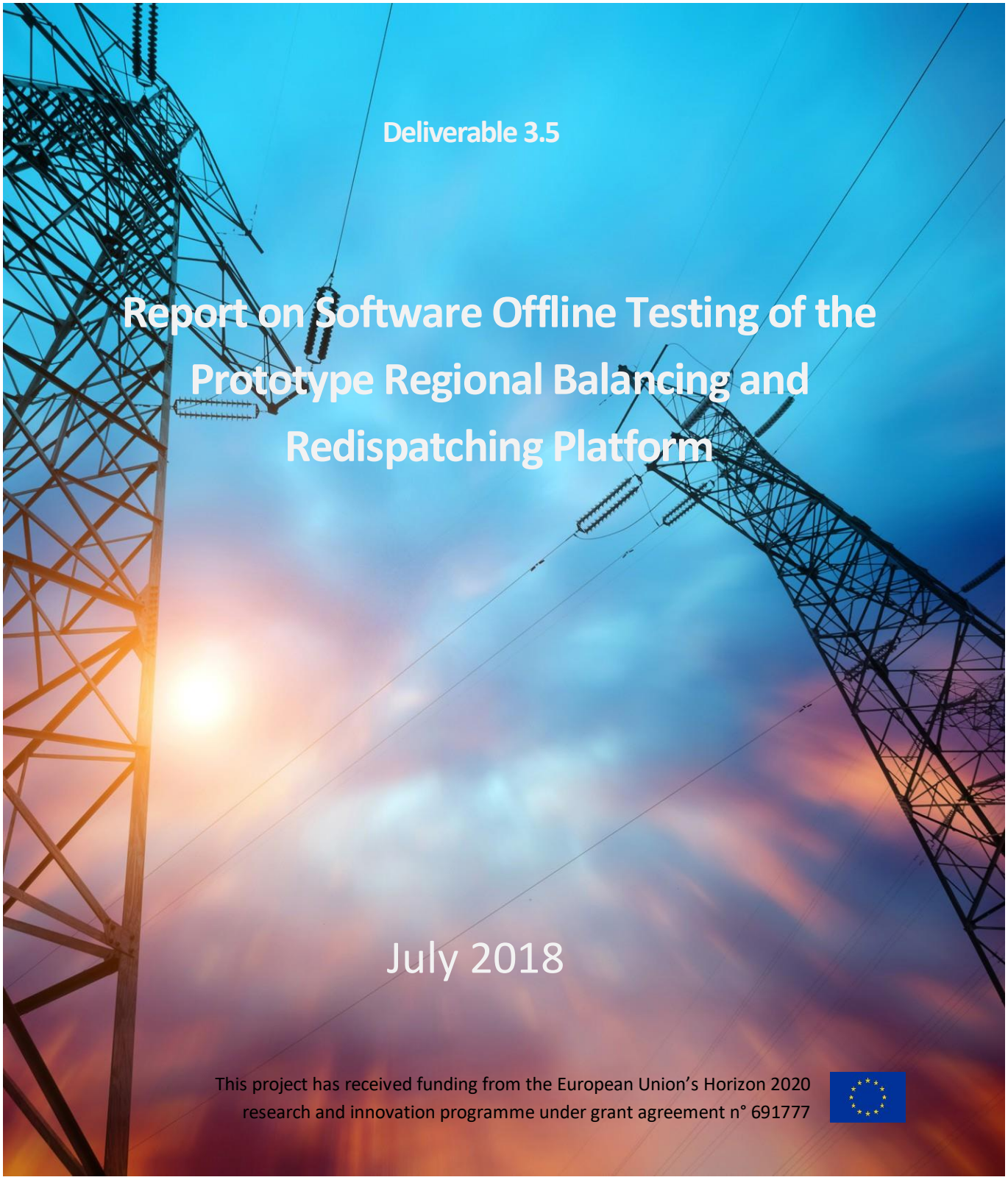
FutureFlow



Deliverable 3.5

Report on Software Offline Testing of the Prototype Regional Balancing and Redispatching Platform

July 2018

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FutureFlow

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0.5	30.07.2018	EIMV, CG	Comments, suggestions and review
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TABLE OF CONTENTS

1 EXECUTIVE SUMMARY

FutureFlow Task 3.4 is concerned with the software offline testing for the Prototype Regional Balancing and Redispatching Platform with Common Activation Function for FRR, which is also referred to in the current document as the "FutureFlow Cloud Platform". The platform was developed by SAP according to specifications in FutureFlow deliverables 3.1 (Specifications of the Prototype Regional Balancing and Redispatching Platform), 1.2 (Cross-border balancing and redispatching mechanisms tailored to congested borders situation and design of a Common Activation Function), 1.3 (Data needed to implement the Common Activation Function) and incorporating guidance from a series of technical workshops and knowledge sharing sessions that were conducted mainly between SAP, EKC, EIMV and TSOs representatives.

The platform is securely hosted by SAP in the SAP Cloud Platform (public cloud infrastructure that offers a multitude of enterprise services, including identity authentication) and interfaces with the TSO common real-time processing function developed in FutureFlow task 3.3 (FutureFlow Demo Site).

FutureFlow Cloud Platform also hosts the FutureFlow Data Warehouse, which will store both the data input, as well as the data generated as part of using the regional balancing of the FutureFlow Cloud Platform and is developed following specifications in FutureFlow Deliverable 3.1 and in compliance with FutureFlow Deliverable 7.4 (Data Management Plan).

This document marks the finalization of FutureFlow Task 3.4 and describes in detail the process and results of the software offline testing of the Prototype Regional Balancing and Redispatching Platform (FF Cloud Platform).

2 LIST OF ACRONYMS AND FIGURES

2.1 List of acronyms

Acronym	Description
(a)FRR	(Automated) Frequency Reserve Response
API	Application Programming Interface
BSP	Balancing Service Provider
CAF	Common Activation Function
CBCO	Cross Border Critical Outage
(C)MOL	(Common) Merit-Order List
CTCR	Control Target – Control Request (type of imbalance input to the FF Cloud Platform)
CZC-ATC	Cross-zonal capacity based on Available Transfer Capacity
CZC-PTDF	Cross-zonal capacity based on Power Transfer Distribution Factors
DWH	Data Warehouse
FF Cloud Platform	Prototype Regional Balancing and Redispatching Platform
HMI	Human Machine Interface
HTTP(s)	(Secure) Hypertext Transfer Protocol
MQTT	Message Queuing Telemetry Transport

PD	P_{demand} (type of imbalance input to the FF Cloud Platform)
PTDF	Power Transfer Distribution Factors
TLS	Transport Layer Security
TSO	Transmission System Operator
UTC	Universal Time Coordinated

2.2 List of figures

3 STRUCTURE OF THE DOCUMENT

The structure of this document covers several key aspects of the software testing process, as described below. Wholly covering all these dimensions is considered necessary and sufficient condition to ensure the reliability and robustness of the Prototype Regional Balancing and Redispatching Platform (FF Cloud Platform).

1) Context of tested systems, test plan and roles and responsibilities
2) Definition of test cases per functional unit (with data, where applicable), which include:
    a. test cases for the “view looking-in”, i.e. the interface, of the functional unit (incl. cyber-attack)

b. test cases for the “inside” of the functional unit, i.e. the algorithms

3) Definition of integration tests - round-trip tests which span across more than one component (generally within a functional entity)

4) Tests which simulate real time conditions

5) Non-functional tests for availability, performance, scalability and security

In terms of functional units, the FutureFlow Cloud Platform solution is comprised of three major components, which will be addressed separately: redispatching, balancing and data warehouse. Each functional unit is presented in a dedicated chapter in the rest of this document.

4 REDISPATCH SIMULATION FUNCTIONAL MODULE

4.1 Architecture context

Redispatching is one of the two core functionalities implemented, alongside with the real-time balancing system. (A third supporting functionality consists of a data warehouse that will store all data input or generated in the real-time balancing system).

Generic architecture (with focus on relevant functionality) is presented in the Figure 1 below.

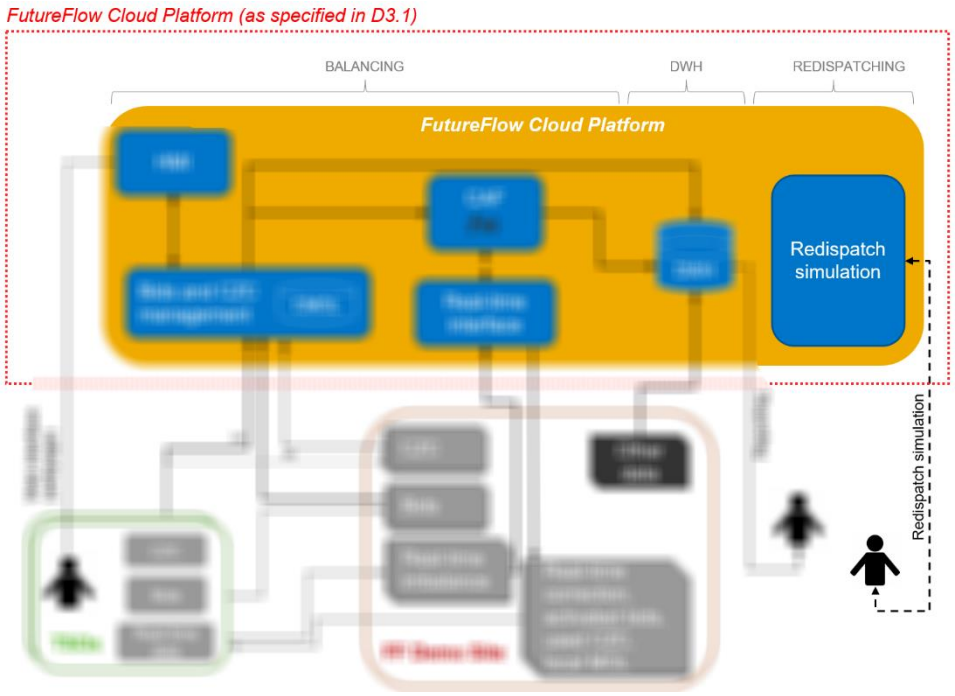

Figure 1: FutureFlow Cloud Platform architecture for redispatch simulation

4.2 Interfaces

The redispatch simulation application is accessible solely via HMI, as it is designed to consume inputs uploaded from user files, run redispatching, display summary KPIs and export full results of redispatching. This method of access enables testing the component.

4.3 Test cases

Redispatch functionality is tested at multiple levels:

- Functional test: Redispatching UI
- Interface test: Redispatching frontend-backend communication
- Interface test: Redispatching security

- Algorithm test: Redispatching optimization
- Non-functional test: Redispatching availability, scalability and performance test

4.3.1 Functional test: Redispatching UI

This user interface testing activity is focused on the functionality and responsiveness of the web-based user interface that is used to command redispatch simulations (including input of data, error messages where the case, retrieval of results and visualizations).

Testing is performed by SAP (as platform developers), in accordance with development specifications in FutureFlow Deliverable 3.1 (Specifications of the Prototype Regional Balancing and Redispatching Platform with Common Activation Function for FRR).

4.3.1.1 Test methodology

The test is performed by in the sequence below, getting the following results:

- Accessing the Redispatch simulation application in FutureFlow Cloud HMI (expected result: ability to access)
- Either:
    - Uploading compliant input files (expected result: files are uploaded)
    - Uploading non-compliant input files (expected result: an error message)
- (Assuming full and correct input above) Triggering of optimization
- After optimization completed:
    - Correct visualization of KPIs and summary results
    - Correct functionality of downloading result

Testing is performed using internet browsers Google Chrome version 56 and Microsoft Internet Explorer version 11.

4.3.1.2 Reproducibility steps

UI functionality test is performed manually and covers the expected functionality regarding redispatch simulation, as described in FutureFlow Deliverable 3.1 – Specification of the Prototype Regional Balancing and Redispatching Platform.

For the reproducibility of the test described below, please consult the details regarding access to FF Cloud Platform HMI that are provided in FutureFlow Deliverable 3.2 – Documentation of Prototype Regional Balancing and Redispatching Platform.

Redispatch simulation represents one of the entry points in the FutureFlow Cloud HMI and can be accessed by clicking on the respective tile (see Figure 2 below).

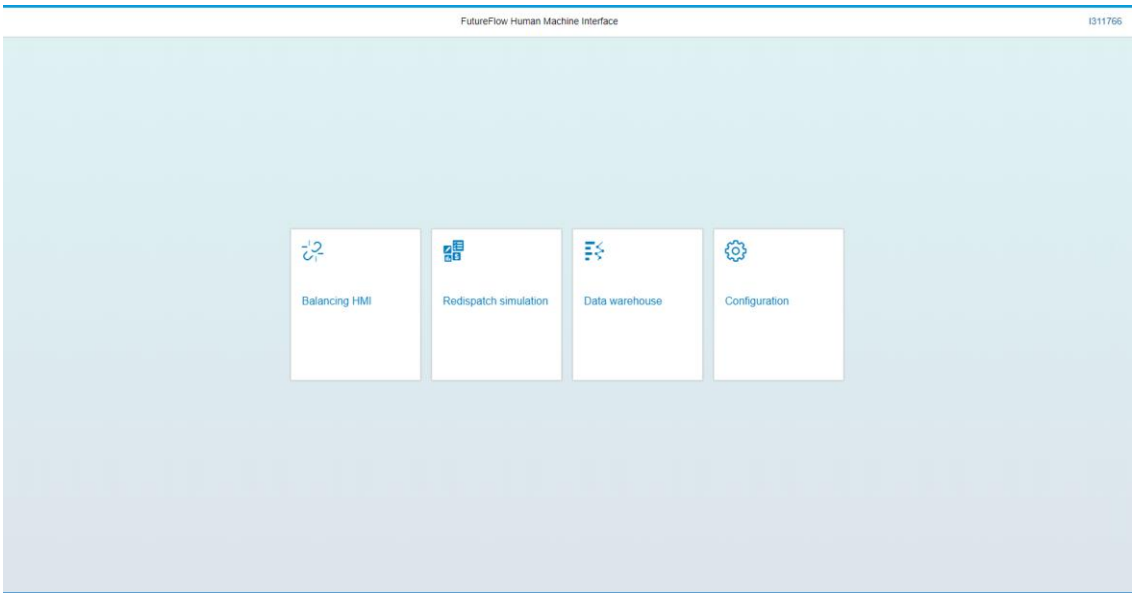

Figure 2: Human Machine Interface Landing Page

In the interface, the user is expected to upload a set of required input files, one by one. The uploading order is not important, yet for each input the following steps need be performed (see Figure 3 and Figure 4 below):

- click "Add files"
- pick up a file from the local computer
- click in the list on the kind of file that was selected

The required input files are:

- Merged network model (UCT)
- CBCO / PTDF node-to-reference matrix
- Common redispatch biding list

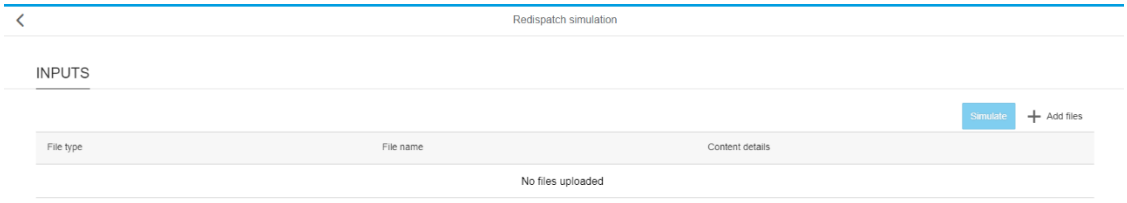

Figure 3: Redispatch Simulation Landing Page

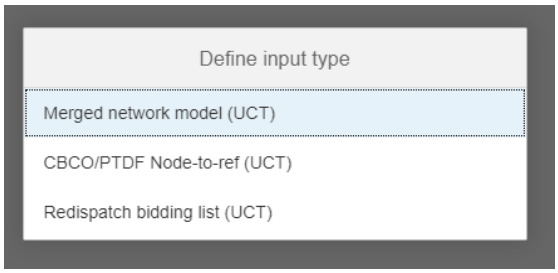

Figure 4: Redispatch Simulation Input Type Selection

Note: prior to launching the optimization, should the user need to make corrections or update the input, the interface permits the deletion of any already uploaded file. (To ensure full and correct input, the user should upload another file of the kind they just deleted; for example, if the file describing the merged network model has been uploaded and then deleted, another file of the same kind, i.e. merged network model, should be uploaded instead).

