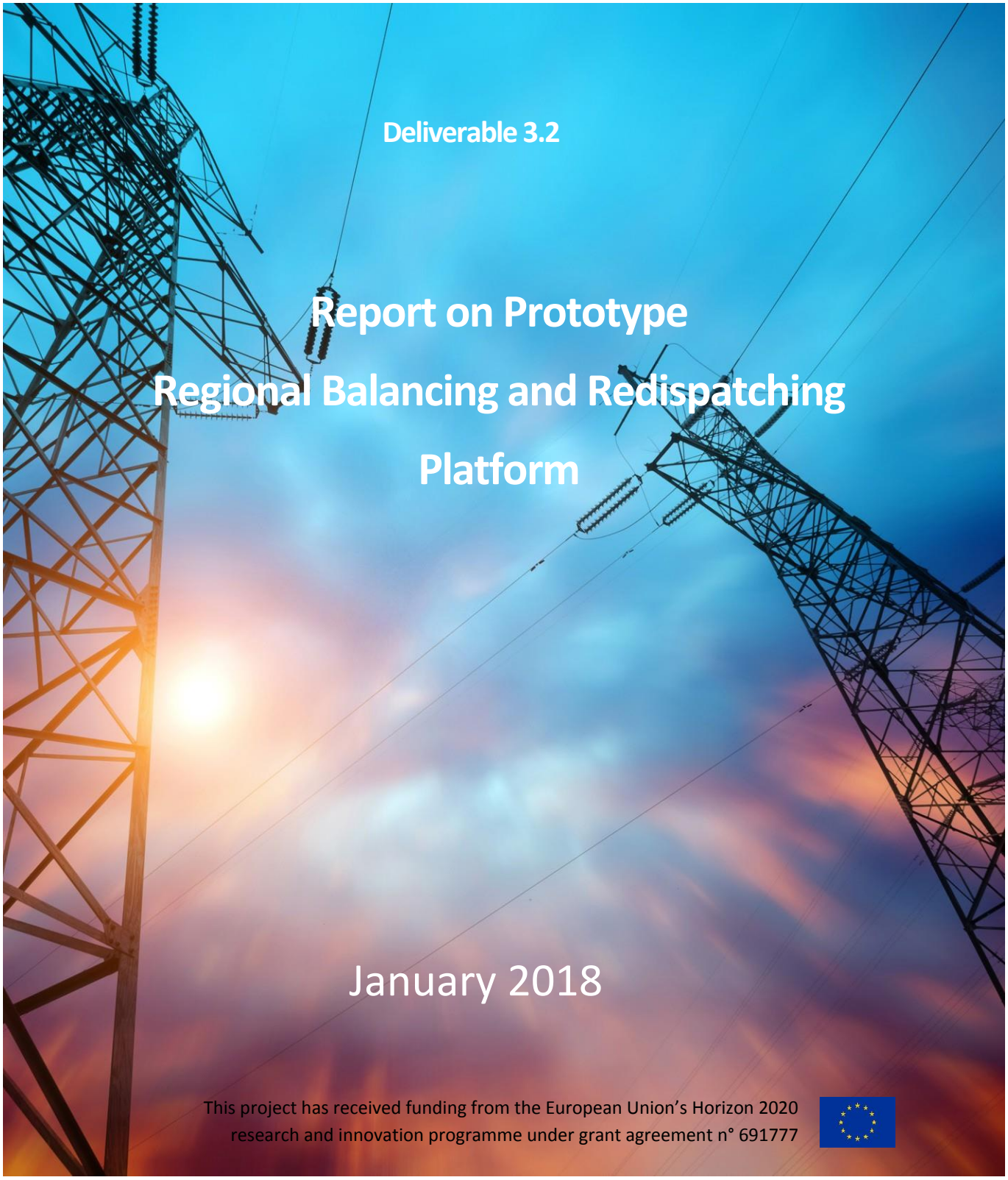
FutureFlow



Deliverable 3.2

Report on Prototype Regional Balancing and Redispatching Platform

January 2018

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 691777

FutureFlow

Document Information

Programme	Horizon 2020 – Cooperation / Energy
Project acronym	FutureFlow
GA number	691777
Deliverable	D3.2
WP/Task related	W3 / T3.2
Type	Other
Confidential:	Public
Date of delivery	15.02.2018
Status and Version	Version 1.0
Number of pages	21 pages
Document Responsible	SAP

Authors

SAP	Lucian Moldovanu, Viorel Marcu

Reviewer(s)

EKC	Zoran Vujasinovic, Dusan Vlaisavljevic, Nebojsa Jovic
EIMV	Andrej Souvent, Radovan Sernec

Document versions

Version	Date	Author(s)	Notes
0.1	10.01.2018	SAP	Initial version (draft)
1.0	16.01.2018	SAP, EIMV, EKC	Incorporating review by EIMV and EKC
1.1	15.02.2018	SAP	Update following consortium review

FutureFlow

TABLE OF CONTENTS

1 EXECUTIVE SUMMARY

FutureFlow Task 3.2 was concerned with the software development for the Prototype Regional Balancing and Redispatching Platform with Common Activation Function for FRR, which is referred to in the current document also as “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 securely hosted by SAP in 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 tasks 3.2 and 3.3 (FutureFlow Demo Site).

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

2 LIST OF ACRONYMS

Acronym	Description
BSP	Balancing Service Provider
CAF	Common Activation Function
(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
MQTT	Message Queuing Telemetry Transport
PD	P_{demand} (type of imbalance input to the FF Cloud Platform)
TSO	Transport System Operator
UTC	Universal Time Coordinated

Table 1 List of acronyms

3 OVERALL ARCHITECTURE

The regional balancing and redispatching platform (“FF Cloud Platform”) is developed by SAP for FutureFlow and built using a scalable architecture and deployed in the SAP Cloud Platform. Two core functionalities are implemented, i.e. a redispatch simulation tool and real-time balancing system, alongside a data warehouse that will store all data input or generated in the real-time balancing system.

As part of the balancing process, the platform receives XML-encoded data originating from the four TSOs involved in the project via an API over MQTT over Secure Web Sockets. A Human Machine Interface (web page) is accessible not only before gate-closure-time but also during real-time operation for TSOs to take corrective action when necessary (update/delete bids, override CZC).

The redispatch simulation tool is also accessible via HMI. It is designed to consume inputs uploaded from user files, run redispatching, display summary KPIs and export full results of redispatching.

The prototype architecture initially proposed in the FutureFlow project specifications is presented in Figure 1 below.

