



GC0166 Work Group 2

7 March 2024

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Investigation

A simple battery model

Model should be simple enough to include in large scale problems, e.g.:

$$SOC_t = SOC_{t-1} + P_t^{IM} \cdot \eta - \frac{P_t^{EX}}{\eta}$$

With some additional constraints:

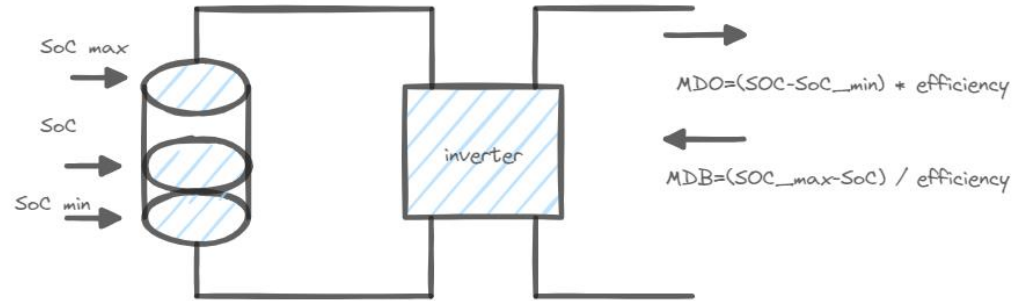
$$SOC_t^{MN} \leq SOC_t \leq SOC_t^{MX}$$

$$0 \leq P_t^{IM} \leq P^{MX}$$

$$0 \leq P_t^{EX} \leq P^{MX}$$

$$P_t^{EX} \cdot P_t^{IM} = 0$$

The time-varying limits in SOC may reflect commercial considerations (e.g. limitations due to future provision of a service).



One way to define MDO/B would then be

$$MDO_t = (SOC_t - SOC_t^{MN}) \cdot \eta$$

$$MDB_t = (SOC_t^{MX} - SOC_t) / \eta$$

So given battery limits, MDO/B and SOC can be equivalent.

Key points

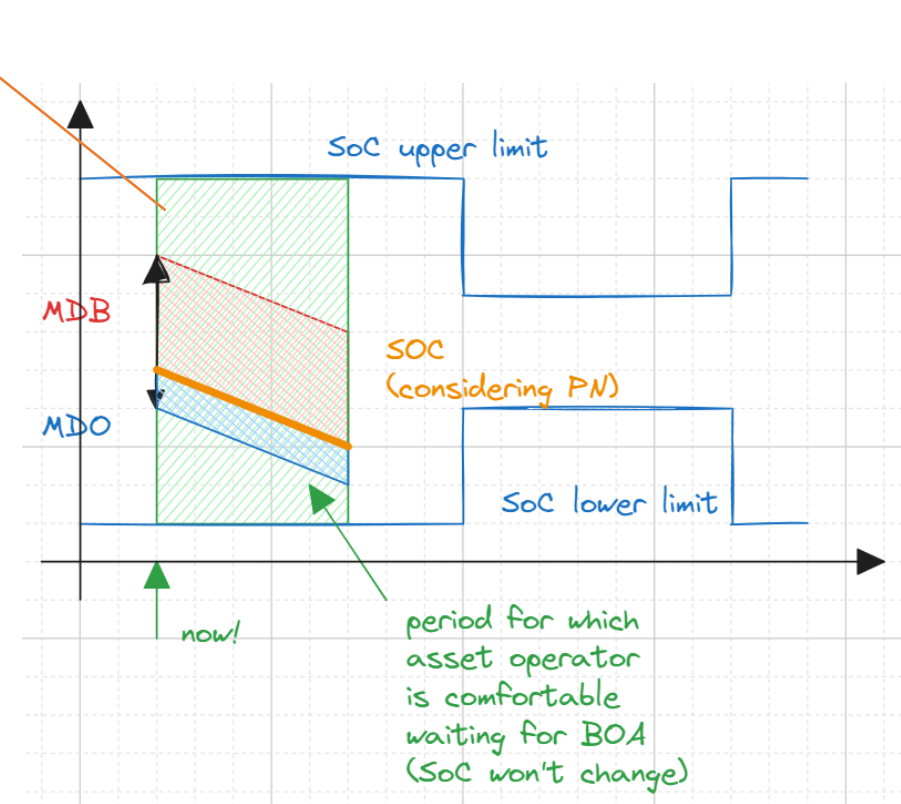
- Model could be used to form a view of impact of BOAs on future margins.
- These instantaneous MDO/B values are not the same as what the asset would be OK to deliver in BM over a period of time. This would only be the case if the asset did not “move” from current state going forward.

