Balancing Programme Optimisation Stakeholder Focus Group

February 2024

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Agenda

14:00 Introduction & recap

14:10 Control room process overview

A quick overview of control room processes and relation to OBP.

14:20 Bulk Dispatch Optimiser

A quick recap of our November session – with a few updates.

14:40 OBP in production

Focus on high-cost clipping - what happened and how it was addressed.

Further development.

15:05 Fast Dispatch

Overview of the new control room tool.

15:15 AOB

15:30 Close

Optimisation Group Timeline & Feedback

June 2023 (online)
- Initial kick-off / group scope
- Bulk dispatch introduction

November 2023
(Balancing Programme engagement event, London – Optimisation session)
- Control processes structure
- Bulk dispatch optimiser details

February 2024 (online)
- BDO details (costs)
- Fast Dispatch

June 2023 - You asked for …

- Documentation
- Details on algorithms / logic
- Examples / demos [1]
- Application context

- Regular meetings
- More feedback / engagement opportunities [2]

- More on future challenges/problems
- How other SOs manage the system

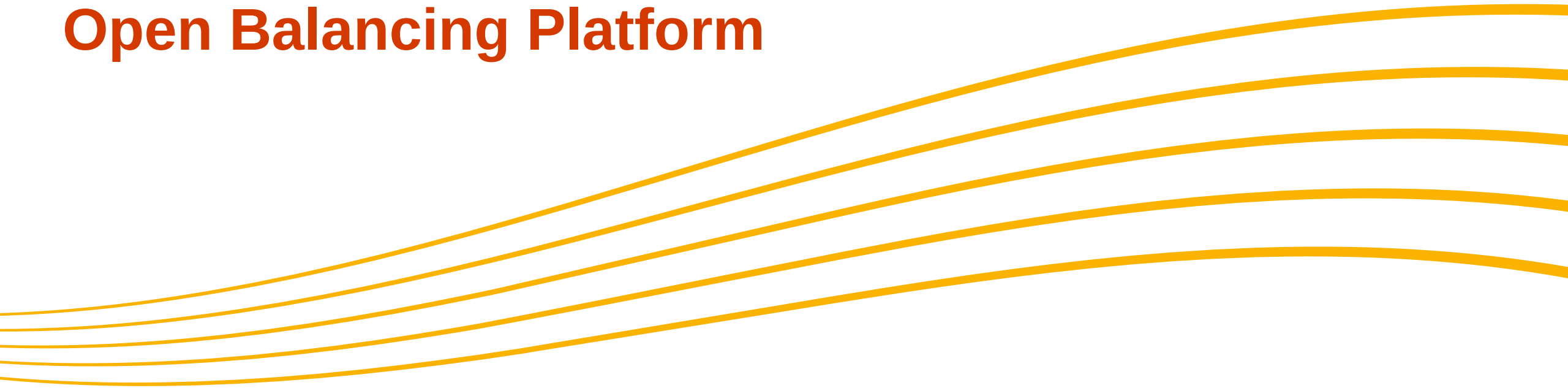
- OBP roadmap updates / version details [3]

November 2023 - You asked for …

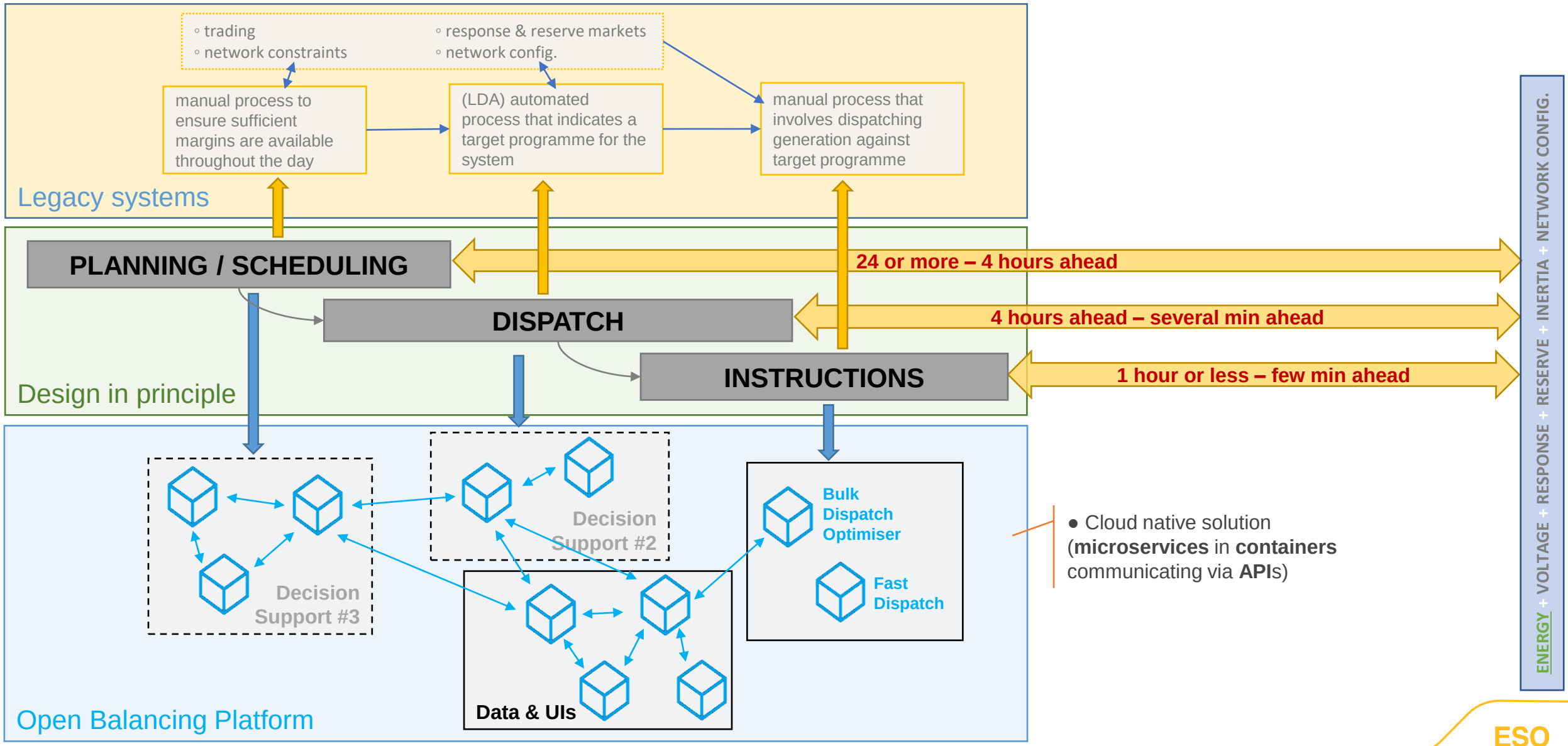
- Instruction algorithm
- Constraints
- Risk management in control
- Details on dispatch (LDA)

Notes:
[1] Separate OBP demo session at event – PI9 Demo & OBP demo
[2] See slide 26 of this presentation
[3] OBP roadmap presented at November 2023 Balancing Programme event; additional update will be provided during March 24 Balancing Programme webinar.