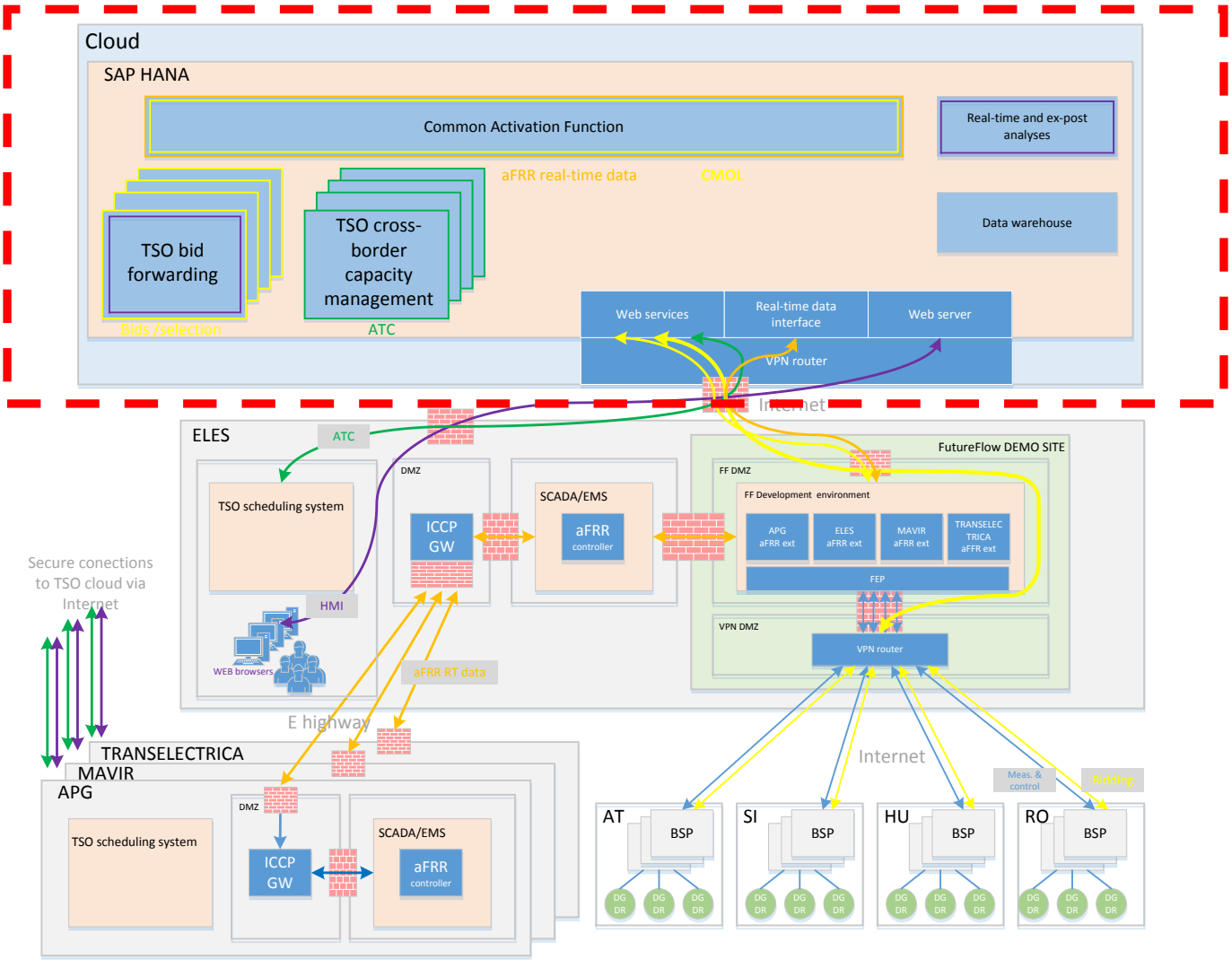


Figure 1 FutureFlow overall architecture

The functional building blocks for implementation and data sources are plotted in Figure 2 below.

Redispatch simulation is performed via HMI. Balancing data flows via automated interfaces (MQTT messaging), with the possibility to take corrective action after gate-closure-time via the HMI.

In terms of security, 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.

A user interface is used to access the redispatch simulation tool and the Human Machine Interface for balancing operations, while real-time data for the balancing process is consumed via a messaging interface (MQTT protocol).

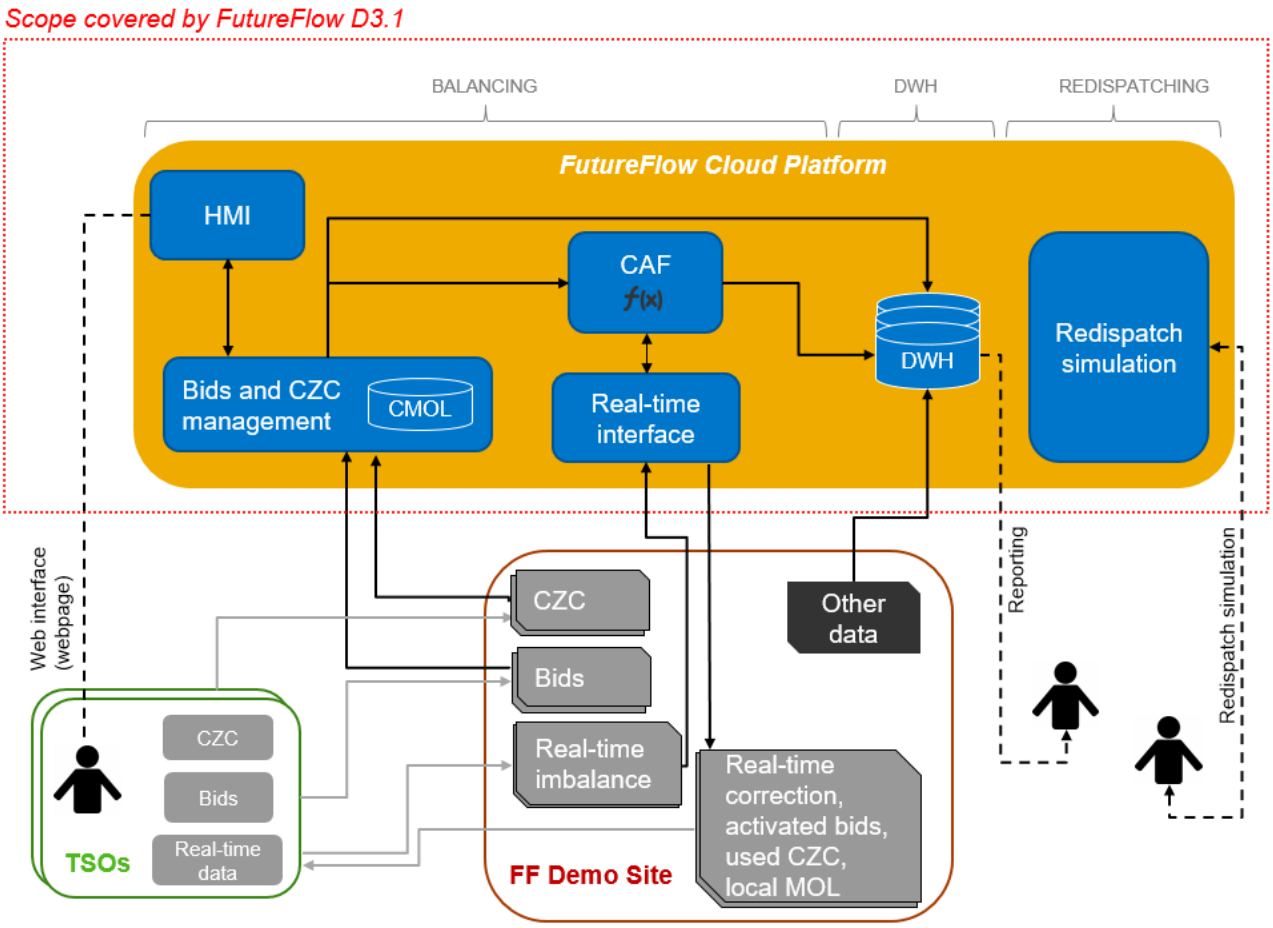


Figure 2 FutureFlow Cloud Platform implementation, building blocks and data sources (presented in Deliverable 3.1)

3.1 Responsive architecture based on messaging

SAP designed a scalable architecture for the balancing process, with all communication taking place via asynchronous messaging interfaces. As opposed to a request-response interaction, in an asynchronous architecture, requesters don't submit requests to other actors, but instead **publish** a notification message to a broker (i.e. which has the function of a 'server') on a specific topic, while other actors in the system **subscribe** to specific topics to receive messages. Thus, the sender (requestor) is decoupled from the receiver (executor), allowing the system to easily scale and expand.

Building on top of the asynchronous architecture, the architecture is 'responsive', meaning that actors (i.e. TSOs directly or FF Demo Site on behalf of TSOs) generate events (i.e. "bid accepted by TSO and ready to take part in activations", "cross-border transfer capacity issued by TSO" etc.) and FF Cloud Platform takes

action based on these events by only observing them instead of listening for specific commands (i.e. as soon as a bid creation message is issued by a TSO on the messaging topic with the cloud platform, the cloud platform automatically takes that bid and considers it ready to take part in regional activations). The alternative (of actors directly issuing actions to the cloud - “use this specific bid for activations”, “run”, “trigger optimization” etc.) increases the coupling between systems at an IT architecture level and harms the scalability of the solution. Still, from a functional point of view, the result is the same.