MDO/B from instantaneous value to valid period

Instantaneous MDO/B depending on definition could potentially reach max available capacity, but changes instantly as well.

MDO/B as a BM parameter would indicate what is available from the asset for use within a defined period of time.

MDO/B effectively (after adjusting for efficiency) should indicate (similar to BOD) how far above, or below SoC the asset could move due to a BOA, over a period of time. They would be defined over a period of time, and they can be commercially set.



Key points

- MDO/B shifts calculations to asset operator, and has a clear definition for a period starting now.
 - In contrast to SoC limits (if defined to match asset capability minus service requirements), MDO/B needs to be adjusted when SoC changes (it is relative to SoC).
- Passing information regarding MWh availability over long periods of time is more complicated with MDO/B.

ESO problem specifics

In principle if we were to 'optimise' against the predicted imbalance we would see storage assets being used to cancel the imbalance, possibly making use of cheaper offers to charge while discharging at more expensive hours.

We need to approximately model the impact of BOAs on future asset availability (how long can it be dispatched for), and system margins. Errors would be effectively 'corrected' by BMU submissions / redeclarations in BM.

Consideration of reserve / margins, or unit capabilities (e.g. fast ramping) could imply that we might want to retain a certain amount of energy for future use – these would be additional constraints to the solution.

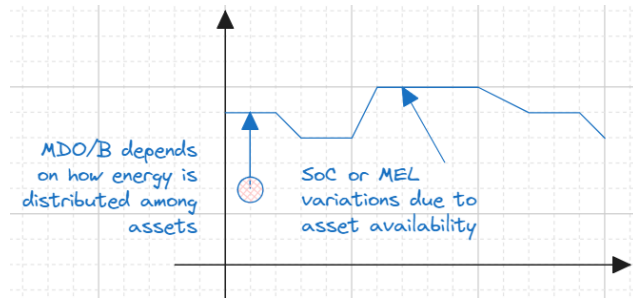


Key points

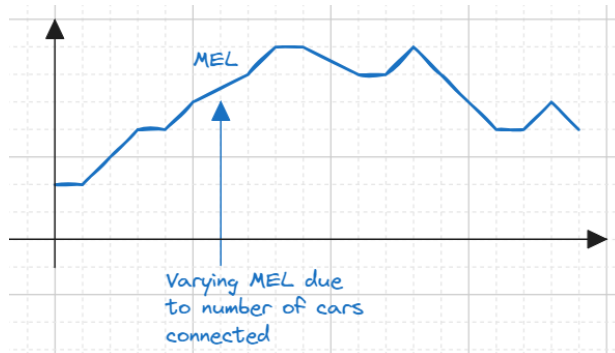
- When solving scheduling over longer time-frames ESO would be able to apply only part of the solution (i.e. the part that is within the BM window). The solution would be affected by assumptions around asset availability.
- It is very important that any forward looking data have very clear definitions and consistent assumptions on calculations across BMUs.

Aggregated assets

(1) Consider an **aggregation of battery storage assets** – it could arguably be modelled approximately through an equivalent single storage model (with some errors).



(2) Consider an **EV aggregator** (or any demand shifting capability) – it is not that much different, however the requirement changes, i.e. it would be to have a specific amount of energy consumed by some point in the day. MDB gives indication of capability, but not clear indication of requirement. SoC model would not work either.