Once all required inputs are provided, the simulation button becomes enabled. If the user is satisfied with the inputs they provided, they can thereby trigger the simulation (see Figure 5 below).

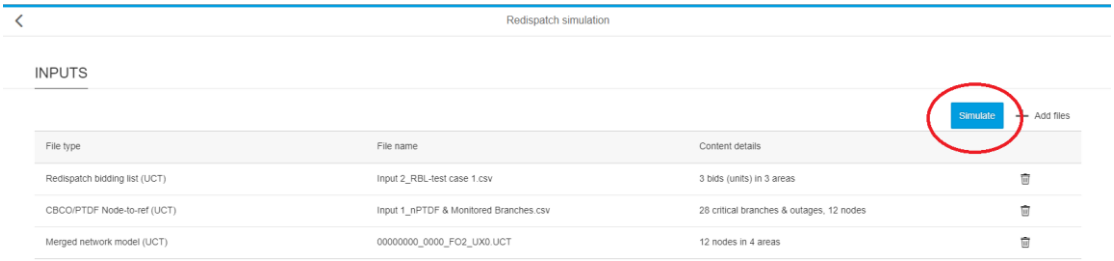

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Figure 5: Triggering A Redispatch Simulation

After optimization is finished (synchronously), the results are presented, alongside with the option to download them. Additionally, there is a set of visualizations immediately available, as follows.

a) Visualization of lines loading before and after redispatch, in Baseline and Worst-CO scenarios

This visualization has two tabs (representing before- and after-redispatching scenarios), each displaying a plot of the lines on a geographical map, colored in a gradient raging between green and red according to the loading % of the capacity of the respective line. Green correspond to loading < 80%, while Red represents a loading exceeding 100%. Hovering over each line displays information regarding the line identifier, line capacity (in MW) and line loading (in MW and %) – see Figure 6 below.

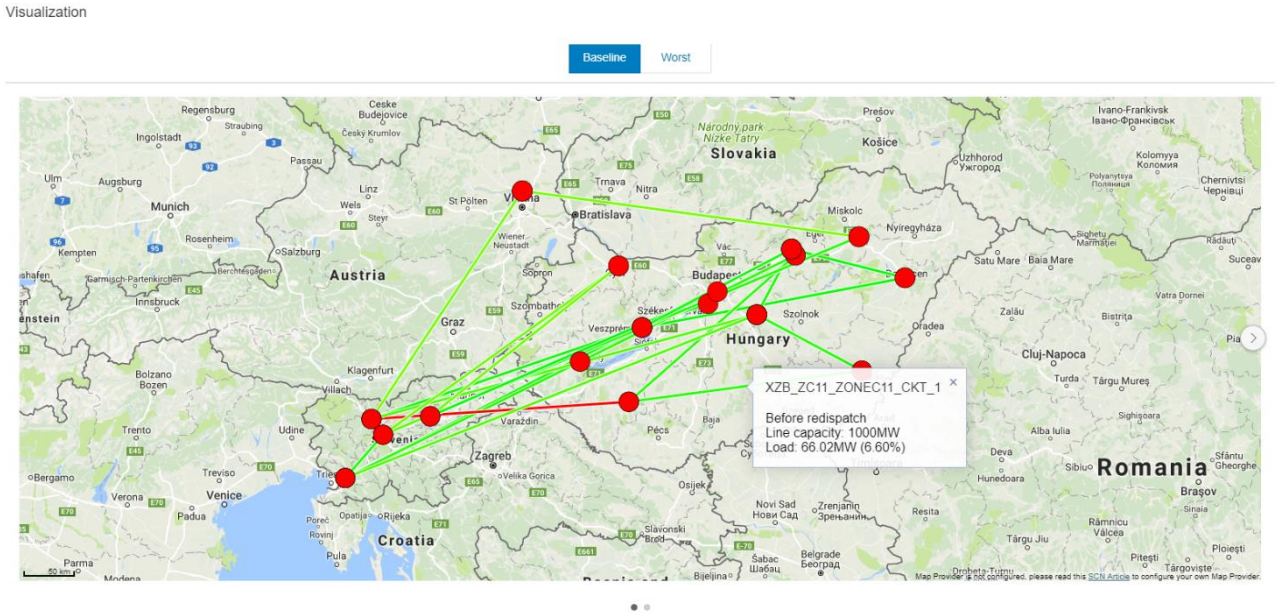


Figure 6: UI Visualization (A): Lines Loading Before And After Redispatch

b) Table of line loadings before and after redispatch

The table displays lines (described by PTDF factors) taking part in the redispatch simulation exercise. Information is displayed regarding line (from- and to- nodes), critical outage name (or blank if baseline scenario), load before and after redispatching (in MW), line limit (in MW) and a micro-chart displaying the % line load before and after redispatching – see Figure 7 below.

CBCO Table

CB Node From	CB Node To	CO Name	Load Before	Load After	Power Limit	Chart
XZC_ZO11	ZONEC21		-20.000 MW	-20.000 MW	1,000.000 MW	Before 2% / After 2%
ZONEA11	ZONEA21		169.800 MW	155.696 MW	1,000.000 MW	Before 16.98% / After 15.56%
ZONEA11	ZONEA21	XZA_ZB11_ZONEB11_CKT_1	170.860 MW	156.803 MW	1,000.000 MW	Before 17.08% / After 15.68%
ZONEA21	ZONEA31		-45.150 MW	-47.381 MW	1,000.000 MW	Before 4.51% / After 4.73%
ZONEA21	ZONEA31	ZONEB11_ZONEB21_CKT_1	-50.240 MW	-53.212 MW	1,000.000 MW	Before 5.02% / After 5.32%
ZONEA31	ZONEA41		-49.680 MW	-43.485 MW	1,000.000 MW	Before 4.96% / After 4.34%
ZONEA41	ZONEA11		-49.680 MW	-43.485 MW	1,000.000 MW	Before 4.96% / After 4.34%
XZA_ZB11	ZONEB11		7.580 MW	7.913 MW	1,000.000 MW	Before 0.75% / After 0.79%

Figure 7: UI Visualization (B): Table of line loadings before and after redispatching

4.3.1.3 Test results

Testing was performed using internet browsers Google Chrome version 56 and Microsoft Internet Explorer version 11.

Test case	Results
Accessing Redispatch simulation application in FutureFlow Cloud HMI	PASS
Uploading compliant input files, with confirmation message	PASS
Uploading non-compliant input files, with error message	PASS
Triggering of optimization after all files are uploaded	PASS
Correct visualization of KPIs and summary results	PASS
Correct functionality of downloading results	PASS

4.3.2 Interface test: Redispatching frontend-backend communication

This integration testing activity is focused on the communication between frontend and backend applications, including correct validation and parsing of input files, correct trigger of the optimization process and retrieval of optimization results (both summary KPIs and plots in the UI, as well as full export data).

Testing is performed by joint effort between SAP (as platform developers), EKC (as redispatching methodology developers) and TSOs (as stakeholders of redispatching functionality), in accordance with development specifications in FutureFlow Deliverable 3.1 (Specifications of the Prototype Regional Balancing and Redispatching Platform with Common Activation Function for FRR).

4.3.2.1 Test methodology

Test comprises:

- Preparing and uploading a complete set of input files
- Triggering optimization
- Visualize summary details regarding optimization
- Download optimization results for further analysis

4.3.2.2 Reproducibility steps

The following generic assumptions need to hold, regarding the input files:

- merged network model must follow the UCT format
- if multiple regions are involved in the redispatch simulation, the redispatch bidding list need to be concatenated in a single file
- all input files need to be consistent in terms of node names, meaning all nodes in CBCO/PTDF need to be among nodes in UCT file, all nodes in RBL need to exist in UCT file.

Syntactic and semantic assumptions regarding the “Merged network model / UCT” input file:

- text file drafted in accordance with “UCTE data exchange format for load flow and three phase short circuit studies” Lines starting with “##_” (two hashes followed by one letter) indicate document sections; lines starting with “##_ _ _” (two hashes followed by three letters) indicate document subsections
- the document should contain at least sections C (Comments) and N (Nodes)
- The comment line should include the date when the model was saved; expected format is YYYY.MM.DD and is required because it is also included in redispatch outputs
- each subsection of the Nodes section contains three letters (Z_ _), out of which the last two indicate the region of the nodes

Syntactic and semantic assumptions regarding the “CBCO and PTDF matrix” input file:

- uses comma (“,”) as a separator
- has a header section (which is not considered in the redispatch simulation) and a table section
- the table section has a fixed structure and is composed of a header row and one or multiple content rows
- the header row starts with “CIM ID,CB Name…”
- the expected columns are:
  - CIM ID
  - CB Name
  - CB Type
  - CB Node 1
  - CB Node 2
  - CB Node 3
  - CB Area 1
  - CB Area 2
  - CB Status
  - CO Name
  - CO Element CIM ID
  - CO Element Name
  - Load Flow [MW]
  - Plimit [MW]
  - followed by a non-specified number of columns that should contain the pattern “NODEID > REFNODE”, where REFNODE should be the same across the entire file, whereas NODEID represents the node for which the respective factors in the column are calculated

Syntactic and semantic assumptions regarding “Redispatch bidding list” input file:

- custom CSV file
- uses comma (“,”) as a separator
- the expected columns are:
  - Unit
  - Area
  - Node 1
  - Node 2
  - Node 3
  - Node 1 coefficient
  - Node 2 coefficient
  - Node 3 coefficient
  - Injection type
  - Upward shift (MW)
  - Price for upward shift (EUR/MWh)
  - Downwards shift (MW)
  - Price for downward shift (EUR/MWh)

4.3.2.3 Test results

Test case	**Results**
Preparing and uploading a complete set of input files	PASS
Triggering optimization	PASS
Visualize summary details regarding optimization	PASS
Download optimization results	PASS

Testing with non-compliant input files or formats triggered user-friendly notification via the User Interface with indication towards corrective action.

For testing, a complete set of compliant input files was used (as described in the attachment below):

Redispatching end-to-end test.zip

4.3.3 Interface test: Redispatching security

The FF Cloud Platform is deployed in the SAP Cloud Platform, a public cloud infrastructure. An extensive set of security measures are provided as platform defaults and ensure the security of data in-transfer and at-rest.

All communication channels to the SAP Cloud Platform are secured with TLS (transport layer security). Authorization is provided by SAP Cloud Platform Identity Authentication service (provided by the SAP Cloud Platform).

Access to the HMI is controlled at the level of individual users created in SAP Cloud Platform Identity Authentication and enrolled in the FutureFlow application. Access to messaging broker (for balancing) is controlled with technical username and password allocated per TSO and restricted access to topics at the level of TSO.

Additionally, the HTML5 container in SAP Cloud offers several security features, which come natively with the SAP Cloud Platform, as detailed below:

- Web Messaging / Cross Domain Messaging:
  - Explicit stating of the expected origin by the posting page
  - Explicitly checking of the origin by the receiving page
  - Input validation on the data attributes by the receiving page
  - Interpretation of the exchanged message as data, not as code.
- Cross Origin Resource Sharing:
  - Validation of URLs
  - Discarding requests received over plain HTTP with HTTPS origin
  - Protecting of data using application-level protocols (not relying on origin header)
- WebSocket's:
  - Disabled backward compatibility for outdated protocol versions.
  - Application-level protocols (instead of WebSocket protocols which do not handle authorization or authentication)

Messages are treated as data (instead of as code) and not inserted directly to the domain object model of the page.

This testing activity is focused on the security aspects relevant to the full round-trip between the frontend (user interface) and backend (logic and database) modules.

Testing is performed by SAP (as platform developers).

4.3.3.1 Test methodology

The test is performed by attempting to perform all major steps in the orchestration, both when the user is carrying the required credentials or not.

Specifically, this refers to:

- Uploading input files can only be performed by eligible platform users, as regulated by the rights
- Running the simulation can only be performed by eligible platform users, as regulated by the rights
- Visualization of the summary KPIs in the UI can only be performed by eligible platform users, as regulated by the rights
- Downloading the archive of results can only be performed by eligible platform users, as regulated by the rights
- Persistence of input / output files: As per requirements and to minimize the attack surface of data, redispatch simulation sessions are not persisted in the FF Cloud Platform. As an effect, if the

browser window is inactive or the user logs out, the session is destroyed, and the uploaded files and results are lost
- Login and enrollment: a user cannot login until they complete the enrollment process

4.3.3.2 Reproducibility steps

N/A

4.3.3.3 Test results

As FF Cloud Platform runs on top of the SAP Cloud Platform, which means that it comes by default with several built-in key security features.