The combination of an asynchronous, responsive architecture ensures that the system is easily scalable component-wise, easy to test and easy to augment with new functionality.

3.2 Public interfaces exposed by FF Cloud Platform

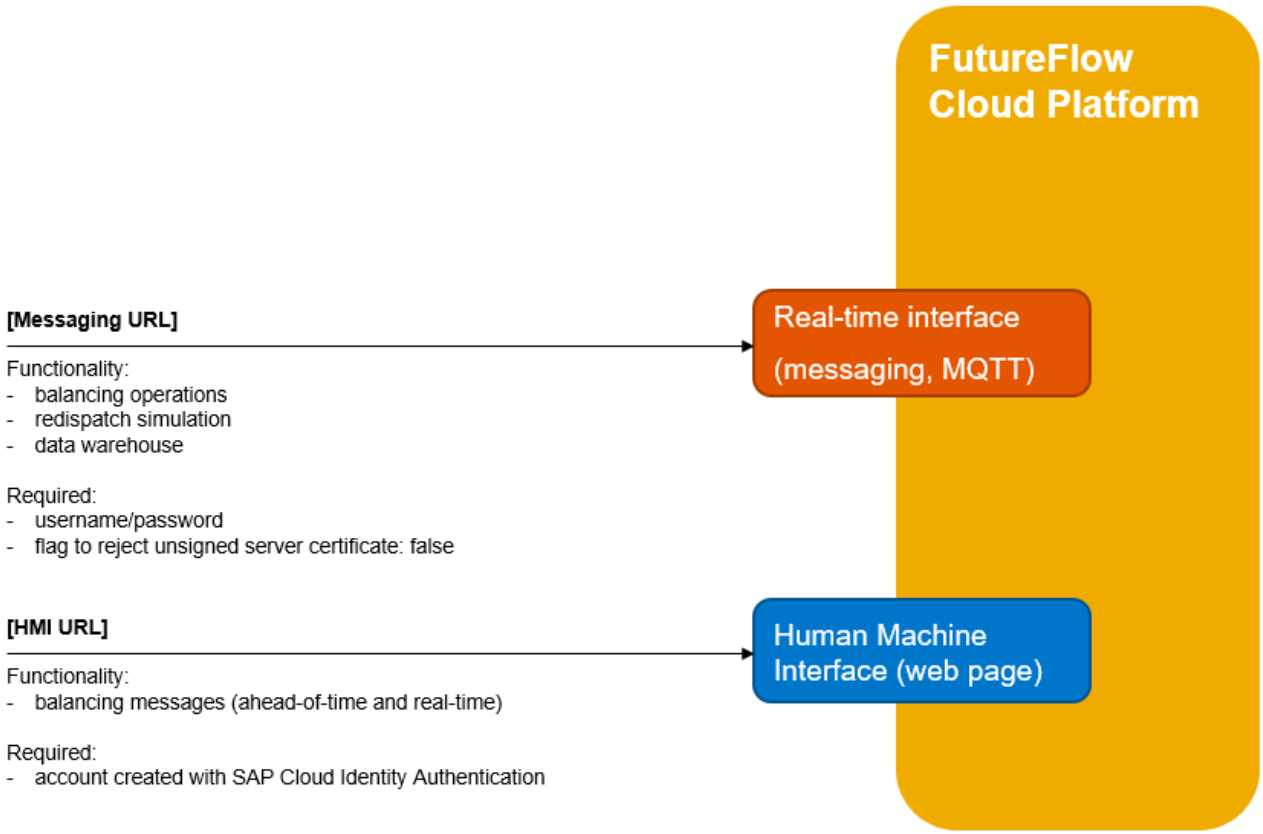


Figure 3 FutureFlow Cloud Platform data interfaces

Application links [Messaging URL] are [HMI URL] are available in the document [FutureFlow Cloud Platform technical documentation (internal)] available to consortium members.

3.2.1 Human Machine Interface

Area	Functionality/description
Balancing operations	HMI is to be used during real-time platform operation to support TSO actions on bids and CZC-ATC after gate closure time or during eligible activation interval (intervals during which updates cannot be submitted via automated interfaces anymore): - Delete bid - Override CZC-ATC TSOs have access to the balancing operations area and will only be allowed to visualize or act on bids and CZC-ATC data that are related to their control zone.
Redispatch simulation	HMI represents the sole entry point for redispatch simulation. Eligible platform users will be allowed to upload input files prepared in advance, run the simulation, visualize summary KPIs and export the full results (archive file).
Data Warehouse	Eligible platform users will be allowed to visualize (in tabular format) and download data stored in the Data Warehouse related to the balancing process.

Table 2 Human Machine Interface functionalities

4 PLATFORM FUNCTIONALITY

The FF Cloud Platform provides three main functionalities: balancing, redispatch simulation and data warehouse.

4.1 General assumptions

4.1.1 UTC time is the reference

All timestamps/datetime data fields that appear in the data interfaces of FF Cloud Platform and are mentioned in the current document are represented in UTC format, conform to ISO 8601 and follow the pattern YYYY-MM-DDTHH:MM:SSZ or YYYY-MM-DDTHH:MM:SS.sssZ.

UTC is the reference time for FutureFlow. No local times (i.e. containing time zones) should be used.

4.1.2 No centralized real-time reference

There is no single notion of real-time across the platform and TSOs. The real-time reference in each control area is inferred based on the <ReferenceDateTime> field in the imbalance input messages received on topic _tsoid_/in/imbalance/+ (either PD or CTCR).

The implication of this assumption is that:

a) the decision on whether bids/czc submitted to the FF Cloud should be accepted based on the gate closure time validation is dependent on the <SenderDateTime> and <TimeIntervalFrom> fields in the input messages. The platform assumes that <SenderDateTime> represents the current time in the control area (TSO) at the moment the message was submitted to the FF Cloud, thus the validation is the following:

$$< SenderDateTime > \leq < TimeIntervalFrom > - < GateClosureTimeMinutes >$$

b) in the balancing section of HMI, **only those bids and czc-atc records are displayed for which the current TSO time reference (as inferred from the imbalance input messages) is either a) between gate-closure-time and activation eligibility, b) during real-time activation eligibility window or c) in the future**; because the real-time reference depends on the imbalance input, using simulated values for the imbalance input that are too far in the future will invalidate all bids up to the

respective time; as a matter of consequence, bids may suddenly ‘disappear’ from the HMI. During testing, imbalance inputs can be submitted regardless of the real-time reference, thus submitting an imbalance with a past real-time reference will make bids and czc visible in the HMI.

c) the decision on which bids/czc are eligible to take part in an activation in each control area (i.e. every two seconds) depends on the <ReferenceDateTime> field sent in the imbalance inputs (PD or CTCR). It is possible that, due to clock misalignments between control areas, a different reference is received for each control area (i.e. when <ReferenceDateTime> from ELES is 13:59:50 and from APG is 14:00:10, bids/czc between 13:00:00 and 14:00:00 are considered from ELES and between 14:00:00 and 15:00:00 from APG.

This assumption is intended to ensure that the real-time operation for balancing is robust. The alternative of using a single common measure of time and the prior alignment (synchronization) of clocks among control areas was considered in the design but discarded in implementation due to the strategic importance of the IT landscapes at TSOs.

4.1.3 Platform operation modes for balancing

This section describes the platform operation modes. Only one operation mode can be in effect at any single time and switching the platform operation mode can only be provided on-demand with the support of SAP.

Operation mode	Description
1	The imbalance signal is expected from control areas every two seconds. A single-step optimization is performed, including imbalance netting and bid activations. The platform waits for imbalances submitted on topic _tsoid_/in/imbalance/pd and sends responses on topic _tsoid_/out/corr.
2	Two types of imbalance signals are expected from control areas every two seconds: a P_{DEMAND} signal (Open-loop ACE, PD) and a Control Target/Control Request signal (CTCR). A separate optimization is performed and response is provided for each of the inputs: in the case of PD, the optimization represents the results of a pure imbalance netting with no activations, while for CTCR it represents a full single-step optimization (which may include imbalance netting and explicit unit activations). The platform waits for imbalances submitted on topics _tsoid_/in/imbalance/pd and _tsoid_/in/imbalance/ctcr and provided responses on topics _tsoid_/out/corr/pd and _tsoid_/out/corr/ctcr.