(3) Consider **storage collocated with demand/generation** – this is a more complex case, as the power from storage overlaps power from demand or other generation. Asset operator could estimate an MDO/B, but we cannot explicitly model it because we lack the data (i.e. time-series of underlying demand, generation).

In this case MDO/B calculations would have to include volume that could be shifted by using available controls in demand / generation.

Key points

- A more abstract model (e.g. MDO/B based) would allow representing any type of BMU (calculations are shifted to asset operator's side).
- Data submissions past the first one (immediately in effect within the BM window) value would involve additional forecasting errors on underlying models and parameters. Establishing a clear standard for time-varying parameters could be challenging.

What do we need so far

For battery BMUs:

- current state of charge/energy
- model parameters / efficiency
- SoC limits indicating asset capability minus firm contractual obligations

Note:

- Aggregated / co-located assets would not all be covered by a SoC based model. There is a wider discussion to be had if and how it would be appropriate to model them.

Getting the data: efficiency

Assuming we have an

- initial SoC
- metered MW
- and metered MWh

we could potentially fit a model to the data.

E.g. we could go through a simple process of testing efficiency values and selecting the one that minimizes modelling errors.

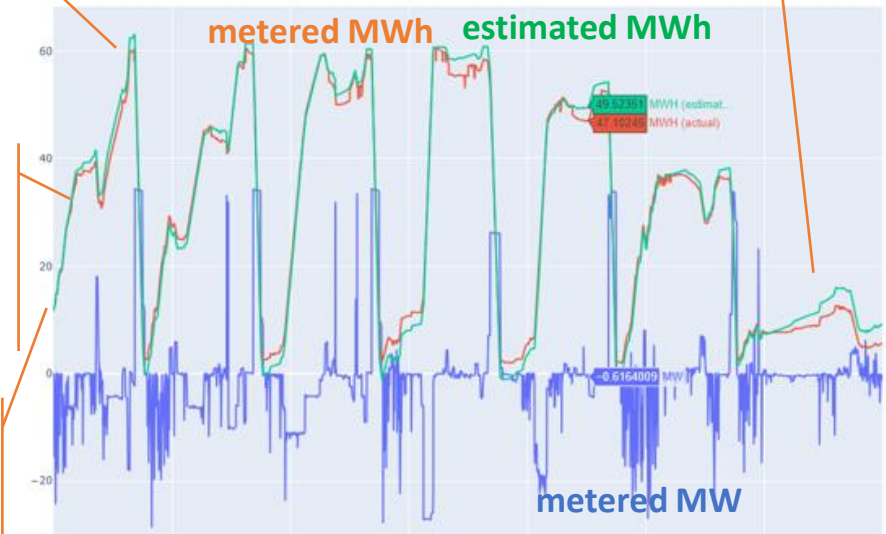
For that purpose we could use currently available SCADA data.

There will still be an error, possibly more importantly when larger volumes are dispatched.

Errors would vary over days and operation patterns; and among different assets depending on their data.

There is a possibility that the initial SoC may be inferred as well, but that can be less reliable

There will always be some drift – model is not accurate (misses efficiency, misses standby losses, etc.) – but still good enough for scheduling.



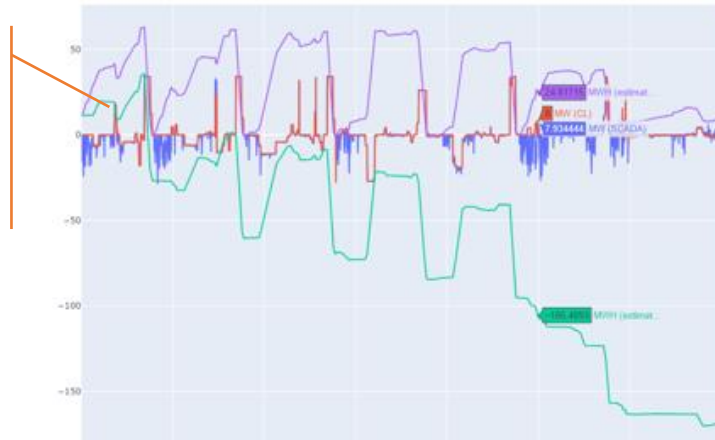
Key points

- The simple storage model may be good enough for ESO modelling needs (dispatch / scheduling time-frames).
- If we have the right SCADA data, we do not need additional parameters (from BM) – we can estimate the model.
- Further investigation would be needed to assess whether this is a valid approach that we can confidently adopt.