Running the test yields the following results:

Test case	**Results**
Uploading input files can only be performed by eligible platform users, as regulated by the rights	PASS
Running the simulation can only be performed by eligible platform users, as regulated by the rights	PASS
Visualization of the summary KPIs in the UI can only be performed by eligible platform users, as regulated by the rights	PASS
Downloading the archive of results can only be performed by eligible platform users, as regulated by the rights	PASS
Persistence of input / output files: As per requirements and to minimize the attack surface of data, redispatch simulation sessions are not persisted in the FF Cloud Platform. As an effect, if the browser window is inactive or the user logs out, the session is destroyed, and the uploaded files and results are lost	PASS
Login and enrollment: a user cannot login until they complete the enrollment process	PASS

4.3.3.4 Additional security notes

The HTML5 container in SAP Cloud offers several security features, which come "for free" with the FF Cloud Platform, as detailed below:

Web Messaging / Cross Domain Messaging:

- Explicit stating of the expected origin by the posting page
- Explicitly checking of the origin by the receiving page
- Input validation on the data attributes by the receiving page
- Interpretation of the exchanged message as data, not as code.

Cross Origin Resource Sharing:

- Validation of URLs
- Discarding requests received over plain HTTP with HTTPS origin
- Protecting of data using application-level protocols (not relying on origin header)

WebSocket:

- Disabled backward compatibility for outdated protocol versions.
- Application-level protocols (instead of WebSocket protocols which do not handle authorization or authentication)
- Messages treated as data, not as code, and not inserted directly to the DOM of the page

4.3.4 Algorithm test: Redispatching optimization

For a complete end-to-end assessment of the optimization component, please refer to the inserted annex, which contains pre-validated testcases and results.

Cost function components: as implemented, the cost function components for redispatching optimization are represented by the net monetary cost of activations (cost of power up activations minus cost of power down activations).

Slack in terms of CBCO capacities is permitted and reported explicitly in the optimization output results.

Optimization constraints: the following optimization constraints are in place:

- Activated power per unit is smaller than or equal to the respective bid
- Net activated power (sum of power up and power down activations) is zero
- Post-redispatch line power flows are within CBCO limits (slack acceptable)

Testing is performed by joint effort between SAP (as platform developers) and EKC (as redispatching methodology developers).

Test results and assessment is already covered in FutureFlow Deliverable 1.4 – Results from simulations of XB balancing and redispatching mechanisms with Common Activation Function, Chapter 6.2 – Redispatching simulation results.

4.3.5 Non-functional test: Redispatching availability and performance test

For the guarantee of availability, the entire FutureFlow Cloud Platform deployment - as well as each of its core components (redispatching, balancing and DWH) - are periodically “pinged” to test for online / offline status. Should the platform, or any of its components, not respond to such a ping, a notification is immediately sent to the maintenance team. In SAP’s experience, the uptime of the platform, thus the worst expected uptime of any of its components, stands well above 99%, which ensures a smooth outage-free usage in real-life conditions.

4.3.5.1 Test methodology

Test comprises:

- Periodic assessment for availability of production environment (uptime > 99%)
- Performance testing for large optimization exercise (<8 seconds)

Availability testing is performed by SAP using periodic queries (ping), configured such that both the length of the sequence as well as the period covered are statistically relevant (e.g. 1.440 pings / day, averaging a ping per minute, for a period of 10+ days).

Performance testing is performed by SAP and EKC, in line with requirements stated in Chapter 4.3.2 11Interface test: Redispatching frontend-backend communication, by defining large-size complex test sets having approximate dimensionality of:

- at least 10.000 nodes
- at least 100 available units from 4 regions
- at least 100 branch/outage (CBCO) constraints

For data confidentiality purposes, the composition of the test dataset is not reproduced in the current deliverable.

Testing is performed by SAP (as platform developers) and EKC (as developer of redispatching methodology), as described above.

4.3.5.2 Reproducibility steps

N/A

4.3.5.3 *Test results*

Test case	Results
Periodic assessment of availability of production environment (uptime > 99%)	PASS
Performance testing for large optimization exercise (runtime < 8 seconds)	PASS

5 REAL-TIME REGIONAL BALANCING FUNCTIONAL MODULE

5.1 Architecture context

Real-time regional balancing using common activation functionality is implemented in FF Cloud Platform. Generic architecture (with focus on relevant functionality) is presented in Figure 8 below.

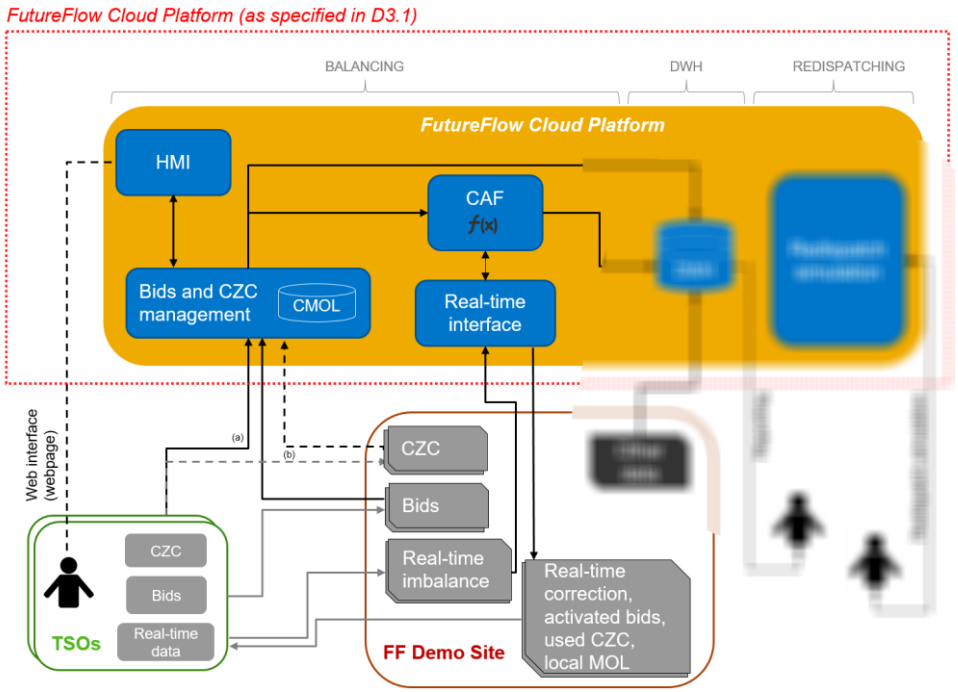


Figure 8: FutureFlow Cloud Platform architecture for real-time balancing

5.2 Interfaces

There are two interfaces available for interaction with the balancing functional module, with summary interaction described in Figure 9 below.

- Automated interface, messaging API
- Human Machine Interface (Cloud HMI)

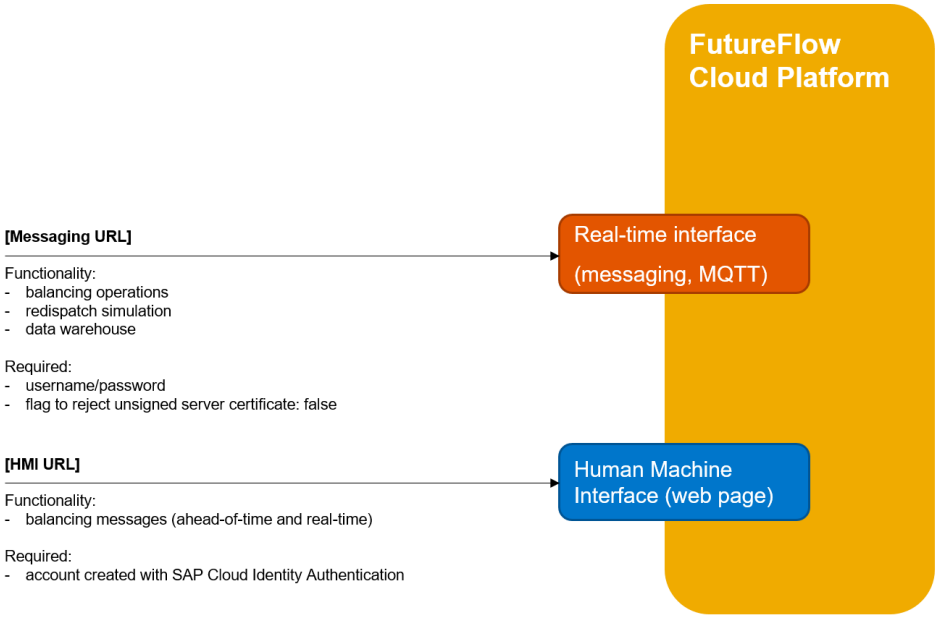


Figure 9: FutureFlow Interface And Interactions

5.3 Test cases

Balancing functionality is tested at multiple levels:

- Interface test: automated messaging API
- Non-functional test: security of automated messaging API
- Functional test: Balancing UI in HMI
- Non-functional test: security of balancing UI in HMI
- Integration test: regional optimization under near-real-time conditions
- Algorithm test: regional balancing optimization
- Non-functional test: balancing scaling and performance

5.3.1 Interface test: automated messaging API

This interface testing activity is focused on the infrastructure connectivity and syntactical correctness of exposed messaging API endpoints, for messages in both directions (to and from the Cloud Platform – data and acknowledgements).

Sample messages for communication interfaces are provided in Annex 1 – Interface testing of automated messaging API. Schema validation rules (in jsonSchema dialect) are provided in Annex 2 – Validation schemas for balancing inputs.

5.3.1.1 Test methodology

Test is performed by:

- Subscribing to the FF Cloud Platform messaging broker:
  - Client sends a connection request to the Cloud MQTT broker (username and password)
  - Client sends a topic subscription request to a topic which it has access to (topic access control is based on username)
- Sending a bid message and receiving acknowledgement
- Sending a CZC-ATC message and receiving response
- Sending a CZC-PTDF message and receiving response
- Sending a set of imbalances and receiving response

Testing is performed by joint effort between SAP (as platform developers) and EIMV (as developers of FF Demo Site).

5.3.1.2 Reproducibility steps

For testing, we used Mqtt.js NPM package as MQTT protocol client (https://www.npmjs.com/package/mqtt).

Full reproducibility steps for this test case are described in Annex 1 – Interface testing of automated messaging .

The following assumptions need to hold:

- Connection is established using MQTT 3.1.1 protocol, using mandatory username and password and client-defined keepalive of at least one minute.
- Test client supports monitoring of broker administrative channel and connection status details to assess whether connection request is accepted or not.

5.3.1.3 Test results

Test case	Results
Subscribing to the FF Cloud Platform messaging broker	PASS
Sending a bid message and receiving acknowledgement	PASS
Sending a CZC-ATC message and receiving response	PASS
Sending a CZC-PTDF message and receiving response	PASS
Sending a set of imbalances and receiving response	PASS

5.3.2 Non-functional test: security of automated messaging API

Security testing focuses on authentication and authorization topics regarding the automated messaging API interface.

Testing is performed by SAP (as platform developers).

5.3.2.1 Test methodology

Test is performed by:

- Subscribing to an authorized topic (successfully)
- Subscribing to an unauthorized or non-existent topic (unsuccessfully)
- Connecting to broker and subscribing to topics without using credentials (unsuccessfully)

5.3.2.2 Reproducibility steps

Testing is performed exclusively from HMI using browser sessions clean of any persisted cookies or default certificates.

Automated data interfaces (messaging) are exposed by the MQTT broker. Connections are accepted via Secure Web Sockets protocol at endpoint.

Connections are secured using transport-layer security (SSL / TLS). Currently, an SAP self-signed certificate is used on the server-side and clients must accept this certificate (if it is not recognized by default).

MQTT connections to the MQTT broker are authorized based on account credentials (username & password) combination. In addition, each connection can specify a unique client id, otherwise a random one will be allocated by the broker.

As soon as a connection is established, the client can subscribe or publish to one or multiple topics.

By default, an authorized account is mapped to a specific TSO and has subscribe & publish access to the following topics:

1) _tsoid_/in/* (bids/czc-atc/czc-ptdf)
2) _tsoid_/in/imbalance/* (pd/ctcr)

3) _tsoid_/ack/* (bids/czc-atc/czc-ptdf)
4) _tsoid_/out/corr/* (pd/ctcr)

Depending on the client, attempting to access other topics may or may not output an error message but will nonetheless be immediately rejected by the message broker.

MQTT account credentials can be created in the **Configuration / MQTT user management** section in HMI (thus access to HMI is required first to be able to create MQTT users).

The landing page displays active (existing) MQTT users subject to the following criteria:

- users which were initially created by the current HMI user, and
- users which are granted rights to (at least one of) the TSOs of which the current HMI user is a master of.

The granting of master user rights to HMI users is performed offline (as part of initial platform deployment) and will be handled by SAP.

5.3.2.3 Test results

Test case	Results
Subscribing to an authorized topic (successfully)	PASS
Subscribing to an unauthorized or non-existent topic (unsuccessfully)	PASS
Connecting to broker and subscribing to topics without using credentials (unsuccessfully)	PASS

5.3.3 Functional test: Balancing UI in HMI

This functional test focuses on functionality of user interface that are part of Balancing HMI.

Testing is performed by SAP (as platform developers).

5.3.3.1 Test methodology

Test is performed by:

- Accessing the Balancing HMI application
- Visualizing list of active bids
- Deleting one or multiple bids
- Visualizing list of active ATC CZC limits
- Overriding one or multiple ATC CZC limits
- Managing MQTT user credentials

Testing is performed using internet browsers Google Chrome version 56 and Microsoft Internet Explorer version 11.

5.3.3.2 Reproducibility steps

Accessing the Balancing HMI application – the application permits authorized users to access the Balancing tile inside the main landing page.

