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ISGAN
International Smart Grid Action Network
ISGAN Academy Webinar

Demonstration of close-to-real-time cross border flexibility market

(OSMOSE project)

21. 04. 2022
Online Webinar

ISGAN in a Nutshell

ISGAN is the short name for the *International Energy Agency* (IEA) *Technology Collaboration Programme* (TCP) for a Co-operative Programme on Smart Grids (ISGAN – *International Smart Grids Action Network*).

It is also an initiative of the *Clean Energy Ministerial* (CEM) and was formally established at CEM2 in Abu Dhabi, in 2011 as an Implementing Agreement under a framework of the *International Energy Agency* (IEA).

The *International Smart Grid Action Network* (ISGAN) creates a strategic platform to support high-level government attention and action for the accelerated development and deployment of smarter, cleaner electricity grids around the world.

ISGAN in a Nutshell

ISGAN currently consists of 27 Contracting Parties.
Their nominated representatives form the Executive Committee headed by the Presidium, assisted by two co-Secretariats and the Operating Agent of ISGAN.

Co Secretariat

AUSTRIAN INSTITUTE OF TECHNOLOGY

ISGAN Presidium

ISGAN Executive Committee

Co Secretariat

Korea Smart Grid Institute

Vision

ISGAN's vision is to accelerate progress on key aspects of smart grid policy, technology, and investment through voluntary participation by governments and their designees in specific projects and programs. Its activities center foremost on those aspects of the smart grid where governments have regulatory authority, expertise, convening power, or other leverage, focusing on five principal areas:

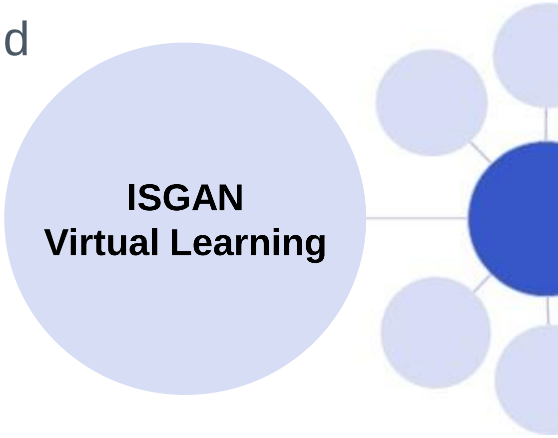
- Policy standards and regulation
- Finance and business models
- Technology system development
- Workforce skills and knowledge
- Users and consumers engagement

ISGAN facilitates dynamic knowledge sharing, technical assistance, peer review and, where appropriate, project coordination among its Contracting Parties.

Value proposition

ISGAN Virtual Learning

- Offer the ISGAN community of high level engineers and decision makers a means of rational and efficient continuous technical skills complement and update in the field of smart grids
- ISGAN Virtual Learning proposes e-learning core modules dealing with the entire value chain of smart grid
- Fundamentals and further reading modules are also provided as appendices
- Webinars organized every two months or co-hosted with the Clean Energy Solutions Center



ISGAN Website: www.iea-isgan.org

Demonstration of close-to-real-time cross border flexibility market

The speakers:

- Gorazd Ažman, Assistant Director | Strategic Innovation, ELES
- Andrea Bello, Energy Engineer, HDE
- Miran Kavrečić, Head of general analytics department, HSE
- Dusan Vlaisavljevic, Head of Energy Market Team, EKC
- Marilena Lazzaro, Researcher, ENG
- Charles Payement, Research Engineer, RTE

Please, use the **Q&A tool** to pose questions, the speakers will answer at the end of the presentation.

The recording will be available through the **ISGAN YouTube channel.**

Agenda

- Introduction to OSMOSE and WP6 demos (ELES)
- Creating flexibility providers bids (HDE & HSE)
- FEB-creator pre-processing and merge software description (ENG)
- Common grid model design and EN4M software presentation (EKC)
- Optimization platform development based on model-predictive control methodology (RTE)
- Conclusion & key take-away (ELES)

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Close to real-time potential of flexibility

There is a potential of available flexibility close to real time :

- **Latest RES forecasts** are available and can reveal an excess/a lack of generation
- Remaining **transmission capacity** can be exploited

How to capture this close to real-time flexibility given that processes need to be:

- Very **fast**
- **Secure** for the grid since no operator will be able to act after

WP6 demo objective

Experiment a close-to-real-time joint optimization of generation/storage/demand & grid, in order to extract the most value from remaining flexibilities of the electrical system

Congestion management

Flexibility markets

A hot research topic

- Although feedback controls have been used for specific subjects as frequency control, the utilization of the technics for **AC Optimal Power Flow (OPF)** problem is recent.
- Several universities and laboratories currently work on the subject.
- Open questions remain and the praticalibility is still to demonstrate on a real system.

[1] A Survey of Distributed Optimization and Control Algorithms for Electric Power Systems, Molzahn, Daniel K.
Dörfler, Florian; Sandberg, Henrik; Low, Steven H.; Chakrabarti, Sambuddha; Baldick, Ross; Lavaei, Javad, **2017**

[2] An optimization-on-manifold approach to the design of distributed feedback control in smart grids, Saverio Bolognani; Florian Dörfle; Automatic Control Laboratory ETH Zürich; **2016**

[3] Networked Feedback Control for a Smart Power Distribution Grid Saverio Bolognani, Saverio Bolognani; **2017**

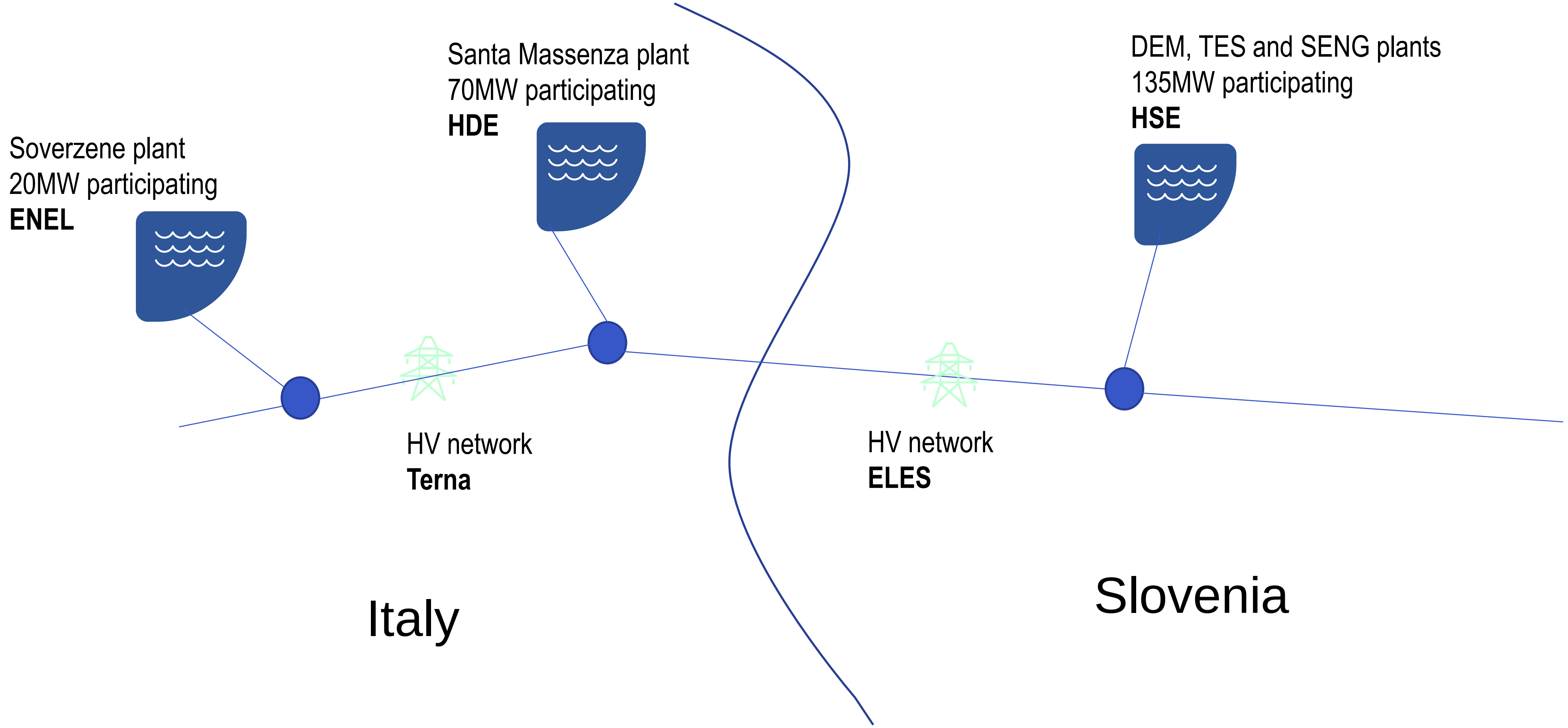
[4] Distributed reactive power feedback control for voltage regulation and loss minimization, Saverio Bolognani

