB preprocessing and merge tool, the denominator is about the number of FEBs files that have been submitted by the FEB-CT.

From the beginning of the experimentation about 3030 FEBs files were submitted and only few FEBs (around 30 FEBs files) were discarded, and the main reason was that the related xml files weren't compliant to the schema provided in D6.4. Therefore, the KPI can be computed as follow:

$$KPI \quad = \frac{3000}{3030} = \ 0{,}99$$

As expected, the obtained value is close to 1 since only few bids were discarded.

8.2.7 Level of Remaining Available Margin

The level of remaining available margin on the lines was always sufficient to enable exchanges of the bids during the test. This is probably since the volume involved in the demonstration test were small compared to the other flows on the transmission power network. So, the level of remaining available margin was also bigger than 5 MW of the cross-border lines.

8.2.8 RAM usage: Occurrence of security constraints

The maximum activation was 10 MW of energy on the transportation network which is very low. So, we didn't encounter any restriction due to the security constraints of the network during our closed-loop tests.

The value is then 0.

8.2.9 Congestion relief

We didn't observe cases with congestion at the same time as our bids were available during our closed-looped tests sessions. So no congestion were relieved during those tests. Moreover, the optimization didn't allow those kinds of actions to avoid possible simultaneous actions with the human dispatchers.

The value is then 0.

8.2.10 Active flow forecasts

The bids were designed by quarter, so the forecast horizon is 15 min. During this time horizon, we can forecast the impact of our activation but not the other power injections on the network.

8.3 Software related KPIs

8.3.1 Snapshots/IGM delivery time

IGM delivery time is measured as the time needed for TSOs (ELES, TERNA, RTE) to produce the snapshot models and deliver them to the EKC input folder at the ELES server. This time variates among TSOs as follows:

- ELES SN models are delivered within 30-60s
- TERNA SN models are delivered within 90-120s
- RTE SN models are delivered within 60-120s

- CH SN models are delivered within 8-12 min

This is the reason why target time cannot be unique for all the models and is defined following realistic delivery time. During closed-loop tests, when all delivery procedures were up and running successfully, no significant time delays were detected for any of the models and this KPI was lower than 0.2 referring to the specific target time agreed for every TSO.

Several unexpected shortcomings impacting this KPI were detected in the complete monitoring and testing period and are noted here. ELES SN models are sometimes delivered with a 5-minutes delay, which directly postpones the complete network creation procedure, as this model is essential for the model creation procedure. Additionally, the Swiss model is always in time discrepancy with the rest of the models due to its very late delivery procedure with a delay between 8-12 minutes. This will always influence certain mismatches.

8.3.2 CGM processing and preparation time

The complete procedure of CGM creation includes raw input data collection and validation, creation of the AC load flow model, and its conversion to the final DC-ready model and takes less than 2 minutes. In most tested cases, this process is completed and the final CGM is exported and available for the optimization process within 90 seconds from the moment of receiving network data from state estimators. This time is mostly dependent on the size of the network model, which is quite persistent.

8.3.3 UCTE format data quality check indicators

Every UCT model imported to the EN4M tool is being checked against UCTE DEF2 rules defined in the document “UCTE data exchange format for load flow and three phase short circuit studies”. To avoid any inconveniences caused by erroneous files, raw state estimation data are taken from input files and used for the creation of CGM. This enabled a smooth network creation process and a high level of suitability of the data delivery process, with all files processed during the complete demonstration period.

For every CGM created using the EN4M tool, a validity check according to the UCTE rules is performed before the export and thus eliminates the possibility of delivering invalid network files to optimization.

8.3.4 Total time required for CGM+CRAC processing

The total time needed for EN4M to process and deliver both DC-ready CGM and corresponding presolve CRAC list took 110-120 sec in most of the cases during the demonstration period. In addition to the previously described creation of CGM, the list of constraints is filtered through EN4M Presolve function, leaving only non-redundant and potentially limiting CNECs. This optimization process is time demanding and dependent on the hardware resources and the size of the initial CNEC list since it requires the calculation of the nodal PTDF matrix for the CNEC list. The size of the initial CNEC list was quite stable during the demonstration period and all calculations were performed on the specific machine on the ELES server resulting in the total time for network data creation up to 2 minutes.