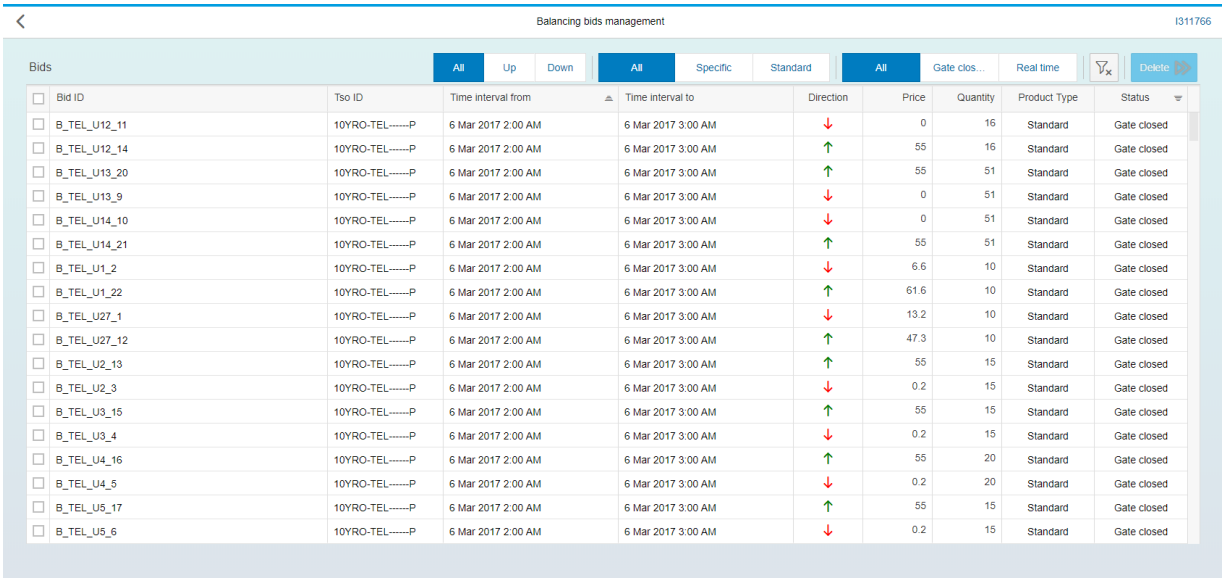
Visualizing the list of active bids – the application permits authorized users to visualize the bids ((current / future), as well as filtering them. The following filters are in place:

- filter on bid direction (All / Up / Down),
- filter on bid type (All / Specific / Standard)
- filter on bid status (All / During gate closure time / During real-time activation eligibility interval)
- filter on text (case-sensitive), applied directly to column headers,

Deleting bids – the application permits authorized users to select a subset of bids (via row headers). The function is intended to be used by TSOs during gate closure time / real-time operation, they realize that a bidder would not able to deliver on its promises and thus should not take part any longer in the regional

optimization. Deleting bids requires a confirmation, after which the table of bids is automatically refreshed. This action is traced and audited.

The bids management screen is presented in Figure 10 and Figure 11 below.



Bid ID	Tso ID	Time interval from	Time interval to	Direction	Price	Quantity	Product Type	Status
B_TEL_U12_11	10YRO-TEL------P	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	↓	0	16	Standard	Gate closed
B_TEL_U12_14	10YRO-TEL------P	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	↑	55	16	Standard	Gate closed
B_TEL_U13_20	10YRO-TEL------P	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	↑	55	51	Standard	Gate closed
B_TEL_U13_9	10YRO-TEL------P	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	↓	0	51	Standard	Gate closed
B_TEL_U14_10	10YRO-TEL------P	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	↓	0	51	Standard	Gate closed
B_TEL_U14_21	10YRO-TEL------P	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	↑	55	51	Standard	Gate closed
B_TEL_U1_2	10YRO-TEL------P	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	↓	6.6	10	Standard	Gate closed
B_TEL_U1_22	10YRO-TEL------P	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	↑	61.6	10	Standard	Gate closed
B_TEL_U27_1	10YRO-TEL------P	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	↓	13.2	10	Standard	Gate closed
B_TEL_U27_12	10YRO-TEL------P	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	↑	47.3	10	Standard	Gate closed
B_TEL_U2_13	10YRO-TEL------P	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	↑	55	15	Standard	Gate closed
B_TEL_U2_3	10YRO-TEL------P	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	↓	0.2	15	Standard	Gate closed
B_TEL_U3_15	10YRO-TEL------P	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	↑	55	15	Standard	Gate closed
B_TEL_U3_4	10YRO-TEL------P	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	↓	0.2	15	Standard	Gate closed
B_TEL_U4_16	10YRO-TEL------P	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	↑	55	20	Standard	Gate closed
B_TEL_U4_5	10YRO-TEL------P	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	↓	0.2	20	Standard	Gate closed
B_TEL_U5_17	10YRO-TEL------P	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	↑	55	15	Standard	Gate closed
B_TEL_U5_6	10YRO-TEL------P	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	↓	0.2	15	Standard	Gate closed

Figure 10: UI – Balancing HMI – Balancing Bids Management

The deletion of bids needs to be confirmed by the user. As soon as the confirmation is provided, the table is automatically refreshed, and the respective bids will be disregarded from regional optimizations with immediate effect.

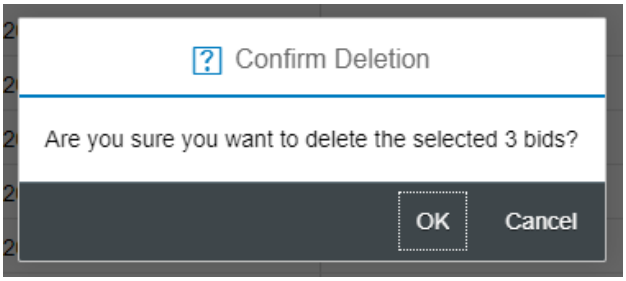
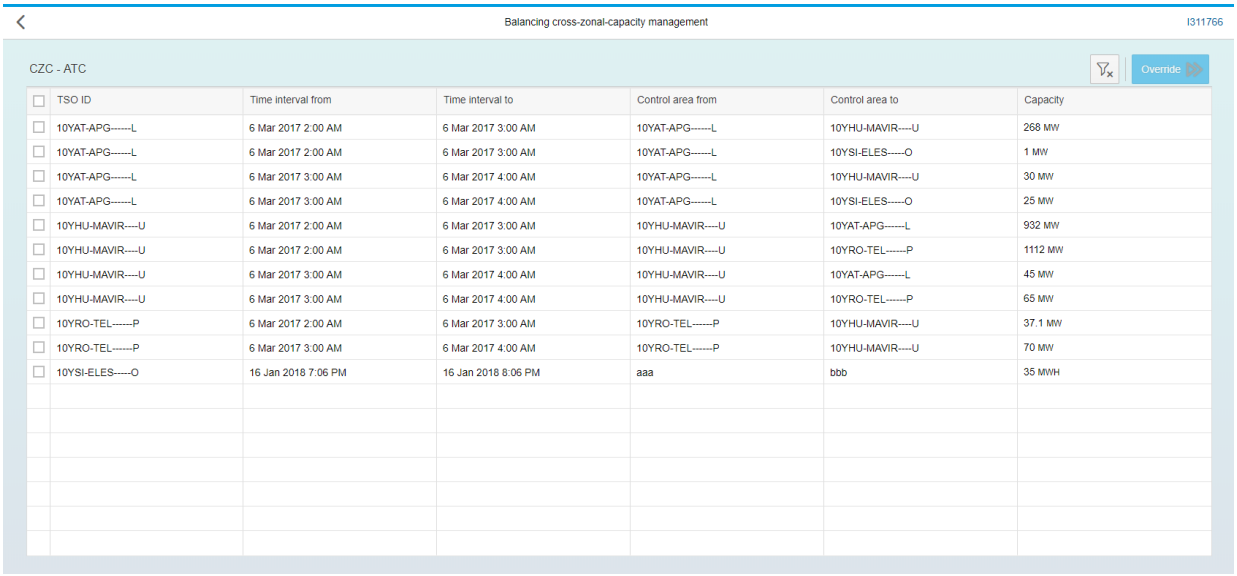


Figure 11: UI - Balancing HMI - Bid Deletion Confirmation

Visualizing / overriding the list of active ATC CZC limits

The cross-zonal capacity management is performed as in the Figure 12 shown below.



TSO ID	Time interval from	Time interval to	Control area from	Control area to	Capacity
10YAT-APG------L	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	10YAT-APG------L	10YHU-MAVIR----U	268 MW
10YAT-APG------L	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	10YAT-APG------L	10YSI-ELES-----O	1 MW
10YAT-APG------L	6 Mar 2017 3:00 AM	6 Mar 2017 4:00 AM	10YAT-APG------L	10YHU-MAVIR----U	30 MW
10YAT-APG------L	6 Mar 2017 3:00 AM	6 Mar 2017 4:00 AM	10YAT-APG------L	10YSI-ELES-----O	25 MW
10YHU-MAVIR----U	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	10YHU-MAVIR----U	10YAT-APG------L	932 MW
10YHU-MAVIR----U	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	10YHU-MAVIR----U	10YRO-TEL------P	1112 MW
10YHU-MAVIR----U	6 Mar 2017 3:00 AM	6 Mar 2017 4:00 AM	10YHU-MAVIR----U	10YAT-APG------L	45 MW
10YHU-MAVIR----U	6 Mar 2017 3:00 AM	6 Mar 2017 4:00 AM	10YHU-MAVIR----U	10YRO-TEL------P	65 MW
10YRO-TEL------P	6 Mar 2017 2:00 AM	6 Mar 2017 3:00 AM	10YRO-TEL------P	10YHU-MAVIR----U	37.1 MW
10YRO-TEL------P	6 Mar 2017 3:00 AM	6 Mar 2017 4:00 AM	10YRO-TEL------P	10YHU-MAVIR----U	70 MW
10YSI-ELES-----O	16 Jan 2018 7:06 PM	16 Jan 2018 8:06 PM	aaa	bbb	35 MWH

Figure 12: UI – Balancing HMI – Cross-zonal Capacity Management

Managing MQTT user credentials

The management of the MQTT users in performed as shown below.

Step 1: the user goes to the Configuration tile, see Figure 13 below.

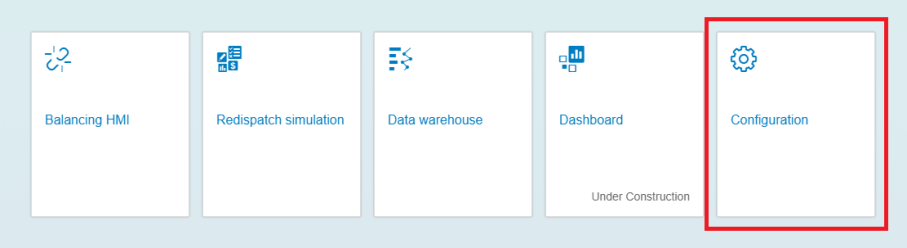


Figure 13: UI – Configuration - Managing MQTT Users

Step 2: the user clicks on MQTT user management, see Figure 14 below.

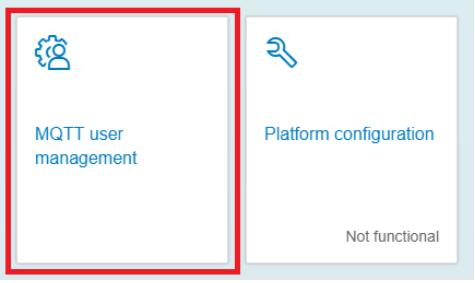


Figure 14: UI – Managing MQTT Users – MQTT User Management

Step 3: the user can manage only users they created, and which have access to the TSOs managed by the logged-in user, see Figure 15 below.

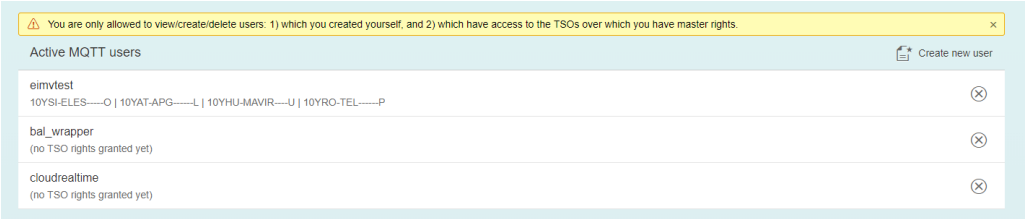


Figure 15: UI – Managing MQTT Users – Rights Management.

Step 4: the user can grant access to the TSOs they manage, see Figure 16 below.

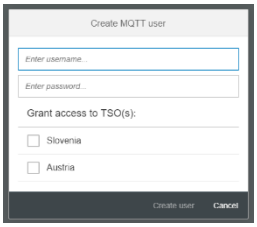


Figure 16: UI - Managing MQTT Users – Management of TSO rights

5.3.3.3 Test results

Test case	**Results**
Accessing the Balancing HMI application	PASS
Visualizing list of active bids	PASS
Deleting one or multiple bids	PASS
Visualizing list of active ATC CZC limits	PASS
Overriding one or multiple ATC CZC limits	PASS
Managing MQTT user credentials	PASS

5.3.4 Non-functional test: security of balancing UI in HMI

The FF Cloud Platform is deployed in the SAP Cloud Platform, a public cloud infrastructure. An extensive set of security measures are provided as platform defaults and ensure the security of data in-transfer and at-rest.

All communication channels to the SAP Cloud Platform are secured with TLS (transport layer security). Authorization is provided by SAP Cloud Platform Identity Authentication service (provided by the SAP Cloud Platform).

Access to the HMI is controlled at the level of individual users created in SAP Cloud Platform Identity Authentication and enrolled in the FutureFlow application. Access to messaging broker (for balancing) is controlled with technical username and password allocated per TSO and restricted access to topics at the level of TSO.

Additionally, the HTML5 container in SAP Cloud offers several security features, which come out-of-the-box with SAP Cloud Platform, as detailed below:

- Web Messaging / Cross Domain Messaging:
  - Explicit stating of the expected origin by the posting page
  - Explicitly checking of the origin by the receiving page

    - Input validation on the data attributes by the receiving page
    - Interpretation of the exchanged message as data, not as code.
- Cross Origin Resource Sharing:
    - Validation of URLs
    - Discarding requests received over plain HTTP with HTTPS origin
    - Protecting of data using application-level protocols (not relying on origin header)
- WebSocket:
    - Disabled backward compatibility for outdated protocol versions.
    - Application-level protocols (instead of WebSocket protocols which do not handle authorization or authentication)

Messages treated as data (instead of as code) and not inserted directly to the DOM of the page.

Security testing focuses on authentication and authorization topics regarding the Balancing HMI in FF Cloud Platform.

Testing is performed by SAP (as platform developers).

5.3.4.1 Test methodology

Test is performed by:

- Accessing the application with incorrect credentials or without authentication (unsuccessfully)
- Deleting bids outside of responsible control area (unsuccessfully)
- Overriding ATC CZC outside of responsible control area (unsuccessfully)
- Managing MQTT users outside of responsible control area (unsuccessfully)

5.3.4.2 Reproducibility steps

Testing is performed exclusively from HMI using browser sessions clean of any persisted cookies or default certificates.