[5] Online Optimization in Closed Loop on the Power Flow Manifold, Adrian Hauswirth; Alessandro Zanardi; Saverio Bolognani, Florian Dorfler; and Gabriela Hug, Automatic Control Laboratory ETH Zürich, **2017**

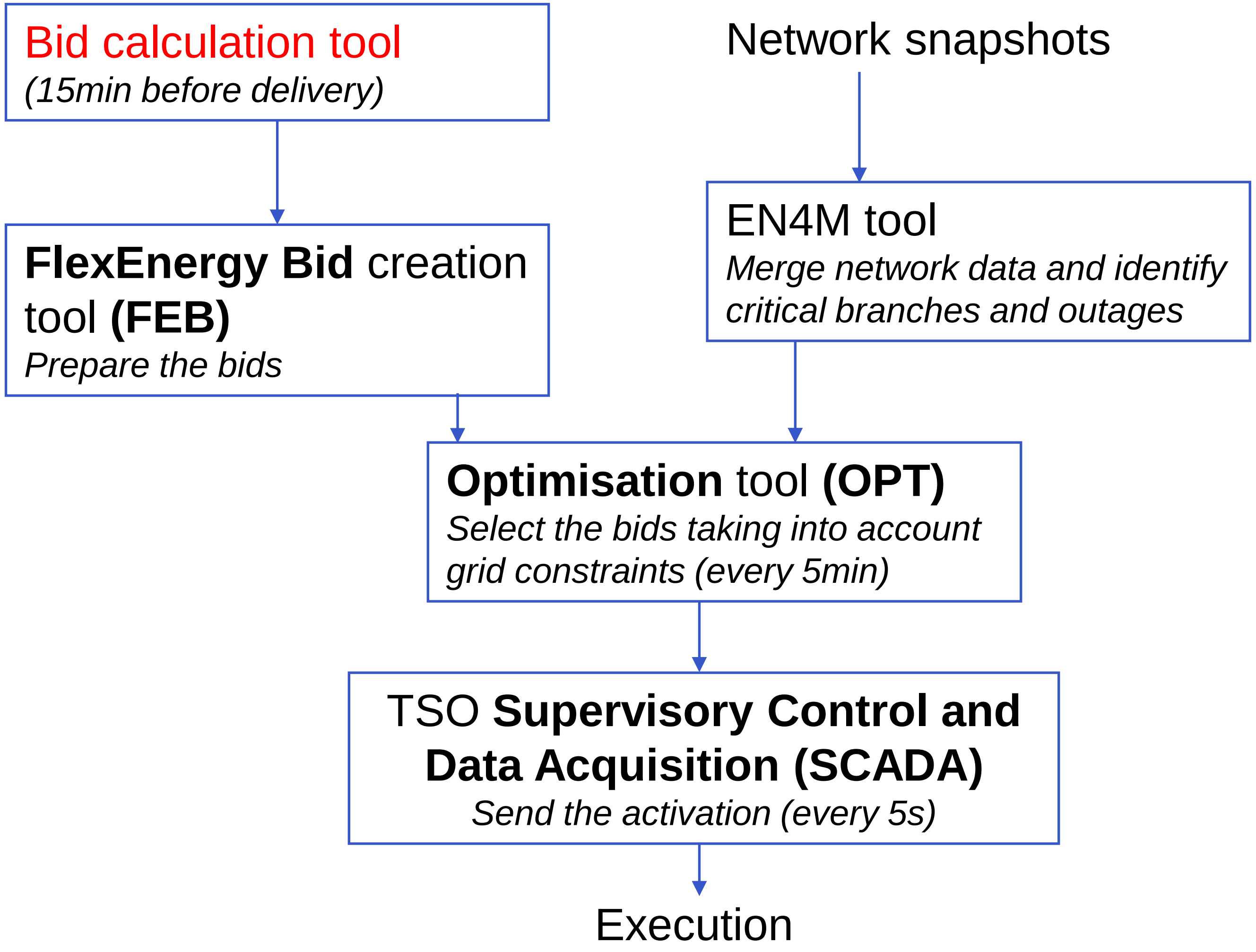
[6] D. B. Arnold, M. Negrete-Pincetic, M. D. Sankur, D. M. Auslander, and D. S. Callaway, "Model-free optimal control of var resources in distri- bution systems: An extremum seeking approach," IEEE Transactions on Power Systems, vol. 31, no. 5, **2016**.