Control Structure & the Open Balancing Platform



Context



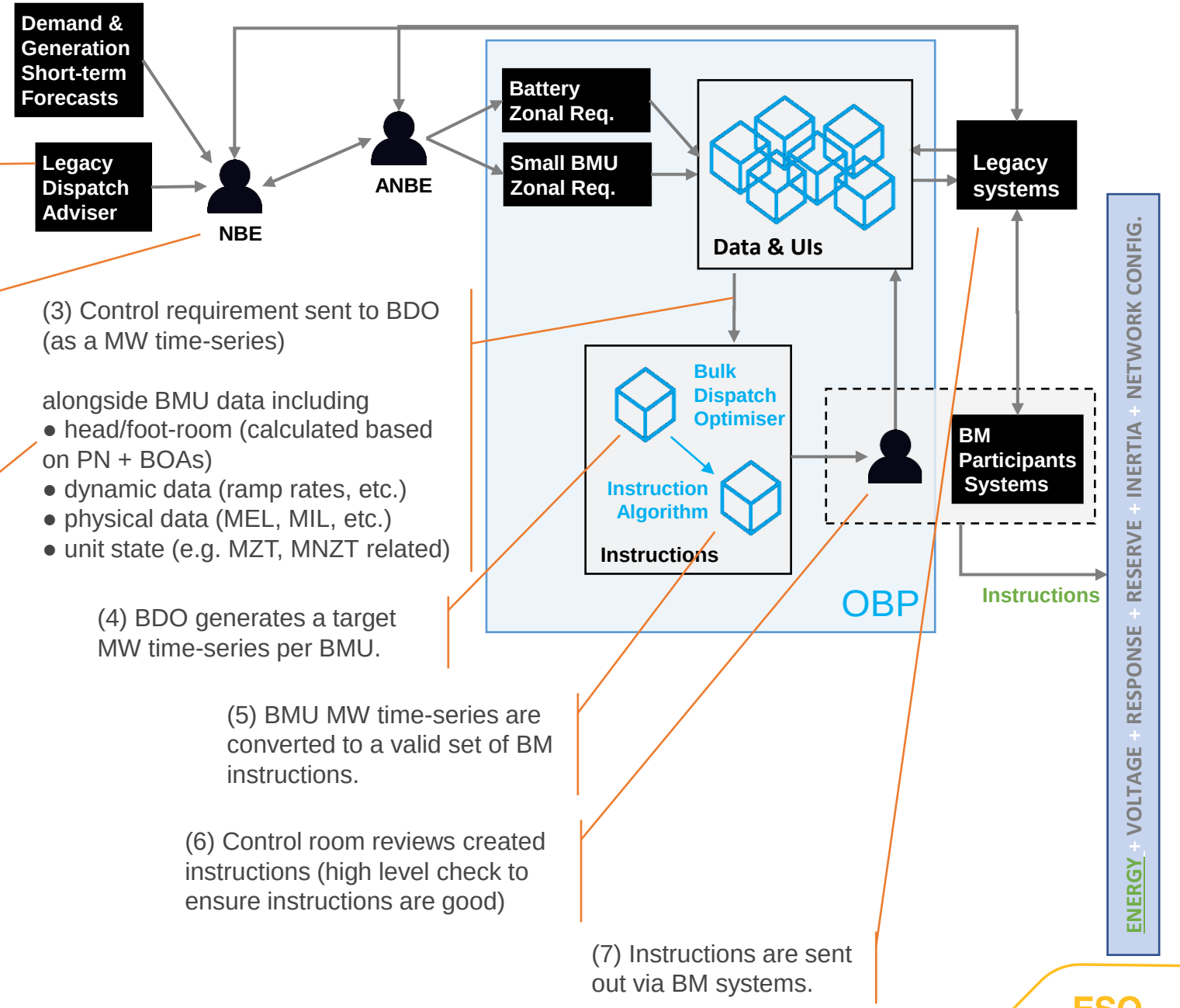
- Cloud native solution (**microservices** in **containers** communicating via **APIs**)

BDO workflow

(1) Dispatch software calculates a target energy profile for the system and per zone

(2) Control room engineers review system state and manage risk
→ then derive power requirement by zone

Head/foot-room is affected by the exceptions logic.



(3) Control requirement sent to BDO (as a MW time-series)

alongside BMU data including
- head/foot-room (calculated based on PN + BOAs)
- dynamic data (ramp rates, etc.)
- physical data (MEL, MIL, etc.)
- unit state (e.g. MZT, MNZT related)

(4) BDO generates a target MW time-series per BMU.

(5) BMU MW time-series are converted to a valid set of BM instructions.

(6) Control room reviews created instructions (high level check to ensure instructions are good)

(7) Instructions are sent out via BM systems.

Points of interest

- The combination of advice from LDA, forecasts, risk management approach (following a least regret logic) defines volumes required at each step

- Split of required volume among zones may also have an impact (this is not yet an automated process)

Bulk Dispatch Optimiser (BDO) Recap

About BDO

Key function:

- Creating target profiles for each BMU, subsequently used in the creation of BOAs
- This is cast as a Mixed Integer Linear Programming cost-minimisation problem

We refer to moving the unit from its scheduled position as **(re)dispatch**

Modelling considerations:

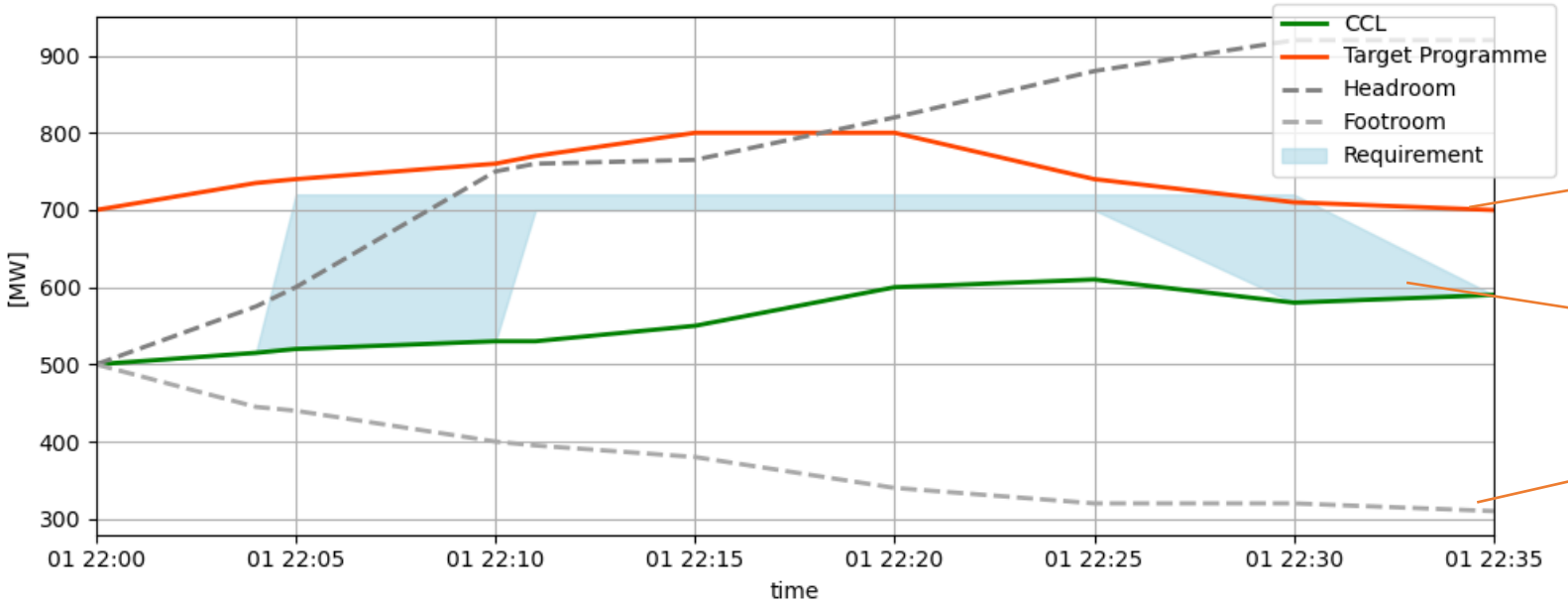
- Control room requirement & BOA costs
- ramp-rates
- SEL/SIL (stable import/export limits) and MZT/MNZT (minimum zero/non-zero times)
- MFTT (minimum flat top time)
- energy available for duration-limited assets

BMU technical parameters limit what it can deliver – as such they are **constraints** in how it operates

In addition…

- BM data do not necessarily adhere to submitted BMU parameters – constraints are applied only when we redispatch
- Dispatching under a “do not make worse principle” – even when we redispatch, we do so in a way that is no worse than what the BM data suggest

Control requirement



(1) Target programme is derived from preceding decision support tools

(2) Requirement volume and shape defined by the control room engineers (defined as a band as meeting an exact profile is more likely to lead to uneconomic decisions)

(3) Limits defined by available BOD and BMU technical limitations

… generation requirement

$$R_t^{DN} \leq \Sigma P_{u,t} \leq R_t^{UP}$$

Constraints are in practice "relaxed" to ensure we get a solution independently of actual availability.

BMU Power total

Upper Requirement Bound

… cost minimisation

$$min\{\sum cost_{u,t}\}$$

$$P_{u,t} = CL_{u,t} + \Delta P_{u,t}$$

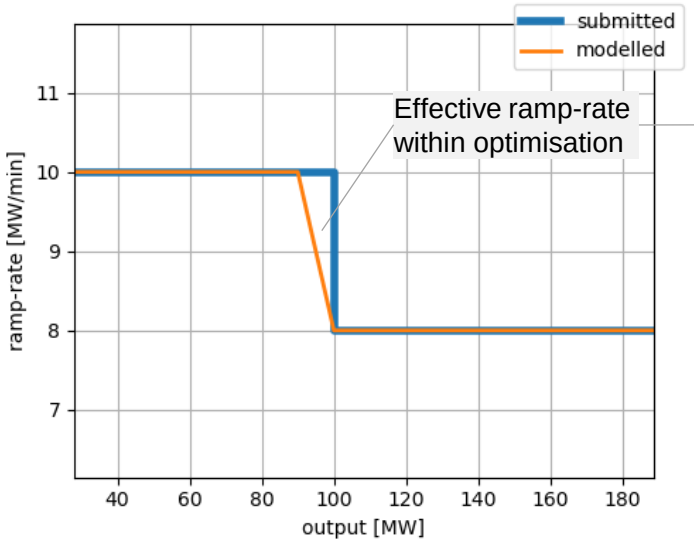
$$cost_{u,t} = f(\Delta P_t)$$

Cost is defined based on BOD, PN and BOAs.