Table 3 Platform operation modes

4.2 Balancing

Balancing operation modes consists of ahead-of-time and real-time communication.

4.2.1 Ahead-of-time communication

Ahead-of-time messages ("bids", "czc-atc" and "czc-ptdf") can be submitted before gate closure time. Note that, as there is no centralized real-time reference across all control areas, all ahead-of-time messages will include a SenderDateTime field which should be set to the sender current timestamp (UTC) and which will be used to validate the gate closure time constraint.

Message submission is idempotent (the end-effect is the same regardless of how many time an exact message is submitted). Resubmission has the effect of invalidating the resources already existing in the system and replacing them with the currently-submitted resource. For bids, the matching is performed by SenderIdentification and ReserveBidIdentification while for CZC the matching is performed by SenderIdentification, TimeIntervalFrom, TimeIntervalTo, ControlAreaFrom and ControlAreaTo.

Deleting a bid can be achieved by submitting a message with "Qty" = 0, with a similar effect for CZC-ATC being achieved by submitting a message with "Capacity" = 0. *"Qty" and "Capacity" are input data fields in the corresponding XML-encoded data structure, according to Section 4 – Sample Messages for Balancing Inputs in the document [FutureFlow Cloud Platform technical documentation (internal)] available to consortium members.*

Ahead-of-time messages are always acknowledged, either with a confirmation or a rejection (in which case it will be accompanied by the reason for rejection). The client has the responsibility to implement the logic of handling corrective action (if required) in case a submission is rejected. Rejection reasons include lack of authorization, xml syntax errors or gate closure time non-compliance.

Sample messages for ahead-of-time messages are provided in document [FutureFlow Cloud Platform technical documentation (internal)] available to consortium members.

4.2.2 Real-time communication

Real-time messages ("imbalance-pd" in platform operation mode 1, alongside "imbalance-ctcr" in operation mode 2) are expected with a periodicity of two seconds from each control area. FutureFlow Cloud Platform does not issue acknowledgements for real-time messages, however the optimization response is directly provided on dedicated topics.

Imbalances are accumulated by the platform and either one (in operation mode 1) or two (in operation mode 2) optimizations are performed every two seconds. The platform is robust to synchronization time mismatches, thus:

- if an imbalance is not received from an imbalance area, the platform will continue to consider as valid (for a short period of time, ~10 seconds) the last valid imbalance message that was received;
- if multiple imbalances are received from an imbalance area within the expected 2-second time window, only the last message is considered as valid and used in the optimization.

Sample messages for real-time messages are provided in document [FutureFlow Cloud Platform technical documentation (internal)] available to consortium members.

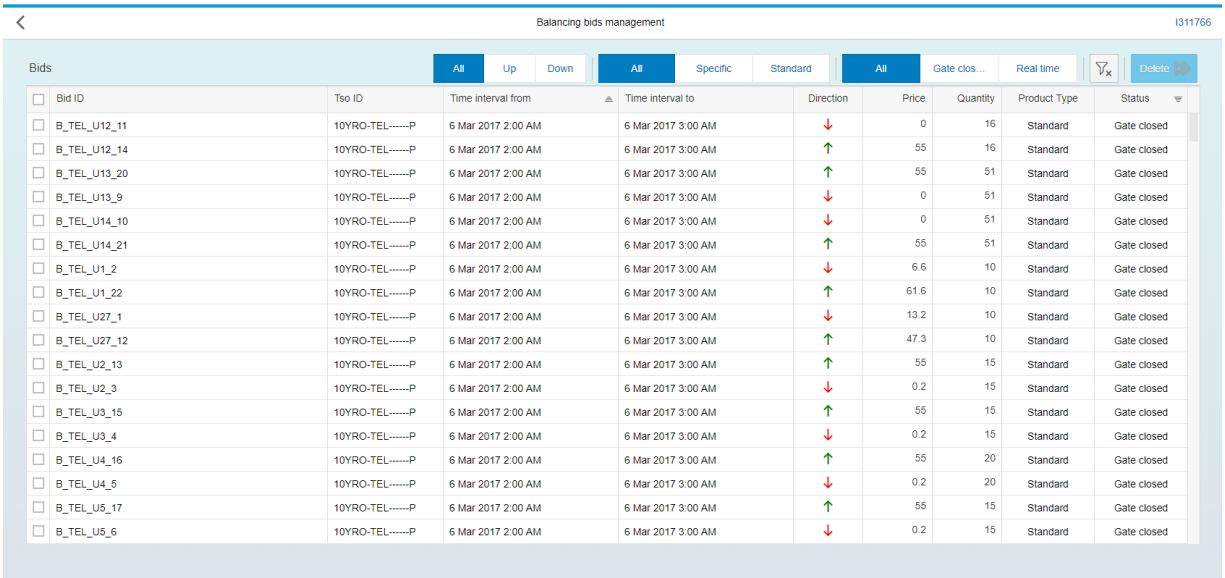
4.2.3 User guide

The Balancing Bids Management section of Balancing HMI permits authorized users to:

- **Visualize current and future bids using filters**
  Filtering can be applied using the buttons on top of the table based on bid direction (All/Up/Down), bid type (All/Specific/Standard) and/or bid status (All/During gate closure time/During real-time activation eligibility interval). Additionally, case-sensitive textual filters can be applied directly to column headers and in will be applied to the respective column using the "includes" criteria (i.e. in Figure 4 below, filtering on the Bid ID column header using "TEL" will filter out of the table all rows the don't contain "…TEL…" in the Bid ID column).

- **Delete one or multiple bids (selected using row headers)**
  "Deletion" has the effect of bids not being able to take part in activations and is intended to be used after gate closure time or during real-time operation, when TSOs realize that a bidder would not able

to deliver on its promises and thus should not take pare anymore in regional optimization. This action is traced and audited.



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 4 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.

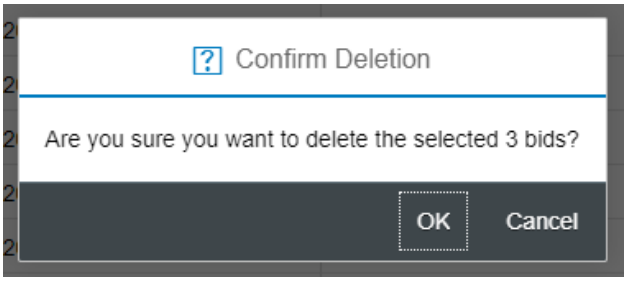
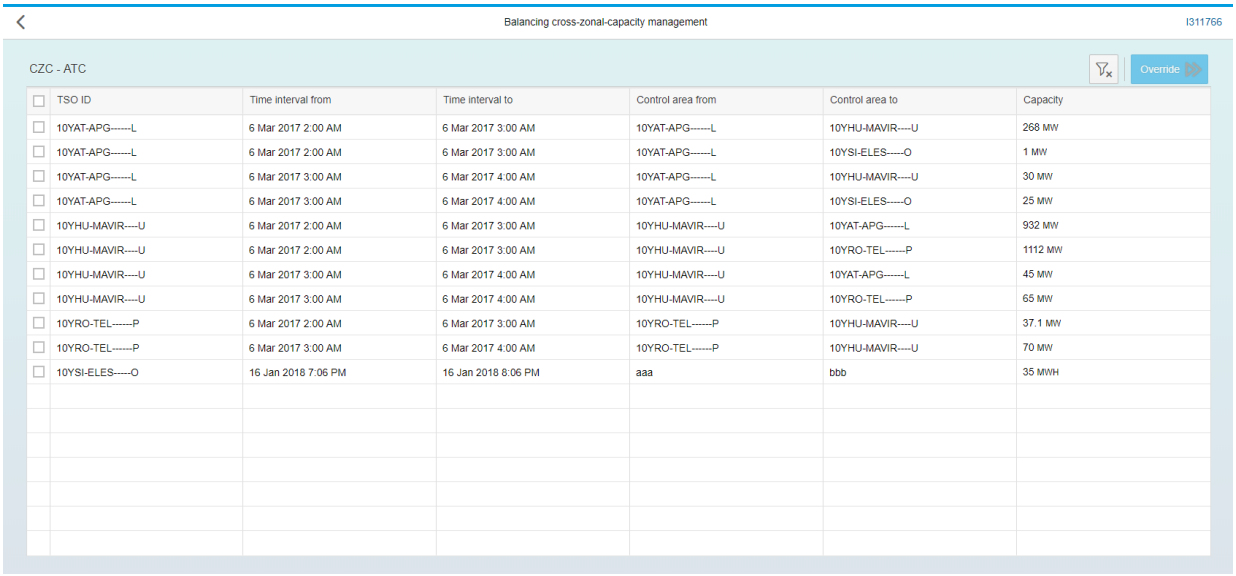