5.3.4.3 Test results

Test case	**Results**
Accessing the application with incorrect credentials or without authentication (unsuccessfully)	PASS
Deleting bids outside of responsible control area (unsuccessfully)	PASS
Overriding ATC CZC outside of responsible control area (unsuccessfully)	PASS
Managing MQTT users outside of responsible control area (unsuccessfully)	PASS

5.3.5 Integration test: regional optimization under near-real-time conditions

This integration test is focused on the end-to-end flow of submitting bids, cross-border constraints (ahead of time), imbalances (in real time) and receiving appropriate correction responses under a multitude of scenarios (i.e. regional vs local optimization, ATC vs PTDF cross-border capacity constraints etc.). Only platform operation mode 1 (PD) is analyzed, according to decision to use this option rather than Option 2 – CTCR – for ongoing research and implementation in FutureFlow project.

Testing is performed by joint effort between SAP (as platform developers) and EIMV (as developers of FF Demo Site).

5.3.5.1 Test methodology

Test is performed by:

- Submitting bid(s) and ATC CZC messages ahead of time for a single control zone, followed by real-time imbalances and correction responses (successfully)

- Submitting bid(s) and PTDF CZC messages ahead of time for a single control zone, followed by real-time imbalances and correction responses (successfully)
- Submitting imbalance messages with a periodicity of 2 seconds from 4 control zones and ensuring each region receives appropriate correction messages (following regional optimization

5.3.5.2 Reproducibility steps

Testing is based on the infrastructure described in test case 5.3.1 Interface test: automated messaging API above.

5.3.5.3 Test results

Test case	Results
Submitting bid(s) and ATC CZC messages ahead of time for a single control zone, followed by real-time imbalances and correction responses (successfully)	PASS
Submitting bid(s) and PTDF CZC messages ahead of time for a single control zone, followed by real-time imbalances and correction responses (successfully)	PASS
Submitting imbalance messages with a periodicity of 2 seconds from 4 control zones and ensuring each region receives appropriate correction messages (following regional optimization	PASS

5.3.6 Algorithm test: regional balancing optimization

The balancing optimization algorithm is described in FutureFlow Deliverable 1.2, yet during implementation the need to create additional constraints and slight adjustments has been identified.

Observation: the netting and cross-border flows are modeled separately, as they are explicitly required in output, thus ensuring maximum optimization benefits.

Cost function components: as implemented, the cost function components for balancing optimization are represented by:

- The remaining absolute imbalance for each control area; a penalization named _PENALTY_ACE is applied for each MW-region
- The remaining imbalance after imbalance netting flows; a penalization named _PENALTY NETTING_ACE is applied for each MW-region
- The net cross-border flows related to bid activations; a penalization named _PENALTY_XB is applied for each MW-border
- The net cross-border flows related to imbalance netting; a penalization named _PENALTY_XB_NETTING is applied for each MW-border
- The net cost of bid activations (positive – negative); a penalization named _PENALTY_BIDS is applied for each monetary unit (EUR).

Values for each penalty: to guide the optimization algorithm towards achieving the imposed deliverables, the following penalty values are used:

- _PENALTY_ACE = 100.000 (/MW-region)
- _PENALTY_NETTING_ACE = 10.000 (/MW-region)
- _PENALTY_XB = 1 (/MW-border)
- _PENALTY_XB_NETTING = 1 (/MW-border)
- _PENALTY_BIDS = 100 (/monetary unit, EUR)

Optimization constraints: the following optimization constraints are in place:

- cross-border flows need be positive for both standard and specific product flows (due to algorithm representation)
- cross-zonal capacities must not be exceeded (by sum of standard and specific product flows)

- national supply condition for netting flows (cannot export more than positive initial ACE)
- national supply condition for activation-related flows: net exports plus national consumption must not exceed national activations
- when initial imbalance is positive:
    - up to full amount can be exported (including netting imports pass-through)
    - the region cannot make use of positive activations
- when initial imbalance is negative
    - imports must exceed or equal exports
    - cannot use negative activations
- imbalance cannot overshoot (the region can only end up with "lower" imbalance than initially)

Testing is performed by joint effort between SAP (as platform developers), EKC (as developers of balancing optimization methodology) and EIMV (as developers of FF Demo Site).

Balancing optimization methodology assessment and implementation on behalf of FutureFlow Demo Site is covered in FutureFlow Deliverable 1.4 – Results from simulations of XB balancing and redispatching mechanisms with Common Activation Function, Chapter 4.1.2 - Balancing simulations - verification process. Work described in this deliverable covers FutureFlow Cloud Platform implementation and further validations between SAP (as platform developers of SAP Cloud Platform) and EIMV (as platform developers of FutureFlow Demo Site).

5.3.6.1 Test methodology

A set of very specific test cased was defined, performed and analyzed.

Components of a test: each such test case shows:

- the initial imbalances
- the bids that would have submitted
- the CZC-ATC matrix
- the resulting bid activations
- the resulting imbalance left after netting
- the resulting XB flows

Value-add of each test: the tests are focused on demonstrating following key points:

- Imbalance netting flows are prioritized ahead of activation-related flows when coloring cross-border flows
- given similar total remaining imbalance, the optimization might decide to activate opposite direction bids, if there is an economic justification for it
- cross-border flows may be netted (i.e. if SI -> AT limit is 25 MW, there may still be a SI -> AT flow of 40 MW partly compensated by a flow AT -> SI of 15 MW)
- cross-border netting feature permits more efficient activation of binds under limited cross-border capacities
- the optimization function focuses on (in this order):
    - remaining imbalance (final)
    - remaining imbalance after imbalance netting
    - bid costs / revenue
    - amount of XB flows
- only when multiple solutions exist in terms of one criteria (i.e. similar finance imbalance netting) are the other factors considered (i.e. which solution maximizes netting flows)

5.3.6.2 Reproducibility steps

N/A

5.3.6.3 Test results

See Annex 3 – Test cases for balancing optimization in 5.3.6 Algorithm test: regional balancing optimization for complete description of test cases that were considered.

5.3.7 Non-functional test: balancing scaling and performance

For the guarantee of functionality during FutureFlow prototyping phase as well as potential extension after FutureFlow project is finished, the real-time balancing platform is tested using a set of specific tests targeting scalability and performance behavior.

Testing is performed by SAP (as platform developers).

5.3.7.1 Test methodology

Test is comprised of:

- Assessing the behavior (robustness of process, correctness and time-bound provisioning of optimization results) when imbalance message periodicity is reduced from 2 seconds to 0.5 seconds (sequence of actions is retained, optimization is finished, complete responses are provided within a cycle)
- Assessment of correlation between increase in number of control areas involved in regional optimization and increase in optimization time (pseudo-logarithmic growth is acceptable)

5.3.7.2 Reproducibility steps

Testing is based on the infrastructure described in test case Interface test: automated messaging API above.

5.3.7.3 Test results

Test case	**Results**
Assessing the behavior (robustness of process, correctness and time-bound provisioning of optimization results) when imbalance message periodicity is reduced from 2 seconds to 0.5 seconds (sequence of actions is retained, optimization is finished, complete responses are provided within a cycle)	PASS
Assessment of correlation between increase in number of control areas involved in regional optimization and increase in optimization time (pseudo-logarithmic growth is acceptable)	PASS 1 area – 0.79 sec 4 areas – 0.92 sec

6 CLOUD DATA WAREHOUSE (DWH) FUNCTIONAL MODULE

6.1 Architecture context

FutureFlow Cloud Data Warehouse functionality is intended to allow the assessment of FutureFlow project results after performance of pilot tests or at the completion of the project.

Generic architecture (with focus on relevant functionality) is presented in the Figure 1 below.

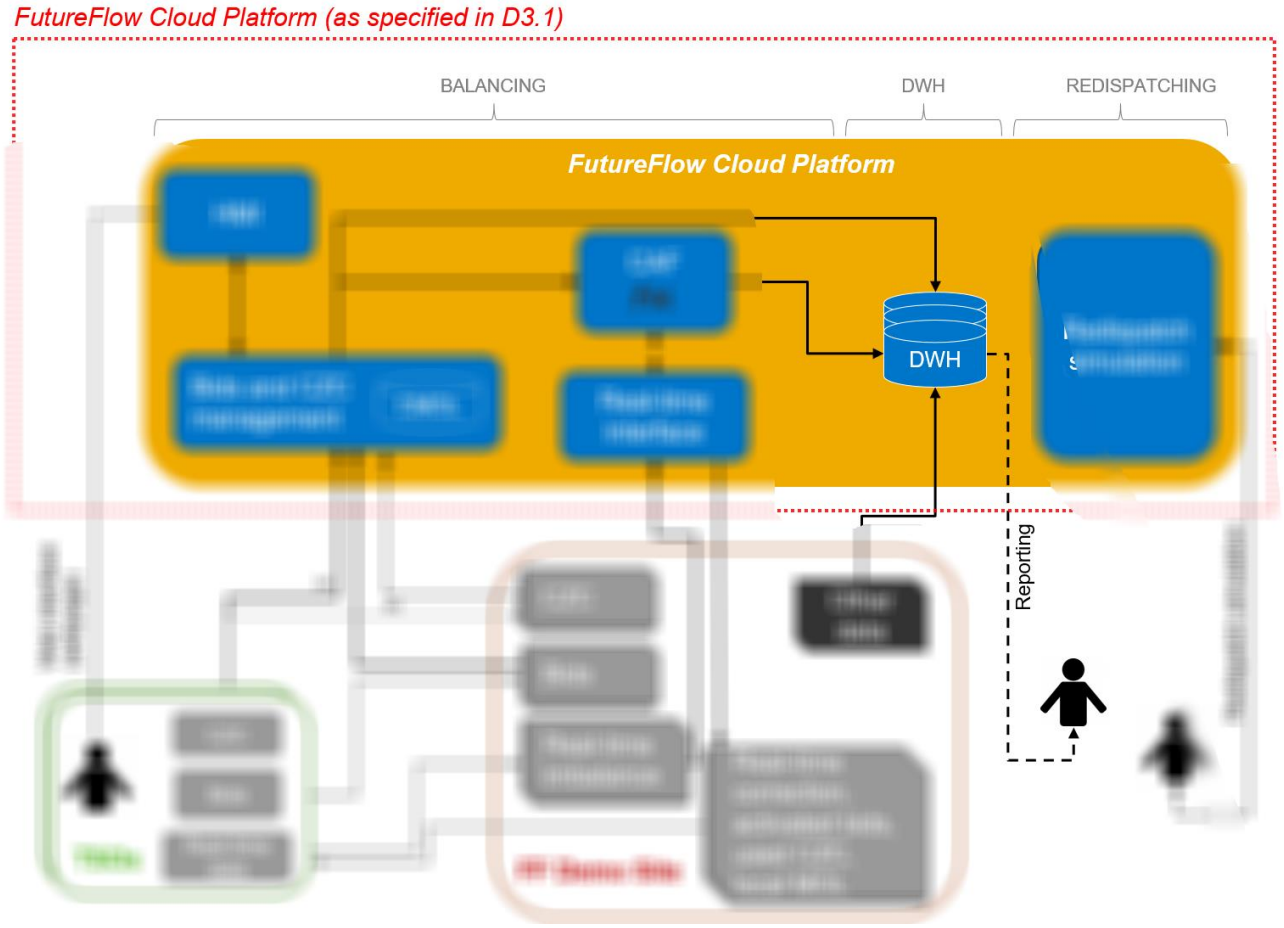


Figure 17: FutureFlow Cloud Platform architecture for data warehouse

6.2 Interfaces

The cloud data warehouse is accessible as a separate application in Cloud HMI and uses the same generic authentication mechanisms as all other HMI applications. Authorization is provided in accordance with FutureFlow Deliverable 7.4 (Data management plan).

6.3 Test cases

Data warehouse is tested at multiple levels:

- Functional test: DWH UI in HMI
- Non-functional test: security of DWH UI in HMI

6.3.1 Functional test: DWH UI in HMI and data correctness

This functional testing activity is focused on the usability of the data warehouse application user interface and correct implementation of features specified in FutureFlow Deliverable 3.1.

Testing is performed by SAP (as platform developers).

6.3.1.1 Test methodology

Test comprises:

- Accessing the DWH HMI application
- Preparing export dataset based on definition criteria (reference data, submission date, control area)
- Preparing export dataset based on imbalance tag (as imbalance tags are transmitted only with imbalance messages, all related bid/czc-atc/czc-ptdf/correction messages should also be automatically selected for export)
- Including deleted records in export dataset (configuration option, disabled by default)
- Correctness of data export according to definition criteria

Testing is performed using internet browsers Google Chrome version 56 and Microsoft Internet Explorer version 11.

6.3.1.2 Reproducibility steps

FutureFlow Cloud Data Warehouse can be accessed via the Cloud HMI, see Figure 18 below.

DWH allows users to download available data in batches. Authorized users are presented with a set of filter criteria to narrow down the batch selection. This also gives the set of usage scenarios for the DWH:

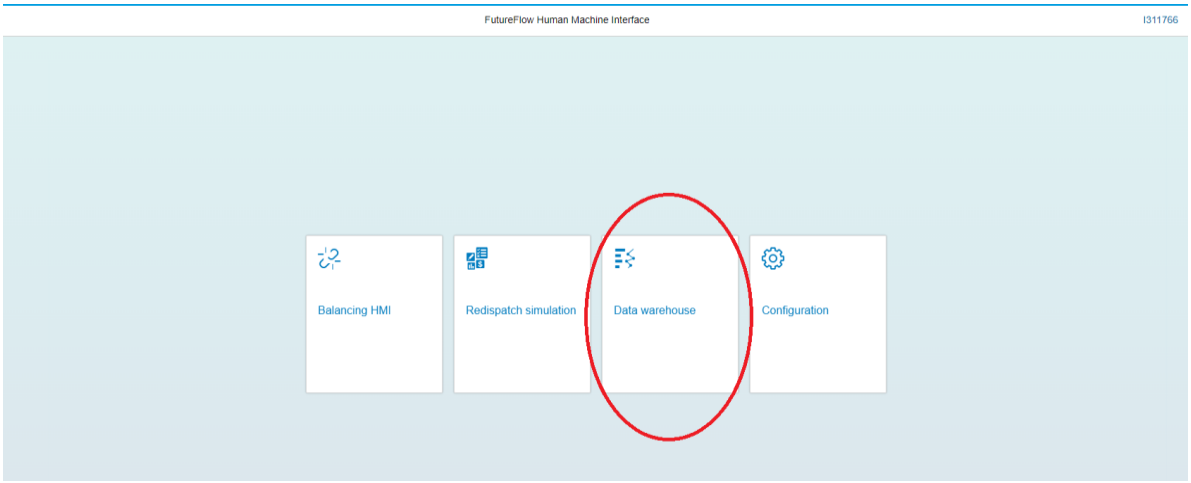


Figure 18: Cloud data warehouse application in HMI

The DWH can be used in several ways, as detailed below:

- Scenario 1: **filtering by Reference date (UTC)**. This refers to the real-time date reference to which all entries are based off of, meaning this will match:
    - the *TimeIntervalFrom* / *TimeIntervalTo* fields for bids and czc inputs
    - the *ReferenceDateTime* for imbalance input and the associated outputs.