Points of interest

- Difference between bounds defines how fast ramping is required
- Duration of requirement will impact which units will be selected based on their state and relevant parameters (e.g. MZT, MNZT)

Ramp rates



… ramp rates model

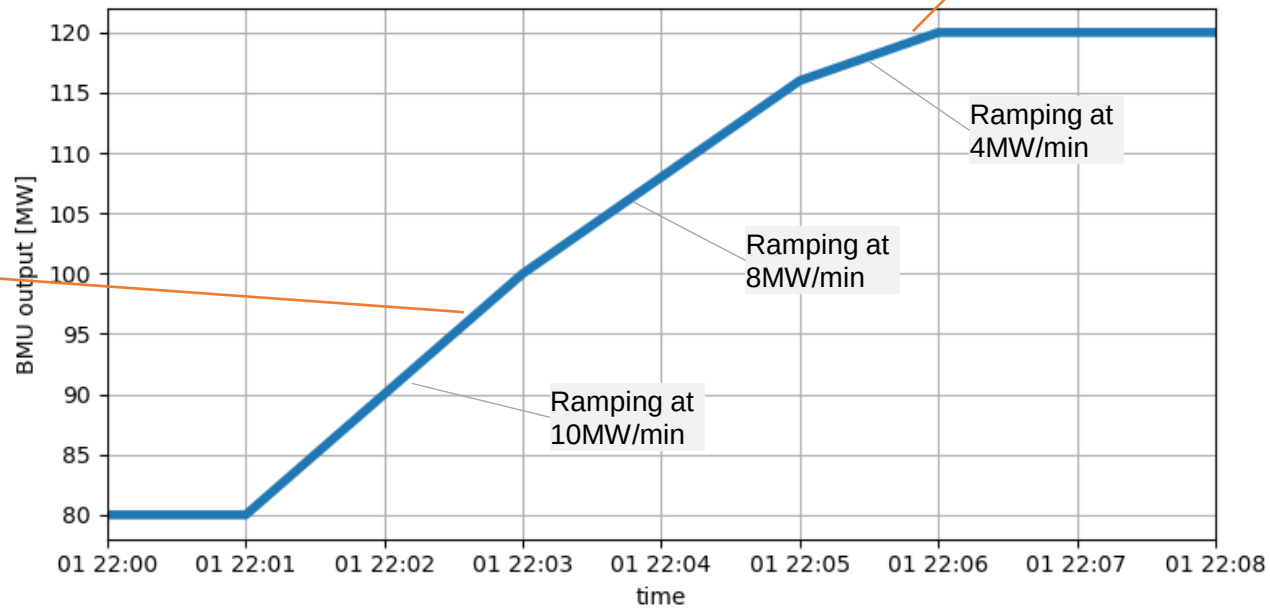
$$P_{u,t+1} - P_{u,t} \leq RUR_{u,t}(P_{u,t})$$

$$P_{u,t+1} - P_{u,t} \geq RUR_{u,t}(P_{u,t}) - M \cdot u^*$$

Most of the time ramp-rate is forced to maximum.

… but we relax this constraint to allow for slower ramping at the last time-step

(2) We still relax the constraints to allow BMU to reach any possible output level



(1) BMUs generally dispatched at maximum rates
… this is to account for conventional BMUs which cannot do any ramp-rate
… and aligns with existing control room practices to dispatch as close to real-time to avoid unwinding

Points of interest

- BOD and ramp-rates, alongside requirement largely determine dispatched units.
- Max. ramp rates requirement constrains the solution.

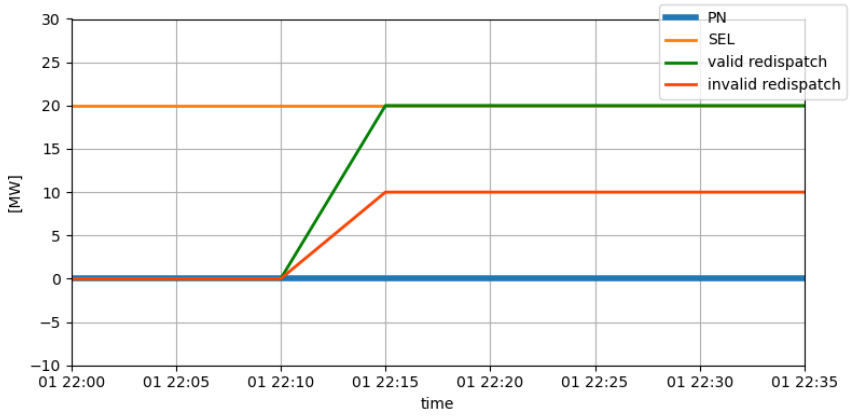
SEL/SIL & MZT/MNZT

… SEL/SIL

$$P_{t+1} \geq (r_t^U - r_{t+1}^U) \cdot SEL + M \cdot u^*$$
$$P_{t+1} \geq (r_t^D - r_{t+1}^D) \cdot SEL + M \cdot u^*$$

If BMU is not ramping… it should be above SEL.

e.g. SIL limits are not relevant if BMU is
- not re-dispatched
- not in the export region (SIL applies otherwise)



… MZT, MNZT

$$\sum_t^{t+MZT} x_i^{exp} \leq M\left(1 - x_t^{exp} + x_{t+1}^{exp}\right)$$

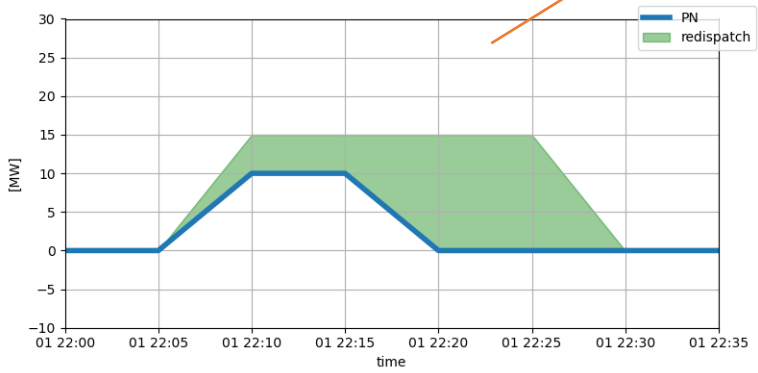
If unit has been in export region in the last MZT minutes…

… then BMU cannot switch state to export

$$\sum_t^{t+MNZT} \zeta_t \leq M(1 - \zeta_t + \zeta_{t+1} + \cdots)$$

Similar to the above (with some added terms)

(1) For bidirectional assets we assume that
… if an asset leaves the import/export region it cannot go back into it unless MZT time has expired.
… if an asset leaves its zero/off state, it has to remain on for at least MNZT.



(2) *Do not make worse principle*
… MNZT appears to be 15min where its declared value is 40min, we will redispatch in such a way that the resulting NZT is no less than 15min.

Points of interest

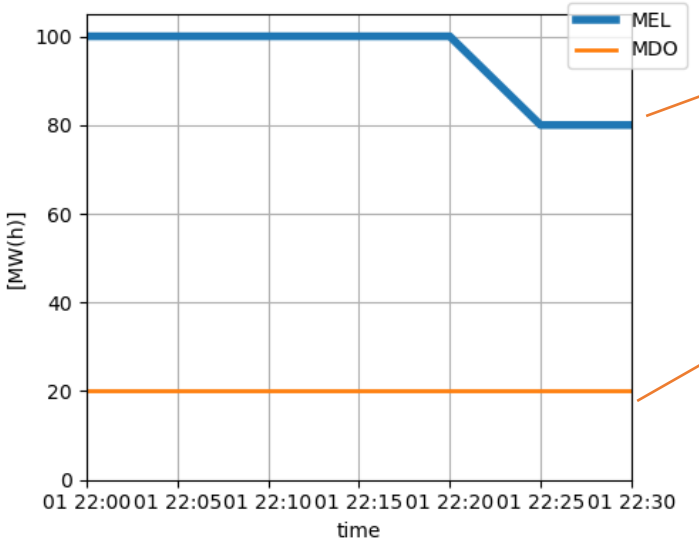
- **[SEL/SIL]** Restricts how much the unit can be moved, or can force a larger redispatch amount than actually needed. In cases where e.g. SEL is much larger than the amount of power required, a more expensive unit without a similar limitation could be part of the least-cost solution.
- **[SEL/SIL]** Any unit with an MNZT>2min is assumed to have a minimum SEL/SIL=1 (if unit is switched on, it is dispatched to at least 1MW).
- **[SEL/SIL]** BMUs that are syncing / de-syncing at the start of the optimisation window are not re-dispatched until the sync / de-sync event is completed.
- **[MZT/MNZT]** State of BMU before and after optimisation horizon, can impact whether the unit is re-dispatched. BDO will not change the state of the unit outside the horizon.
- **[MZT/MNZT]** We are currently reviewing how BMUs with MZTs/MNZTs longer than the optimisation horizon should be scheduled.