Note: Uncertainty & other sources of errors

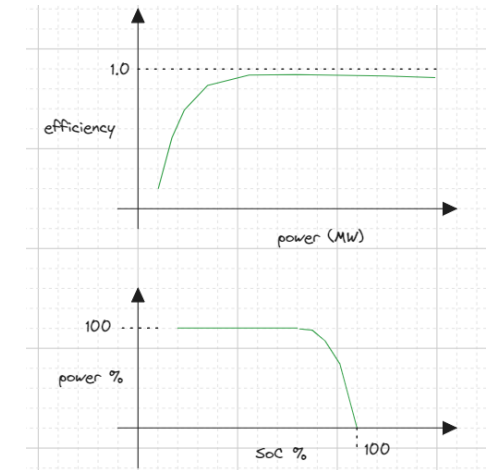
In this example we consider the model fitted in the previous example – so should be accurate given metered MW. Instead we are assuming the asset's CL is equal to the metered MW.

After a single day the error in the model can be significant – it is likely this unit was doing DC over the period



Additional sources of errors include (beyond efficiency) e.g. derating of asset capacity based on state.

Modelling and underlying assumptions differences / errors, could lead to the combined SoC + SoC limits + PN dataset to be inconsistent.



Key points

- Time-varying data submissions looking forward can be unreliable.
- A combination of SoC and SoC limits, given a certain PN submissions, can lead to inconsistent data – i.e. data that do not give feasible states.
- It could greatly simplify processes if all critical considerations around BOA volumes are left with the asset operator.

What do we need so far

For battery BMUs:

- current state of charge/energy
- model parameters / efficiency
- SoC limits indicating asset capability minus firm contractual obligations

→ These could be evaluated based on SCADA data. This would imply establishing required pipelines on OBP, and whether we can confidently use the result requires further investigation

→ These could be inferred given that we know existing contracts the ESO has with operators. This would not work with other contracts for e.g. DSO services which the ESO does not have visibility off. However, are BM parameters the best option for this?

Note:

- Aggregated / co-located assets would not be covered by a SoC based model. There is a wider discussion to be had if and how it would be appropriate to model them.
- Shifting BOA related volumes calculations to asset operators side (via MDO/B) can significantly simplify processes at the moment. This does not exclude the additional submission of SoC or relevant limits.
- It is critical to have clear assumptions for any forward looking data derivation, linked to other submitted BM data.

Estimating state with MDO/B (for battery BMUs)

Although MDO/B do not describe physical characteristics of the asset, we can easily move to a SoC based model if we needed to do so (i.e. to account for impact of re-dispatching the asset).

$$\begin{aligned}MDO_t &= MDO_{t-1} - P_t^{EX} + P_t^{IM} \\MDB_t &= MDB_{t-1} + P_t^{EX} - P_t^{IM}\end{aligned}$$

This does not account for efficiency, but could be easily adjusted.

The general expectation is that after the first BOA, asset operators would redeclare the volumes anyway.

One alternative to simplify equations would be to move back to SoC type of model using MDO/B values, i.e.:

$$\begin{aligned}SoE_0 &= MDO/\eta \\0 \leq SoE_0 &\leq SoE^{MX} = MDO + MDB \\SoE_t &= SoE_{t-1} + P_t^{IM} \cdot \eta - \frac{P_t^{EX}}{\eta}\end{aligned}$$

This is similar to the earlier model, with a different initial state of energy value.