Figure 5 UI – Balancing HMI bid deletion confirmation

The Balancing Cross-zonal capacity (ATC) section of Balancing HMI permits authorized users to override (i.e. replace by overwriting) one or multiple current or future CZC. Note that only one CZC-ATC message per country pair (i.e. border), direction and time interval (hour) can be existing in the system at a time.

The same contextual column filtering options apply as described above in Balancing Bids Management.

The effect of overriding CZC-ATC takes effect immediately after the user confirm the action in the UI.



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 6 UI – Balancing HMI – Cross-zonal capacity management

4.3 Redispatch simulation

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.

4.3.1 Input files

4.3.1.1 Merged network model / UCT

The input represents a text file drafted in accordance with “UCTE data exchange format for load flow and three phase short circuit studies” and has the following underlying structure:

- 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

4.3.1.2 CBCO and PTDF matrix

Custom file format (CSV structure) with the following properties:

- 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 (variable number of) columns that should contain the pattern “NODEID > REFNODE”; REFNODE should be the same across the entire file, while NODEID represents the node for which the respective factors in the column are calculated

4.3.1.3 Redispatch bidding list

Custom file format (CSV structure) with the following properties:

- 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 User guide

a. Access Redispatch Simulation section in HMI

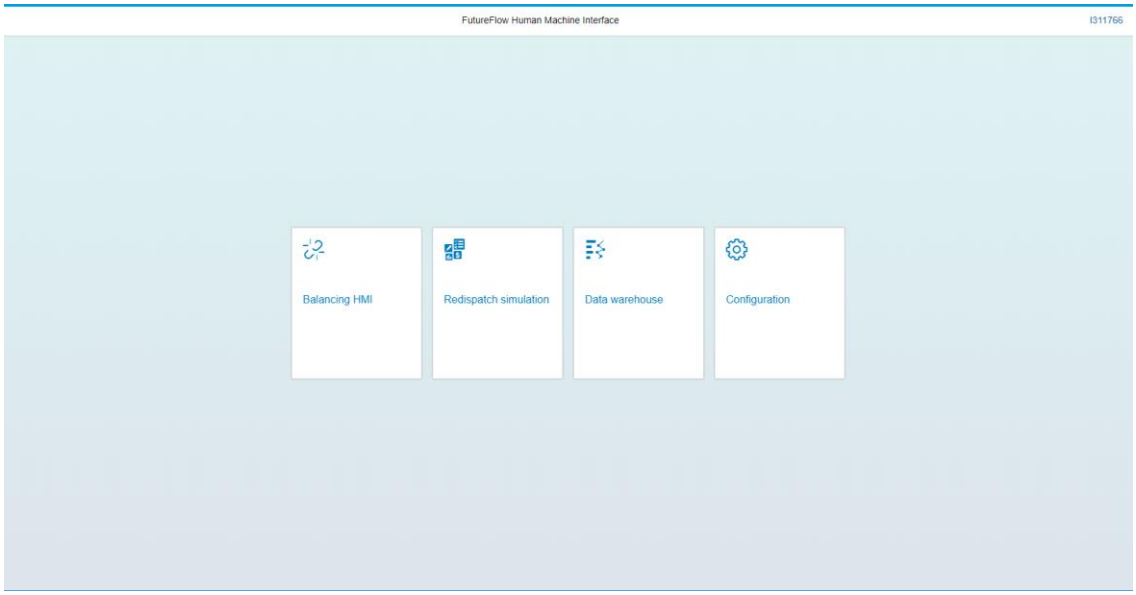


Figure 7 UI – Human Machine Interface landing page

b. Upload the required input files one by one. The order is not important. For each input: click "Add files" > pick up a file from your computer > click in the list on the kind of file that was selected.

There are three types of files required as input:
- Merged network model in UCT format
- Redispatch bidding list (if there are multiple regions involved, these need to be concatenated in a single file and conform to the required format – see test example)
- CBCO and PTDF matrix (includes line loading and capacities alongside PTDF factors)

All these input files need to be consistent in terms of node names (i.e. all nodes in CBCO/PTDF need to be among nodes in UCT file; all nodes in RBL need to exist in UCT file).

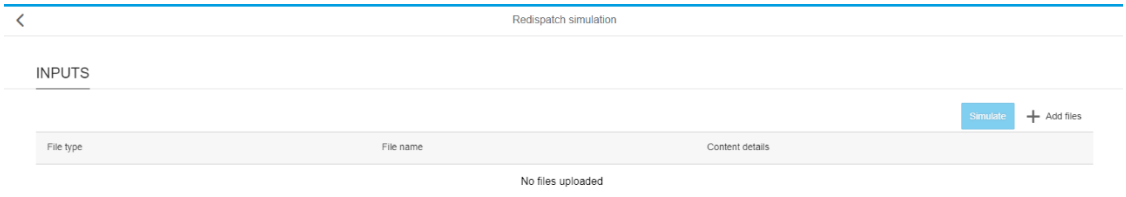


Figure 8 UI – Redispatch simulation landing page

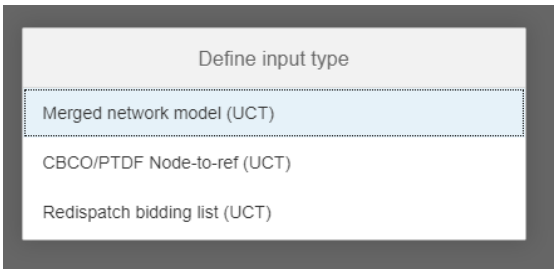


Figure 9 UI – Redispatch simulation data input type selection

c. During the process, you can delete any of the uploaded files, using the bucket button next to the file.

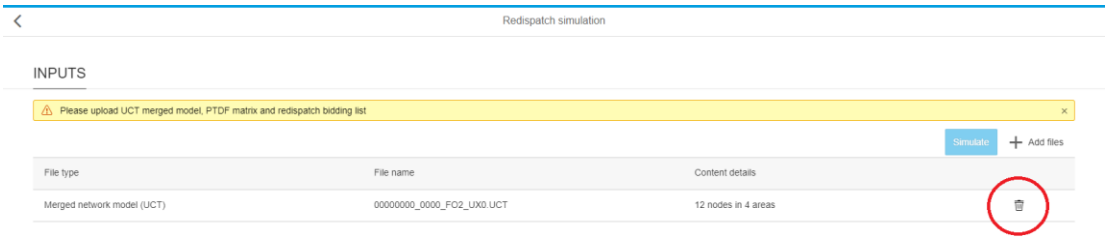


Figure 10 UI – Redispatch simulation input data deletion

d. After you upload all files necessary for simulation, click the blue Simulate button that becomes active.