Utilisation (Energy) & MFTT

… duration-limited BMUs utilisation

$$\frac{1}{60}\Sigma P_{u,t}^{OFFER} \leq MDO$$

$$\frac{1}{60}\Sigma P_{u,t}^{BID} \leq MDB$$



(1) We use the closest to 0 value for the optimisation period as a reference for volume calculation.

(2) BMU assumed available (or as indicated by MEL/MIL or other parameters) during the whole optimisation window

Points of interest

- Asset will be dispatched at any time over optimisation window, at any combination of power and energy allowed by constraints.
- Note that optimisation horizon affects asset utilisation.
- **[MFTT]** These ensure that larger BMUs are dispatched for an acceptable duration of time. Fast/flexible BMUs may be dispatched out of merit-order for very short duration requirements.
- **[MFTT]** Allows controlling the structure of response control expects for a smoother / stable outcome. Currently for e.g. batteries this is set to 1min.

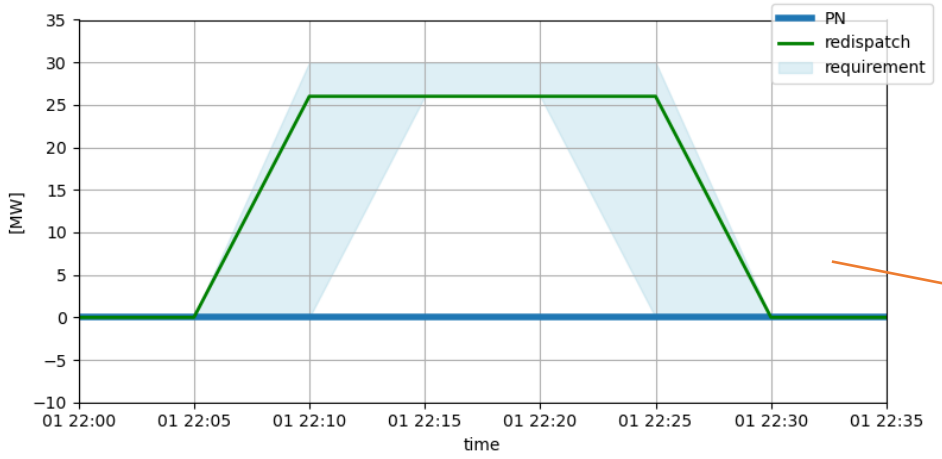
… MFTT

$$\sum_{t}^{t+MFTT} y_t^U \leq M \cdot (y_t^U - y_{t+1}^U)$$

$$\sum_{t}^{t+MFTT} y_t^D \leq M \cdot (y_t^D - y_{t+1}^D)$$

If there is a ramping event in the last MFTT minutes…

… then BMU cannot ramp in the following minute.

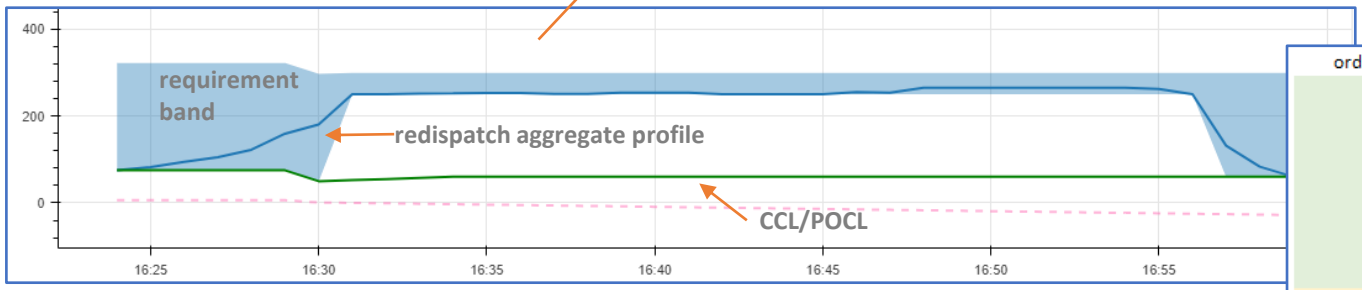


Assuming this asset had an MFTT of 15min, it is dispatched for at least as long.

An indicative example

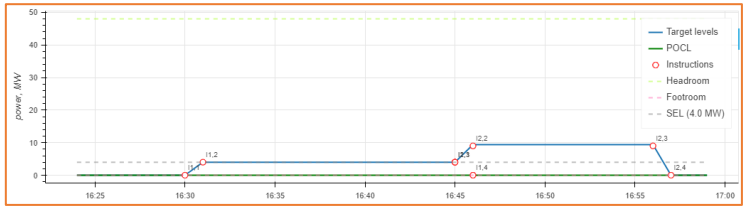
(1) Requirement of about 190MW over 30min

(2) Merit order of units at a random minute (this can vary even within settlement period based on CCL)



order	offer price	redispatched
1	**80.0 £/MWh**	●●●
2	**85.0 £/MWh**	●●●
3	**90.0 £/MWh**	●●
4	**95.0 £/MWh**	●●
5	**100.0 £/MWh**	●●●
6	**125.0 £/MWh**	●●●
7	**130.0 £/MWh**	●
8	132.52 £/MWh	MNZT
9	133.9 £/MWh	SEL/RR
10	**133.9 £/MWh**	●
11	**134.0 £/MWh**	●
12	**134.0 £/MWh**	●
13	**134.0 £/MWh**	●
14	136.66 £/MWh	MNZT
15	137.0 £/MWh	SEL/RR
16	137.0 £/MWh	SEL/RR
17	137.0 £/MWh	SEL/RR
18	137.0 £/MWh	SEL/RR
19	**138.0 £/MWh**	●
20	**138.0 £/MWh**	●
21	139.29 £/MWh	MNZT
22	140.0 £/MWh	SEL/RR
23	**140.0 £/MWh**	●
24	141.0 £/MWh	SEL/RR
25	141.0 £/MWh	TB
26	141.0 £/MWh	MNZT
27	141.0 £/MWh	TB
28	141.0 £/MWh	SEL/RR
29	141.0 £/MWh	SEL/RR
30	141.0 £/MWh	MNZT
31	141.0 £/MWh	TB
32	**141.0 £/MWh**	●
33	141.0 £/MWh	
34	141.0 £/MWh	

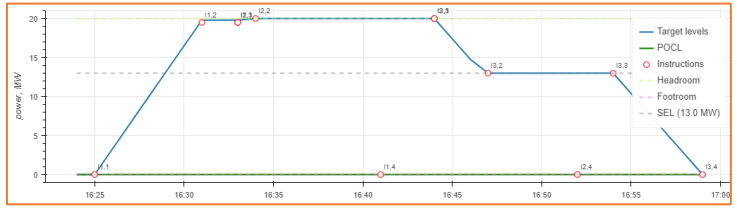
(3) Some units were not included in the solution due to long MNZT values relevant to the requirement



(4) Some units were dispatched out of merit order but in a common pattern – at SEL initially (due to their 30min MNZT) and for their last MFTT minutes at no more than their ramp down rate

(5) Some units were not used relative to others at same cost due to their tie-breaking rank for the day

(6) Units that had a high SEL relative to their ramp down rate were not part of the solution



(7) Some of the cheaper units were ramped down to account for the technical constraints of more expensive units