Key points

- Within the period that MDO/B values cover, it is fairly straightforward to switch to a state based model if that was needed.
- We could consider whether we would want an additional parameter (as part of the data) that would signify if such a modelling approximation would be acceptable by a BMU (this is to support multiple instructions within the BM window, while limiting resubmissions).

Building a model from time-varying MDO/B

Asset operator could start with optimising against the SoC limits – strictly defined based on absolutely necessary restrictions to deliver the service (which might be different to what the same operator would pass to BM if commercially set). What would be useful is something closer to the “blue” limits which would not vary much throughout the day.

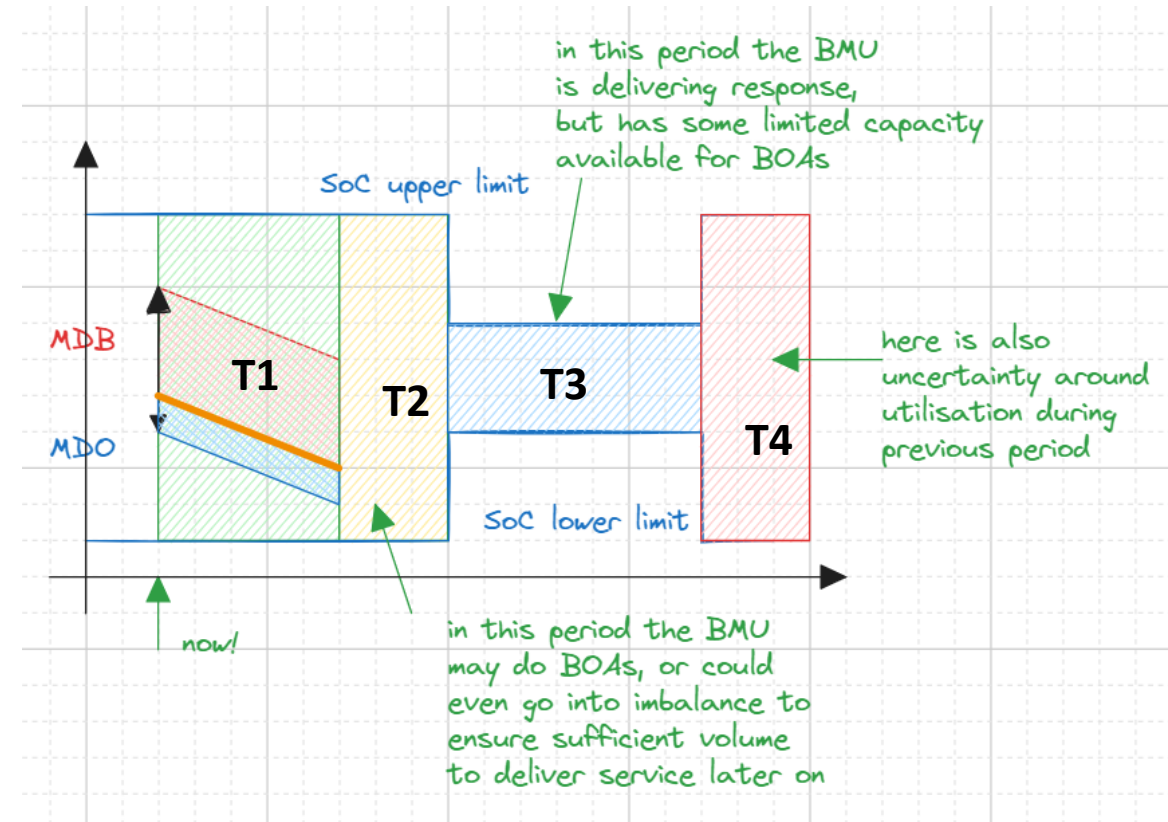
We could use a submission of these limits directly, or two defined MDO/B quantities and a reference SoC (estimated based on current PN and expected service utilisation). MDO/B would reflect these upper and lower bounds, rather than be “fully” commercially set. There are 4 sets of MDO/B-SOC that need to be submitted for this example.

In period T1, MDO/MDB could be commercially set and not necessarily align with the actual capacity of the asset.