8.3.5 Total time required for optimization

Most of the calculation time required less than two minutes which is already not negligeable for the time frequency target (5 min) in this project. Alongside the time required for the network data management, which was also 2 minutes, we decided to impose a maximum lag for the calculation at a 120 second level. The idea was to not delay the process with more than 5 minutes.

Although the calculation time tends to increase with the number of bids (between 1 and 10), the 120 seconds delay was always reached.

9 Summary and conclusions

Near-to-real time exchange of energy is possible even on the most commercially congested borders like between the border of Italy and Slovenia. We proved that this can be technically done in our “proof of concept”.

The game changer that enables our pilot market is the novel approach used by OPT platform where it, rather than relying on commercial defined net transfer capacities, uses almost real-time snapshots from TSOs and estimates if any additional exchanges of flexibility in terms of FEB activations is possible. Exchange of flexibility is not limited to cross-border or cross-zonal exchange but can happen also inside a certain zone (market) since OPT considers a nodal model of the network. Such activation could also decrease congestions if it finds appropriate FEBs.

The main goal of OPT is not to decrease congestions or remove imbalances since the pilot market is not ancillary services oriented. The goal is to maximize the social welfare through maximization of economically matchable FEBs. FEBs are activated only and only if no network constraints are voided.

During PoC such exchange of flexibility was done: energy was exchanged in the commercial congested direction while maintaining the transmission grid safe and stable.

Also, no FEB was rejected because of the transmission grid constraints. The most activated constraint was the gradient constraint which came from FEBs of one flexibility provider.

Demonstration test pointed out a weakness – if small liquidity is present on the market, low social welfare is realized which is the case for this demonstration test. A low volume of matched FEBs came because of few market participants – only three flexibility providers. This was enough to demonstrate the pilot market, but not enough to provide a good liquidity. Economic value of the pilot market is low compared to other markets but increasing demand for flexibility that is coming also from more and more intermittent power sources can increase the market liquidity.

During the implementation and testing a lot of effort was put into overcoming the differences between the rules of different TSOs. For example, on Slovenian side activation signal means a relative set point in MW while on Italian side the activation signal is treated as a semi-band signal where 50 means no activation, 100 means full FEB activation in upward direction and 0 a full FEB activation in downward direction. Such differences introduce additional signal transformation and do not add any value. A harmonization for technical requirements and protocols for FEB activation would be crucial for a wide adoption of the market. Such harmonization makes the implementation not just easier but also economically more affordable since there are less exceptions and region-specific requirements. Harmonization is further discussed in D6.6.

10 Annexes

10.1 Bid Prepocessing and merge tool – example of report file

C:\Users\lmarilena\Desktop\bids-pre-processing-master/localFS/HDE/FEB_HDE_v2.xml,DET_2,Grid node Unit ID: UP_S.MASS.CL_2 not compliant

C:\Users\lmarilena\Desktop\bids-pre-processing-master/localFS/HSE/FEB_HSE_v2.xml,FEB_4,Grid node Area: 10YSI-ELES- not compliant

C:\Users\lmarilena\Desktop\bids-pre-processing-master/localFS/ENEL/FEB_ENEL_2.xml,null,File: C:\Users\lmarilena\Desktop\bids-pre-processing-master/localFS/ENEL/FEB_ENEL_2.xml not compliant with schema,

[error]: Error: invalid xml (status=WITH_ERRORS)

[error] cvc-datatype-valid.1.2.1: '0,5' is not a valid value for 'decimal'. (25:21)

[error] cvc-type.3.1.3: The value '0,5' of element 'Price' is not valid. (25:21)