- Scenario 2: **filtering by Submission date (UTC)**. This refers to the actual time reference when the data was submitted to the FF Cloud Platform. Thus, this feature allows performing simulations in which the actual time is not the real (reference) time and will match the server time when the input messages were received alongside all associated outputs.

- Scenario 3: **filtering by Submitted by (control area/s)**. This refers to showing results only for a subset (one or more) control areas.

- Scenario 4: **tagging of imbalances**. To facilitate platform testing, imbalances can be submitted with a non-blank Tag field; this allows easy retrieval of data based on respective tags; imbalance inputs, all associated outputs and bids / czc that are matching the reference time in the selected imbalances will be exported.

- Scenario 5: **Show/hide deleted records**: DWH retains full traceability when data (bids / czc) is updated or deleted; this option allows users to export full data, including deleted/overwritten records. These records will be marked by a non-blank DATE_DELETED field.

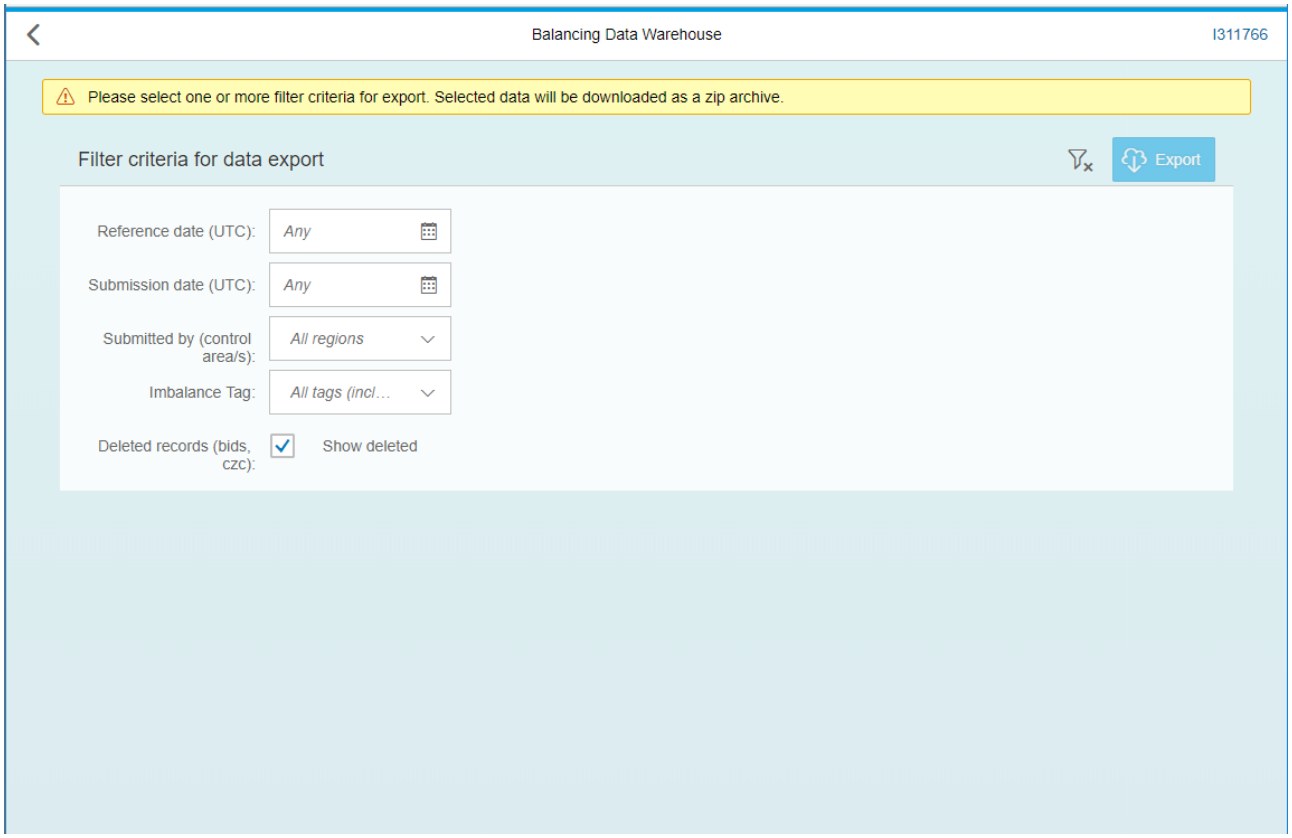


Figure 19: Cloud data warehouse definition of criteria for export

When exporting data, the number of exported records must be between 1 and 1,000,000, otherwise the user will be required to extend/narrow the filter criteria to meet this constraint. To help with this, as soon as the logged-in user selects a combination of filter criteria, the number of estimated records in the DWH (available for export) is displayed on top of the page. Note that as soon as the logged-in user selects a combination of filter criteria, the number of estimated records in the DWH (available for export) is displayed on top of the page.

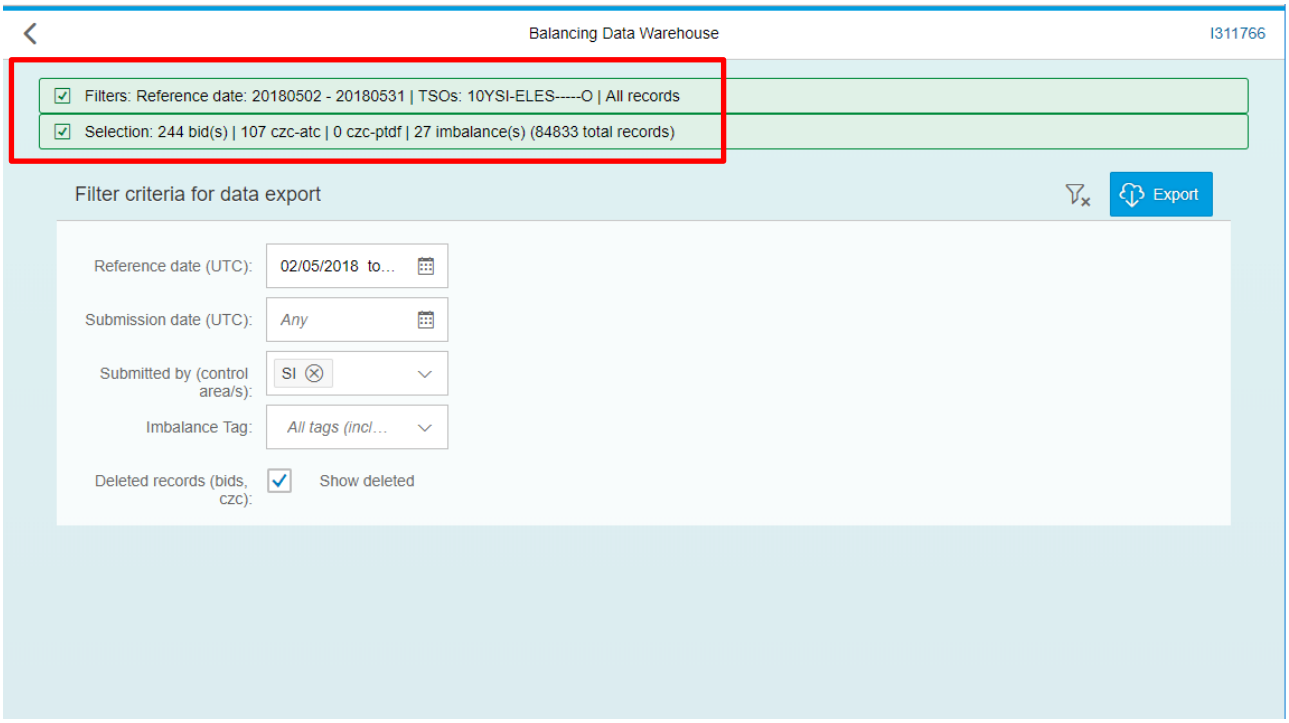


Figure 20: Cloud data warehouse estimation of number of records matching filter criteria

6.3.1.3 Test results

Test case	Results
Accessing the DWH HMI application	PASS
Preparing export dataset based on definition criteria (reference data, submission date, control area)	PASS
Preparing export dataset based on imbalance tag (as imbalance tags are transmitted only with imbalance messages, all related bid/czc-atc/czc-ptdf/correction messages should also be automatically selected for export)	PASS
Including deleted records in export dataset (configuration option, disabled by default)	PASS
Correctness of data export according to definition criteria	PASS

6.3.2 Non-functional test: security of balancing UI in HMI

The FF Cloud Platform is deployed in the SAP Cloud Platform, a public cloud infrastructure. An extensive set of security measures are provided as platform defaults and ensure the security of data in-transfer and at-rest.

All communication channels to the SAP Cloud Platform are secured with TLS (transport layer security). Authorization is provided by SAP Cloud Platform Identity Authentication service (provided by the SAP Cloud Platform).

Access to the HMI is controlled at the level of individual users created in SAP Cloud Platform Identity Authentication and enrolled in the FutureFlow application. Additionally, HTML5 containers in SAP Cloud offers several security features, which come out-of-the-box with the SAP Cloud Platform, as detailed below:

- Web Messaging / Cross Domain Messaging:
  - Explicit stating of the expected origin by the posting page

    - Explicitly checking of the origin by the receiving page
    - Input validation on the data attributes by the receiving page
    - Interpretation of the exchanged message as data, not as code.
- Cross Origin Resource Sharing:
    - Validation of URLs
    - Discarding requests received over plain HTTP with HTTPS origin
    - Protecting of data using application-level protocols (not relying on origin header)
- WebSocket:
    - Disabled backward compatibility for outdated protocol versions.
    - Application-level protocols (instead of WebSocket protocols which do not handle authorization or authentication)

Messages treated as data (instead of as code) and not inserted directly to the DOM of the page.

Security testing focuses on authentication and authorization topics regarding the DWH HMI in FF Cloud Platform.

Testing is performed by SAP (as platform developers).

6.3.2.1 Test methodology

Test is performed by:

- Accessing the application with incorrect credentials or without authentication (unsuccessfully)
- Attempt to export messages belonging to non-authorized control zones (with or without UI filters, manipulation of request to backend service – export should not include communication of other control areas than the requesting user has access to)

6.3.2.2 Reproducibility steps

Testing is performed exclusively from HMI using browser sessions clean of any persisted cookies or default certificates.

6.3.2.3 Test results

Test case	**Results**
Accessing the application with incorrect credentials or without authentication (unsuccessfully)	PASS
Attempt to export messages belonging to non-authorized control zones (with or without UI filters, manipulation of request to backend service – export should not include communication of other control areas than the requesting user has access to)	PASS

7 CONCLUSION

In addition to thorough testing of major releases (described in the current document), all minor releases of platform functionality are accompanied by manual testing of key areas, covering both functional and non-functional perspectives.

Security aspects were integrated since early architecture and design phases of the platform, thus tests after development finalization did not expose latent threats or potential data leakage points. During testing phase, SAP (as developers of FutureFlow Cloud Platform) involved security experts from within the company, with knowledge of technical platform capabilities and limitations as well as with penetration testing experience. Authorization topics were concluded by a testing team separate from the development team to avoid testing bias.

Functionality testing included an exhaustive testing of optimization algorithms, to ensure the robustness of this key piece of functionality in balancing and redispatching functional modules.

The testing process designed and described in the current document did not provide any relevant flaws in platform operation and security, thus rendering the FutureFlow Cloud Platform as a robust platform to support real-time operation during pilot testing during prototype phase, as well as a scalable and reliable solution for potential expansion beyond the four initial control areas after project completion.

8 ANNEX 1 – INTERFACE TESTING OF AUTOMATED MESSAGING API

[attempting to connect client test_scenario_1dfsd]: mqtt.con
[connected to broker: test_scenario_1dfsd]: mqtt.con
starting scenario1...
subscribed to topic +/ack/+
subscribed to topic +/out/corr/pd

submit on: tsosi/in/bids
<BidSubmit>
<SenderIdentification>10YSI-ELES-----O</SenderIdentification>
<CreationDateTime>2017-10-27T10:30:00Z</CreationDateTime>
<SenderDateTime>2017-10-27T10:30:00Z</SenderDateTime>
<OriginIdentification>thermo</OriginIdentification>
<BidDetails>dummyTextDetailsToBeStoredInDWH</BidDetails>
<ReserveBidIdentification>20170405_01_BID_AFRR_SenderXCode_V1</ReserveBidIdentification>
<MeasureUnitQuantity>MAW</MeasureUnitQuantity>
<Currency>EUR</Currency>
<Divisible>A01</Divisible>
<Direction>A01</Direction>
<MeasureUnitEnergyPrice>MWH</MeasureUnitEnergyPrice>
<TimeIntervalFrom>2017-10-27T13:00:00Z</TimeIntervalFrom>
<TimeIntervalTo>2017-10-27T14:00:00Z</TimeIntervalTo>
<Resolution>PT60M</Resolution>
<Qty>150.500</Qty>
<EnergyPrice>20.45</EnergyPrice>
<ConnectingArea>10YSI-ELES-----O</ConnectingArea>
<ProductType>std</ProductType>
</BidSubmit>

await on: tsosi/ack/bids
<Acknowledgement>
<ReserveBidIdentification>20170405_01_BID_AFRR_SenderXCode_V1</ReserveBidIdentification>
<Status>accepted</Status>
<Details/>
</Acknowledgement>

submit on: tsosi/in/czc-atc
<CzcAtcSubmit>
<SenderIdentification>10YSI-ELES-----O</SenderIdentification>
<SenderDateTime>2017-10-27T12:05:00Z</SenderDateTime>
<TimeIntervalFrom>2017-10-27T13:00:00Z</TimeIntervalFrom>
<TimeIntervalTo>2017-10-27T14:00:00Z</TimeIntervalTo>
<ControlAreaFrom>10YSI-ELES-----O</ControlAreaFrom>
<ControlAreaTo>10YAT-APG------L</ControlAreaTo>
<MeasureUnitCapacity>MW</MeasureUnitCapacity>
<Capacity>30</Capacity>
</CzcAtcSubmit>