Convention for T2, T3, T4 calculations could assume that asset follows PN and at 0 utilisation.

Key points

- “Firm” forward looking limits would be more useful, and may be inferred based on contracts the asset may already have with the ESO (but not otherwise).
- Forward looking values will only be useful depending on how they are set.
- The forecast SoC might provide some insight on modelling assumptions on operator side, but is not expected to be used, other than for deriving actual limits.



Time-varying MDO/B + SoC

Data could look as follows

```
MDV = {  
  FROM_TIME : 2024-02-29 Z 00:05T,  
  TO_TIME : 2024-02-29 Z 00:26T,  
  MDO : 100  
  MDB : 20  
  SOE : 57  
}
```

This option combines MDO/B and SOC + limits.

- FROM_TIME and TO_TIME indicate the period within which the declared MDO/B volumes may be used and are valid for. Could be required to cover a minimum period of time.
- MDO/B in MWh would be the energy that may be used for offers/bids.
- SOE in MWh would be the energy stored in the BMU at FROM_TIME, which was used as a basis for the MDO/B calculations. SOE could be optional, so if this is not relevant we could simply use MDO/B directly.
- The closest MDV submission to current-time would be considered binding and MDO/B would be directly used for BOAs.
- For any MDV submissions going forward into the future MDO/B and SOE would be used to infer limitations in SOE, for any relevant model the ESO might choose to use in dispatch/scheduling – MDO/B will not be directly used.

Time-varying SoC limits + SoC

Data could look as follows

```
MDV = {  
  FROM_TIME : 2024-02-29 Z 00:05T,  
  TO_TIME : 2024-02-29 Z 00:26T,  
  SOE_MAX : 100  
  SOE_MIN : 20  
  SOE : 57  
  EFC : 92  
}
```

Alternatively we could consider this SoC based model

- FROM_TIME and TO_TIME indicate the period within which the declared limits are valid.
- SOE would be relevant for the current binding submission only.
- DLAs would have to adjust submissions, so that the output of this model used on ESO side, would reflect asset capability for dispatch.

In summary

For battery BMUs:

- current state of charge/energy
- model parameters / efficiency
- SoC limits indicating asset capability minus firm contractual obligations

These could be evaluated based on SCADA data. This would imply establishing required pipelines on OBP, and whether we can confidently use the result requires further investigation

These could be inferred given that we know existing contracts the ESO has with operators. This would not work with other contracts for e.g. DSO services which the ESO does not have visibility off. However, are BM parameters the best option for this?

Note:

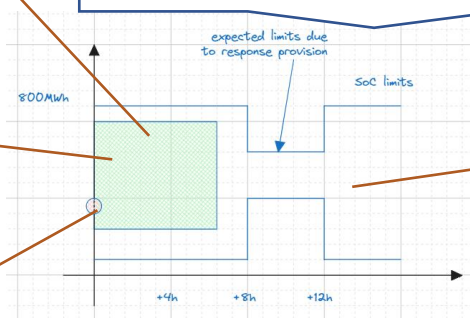
- Aggregated / co-located assets would not be covered by a SoC based model. There is a wider discussion to be had if and how it would be appropriate to model them.
- Shifting BOA related volumes calculations to asset operators side (via MDO/B) can significantly simplify processes at the moment. This does not exclude the additional submission of SoC or relevant limits.
- It is critical to have clear assumptions for any forward looking data derivation, linked to other submitted BM data.

We determine if appropriate to issue multiple instructions either direction based on underlying model.

Asset submits MDO/B (or area is estimated from a SoC submission) and BOAs are limited by these.

We use either SCADA data, or request SOE to be part of the BM data.

We use a simplified SoC based model for dispatch – application of decisions is limited to dispatch; we use available BM (and/or SCADA) data to calculate what is needed for the model to work.



We infer limits based on known contracts, or we calculate them from time-varying MDO/B submissions (or have them directly submitted).