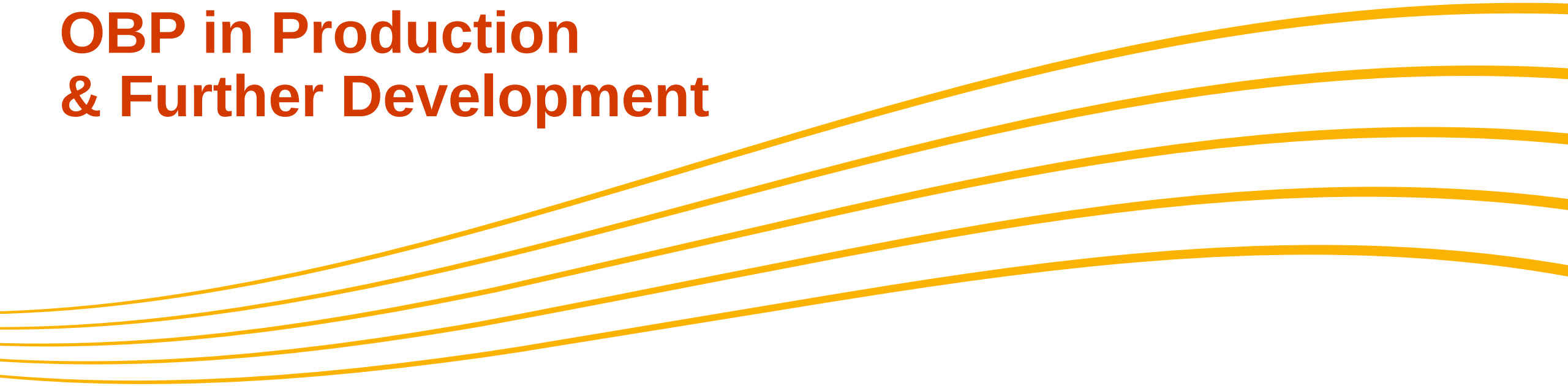
Points of interest

- Reasons for dispatching a unit out of merit order are not always obvious, even in cases where
  … there are no system actions (constraints) involved.
  … and the full data behind the case are available.

- We are working towards standardising and in the future automating all relevant processes.

- Based on internal reviews of production logs, the majority of volume is dispatched in merit.
  We are working with the control room to refine processes around BDO.

OBP in Production
& Further Development



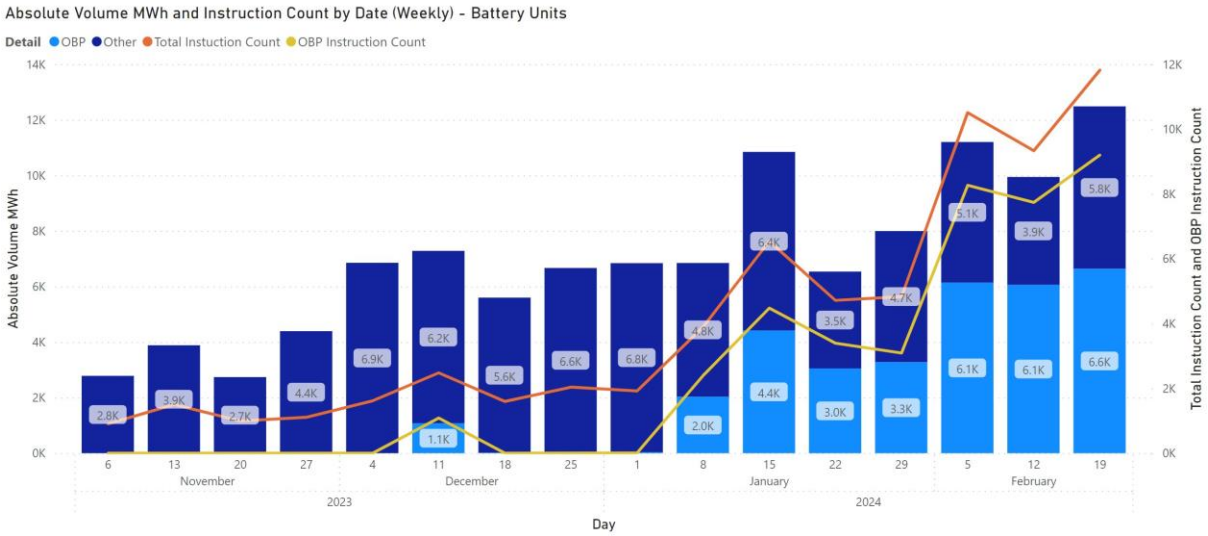
OBP in production

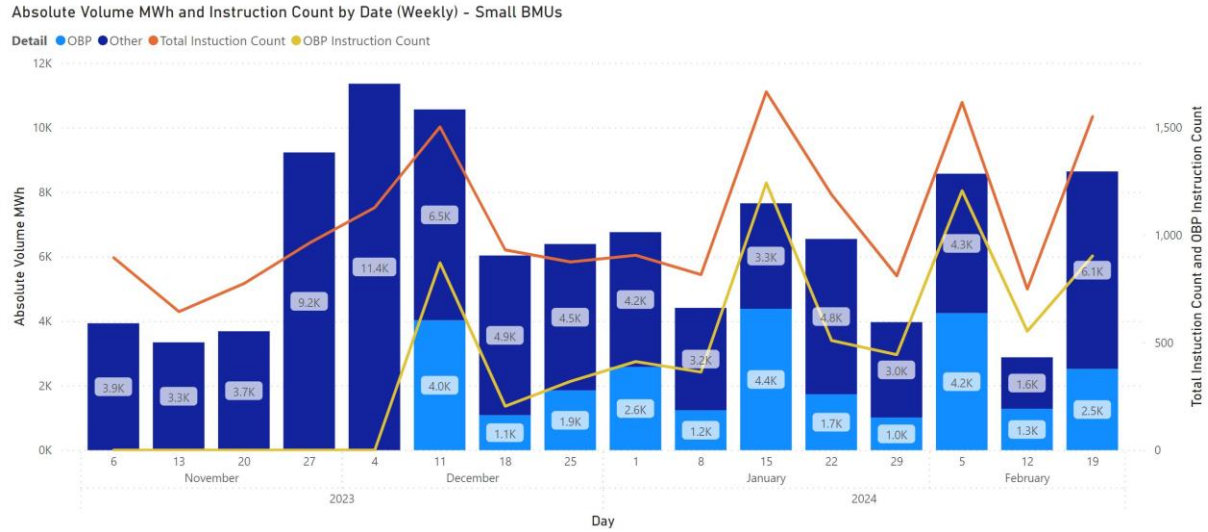
Batteries

- OBP has been used continuously for Batteries since 8 Jan 2024
- In this period there was been a steady rise in the number of instructions and volume sent to Batteries

Small BMUs

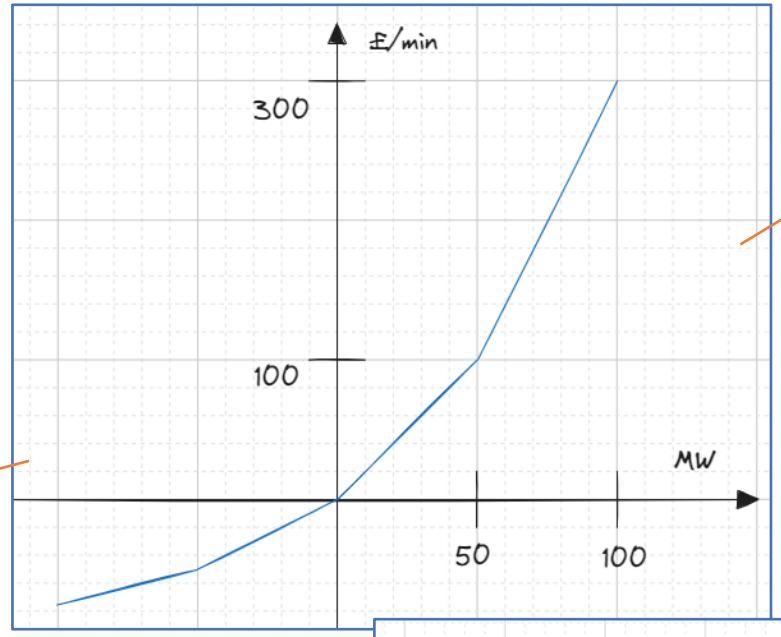
- OBP has been used continuously for Small BMUs since 12 Dec 2023
- During this period there have been many days of high wind and warmer than usual days – as a result Small BMUs have not always been in merit
- Due to this, the number of instructions and volume has stayed relatively unchanged for Small BMUs, but it can be observed that OBP is issuing a larger proportion of these instructions





Cost curves

To MW	Offer £/MWh	Bid £/MWh
50	240	
50	120	
-50		60
-50		6

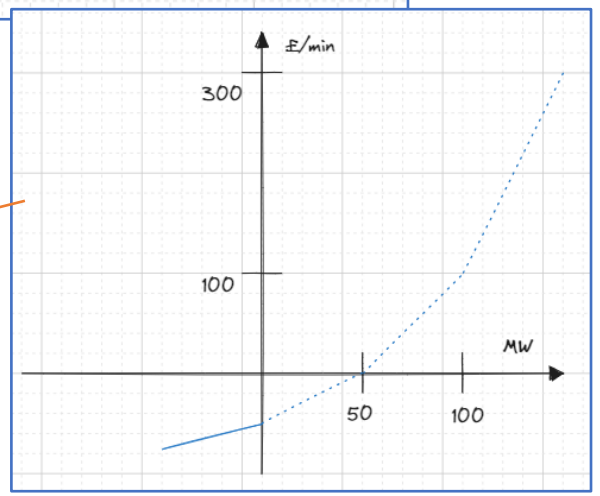


(1) Bid/offer data (BOD) are converted to cost curves (can be modelled efficiently via simple linear constraints)

(3) We are tie-breaking BMUs with equal prices
- Prices are perturbed by a small amount, based on a predefined ordered BMU list.
- That list is randomly generated each day (this is to enable stability of solution over consecutive settlement periods, while ensuring fairness)
- Tie-breaking is only relevant if the MW requirement is such that it could be covered from multiple BMUs all at the same price.