await on: tsosi/ack/czc-atc
<Acknowledgement>
<SenderDateTime>2017-10-27T12:05:00Z</SenderDateTime>
<ControlAreaFrom>10YSI-ELES-----O</ControlAreaFrom>
<ControlAreaTo>10YAT-APG------L</ControlAreaTo>
<TimeIntervalFrom>2017-10-27T13:00:00Z</TimeIntervalFrom>
<TimeIntervalTo>2017-10-27T14:00:00Z</TimeIntervalTo>
<Status>accepted</Status>
<Reason/>
<Details/>
</Acknowledgement>

submit on: tsosi/in/czc-ptdf
<CzcPtdfSubmit>
<SenderIdentification>10YSI-ELES-----O</SenderIdentification>
<CreationDateTime>2017-10-27T10:30:00Z</CreationDateTime>
<TimeIntervalFrom>2017-10-27T13:00:00Z</TimeIntervalFrom>
<TimeIntervalTo>2017-10-27T14:00:00Z</TimeIntervalTo>
<Payload>#TECHNICAL PARAMETERS FOR AUCTION,,,,,,,,,,,,,,,,,,,,
#,,,,,,,,,,,,,,,,,,,,
#BIDDING ZONES PARTICIPATING:,,APG,MAVIR,Transelectrica,ELES,,,,,,,,,,,,,,,
#JOINT BIDDING ZONES:,,,,,,,,,,,,,,,,,,,,

```
		#OTHER BIDDING
		ZONES:,,OST,NOSBIH,ELIA,ESO,Swissgrid,CEPS,DE,REE,RTE,IPTO,HOPS,TERNA,CGES,MEPSO,TTN,PSE,REN,EMS,SEPS,TEIAS,WPS,XX
		#ONLY SHOW |PTDF| >= 0,,,,,,,,,,,,,,,,,,,,
		#,,,,,,,,,,,,,,,,,,,,
		#CREATED ON: ,10/18/2017 15:19,,,,,,,,,,,,,,,,,,,,
		#CREATED BY: ,TNA 2.2.14.420,,,,,,,,,,,,,,,,,,,,
		,,,,,,,,,,,,,,,,,,,,
		CB CIM ID,CB Name,CB Type,CB Node 1,CB Node 2,CB Node 3,CB Area 1,CB Area 2,CB Status,CO Name,CO Element CIM ID,CO Element
		Name,From,To,Fmax,FRM 12,FRM 21,FAV 12,FAV 21,RAM 12,RAM 21,APG>MAVIR,Transelectrica>MAVIR,ELES>MAVIR
		_b10a9115-27a2-a847-0017-0c975f71ecd5,MSZHO_11_XZU_SZ11_CKT_1,AC_LINE_SEGMENT,MSZHO 11,XZU_SZ11,,HU,EU,On,(Base
		Case),,,MAVIR,APG,1363.8,40.9,40.9,0,0,1430.8,1214.9,-0.122321,-0.00577,-0.066659
		_b10a9115-27a2-a847-0017-0c975f71ecd5,MSZHO_11_XZU_SZ11_CKT_1,AC_LINE_SEGMENT,MSZHO 11,XZU_SZ11,,HU,EU,On,Outage
		1,_39b10477-e943-f4ac-e46d-a185eec572df,OZURND11_XZU_SZ11_CKT_1,,,1363.8,40.9,40.9,0,0,1322.8,1322.9,0,0,0
		_b10a9115-27a2-a847-0017-0c975f71ecd5,MSZHO_11_XZU_SZ11_CKT_1,AC_LINE_SEGMENT,MSZHO 11,XZU_SZ11,,HU,EU,On,Outage
		2,_d631b740-98db-e190-3f3c-43eaf1001797,MGYOR_11_XZU_GY11_CKT_1,,,1363.8,40.9,40.9,0,0,1433.6,1212.1,-0.216527,-0.019764,-
		0.135168
		##TIES,,,,,,,,,,,,,,,,,,,,
		_ac33344e-85ad-6215-276d-
		c3b55a159b47,O6MNGN21_XMN_YR21_CKT_1,AC_LINE_SEGMENT,O6MNGN21,XMN_YR21,,AT,EU,On,,,,APG,Swissgrid,,,,,,,0.004262,-
		0.000358,-0.002199
		_5583676a-7fd6-9969-609f-
		af8002df4405,O6MNGN22_XMN_BR21_CKT_1,AC_LINE_SEGMENT,O6MNGN22,XMN_BR21,,AT,EU,On,,,,APG,DE,,,,,,,-
		0.008109,0.000743,0.004819
		</Payload>
</CzcPtdfSubmit>

await on: tsosi/ack/czc-ptdf
<Acknowledgement>
		<SenderDateTime>2017-10-27T12:05:00Z</SenderDateTime>
		<ControlAreaFrom>10YSI-ELES-----O</ControlAreaFrom>
		<ControlAreaTo>10YAT-APG------L</ControlAreaTo>
		<TimeIntervalFrom>2017-10-27T13:00:00Z</TimeIntervalFrom>
		<TimeIntervalTo>2017-10-27T14:00:00Z</TimeIntervalTo>
		<Status>accepted</Status>
		<Reason/>
		<Details/>
</Acknowledgement>

submit on: tsosi/in/imbalance/pd
<ImbalancePD>
		<SenderIdentification>10YSI-ELES-----O</SenderIdentification>
		<ReferenceDateTime>2017-10-27T13:10:02Z</ReferenceDateTime>
		<MeasureUnitQuantity>MW</MeasureUnitQuantity>
		<Tag>tag2</Tag>
		<PD>11</PD>
</ImbalancePD>

await on: tsosi/out/corr/pd
<CorrectionPD>
		<OptimizationDateTime>2018-07-25T13:34:26.548Z</OptimizationDateTime>
		<ImbalanceDateTime>2017-10-27T13:10:02.000Z</ImbalanceDateTime>
		<PCorr>0</PCorr>
		<SelectedBids/>
		<XB>
			<Czc>
				<fromArea>SI</fromArea>
				<toArea>AT</toArea>
				<capacityMW>30</capacityMW>
				<nettingMW>0</nettingMW>
				<activationsMW>0</activationsMW>
			</Czc>
			<Czc>
				<fromArea>AT</fromArea>
				<toArea>SI</toArea>
				<capacityMW>20</capacityMW>
				<nettingMW>0</nettingMW>
				<activationsMW>0</activationsMW>
			</Czc>
		</XB>
</CorrectionPD>
```

9 ANNEX 2 – VALIDATION SCHEMAS FOR BALANCING INPUTS

Extract from actual schema validation code performed by JsonSchema NPM package. Declarative and verbose format is human-readable for the identification of constraints on FF Cloud Platform balancing inputs via MQTT API.

```
schemaInputPd: {
   id: "/ImbalancePdSubmit",
   type: "object",
   properties: {
      "SenderIdentification": {
         type: "string",
         enum: ["10YSI-ELES-----O", "10YAT-APG------L", "10YHU-MAVIR----U", "10YRO-TEL------P"]
      },
      "ReferenceDateTime": {
         type: "string",
         minLength: 20,
         maxLength: 24
      },
      "MeasureUnitQuantity": {
         type: "string",
         enum: ["MW"]
      },
      "Tag": {
         type: "string",
         maxLength: 64
      },
      "PD": {
         type: "string"
      }
   },
   required: ['SenderIdentification', 'ReferenceDateTime', 'MeasureUnitQuantity', 'PD']
}

schemaInputBid: {
   id: "/BidSubmit",
   type: "object",
   properties: {
      "SenderIdentification": {
         type: "string",
         enum: ["10YSI-ELES-----O", "10YAT-APG------L", "10YHU-MAVIR----U", "10YRO-TEL------P"]
      },
      "CreationDateTime": {
         type: "string",
         minLength: 20,
         maxLength: 24
      },
      "SenderDateTime": {
         type: "string",
         minLength: 20,
         maxLength: 24
      },
      "OriginIdentification": {
         type: "string",
         maxLength: 16
      },
      "BidDetails": {
         type: "string",
         maxLength: 512
      },
      "ReserveBidIdentification": {
         type: "string",
         maxLength: 40
      },
      "MeasureUnitQuantity": {
         type: "string",
         enum: ["MAW"]
      },
      "Currency": {
         type: "string",
         enum: ["EUR"]
```

```
      },
      "Divisible": {
        type: "string",
        enum: ["A01"] //A01=yes, A02=no
      },
      "Direction": {
        type: "string",
        enum: ["A01", "A02"] //A01=up, A02=down, A03=up+down
      },
      "MeasureUnitEnergyPrice": {
        type: "string",
        enum: ["MWH"]
      },
      "TimeIntervalFrom": {
        type: "string",
        minLength: 20,
        maxLength: 24
      },
      "TimeIntervalTo": {
        type: "string",
        minLength: 20,
        maxLength: 24
      },
      "Resolution": {
        type: "string",
        enum: ["PT60M"]
      },
      "ProductType": {
        type: "string",
        enum: ["std", "spec"]
      },
      "Qty": {
        type: "string"
      },
      "EnergyPrice": {
        type: "string",
        maxLength: 17
      }
    },
    required: [
      'SenderIdentification', 'SenderDateTime', 'ReserveBidIdentification',
      'Direction', 'TimeIntervalFrom', 'TimeIntervalTo',
      'ProductType', 'Qty', 'EnergyPrice'
    ]
}
```

schemaInputCzcAtc:

```
{
    id: "/CzcAtcSubmit",
    type: "object",
    properties: {
      "SenderIdentification": {
        type: "string",
        enum: ["10YSI-ELES-----O", "10YAT-APG------L", "10YHU-MAVIR----U", "10YRO-TEL------P"]
      },
      "SenderDateTime": {
        type: "string",
        minLength: 20,
        maxLength: 24
      },
      "TimeIntervalFrom": {
        type: "string",
        minLength: 20,
        maxLength: 24
      },
      "TimeIntervalTo": {
        type: "string",
        minLength: 20,
        maxLength: 24
      },
      "ControlAreaFrom": {
        type: "string",
```

```
        enum: ["10YSI-ELES-----O", "10YAT-APG------L", "10YHU-MAVIR----U", "10YRO-TEL------P"]
      },
      "ControlAreaTo": {
        type: "string",
        enum: ["10YSI-ELES-----O", "10YAT-APG------L", "10YHU-MAVIR----U", "10YRO-TEL------P"]
      },
      "MeasureUnitCapacity": {
        type: "string",
        enum: ["MW"]
      },
      "Capacity": {
        type: "string"
      }
    },
    required: [
      'SenderIdentification', 'SenderDateTime', 'TimeIntervalFrom', 'TimeIntervalTo',
      'ControlAreaFrom', 'ControlAreaTo', 'MeasureUnitCapacity', 'Capacity'
    ]
}
```

schemaInputCzcPtdf: {

```
    id: "/CzcPtdfSubmit",
    type: "object",
    properties: {
      "SenderIdentification": {
        type: "string",
        enum: ["10YSI-ELES-----O", "10YAT-APG------L", "10YHU-MAVIR----U", "10YRO-TEL------P"]
      },
      "SenderDateTime": {
        type: "string",
        minLength: 20,
        maxLength: 24
      },
      "TimeIntervalFrom": {
        type: "string",
        minLength: 20,
        maxLength: 24
      },
      "TimeIntervalTo": {
        type: "string",
        minLength: 20,
        maxLength: 24
      },
      "Payload": {
        type: "string"
      }
    },
    required: [
      'SenderIdentification', 'SenderDateTime',
      'TimeIntervalFrom', 'TimeIntervalTo', 'Payload'
    ]
}
```

10 ANNEX 3 – TEST CASES FOR BALANCING OPTIMIZATION IN 5.3.6 ALGORITHM TEST: REGIONAL BALANCING OPTIMIZATION

Test case UC_1 focuses on prioritization (maximization) of coloring of imbalance netting flows ahead of activation-related cross-border flows.

Balancing optimization - Use case 1

- imbalance netting flows are prioritized ahead of activation-related flows when coloring cross-border flows
- Romania contributes +5MW to imbalance netting, out of which 3MW go to Hungary and 2MW go to Austria
- in case there were no additional bids available in Romania, all imbalance netting would terminate in Hungary (nothing would go to Austria anymore)

Inputs

Initial imbalances

Region	ACE (MW)	Region type
SI	-5	Specific
AT	-5	Standard
HU	-5	Specific
RO	5	Specific

Bids

Id (autonumber)	Region	Type (std/spec)	Capacity+	Price+	To activate	Capacity-	Price-	To activate
1	RO	Specific	2	1	2	10	5	
2	AT	Specific	2	1	2	-	-	

CZC-ATC (from ROW to COLUMN)

	SI	AT	HU	RO
SI		50		
AT	50		50	
HU		50		50
RO			50	

Results (CAF in Cloud Platform)

Initial imbalance:
SI : -5 MW
AT : -5 MW
HU : -5 MW
RO : 5 MW

Imbalance after netting:
SI : -5
AT : -3
HU : -2
RO : 0

Bid activations:
SI: +0 | -0 MW
AT: +2 | -0 MW
HU: +0 | -0 MW
RO: +2 | -0 MW

XB flows:
Netg HU -> AT : 2 MW
Netg RO -> HU : 5 MW
Spec AT -> SI : 2 MW
Spec RO -> HU : 2 MW

Remaining imbalance:
SI: -3 MW
AT: -3 MW
HU: 0 MW
RO: 0 MW

--- Total cost: 700415 ---
 # final imbalance : 600000
 # SI: -3 MW
 # AT: -3 MW
 # netted imbalance : 100000
 # SI: -5 MW
 # AT: -3 MW
 # HU: -2 MW
 # activations : 400
 # AT: +2 | -0 MW
 # RO: +2 | -0 MW
 # XB usage : 15
 # netg: 7 MW
 # std : 0 MW
 # spec: 4 MW

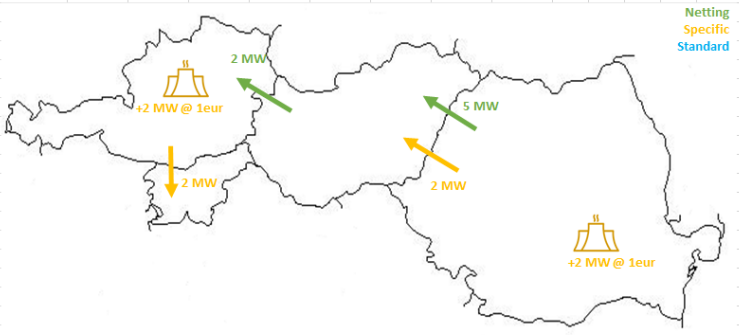


Figure 21: Balancing optimization cost function test case UC_1

Test case UC_2 focuses on ensuring maximization of economic benefit, thus ensuring that in similar end-state scenarios in terms of remaining imbalance and satisfying applicable border constraints, that scenarios is elected which minimizes total regional cost of aFRR.