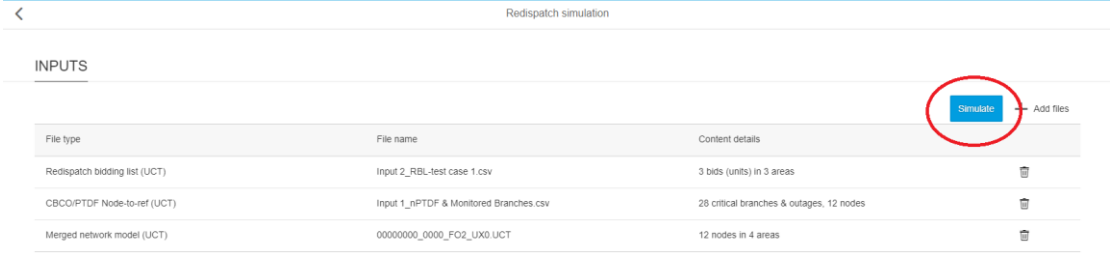


Figure 11 UI – Triggering a redispatch simulation

e. Select the Redispatch areas for the simulation and click "Run simulation"

Figure 12 UI – Redispatch simulation area selection

f. After you have run a simulation (see the previous section), you will see a message that the simulation completed successfully and you can see the results (Summary KPIs, Visualization, Export). The Summary KPIs provide a summary of the results (generic and by area):

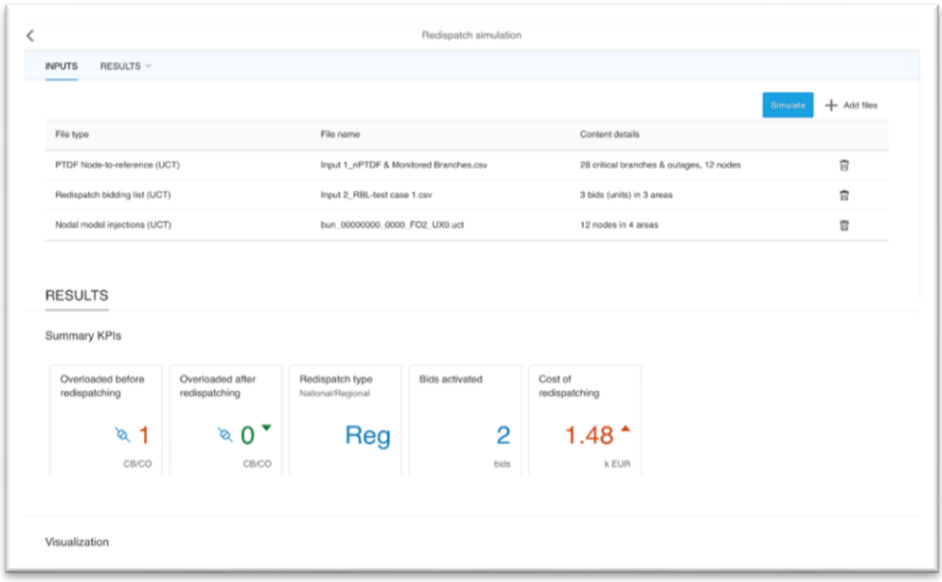


Figure 13 UI – Redispatch simulation summary KPIs

g. The Export section allows the user to export the files with the result by clicking the blue "Download archived results of simulation" button

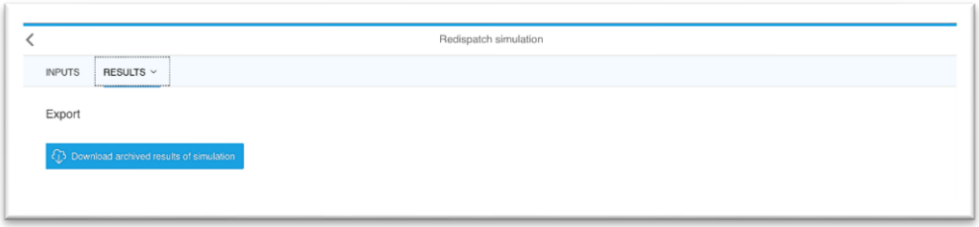


Figure 14 UI – Redispatch simulation export of results

Redispatching results are accompanied by a visualization section which displays the following:

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 %).

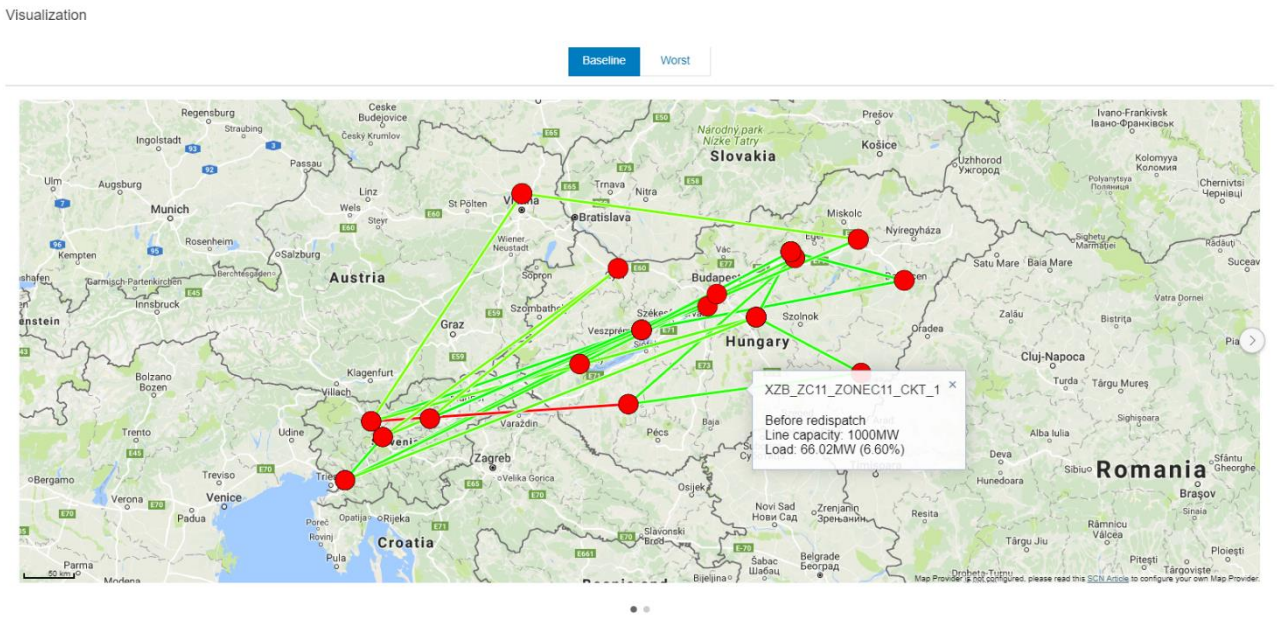


Figure 15 UI Visualization – Visualization of lines loading before and after redispatch

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.

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 16 UI Visualization – b. Table of line loadings before and after redispatch

c. Unit activations

This visualizations plots activated units (following redispatching) on a geographical map. The color of the units represents activated direction (up or down) and a tooltip displays additional details regarding unit name, unit details, activated power (MW) and activated power price (in EUR).

4.4 Data warehouse

The FutureFlow Data Warehouse (DWH) stores data that is collected in the regional balancing process (i.e. data that is input to the FF Cloud Platform, data that is generated as optimization outputs as well as relevant accompanying master data).