(2) Curves are adjusted if we are aware that BMU PN does not reflect is actual output

For example if a BMU redeclared its MEL 50MW below its PN it would have no headroom, and (in principle) a zero volume redispatch (relative to what the BMU currently does) immediately incurs a cost.

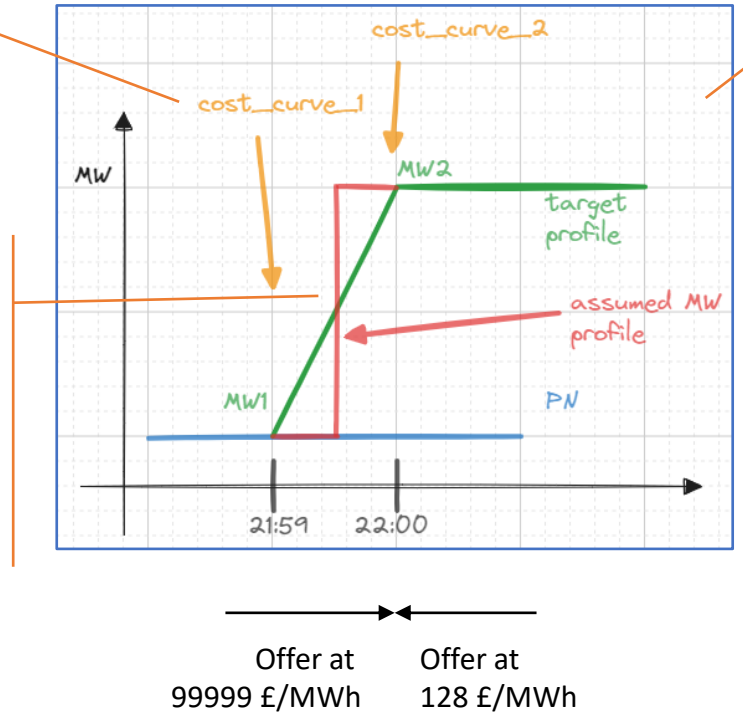


What happens in a minute…

(1) Each timestamp has a cost curve that indicates the cost of "moving" the unit from its CL at the given point in time.

(2) We are approximating costs within the minute – i.e. MW1 for 30'', MW2 for another 30''.

Estimate is exact provided unit does not cross bands when ramping.



(3) Cost curve at 22:00 should reflect costs of preceding half-minute period (with BOD applying from 21:30) plus costs of following half-minute period (with BOD applying from 22:00)

Issue#1 (December release)
Cost curve at 22:00 was effectively calculated only on BOD applying from 22:00.

The error was passed through to microservices that should have flagged a high price warning to users.

Note that compared to volume/numbers of instructions issued, cases where this actually had an impact were rare. This defect was addressed on 8th January fix.

Issue#2 (identified in January)
Similar issues but specifically in cases where the unit did a MEL/MIL redeclaration, overlapping a previously accepted BOA.

Addressed on 6th February.

Issue#3 (occurred in January)
Control room requested high volumes that went into high-cost price range. OBP worked as expected, but existing price warnings were not adequate.

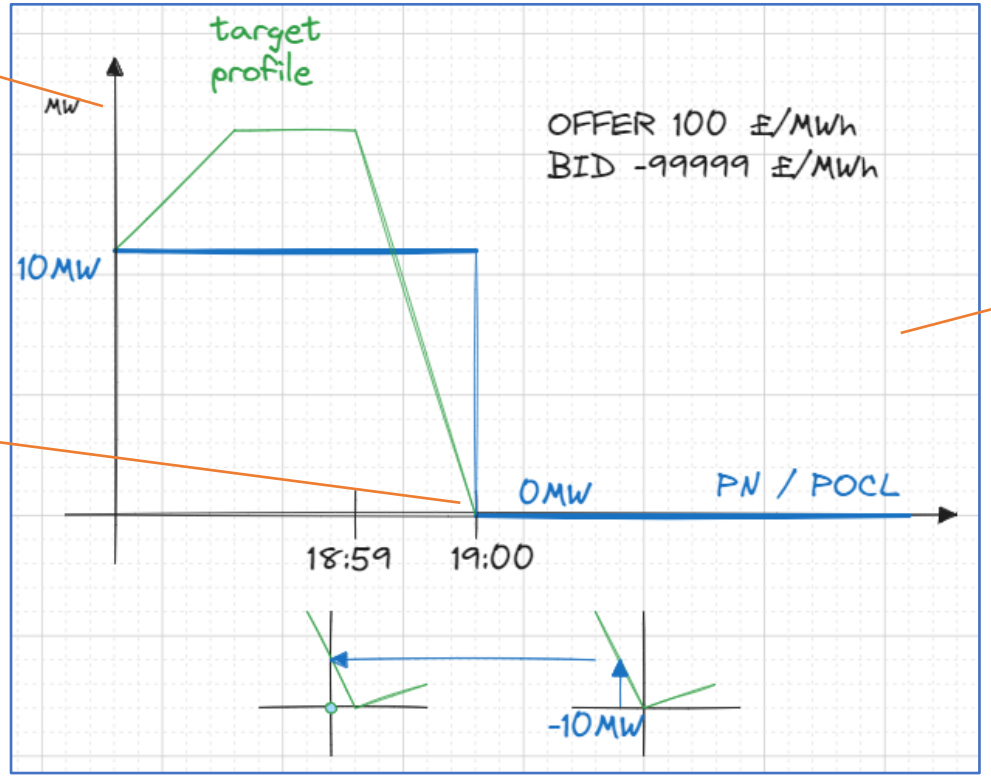
Addressed on 6th February, via improving warning messages to control.

Cases currently being resolved

(1) More complicated cases involve step changes in PN or other associated data.

(2) BDO optimises against the latest (0 MW) value at 19:00.

BOA cost at 19:00 is a combination of two different cost curves – note that “dispatching” at 0 MW at 19:00 incurs a bid cost for -10MW for 30’’.



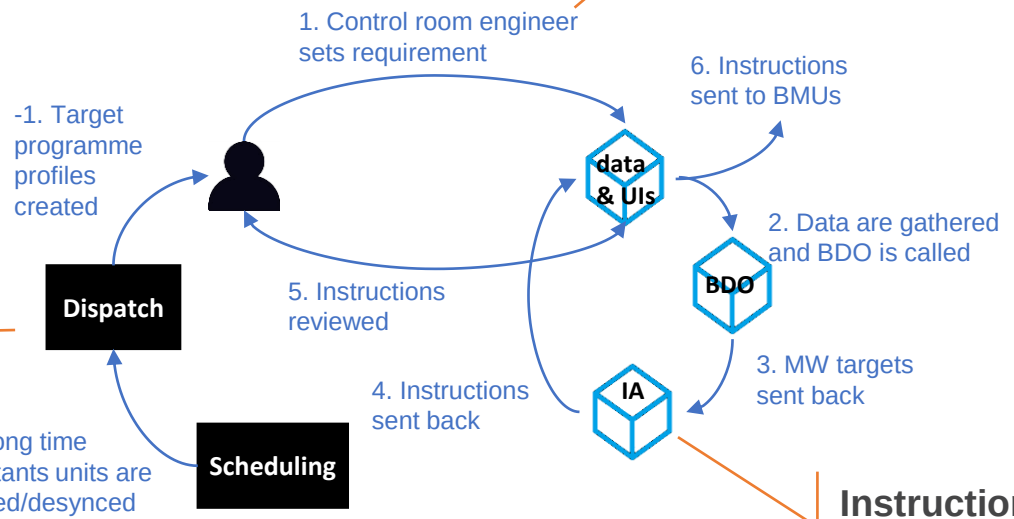
- **Issue#4 (identified early February)**
Updating data pipelines and associated calculations, to account for step-changes.