Etc…

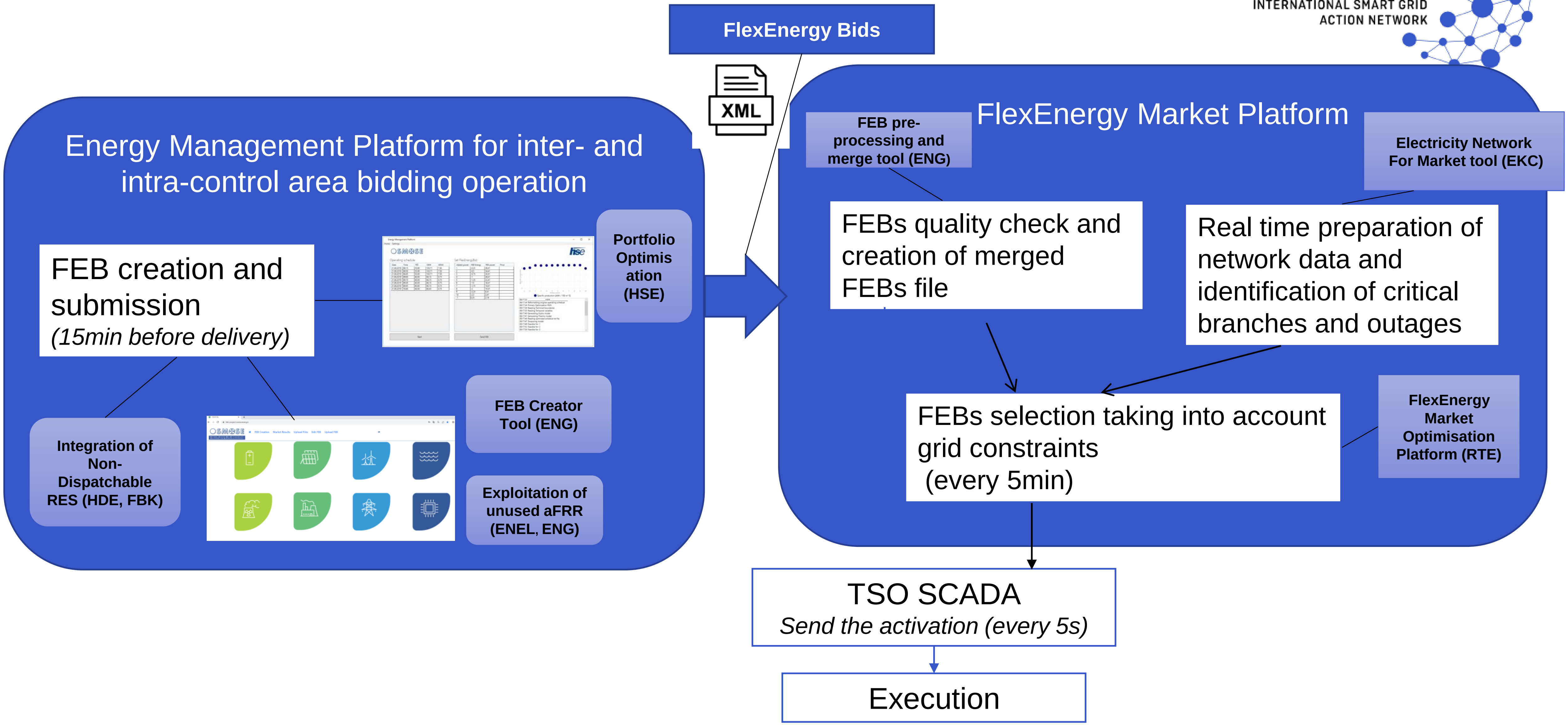
Demo set-up


Soverzene plant
20MW participating
ENEL
Santa Massenza plant
70MW participating
HDE
DEM, TES and SENG plants
135MW participating
HSE
HV network
Terna
HV network
ELES
Italy
Slovenia

Overview of the FlexEnergy market platform



Overview of the WP6 demo – platforms and tools



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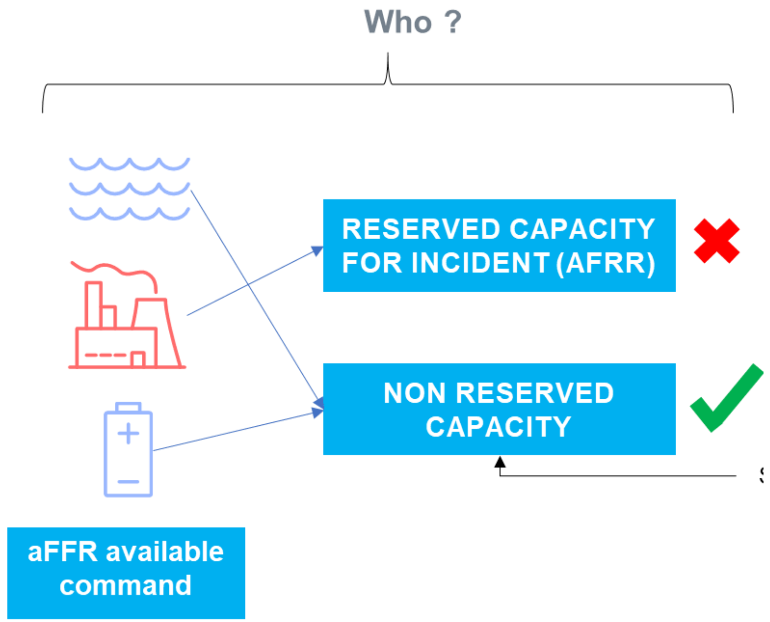
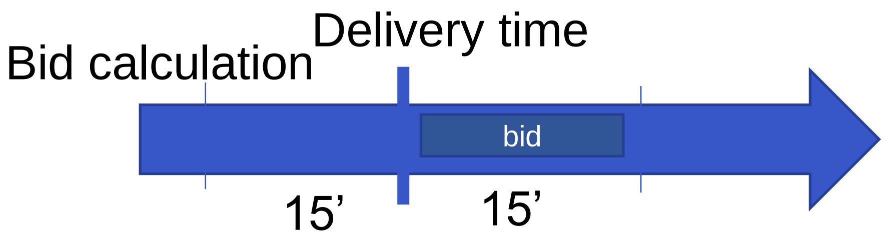
Bids generation by producers





- Step 1 : Evaluate power not exploited by other market or the provision of ancillary services
- Step 2 : Define bids taking into account technical constraints and optimizing the portfolio. **Two innovative algorithm were developed on producer's side and are axplained in Deliverables 6.2 and 6.3:** the *Mixed Integer Linear Program* and the *Integration of Non-Dispatchable RES* with neural network nowcasting.

Bids generation by HSE

- One of three FEB Calculation Modules developed
- FEB from flexibilities not used in the current market
- Or gained from last-minute technical optimization

- Limitations: time (calculation, outage reporting)
- Advantages: possibility to exploit unused flexibility or flexibility gained from optimization after the existing markets

- Whole Automatic Generation Control should be simulated to obtain additional accuracy
- We‘re not so fast as we might think

Bids generation by HDE: INDRES

«Integration of Non-Dispatchable RES», one of the three FEB Calculation Modules developed

The concept of the algorithm:

- ➢ Nowcasting of power production of non-dispatchable RES
- ➢ Comparison with last market schedule → estimation of upcoming imbalances
- ➢ Internal rebalance of portfolio to ‘transfer’ bid opportunities from imbalances of non-disp. to dispatchable power plants
- ➢ Bidding of the rebalanced energy on FlexEnergy Market, from dispatchable units

- Limitations: a specific nowcasting model must be developed for each target power plant; portfolio management is required for redispatch between non-disp. and disp. power plants
- Adv: reduction & valorization of production imbalances from non-dispatchable RES

Ref: Deliverable 6.3 – chap 9.2

Bids generation by HDE: INDRES

Case study. Run-of-the-River **HydroPower Plant** (HPP) ***Ala:*** 38 MW installed power, max 210 m^3/s

Three machine learning nowcasting models were developed and compared:

- input: flow rate (gauge, 25 km upstream of HPP intake); power produced (up to real time)
- output: power produced (from real time to +6h)

Nowcasting + near to real-time market proved to be very effective for imbalance reduction.

Internal rebalancing couldn’t be demonstrated (in Italy, portfolio management is not allowed yet)

Limitations from real-world demo: delay in real-time data acquisition, need for fully automatic bidding (no time for human supervision).

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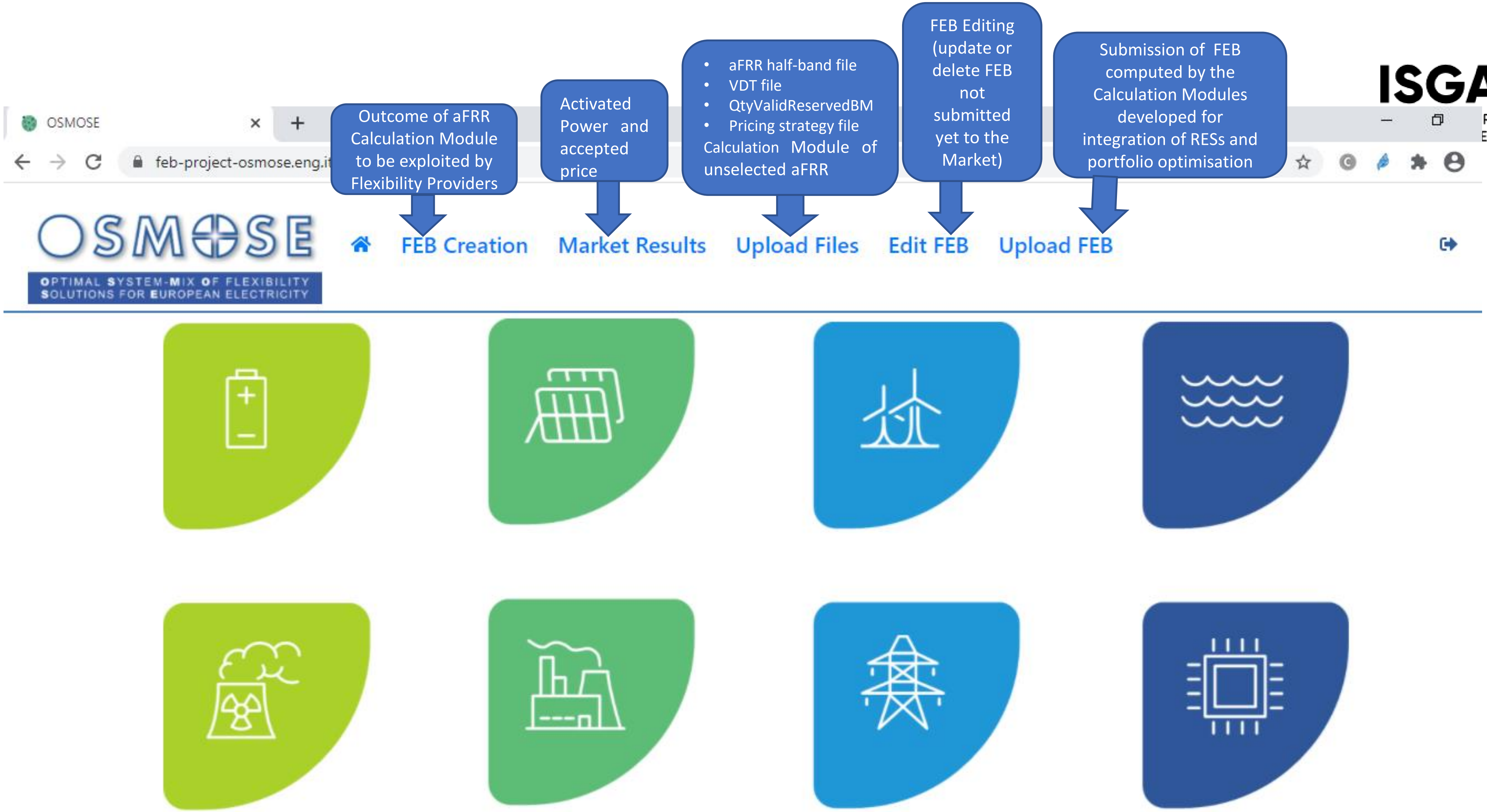
FlexEnergy Bid Creator tool - overview