Analysis

Cases raised at the First Workgroup (1st Feb 2024)

The following scenarios were discussed

1. Ordinary day
 - a) a simple Limited Duration Asset (LDA) that is only participating in the Balancing Mechanism (BM) and does not provide any other services to the System Operator (SO). The resulting Balancing Mechanism Unit (BMU) is therefore made up of one asset.
2. A unit that is successful in the Response auctions
 - a) One asset making up one BMU but in this case the BMU is stacking new Response services Dynamic Containment, Dynamic Moderation and Dynamic Regulation (DC/DM/DR). So it offers capacity into one of DC/DM/DR and the Balancing Mechanism (BM).
3. For a unit made up of LDA and other technologies
 - a) Multiple assets make up the BMU, some are LDA and some are not, participates in one of DC/DM/DR and BM
4. For a unit that has technical issues and must reduce its capacity
 - a) Same as point 3 but has technical issues and must reduce capacity
5. For a unit that has been successful in Balancing Reserve auctions
 - a) Same as point 4 but in addition participates in the Balancing Reserve auctions

Assumptions

The current parameters Maximum Delivery Volume (MDV) and Maximum Delivery Period (MDP) cannot be used

- These are unidirectional and cannot model units that import and export

Maximum Import Limits (MIL) and Maximum Export Limits (MEL) on their own cannot be used to truly represent LDA

- This forces the use of the 15 or 30 minute rule

New parameters are accurate so that they are of practical value to the SO

- Inaccurate data leads to more expensive actions
- The SO would need to create their own forecasts because the values submitted are not useful

New parameters lead to a level playing field for all Market Participants (LDA and non-LDA)

Criteria for success

Support the Market

Market signals must be available so that parties can react in good time

Accurate Information

Reduces the need for expensive corrective actions

Simple Solutions

Easy to implement avoiding unnecessary expense

Reliable Dispatch

BOAs must be deliverable by the BMU to ensure system security

Reliable Planning

It must be possible to forecast future reserve levels etc to support security

Solutions to consider



Take forward



Reject

Measured SoC and energy available

- Have to assume values are accurate
- No indication of limits – either technical or commercial (DC/DM/DR)



Declared State of Charge (SoC) with limits – single value

- Assume declared by BMU when the value changes
- Limits represent battery technical limits and amount of energy needed for DC/DM/DR
- A model must be agreed with the SO allowing SoC to be converted to the available energy available
- May need to share some confidential data with the SO
- After a BOA is issued may not need a redeclaration of SoC as SO can compute



Declared SoC with limits – time varying data

- BMU declares several hours ahead
- Limits represent battery technical limits and amount of energy needed for DC/DM/DR
- A model must be agreed with the SO allowing SoC to be converted to the available energy available
- May need to share some confidential values with the SO
- After a BOA would probably need to redeclare values of the SoCs as the effect on future data is large



Maximum Delivery Bid (MDB)/Maximum Delivery Offer (MDO) – single value

- Assume declared by BMU when value changes
- Technical limits and limits for DC/DM/DR implicit in MDB/MDO
- After a BOA may not need redeclaration as the SO can compute



Maximum Delivery Bid (MDB)/Maximum Delivery Offer (MDO) – time varying data

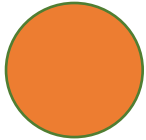
- BMU declares several hours ahead
- Technical limits and limits for DC/DM/DR implicit in MDB/MDO
- After a BOA will need to declare future values because effect is large on future data



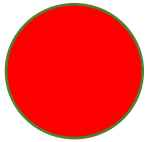
Assessment Symbols



Positive



Neutral























Negative























Unknown





















A BMU consisting of a single LDA – only participates in BM

	Support the market	Accurate information	Simple solution	Reliable Dispatch	Reliable Planning
Declared SoC with limits – single value	Difficult to compare with other assets 	Expect battery to know in short timescales 	SO needs to convert to available energy 	SO needs to convert to available energy 	Timescales are too short so no change 
Declared SoC with limits – time varying data	Difficult to compare with other assets 	Future values become less accurate 	SO needs to convert to available energy 	Doesn't affect short term decisions 	Gives model for planning but needs conversion 
MDB/MDO – single value	Easier to compare with other assets 	Expect asset to know in short timescales 	Gives SO direct information 	SO can act on the declared value 	Timescales too short so no change 
MDB/MDO – time varying data	Same as single value 	Future values become less accurate 	Gives SO direct information, but more complex interpretation 	Doesn't affect short term decisions 	Gives indication of future behaviour but complex 





