Improvements considered going forward

Requirement
- standardising further the requirement given target programmes

BDO
- improving performance to enable longer runs – to account for long MZT/MNZT or limited (but long) duration assets
- … or co-optimisation of zones

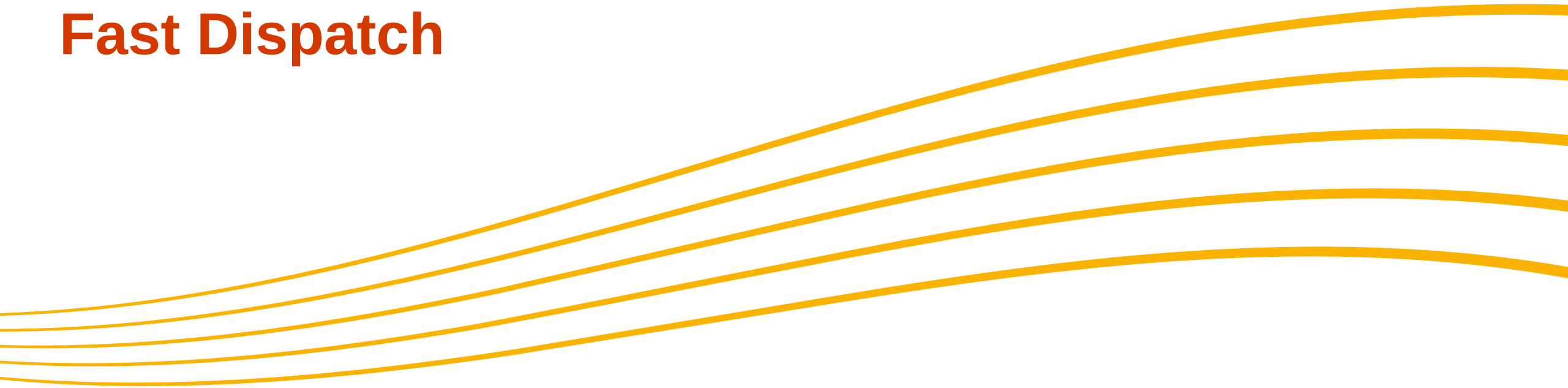
Dispatch / Scheduling
- early stages proof-of-concept
- framework for managing of duration-limited-assets over longer time-frames



Instruction Algorithm
- 6% of currently created instructions are voided due to current BM rounding rules
- creating fewer instructions
- issuing only what is needed for longer periods

We are moving towards an automated, well defined, transparent solution (with hopefully no room for skips).

Fast Dispatch



About Fast Dispatch

Key function:

- provide capability to control to dispatch fast
- to be used in cases where immediate corrections to frequency are required

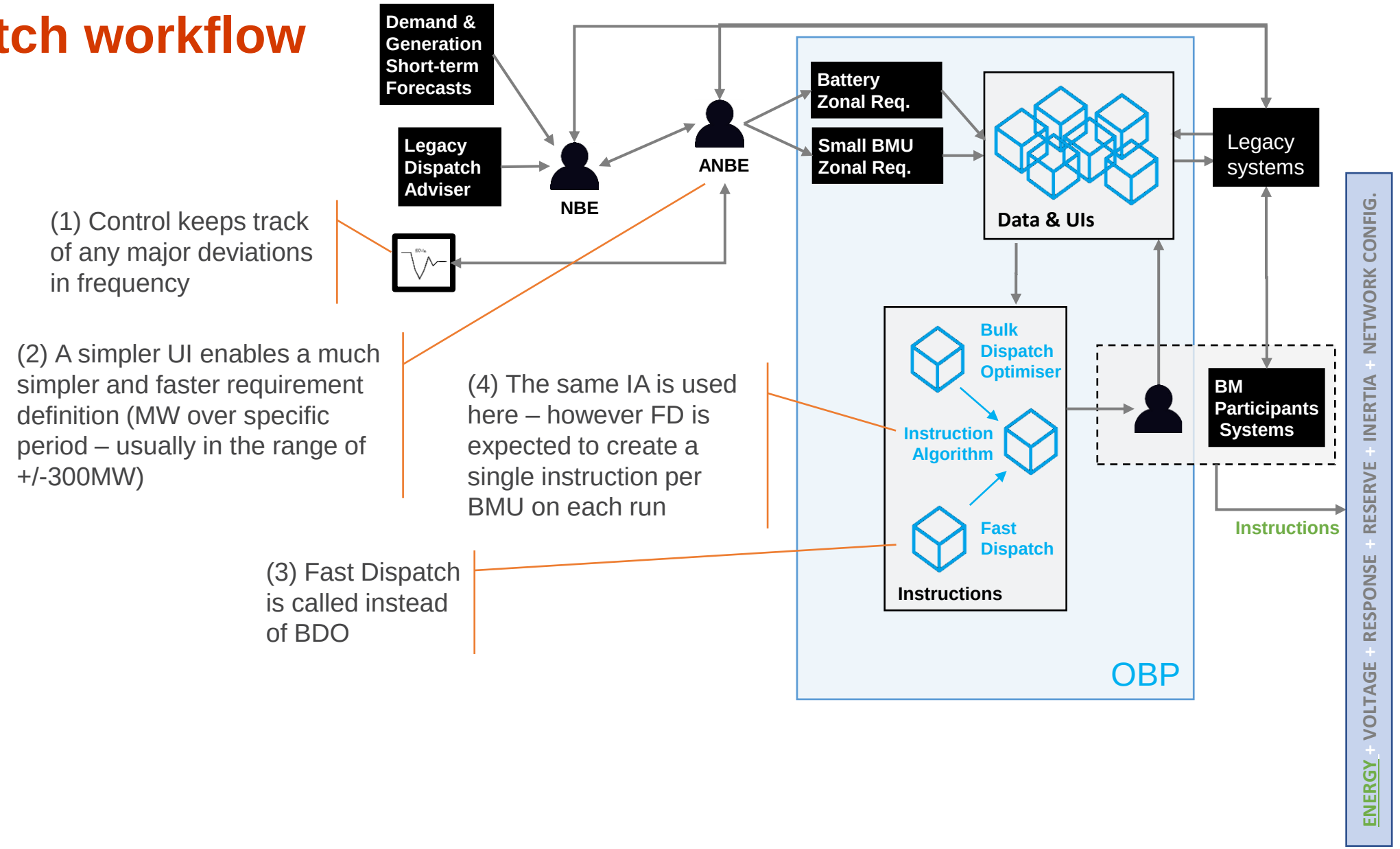
Compared to BDO:

- BDO is designed to produce a solution within about 60sec
- FD is expected to produce a solution in <10sec
- FD runs close to real-time as possible
- FD currently ramps units within a minute
- FD requirement duration is limited to <10min

Points of interest

- Long NTO/Bs may not be dispatched at all
- Units may be dispatched to their ramp-rate rather than their full capacity.
- Long MZT/MNZTs might not be dispatched unless units already on, or their sync/desync can be delayed or be brought forward.

Fast Dispatch workflow



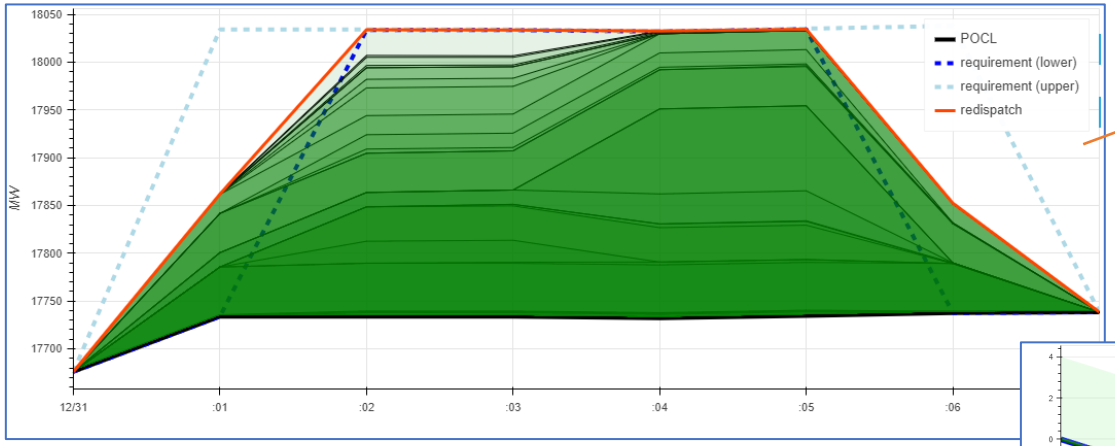
(1) Control keeps track of any major deviations in frequency

(2) A simpler UI enables a much simpler and faster requirement definition (MW over specific period – usually in the range of +/-300MW)