DWH can be accessed via the Human Machine Interface:

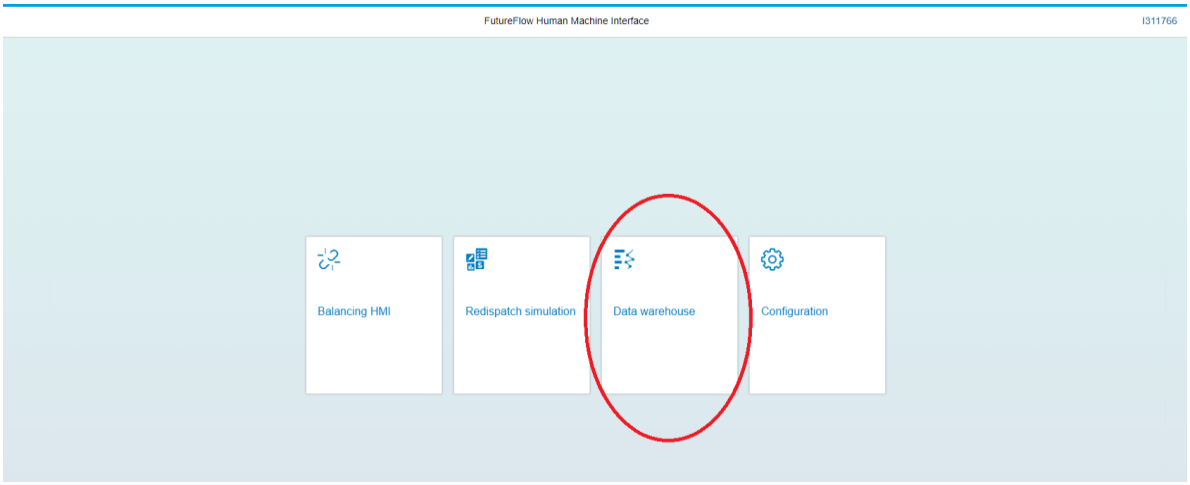


Figure 17 UI – Data warehouse

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:

- **Reference date (UTC)**: the real-time date reference to which all data is referring; this will match the TimeIntervalFrom/TimeIntervalTo fields for bids and czc inputs, ReferenceDateTime for imbalance input and the associated outputs.
- **Submission date (UTC)**: the actual time reference when the data was submitted to the FF Cloud Platform; 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.
- **Submitted by (control area/s)**: filter results only for one (or multiple) control areas.
- **Tag**: in order 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.
- **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.

Important remarks regarding the usage of DWH

- All HMI users have an associated authorization level that allow access to data of (usually) one TSO only; in order to allow the ex-post evaluation of project results, multi-area users will also be created with access to multiple control areas and will aid during platform testing commencing in H1 2018.

  Single-area users will have access only to data that was provided by the respective control area and the associated outputs, regardless of the target choice in the “Submitted by (control area/s)” input filter.

- 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 in order to meet this constraint.

  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.

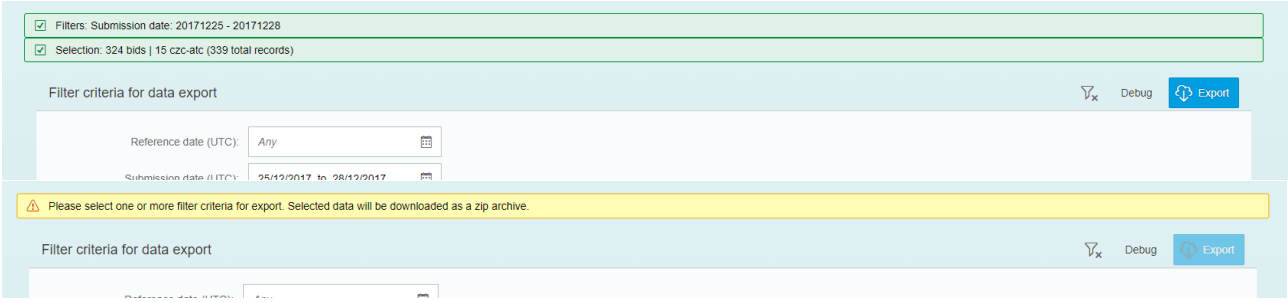


Figure 18 UI – Data warehouse filter criteria selection and record count

5 SECURITY, AUTHENTICATION AND AUTHORIZATION

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 communications with FF Cloud Platform are secured by Transport-Layer-Security. Additionally, authorization is provided using separate means for different functional building blocks of the platform.

5.1 Access control for HMI

User identity and authentication for the Human Machine Interface is provided by the SAP Cloud Platform Identity Authentication service.

In order to get access to HMI, users need to create an account by following the steps in section 3.2.1 below and submit it to SAP. It will then be statically associated with a specific TSO which will grant access and actions restricted in scope to the respective TSO.

Every time the user accesses the HMI via a web browser, a login will be performed with the SAP Cloud Identity Authentication Service which will propagate access to all involved systems in FF Cloud Platform.

5.1.1 User guide

a. Access http://hana.ondemand.com and click "Register"

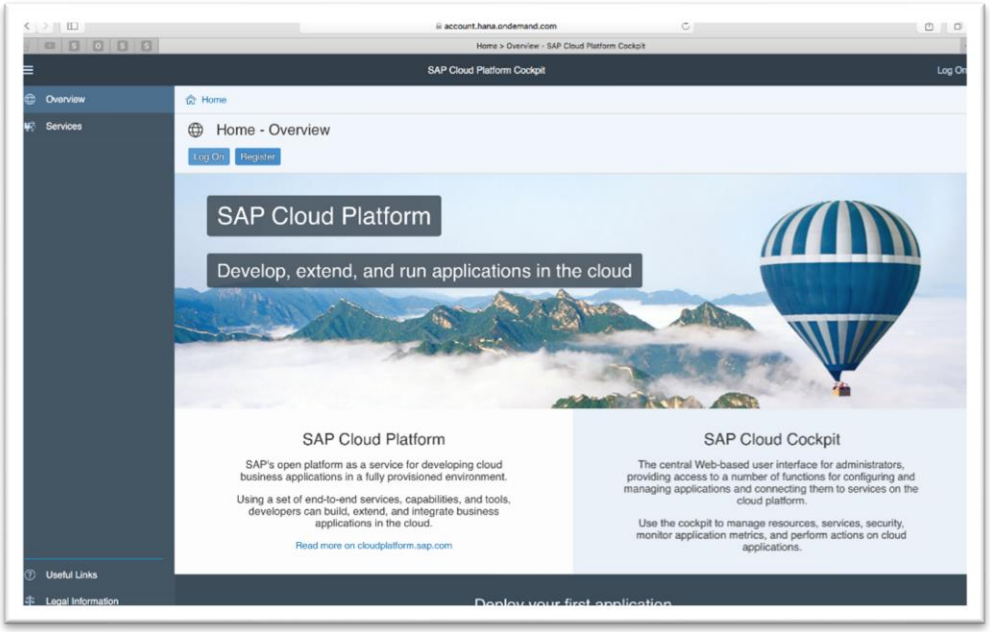


Figure 19 UI – SAP Cloud Platform landing page

b. Fill in the required fields in the form. Please make sure you can access the email address you fill in, as you will be required to access it in the next step

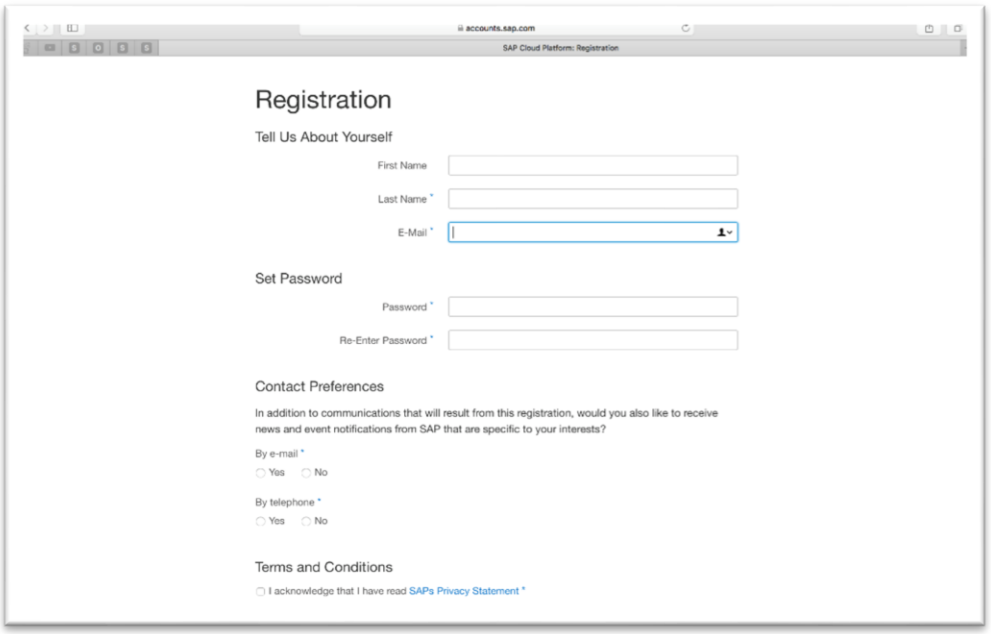


Figure 20 UI – SAP Cloud Platform user registration for Identity Authentication

c. You should receive an email to "Activate Your Account on SAP Cloud Platform". Open it and click to activate the account.

d. Upon activation, you should be able to logon using the email and password that you chose.