- The tool enables Flexibility Providers to offer their flexibility (**FlexEnergy Bid - FEB**) on FlexEnergy Market and to exploit the Market results
- The tool supports different Calculation Modules for the creation of FlexEnergy Bid and addressing the three different FlexEnergy market strategies:
  - Exploitation of unused **automatic Frequency Restoration Reserve aFRR** (ENEL, ENG)
  - Integration of Non-Dispatchable RES (HDE, FBK)
  - Portfolio optimisation (HSE)
- FlexEnergy Bid Creator Tool is a web application available at https://feb-project-osmose.eng.it/login
  - the back-end implements the overall logic of the application including the creation of FEB for unselected aFRR and the automatic submission of FlexEnergy Bid to the FlexEnergy Market. FEBs computed by the others two calculation modules are submitted as well.
  - The front-end is a Graphical User Interface put at disposal of Flexibility Providers for the participation to the FlexEnergy Market



Outcome of aFRR Calculation Module to be exploited by Flexibility Providers
Activated Power and accepted price
• aFRR half-band file
• VDT file
• QtyValidReservedBM
• Pricing strategy file
Calculation Module of unselected aFRR
FEB Editing (update or delete FEB not submitted yet to the Market)
Submission of FEB computed by the Calculation Modules developed for integration of RESs and portfolio optimisation
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OSMOSE
OPTIMAL SYSTEM-MIX OF FLEXIBILITY SOLUTIONS FOR EUROPEAN ELECTRICITY
FEB Creation
Market Results
Upload Files
Edit FEB
Upload FEB

OSMOSE

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FEB Creation | Market Results | Upload Files | Edit FEB | Upload FEB

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Market results

Date 03/03/2022

SOVERZENE POWER PLANT

FEB ID	Timestamp	Power (Activation) (MW)	Max Power (MW)	Price (€/MW)	Status
bd87dae6-0e85-41c2-99d1-71ace6c7a5b3	2022-03-03 12:00:00	-10	10	200	✓
bd87dae6-0e85-41c2-99d1-71ace6c7a5b3	2022-03-03 12:05:00	-10	10	200	✓
bd87dae6-0e85-41c2-99d1-71ace6c7a5b3	2022-03-03 12:10:00	-5	10	200	✓
d6f2a61a-af09-4953-8d06-db4df010257a	2022-03-03 12:15:00	-10	10	200	✓
d6f2a61a-af09-4953-8d06-db4df010257a	2022-03-03 12:20:00	-10	10	200	✓
d6f2a61a-af09-4953-8d06-db4df010257a	2022-03-03 12:25:00	-5	10	200	✓
62dc8034-bb30-4e2e-ba61-b1ef7a862ed8	2022-03-03 12:30:00	-5	10	200	✓
62dc8034-bb30-4e2e-ba61-b1ef7a862ed8	2022-03-03 12:35:00	-5	10	200	✓
62dc8034-bb30-4e2e-ba61-b1ef7a862ed8	2022-03-03 12:40:00	-5	10	200	✓
996e7f13-53a2-476c-b086-2552aa668106	2022-03-03 12:45:00	-5	10	200	✓
996e7f13-53a2-476c-b086-2552aa668106	2022-03-03 12:55:00	-5	10	200	✓
058ff3b2-8911-4e8c-a8bf-a9584d91d3d3	2022-03-03 13:05:00	5	15	190	✓
e4bcbce6-74f5-4406-8fd6-eb7fd409a205	2022-03-03 13:30:00	5	15	190	✓
e4bcbce6-74f5-4406-8fd6-eb7fd409a205	2022-03-03 13:35:00	5	15	190	✓
686285ab-4b03-4d3b-9fa8-676c3ef06537	2022-03-03 13:45:00	5	15	190	✓
686285ab-4b03-4d3b-9fa8-676c3ef06537	2022-03-03 13:50:00	5	15	190	✓
ad979b26-9f43-4227-909c-d959adc05470					X
ad979b26-9f43-4227-909c-d959adc05470					X
ad979b26-9f43-4227-909c-d959adc05470					X

Presentation of the market results from each FlexEnergy Bid

FlexEnergy Bid pre-processing and merge tool

- FEB pre-processing and merge tool is responsible for performing the quality check of FEB.
- Valid FEBs are merged into a single file that is the input of Optimisation platform. The merged XML file is created and uploaded in the respective folder of the sftp server in the ELES environment to be further processed by the FlexEnergy Market Optimisation Platform (RTE).
- The quality check is made in order to check that FEB XML file is compliant to the agreed XSD schema.
- Additional control for checking the consistency of some relevant information provided in the XML file is performed. For example the consistency with the network data like the GridNode ID and the GridArea.
- Number of filtered bids is the KPI responsible for counting the number of valid bids relative to the initial submitted bids. From the beginning of the experimentation about 3030 FEBs files were submitted and only few FEBs were discarded.

$$KPI = \frac{\text{Number of valid bids}}{\text{Number of submitted bids}_i} = 0{,}99$$

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Electricity Network-for-Market software package

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- Software demonstration platform for real time assessment of available cross-zonal capabilities for energy exchanges - **Electricity Network-for-Market software package (EN4M)**
- EN4M software package is a standalone platform for real time preparation of network data and automatic creation of merged network model and lists of constraints (critical branches/critical outages) used within the Optimisation platform (FlexEnergy market optimization platform).
- OSMOSE WP6 solution for the FlexEnergy Market converged towards one-step calculation and usage of the network capacities on nodal network representation, without differing between internal and cross-zonal limitations.