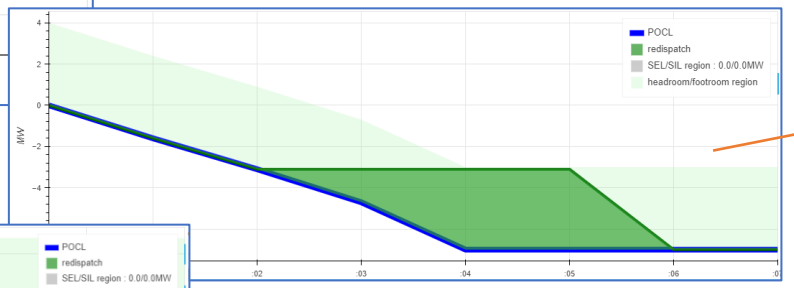
(3) Fast Dispatch is called instead of BDO

(4) The same IA is used here – however FD is expected to create a single instruction per BMU on each run

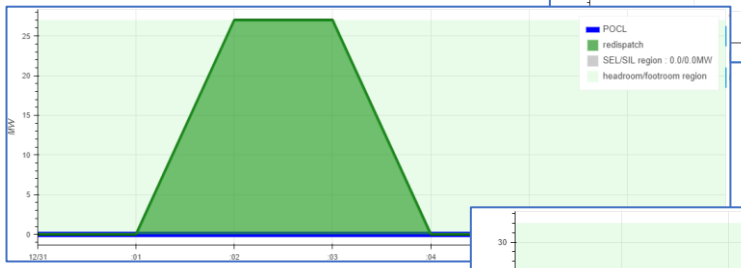
An indicative example

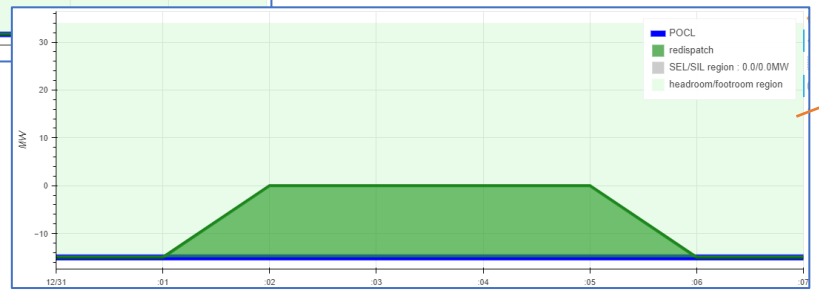


(1) Requirement duration and ramp-time is quite restricted, as close to real-time as possible.



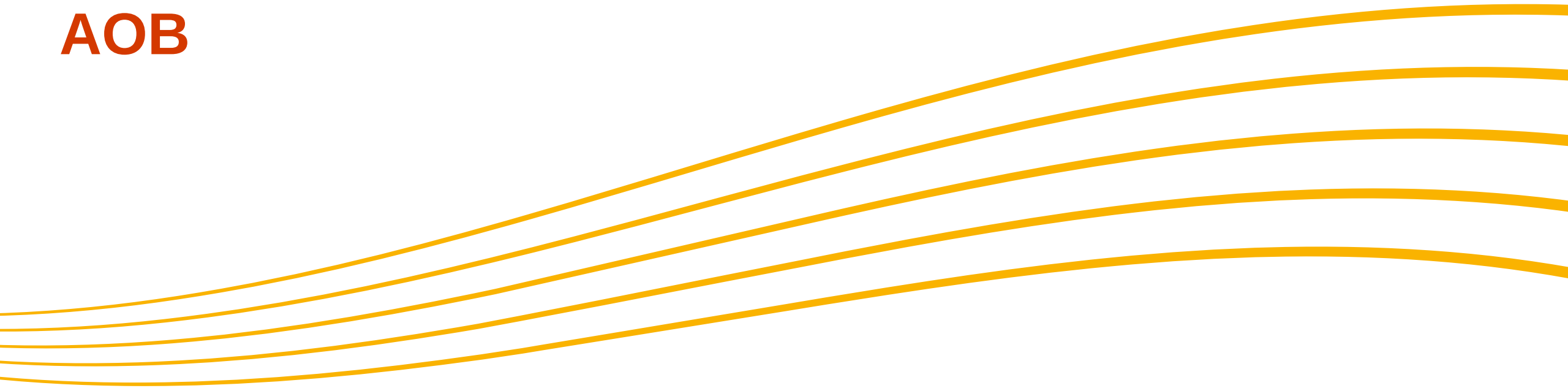
(2) Units may not be dispatched to their full capacity – we are looking for simple (one-off) instructions.





(3) Units would be restricted by their ramp-rates

AOB



Next steps

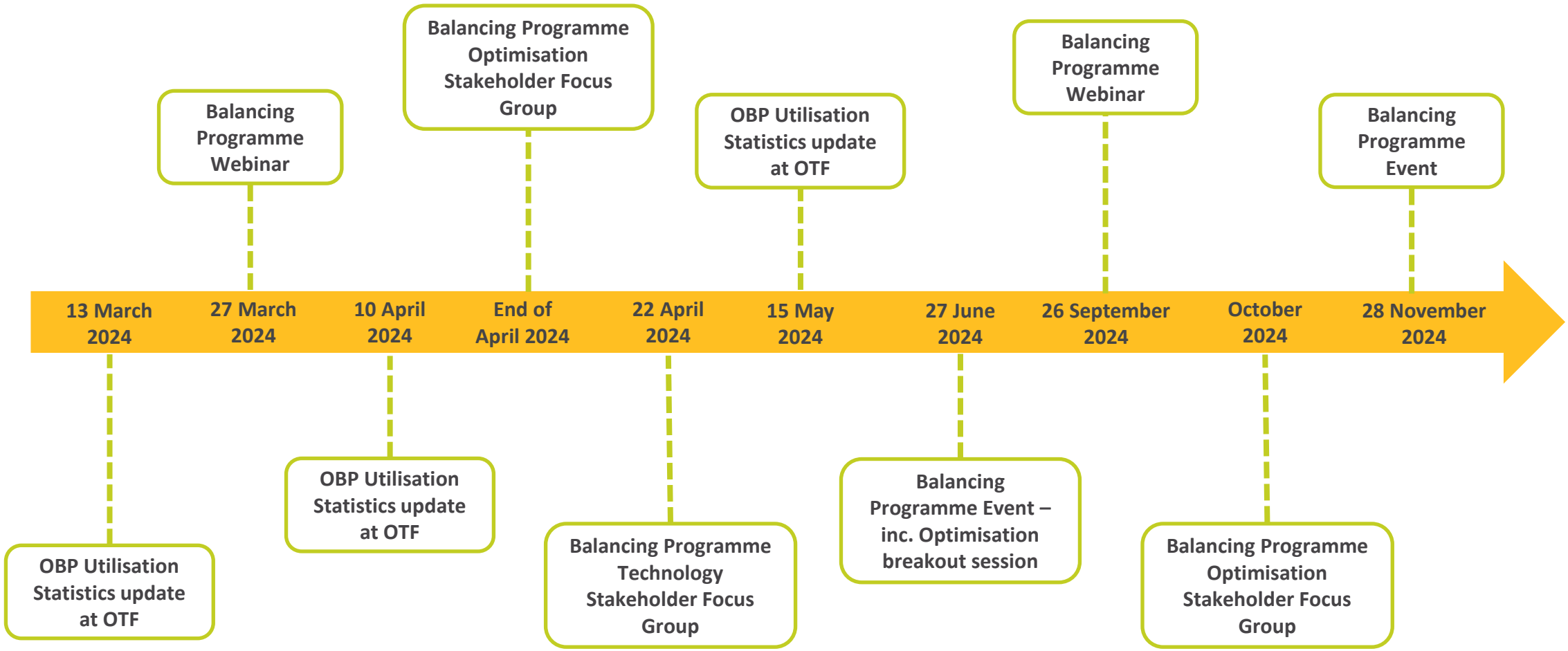
We welcome your feedback – please get in touch via the email address below

Slides from today's session will be published on our website, along with the webinar recording

You can reach out to the Balancing Programme team via email – **box.balancingprogramme@nationalgrideso.com**

Sign up to the Balancing Programme Newsletter for more regular updates - **Get the latest from ESO - Balancing Programme (nationalgrid.co.uk)**

Future engagement opportunities



*Please note that given the advance notice of these events, they may be subject to changes.

Thank you!

Useful terms & abbreviations

PN	Physical notification (MW)
BOA	Bid/offer accepted instruction
CL	Committed Level, that's equal to the BMU PN+BOA
POCL	Pre-optimisation CL :: this is equal to CL, apart from cases where we expect a BMU might not follow its CL – in which case it would be the unit's expected operating level (forecast)
SEL/SIL	Stable Export/Import Limits
MZT/MNZT	Minimum Zero/Non-Zero Time
MFTT	Minimum Flat Top Time :: time in minutes a unit is expected to stay at a flat level after it stops ramping as part of a BOA.