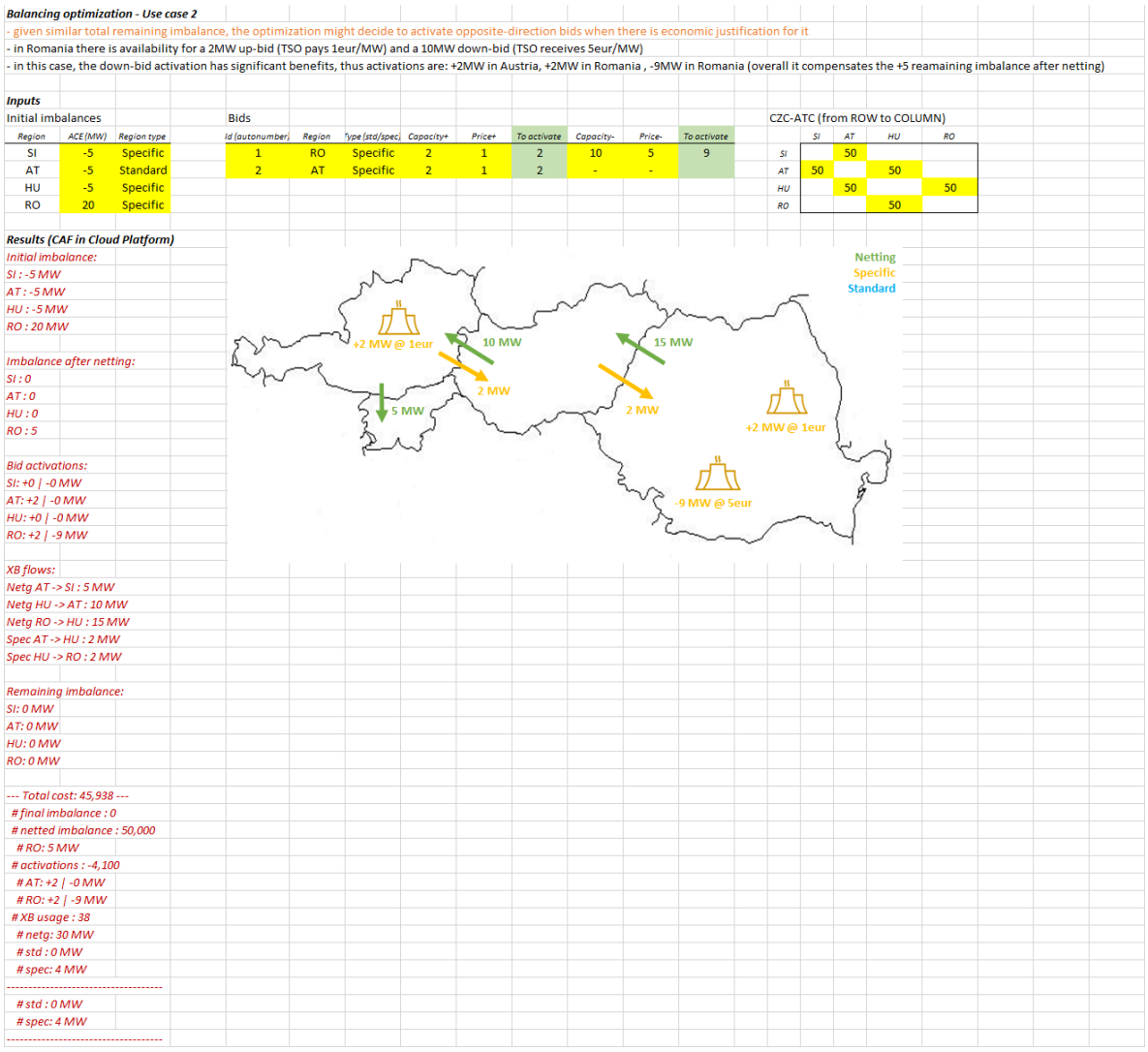


Figure 22: Balancing optimization cost function test case UC_2

Test case UC_1 focuses on permission of netting cross-border unidirectional flows when evaluating border transfer capacities in ATC CZC.

Balancing optimization - Use case 3

- cross-border flows may be netted (i.e. if SI>AT limit is 25MW, there may still be a SI>AT flow of 40MW partly compensated by a 15MW AT>SI flow)
- XB netting feature permits more efficient activation of binds under limited cross-border capacities
- deep imbalances, very limited cross-border capacities, sufficient national reserves

Inputs

Initial imbalances

Region	ACE (MW)	Region type
SI	40	Standard
AT	-80	Standard
HU	70	Specific
RO	100	Specific

Bids

Id (autonumber)	Region	Type (std/spec)	Capacity+	Price+	Activated	Type (std/spec)	Capacity-	Price-	Activated
1	SI	Spec	50	18		Std	50	1.8	
2	SI	Spec	25	23		Std	50	2.3	
3	SI	Spec	10	28		Spec	50	2.8	
4	SI	Spec	5	33		Spec	50	3.3	
5	SI	Spec	50	38		Spec	50	3.8	15
6	SI	Std	50	43		-	-	-	
7	SI	Std	50	48		-	-	-	
8	SI	Std	50	53		-	-	-	
1	AT	Spec	150	19	30	Std	150	1.9	
2	AT	Spec	50	24		Std	150	2.4	
3	AT	Spec	150	29		Std	150	2.9	
4	AT	Std	150	34		Spec	150	3.4	
5	AT	Std	150	39		-	-	-	
1	HU	Spec	50	17		Std	50	1.7	
2	HU	Spec	100	22		Std	100	2.2	
3	HU	Spec	100	27		Std	100	2.7	
4	HU	Spec	100	32		Spec	100	3.2	
5	HU	Std	100	37		Spec	100	3.7	70
6	HU	Std	100	42		-	-	-	
1	RO	Spec	150	16		Std	150	1.6	
2	RO	Spec	100	21		Std	150	2.1	
3	RO	Spec	150	26		Std	150	2.6	
4	RO	Spec	150	31		Spec	150	3.1	
5	RO	Std	150	36		Spec	150	3.6	75
6	RO	Std	150	41		-	-	-	

CZC-ATC (from ROW to COLUMN)

	SI	AT	HU	RO
SI		25		
AT	25		25	
HU		25		25
RO			25	

Results (CAF in Cloud Platform)

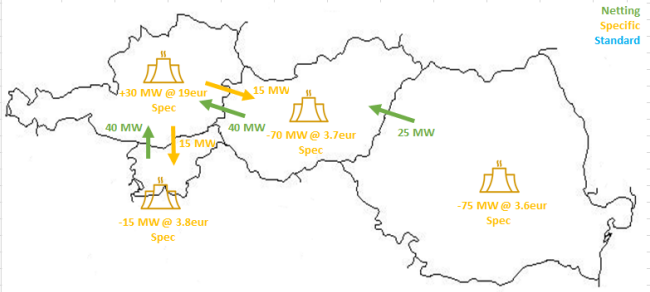
Initial imbalance:
SI : 40 MW
AT : -80 MW
HU : 70 MW
RO : 100 MW

Imbalance after netting:
SI : 0
AT : 0
HU : 55
RO : 75

Bid activations:
SI: +0 | -15 MW
AT: +30 | -0 MW
HU: +0 | -70 MW
RO: +0 | -75 MW

XB flows:
Netg SI -> AT : 40 MW
Netg HU -> AT : 40 MW
Netg RO -> HU : 25 MW
Spec AT -> SI : 15 MW
Spec AT -> HU : 15 MW

Remaining imbalance:
SI: 0 MW
AT: 0 MW
HU: 0 MW
RO: 0 MW




```
--- Total cost: 1.29857e+06 ---
 # final imbalance : 0
 # netted imbalance : 1.3e+06
  # HU: 55 MW
  # RO: 75 MW
 # activations : -1600
  # SI: +0 | -15 MW | cost: -57
  # AT: +30 | -0 MW | cost: 570
  # HU: +0 | -70 MW | cost: -259
  # RO: +0 | -75 MW | cost: -270
 # XB usage : 165
  # netg: 105 MW
  # std : 0 MW
  # spec: 30 MW
----------------------------------
results:{
 "status":"success",
 "pcorr":{
  "SI":-15,
  "AT":30,
  "HU":-15,
  "RO":0
 },
 "activationsMWPositive":{
  "SI":null,
  "AT":{
   "1":30
  },
  "HU":null,
  "RO":null
 },
 "activationsMWNegative":{
  "SI":{
   "5":15
  },
  "AT":null,
  "HU":{
   "5":70
  },
  "RO":{
   "5":75
  }
 },
 "usedCzcNettingMW":{
  "SI>AT":40,
  "HU>AT":40,
  "RO>HU":25
 },
 "usedCzcSpecificMW":{
  "AT>SI":15,
  "AT>HU":15
 },
 "usedCzcStandardMW":null
}
```

Figure 23: Balancing optimization cost function test case UC_3

Test case UC_4 focuses on correctness of prioritization of cost components in balancing optimization (from highest importance to lowest importance): remaining imbalance after imbalance netting and activations, remaining imbalance after imbalance netting, net unit activation costs, absolute total amount of cross-border exchange flows.

Balancing optimization - Use case 4

- optimization function focuses on (in this order): remaining imbalance final >> remaining imbalance after imbalance netting >> bid costs/revenue >> amount of XB flows
- only when multiple solutions exist in terms of one criteria (i.e. similar finance imbalance netting) are other factors considered (i.e. which solution maximizes netting flows etc)
- scenario in which regional collaboration leads to lower costs than purely national balancing, despite national balancing also possible

Inputs

Initial imbalances

Region	ACE (MW)	Region type
SI	40	Standard
AT	-180	Standard
HU	70	Specific
RO	100	Specific

Bids

id (autonumber)	Region	Type (std/spec)	Capacity+	Price+	Activated	Type (std/spec)	Capacity-	Price-	Activated
1	SI	Spec	50	18		Std	50	1.8	
2	SI	Spec	25	23		Std	50	2.3	
3	SI	Spec	10	28		Spec	50	2.8	
4	SI	Spec	5	33		Spec	50	3.3	
5	SI	Spec	50	38		Spec	50	3.8	15
6	SI	Std	50	43		-	-	-	
7	SI	Std	50	48		-	-	-	
8	SI	Std	50	53		-	-	-	
1	AT	Spec	150	19	130	Std	150	1.9	
2	AT	Spec	50	24		Std	150	2.4	
3	AT	Spec	150	29		Std	150	2.9	
4	AT	Std	150	34		Spec	150	3.4	
5	AT	Std	150	39		-	-	-	
1	HU	Spec	50	17		Std	50	1.7	
2	HU	Spec	100	22		Std	100	2.2	
3	HU	Spec	100	27		Std	100	2.7	
4	HU	Spec	100	32		Spec	100	3.2	
5	HU	Std	100	37		Spec	100	3.7	70
6	HU	Std	100	42		-	-	-	
1	RO	Spec	150	16		Std	150	1.6	
2	RO	Spec	100	21		Std	150	2.1	
3	RO	Spec	150	26		Std	150	2.6	
4	RO	Spec	150	31		Spec	150	3.1	
5	RO	Std	150	36		Spec	150	3.6	75
6	RO	Std	150	41		-	-	-	

CZC-ATC (from ROW to COLUMN)

	SI	AT	HU	RO
SI		25		
AT	25		25	
HU		25		25
RO			25	

Results (CAF in Cloud Platform)

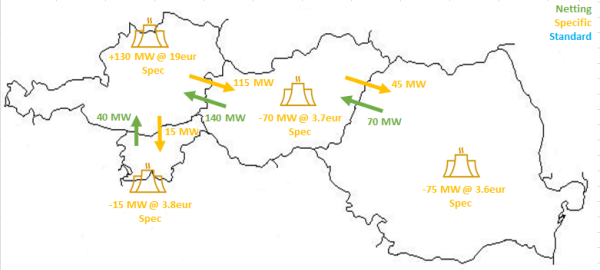
Initial imbalance:
SI : 40 MW
AT : -180 MW
HU : 70 MW
RO : 100 MW

Imbalance after netting:
SI : 0
AT : 0
HU : 0
RO : 30

Bid activations:
SI: +0 | -15 MW
AT: +130 | -0 MW
HU: +0 | -70 MW
RO: +0 | -75 MW

XB flows:
Netg SI -> AT : 40 MW
Netg HU -> AT : 140 MW
Netg RO -> HU : 70 MW
Spec AT -> SI : 15 MW
Spec AT -> HU : 115 MW
Spec HU -> RO : 45 MW

Remaining imbalance:
SI: 0 MW
AT: 0 MW
HU: 0 MW
RO: 0 MW



--- Total cost: 488825 ---
 # final imbalance : 0
 # netted imbalance : 300000
 # RO: 30 MW
 # activations : 188400
 # SI: +0 | -15 MW | cost: -57
 # AT: +130 | -0 MW | cost: 2470
 # HU: +0 | -70 MW | cost: -259
 # RO: +0 | -75 MW | cost: -270
 # XB usage : 425
 # netg: 250 MW
 # std : 0 MW
 # spec: 175 MW


```
----------------------------------
results:{
 "status":"success",
 "pcorr":{
  "SI":-15,
  "AT":130,
  "HU":-70,
  "RO":-45
 },
 "activationsMWPositive":{
  "SI":null,
  "AT":{
   "1":130
  },
  "HU":null,
  "RO":null
 },
 "activationsMWNegative":{
  "SI":{
   "5":15
  },
  "AT":null,
  "HU":{
   "5":70
  },
  "RO":{
   "5":75
  }
 },
 "usedCzcNettingMW":{
  "SI>AT":40,
  "HU>AT":140,
  "RO>HU":70
 },
 "usedCzcSpecificMW":{
  "AT>SI":15,
  "AT>HU":115,
  "HU>RO":45
 },
 "usedCzcStandardMW":null
}
```


Figure 24: Balancing optimization cost function test case UC_4