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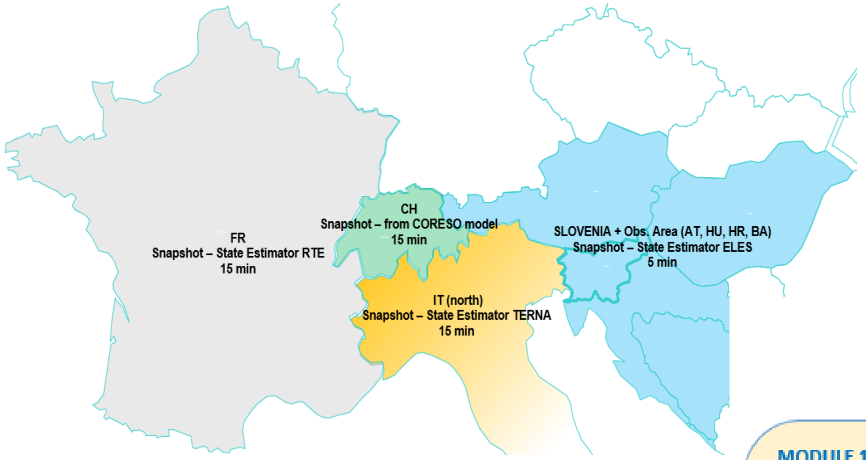
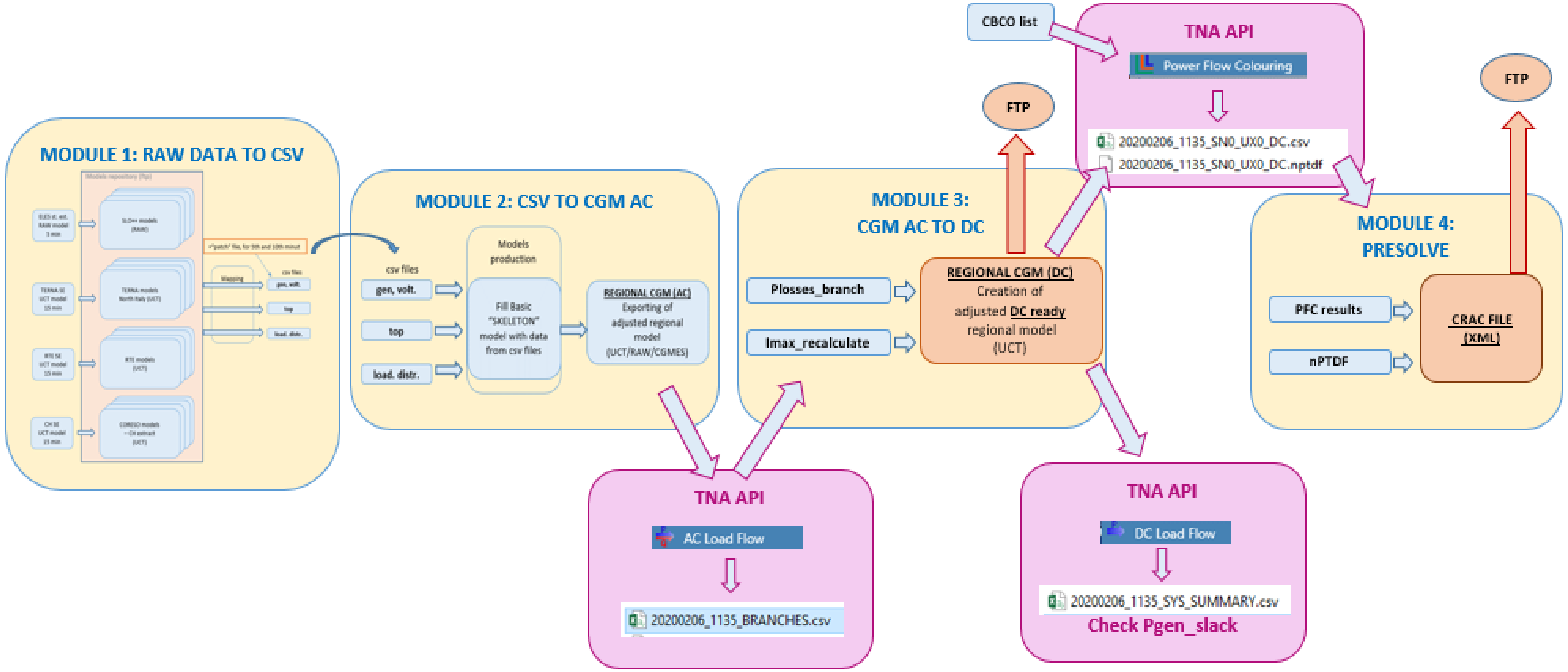
Preparation of the network model

(1) Collection and preparation of raw network data from snapshot models provided from state estimators of each TSO and creation of generation, load, topology, shunt and exchange data files.



(2) Creation of the regional Common Grid Model (CGM) using basic snapshot model (initially merged and successfully validated: snapshot of SI, AT, HU, HR, BA, IT, FR, CH, with boundaries and ties), applying variable data among timestamps from prepared data files (active and reactive power injections, voltage set points, topology statuses, transformers tap positions, net positions) and exporting it in UCTE, RAW or CGMES format.

(3) The Final AC load flow CGM is adjusted to be DC-ready model, by converting active power losses to the injections at the sending end of the branches, and adjusting Imax of branches for the influence of reactive power flows. It is exported in UCTE, RAW or CGMES format.



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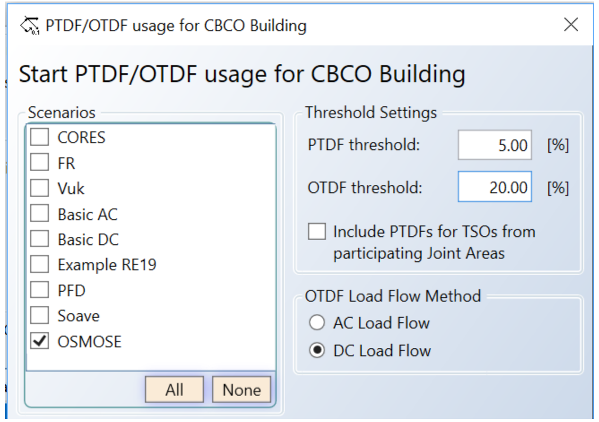
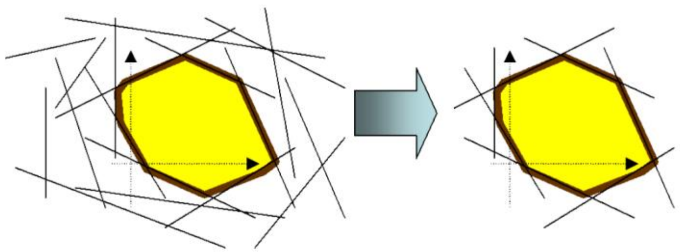
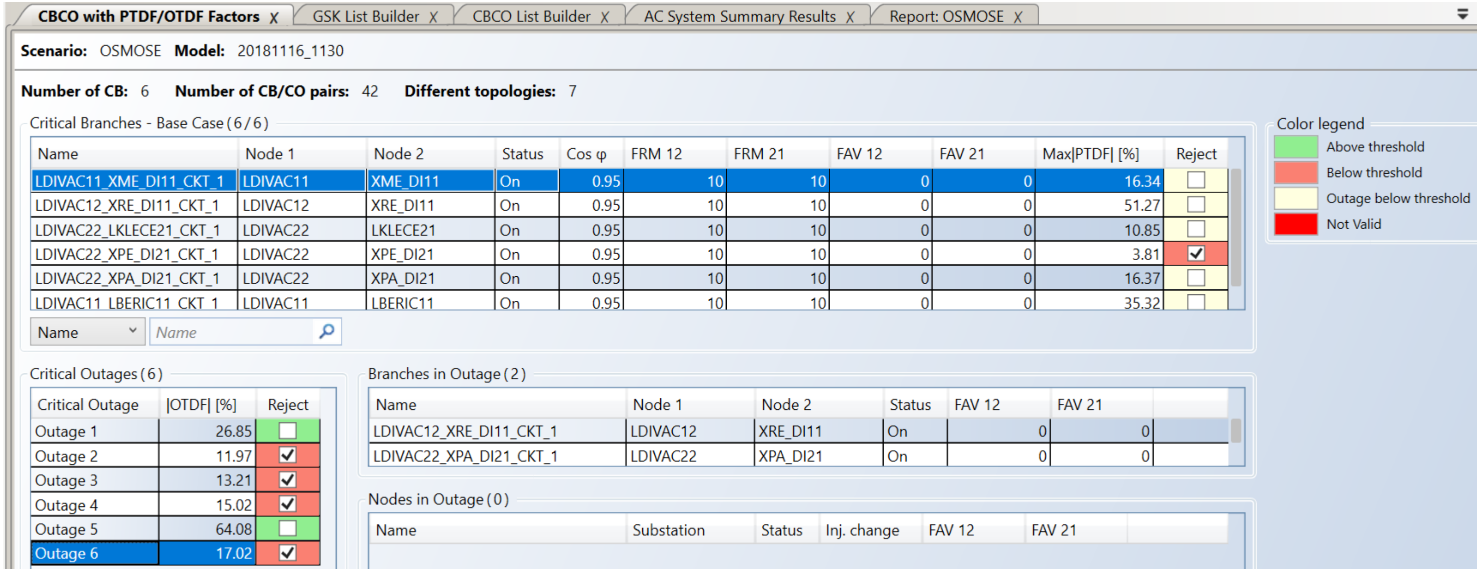
Preparation of the list of constraints