Please note the P-number next to your name and communicate it to SAP (in att: lucian.moldovanu@sap.com).

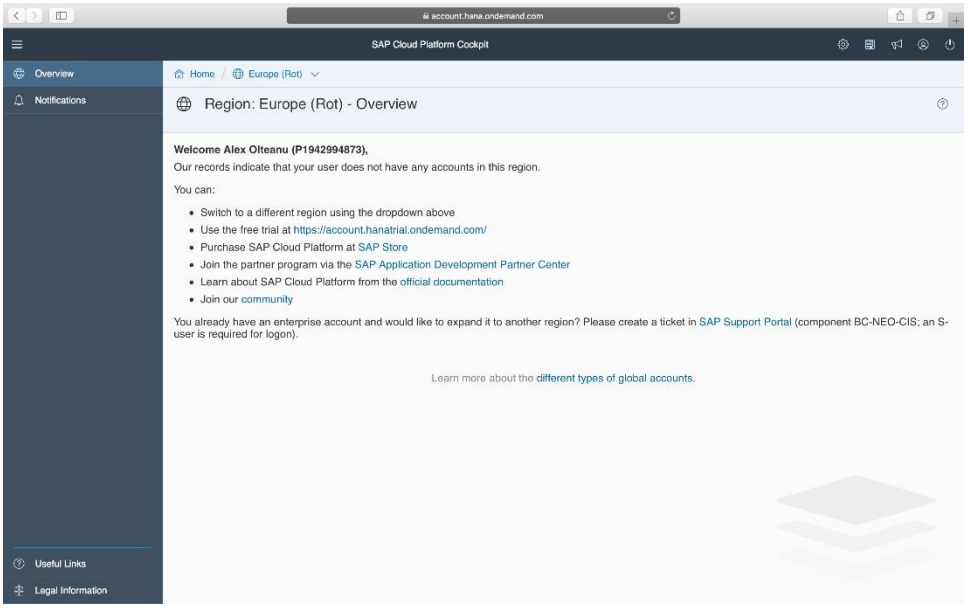


Figure 21 UI – SAP Cloud Platform user registration confirmation

5.2 Access control for automated data interfaces (MQTT)

Automated data interfaces (messaging) are exposed by the MQTT broker. Connections are accepted via Secure WebSockets protocol at endpoint [Messaging URL].

Connections are secured at all times 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:

- _tsoid_/in/* (bids/czc-atc/czc-ptdf)
- _tsoid_/in/imbalance/* (pd/ctcr)
- _tsoid_/ack/* (bids/czc-atc/czc-ptdf)
- _tdoid_/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 in order 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.

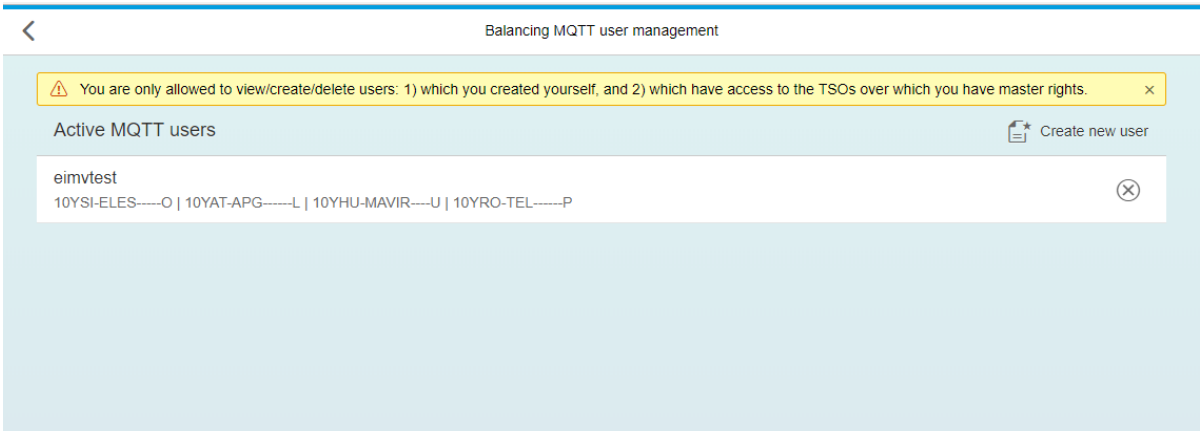


Figure 22 UI – MQTT messaging user management

In order to create an MQTT user, please follow the steps below:

a. Click “Create new user” on top of the active users table.
b. Enter a username, password and select the applicable TSOs to grant access to.
   Granting access to a TSO has the effect of opening the corresponding topics in MQTT broker, thus allowing client connecting with the respective username to submit bids/czc/imbalance and to receive optimization results on behalf of the respective TSO.

By default, users will be a master of only one TSO – thus they will only be able to grant rights to their own control areas. For the facilitation of platform testing (scheduled to take place in Q1 and Q2 2018), global usernames will also be permitted, with access to multiple TSOs.

The username must comply with the following validation criteria:

- must only be composed of letters (small/capital), digits and underscore character (_)
- must necessarily start with a letter (not digit or underscore)
- acceptable length is between 1-16 characters

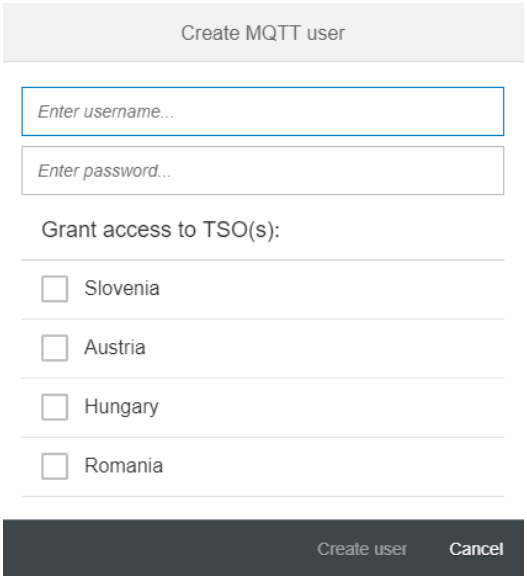


Figure 23 UI – Granting MQTT user area access

c. Click “Create user”. The active user list will be refreshed immediately if the creation is successful.

6 CONCLUSION

SAP produced the first release of FutureFlow Cloud Platform in December 2017 – with work finalized on the three main functionalities: balancing, redispatch simulation and data warehouse. The software solution is developed using a robust, scalable and asynchronous architecture and deployed in the SAP Cloud Platform – the enterprise-level cloud solution provided by SAP. The solution will continue to hosted in the SAP Cloud Platform throughout the duration of FutureFlow according to project specifications.

Integration testing covering the communication interfaces with FutureFlow Demo Site (balancing) was initiated and will continue in H1 2018 according to FutureFlow Deliverable 4.1. Redispatch simulation functionality was already made available to involved consortium members in October 2017 and functional results of simulation are included in FutureFlow Deliverable 1.4.

SAP will continue to support the development and improvement of FutureFlow Cloud Platform by releasing updated versions of the software solution following a close collaboration with involved partners throughout and beyond the pilot testing phase.