- Last module of EN4M tool deals with the preparation of list of **Critical Branches (CB) /Critical Outages (CO)** pairs, as constraints for the FEM optimisation.
- Initial CB/CO list is created using EN4M function and filtered considering relative thresholds of nodal **Power Transmission Distribution Factor PTDF** (for CB) and Outage Transfer Distribution Factor OTDF (for CO).
- CB/CO list is further filtered through EN4M Presolve function, leaving only non-redundant and potentially limiting CB/COs.
- The algorithm shortlist constraints: from **4200** lines & **4200** buses to **30** critical branches/critical outages pairs
- The final list is exported in CSE CRAC format.







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Optimisation of the bids

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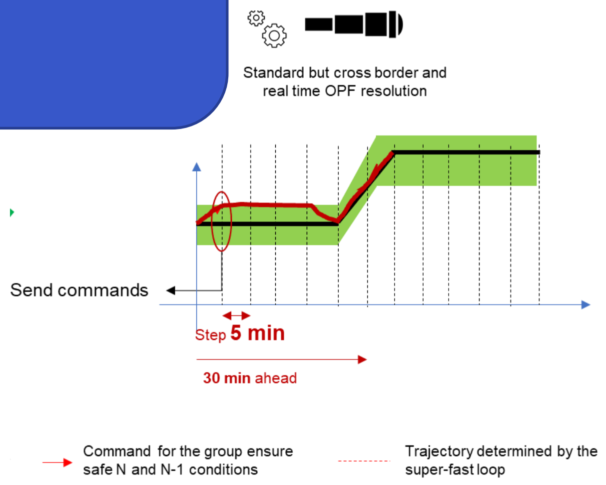
Producers bids

Merged Network file

Critical branches and outages

Security Constrained Optimal Power Flow taking into account N and N-1 limits

Selected bids



The algorithm to select bids ("OPT tool") takes into account the possible grid constraints in N and N-1 in the near future through an innovative security constrained Optimal Power Flow (OPF) using a Model Predictive Control (MPC) to simulate the future states of the grid.

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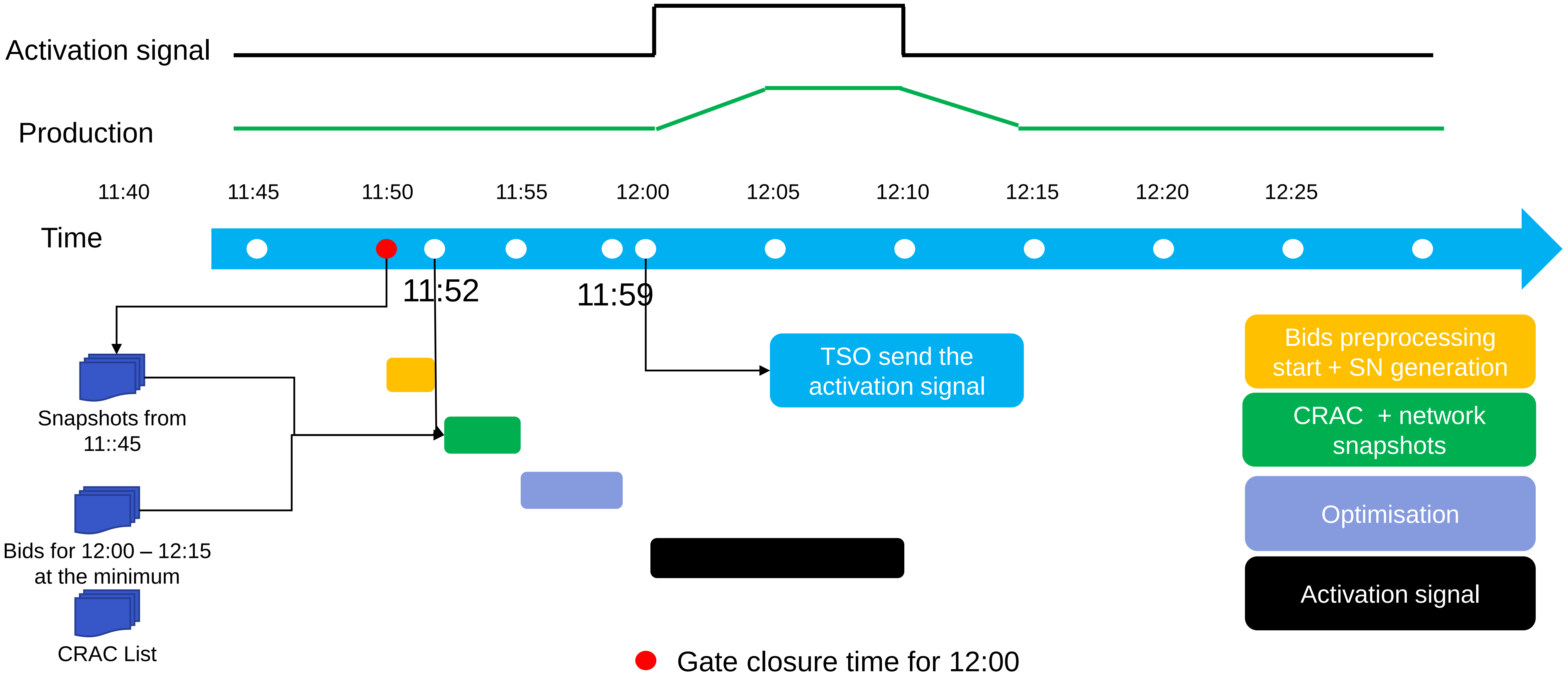
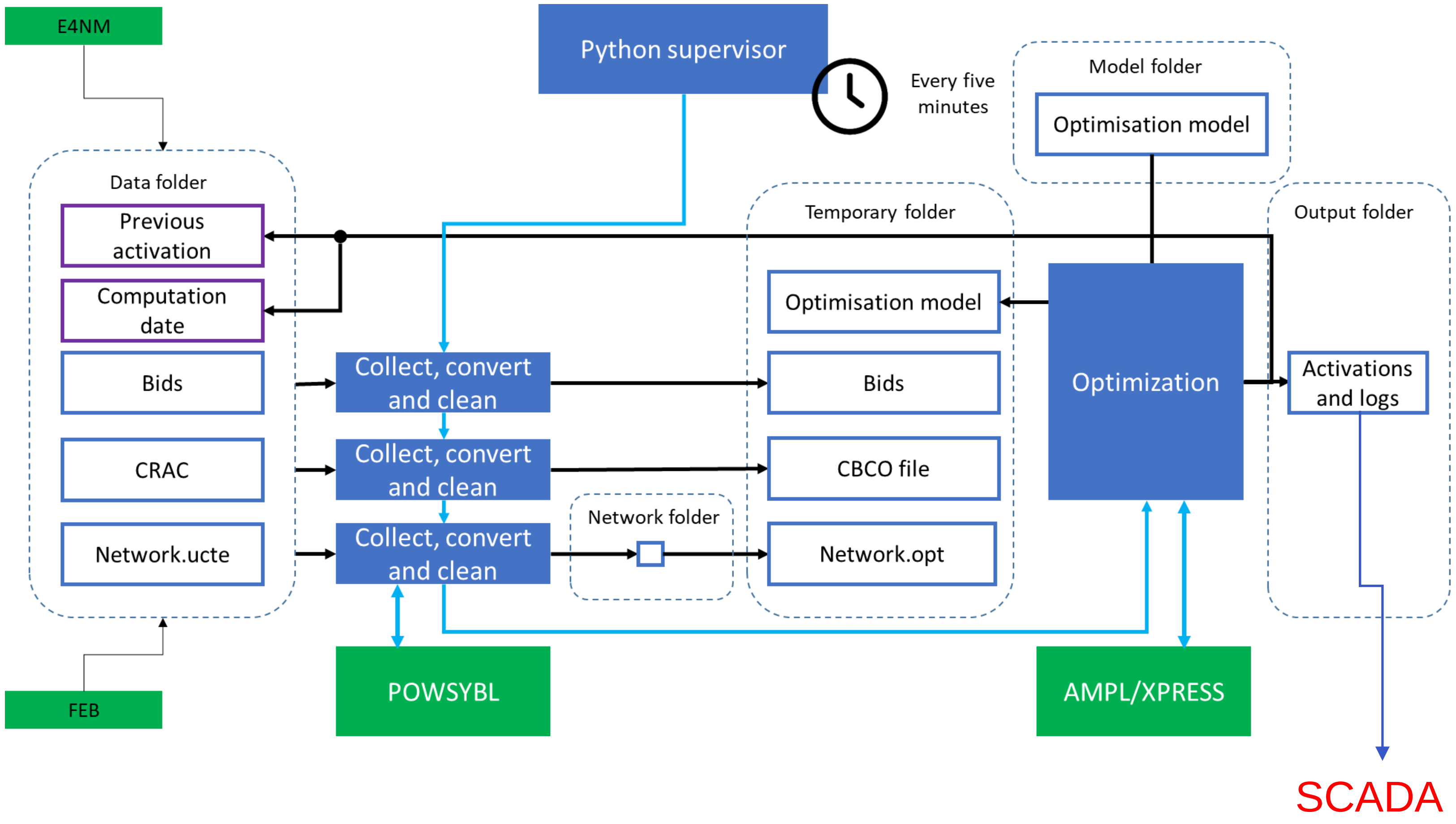
Process description



CRAC : File containing the Critical Branches and remedial actions

Software components



The software is composed of several components :

- Open source library ***powsybl*** for dealing with network snapshots in uct.
- AMPL language to model the probem
- XPRESS for solving the problem
- Python code as *glue code* to deal with data manipulation

Optimal power flow on multiple time steps

Hypothesis

Direct current approximation:

Voltage angle

$$F^s_{ij}[k] = \frac{\theta^s_i[k] - \theta^s_j[k]}{X^s_{ij}}$$

Flow

Reactance

Problem

Volume of bids

MIN $$J_{gen}\left(\Delta \mathbf{P}^{gen}[k]\right) = \sum_{t=1}^{N} \sum_{n \in \mathcal{N}} \Delta P^{gen}_n[k+t] * c^{gen}_n$$

On all time steps in the horizon

Whatever the network states.

Cost of bids

S.C. $$\forall k \in \mathbb{N}, \forall n \in \mathcal{N}^{gen} : \underline{\Delta P^{gen}_n} \leq \Delta P^{gen}_n[k] \leq \overline{\Delta P^{gen}_n}$$

Respect the max and min bid volume

$$\forall k \in \mathbb{N}, \forall s \in \mathcal{S}, \forall (i,j) \in \mathcal{N}^b : \underline{F^s_{ij}} \leq F^s_{ij}[k] \leq \overline{F^s_{ij}}$$

Respect the maximum flow

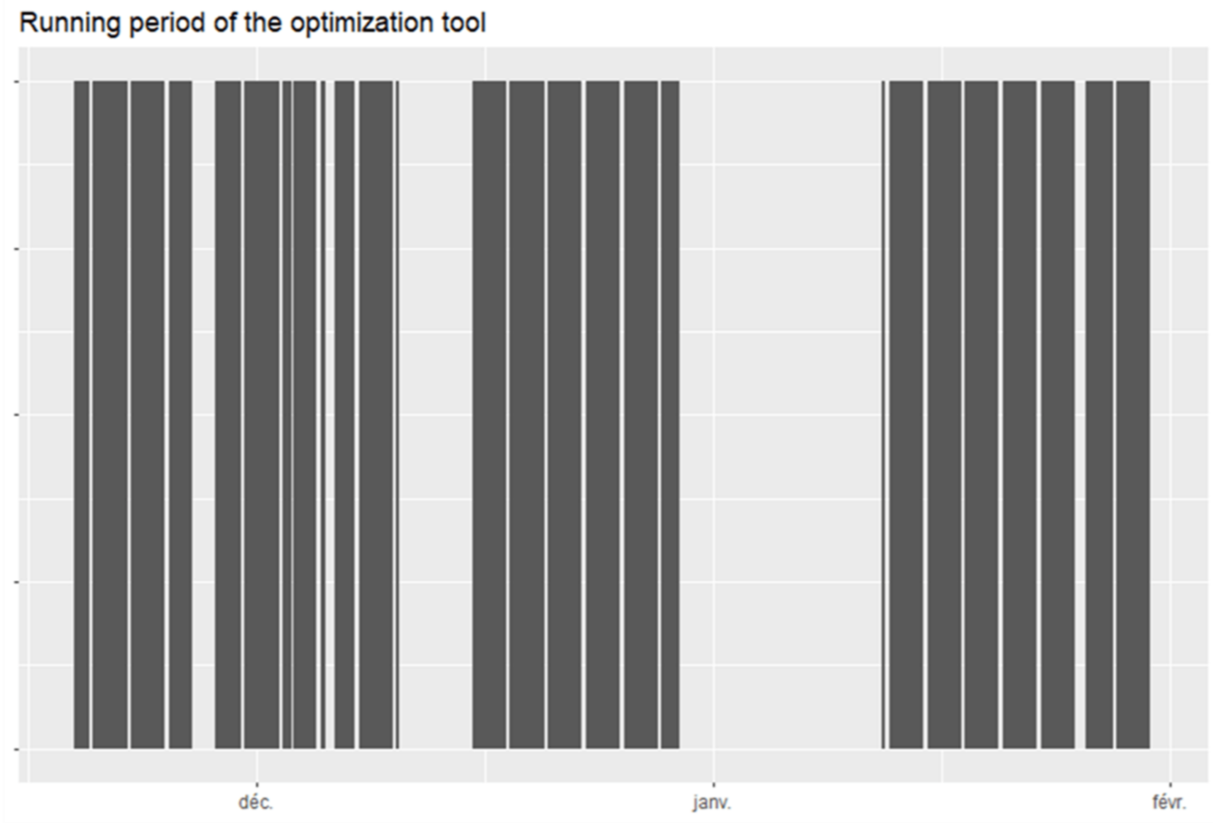
$$\forall k \in N, \forall n \in N^{gen} : Grad\_min^{gen}_n \leq \Delta P^{gen}_n[k] - Pprevious^{gen}_n \leq Grad\_max^{gen}_n$$

Respect the gradient

- We have modeled a standard Optimal Power Flow for the problem using the direct current approximation.
- This is a robust and well known approach.
- The main complexity is the size of the network.

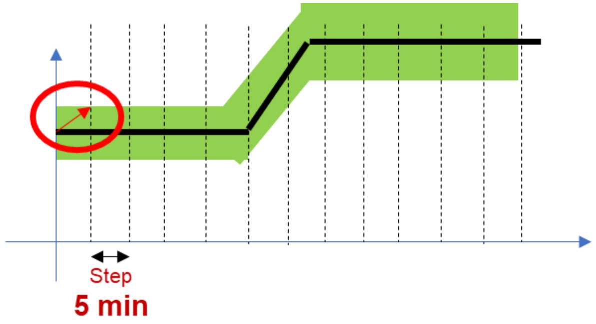
Optimisation tool perfomances

- Merging network data and identifying critical branches/outages took around 2min
- The optimization took most of the time less than 2 min down from 4 minutes in the first runs - mainly thanks to a higher quality Python code
- We managed to keep the whole process time within 5 minutes.
- Optimisation tool ran as expected as less than 2% of the instances failed, mainly due to data issue



Lessons learned

- Assess the most impacting constraints on the problem like the number of CB/CO
- Advice using PTDF rather that full network modelisation for our optimal power flow
- How to integrate an optimization tool in a IT production environment
- Time to transform a prototype in a pre-production tool



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How did we run the demo

- **Step 1** : Open loop tests directed to **input/output performance of platforms**. Platforms were first tested individually then simultaneously.

- **Step 2** : Closed loop tests directed to **tuning of platform parameters** under real system conditions – focused on overall stability of platforms, real time control tests on generator units.

- **Step 3** : Closed loop tests directed to business proof of concept :
  - For 1 month : **Simulating real business environment**, receiving bidding interest of players as made on market, identifying possible liquidity and real system environment challenges without activation
  - On pre-defined selected hours : **Real activation** of generation units

Real activation – closed loop test

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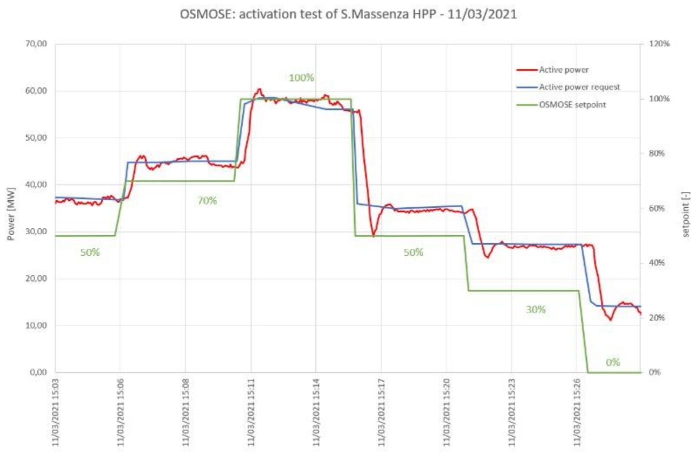
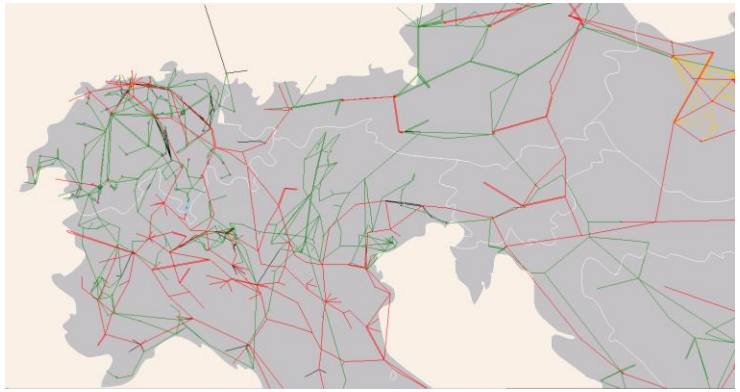
Optimisation and biding



→ Coordinated activation of 3 units
→ Two 5MW/5min and one 10MW/5min
→ Bids successfuly submited using FEB

✔ Otimisation and biding

Joint optimisation



→ Snapshots were provided by 2 TSOs
→ EN4M and OPT worked within time limits
→ OPT provided an activation list that was imported to SCADA
→ Activation signals sent to flexibility providers

✔ Optimisation and activation

Real activation – closed loop test

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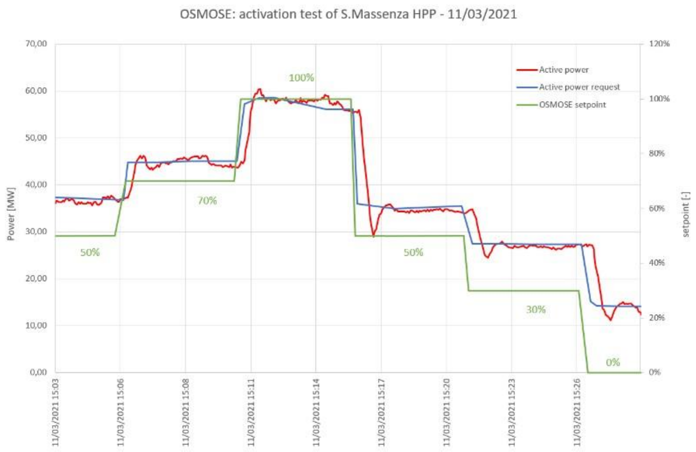
Activation of the units

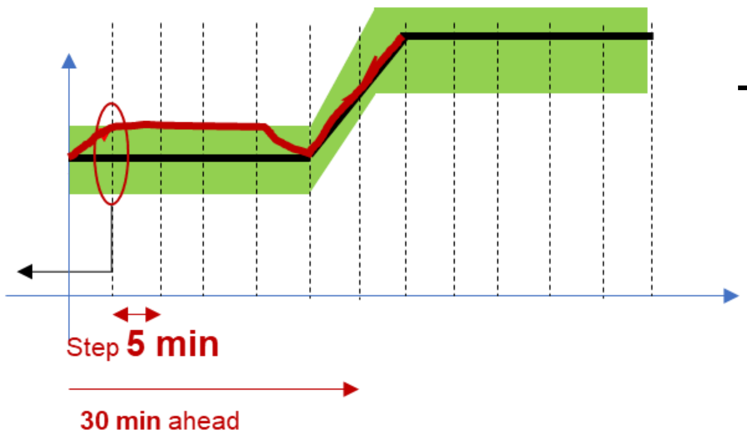


→ Activation signals received

→ Responded as expected

✔ Final activation

Network state monitoring



→ Operational results within boundaries

✔ Secure operation

Key take aways

- The economic potential for such a market is quite small today and then shouldn't be prioritized compared to other evolutions of power markets.

- However, the penetration of renewables capacities in power systems, leading to more uncertainty in real-time, may increase the economic value of those markets in the coming decades.

- Near-to-real time exchange of flexibility it is possible even in cases of commercial congestions when using near-to-real time grid snapshots and near-to-real time bidding.

- Proposed next steps for research or pilot:
  - Separate use of optimization tools (generation, network)
  - Adding DSO network and/or additional TSO data
  - Adding other real time inputs like dynamic line rating data
  - Using of optimization tools for better decision making – higher security of supply

Further reading

Public deliverables

- [D6.1] Mechanism design and specifications
- [D6.5] Demonstration tests
- [D6.6] Impact analysis of the performed field tests and exploitation

Publications

- M. Cosson, C. Payement, G. Azman and Z. Vujasinovic, "Close to real time controller performing energy exchanges under network constraints," *2020 IEEE PES Innovative Smart Grid Technologies Europe (ISGT-Europe)*, 2020, pp. 990-994, doi: 10.1109/ISGT-Europe47291.2020.9248980.

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Webinar Q&A – Demonstration of close-to-real-time cross border flexibility market

Gorazd Ažman, ELES: Gorazd.Azman@Eles.si

Andrea Bello, HDE: Andrea.Bello@hde.tn.it

Miran Kavrečić, HSE: Miran.Kavrecic@hse.si

Dusan Vlaisavljevic, EKC: dusan.vlaisavljevic@ekc-ltd.com

Marilena Lazzaro, ENG: marilena.lazzaro@eng.it

Charles Payement, RTE: charles.payement@rte-france.com

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