A BMU consisting of a single LDA – participates in BM and Response Auctions

	Support the market	Accurate information	Simple solution	Reliable Dispatch	Reliable Planning	Balancing Reserve same as Response Auctions
Declared SoC with limits – single value	Difficult to compare with other assets 	Expect battery to know in short timescales 	SO needs to convert to available energy and response utilisation complicates 	SO needs to convert to available energy 	Timescales are too short so no change 	
Declared SoC with limits – time varying data	Difficult to compare with other assets 	Future values become less accurate 	SO needs to convert to available energy and response utilisation complicates 	SO needs to convert to available energy 	Gives model for planning but needs conversion and response complicates 	
MDB/MDO – single value	Easier to compare with other assets 	Expect asset to know in short timescales 	Direct information but response utilisation complicates 	SO can act on the declared value 	Timescales too short so no change 	
MDB/MDO – time varying data	Same as single value a 	Future values become less accurate 	Direct information but response utilisation complicates 	Doesn't affect short term decisions 	Gives indication of future behaviour but response Complicates 	

A BMU consisting of LDA and multiple technologies – participates in BM and Response Auctions

	Support the market	Accurate information	Simple solution	Reliable Dispatch	Reliable Planning
Declared SoC with limits – single value	Difficult to compare with other assets 	Expect battery to know in short timescales 	SO needs to convert to available energy and needs configuration of asset 	SO needs to convert to available energy and needs asset configuration 	Timescales are too short so no change 
Declared SoC with limits – time varying data	Difficult to compare with other assets 	Future values become less accurate 	SO needs to convert to available energy and needs configuration of asset 	SO needs to convert to available energy and needs asset configuration 	Gives model for planning but needs conversion need configuration 
MDB/MDO – single value	Easier to compare with other assets 	Expect asset to know in short timescales 	Can model both types but response utilisation Complicates 	SO can act on the declared value 	Timescales too short so no change 
MDB/MDO – time varying data	Same as single value 	Future values become less accurate 	Can model both types but response utilisation Complicates 	Doesn't affect short term decisions 	Gives indication of future behaviour but complicated 

A BMU consisting of LDA and multiple technologies – participates in BM and Response Auctions and develops technical issues

	Support the market	Accurate information	Simple solution	Reliable Dispatch	Reliable Planning
Declared SoC with limits – single value	Difficult to compare with other assets 	No future signal 	No future signal 	SO needs to convert to available energy but needs asset configuration 	Timescales are too short so no change 
Declared SoC with limits – time varying data	Difficult to compare with other assets 	Future values become less accurate 	SO needs to convert to available energy and needs asset configuration 	SO needs to convert to available energy but needs asset configuration 	Gives model for planning but needs conversion need asset configuration 
MDB/MDO – single value	Easier to compare with other assets 	No future signal 	No future signal 	SO can act on the declared value 	Timescales too short so no change 
MDB/MDO – time varying data	Same as single value 	Future values become less accurate 	Can model both types but response utilisation Complicates 	Doesn't affect short term decisions 	Gives indication of future behaviour But complicated 

How do we model non-LDA assets with new parameters?

Must non-LDA assets declare these new parameters and if so what values should they declare?

NO

In the case of SoC it makes no sense to ask other asset types to submit these

There could be a default rule that means other asset types need not submit MDB/MDO (e.g. if a BMU can sustain a BOA for all of the BM window of 90 minutes)

YES

In the case of SoC it makes no sense to ask other asset types to submit these

For MDB/MDO could be default – energy volume corresponding MEL/MIL for BM Window

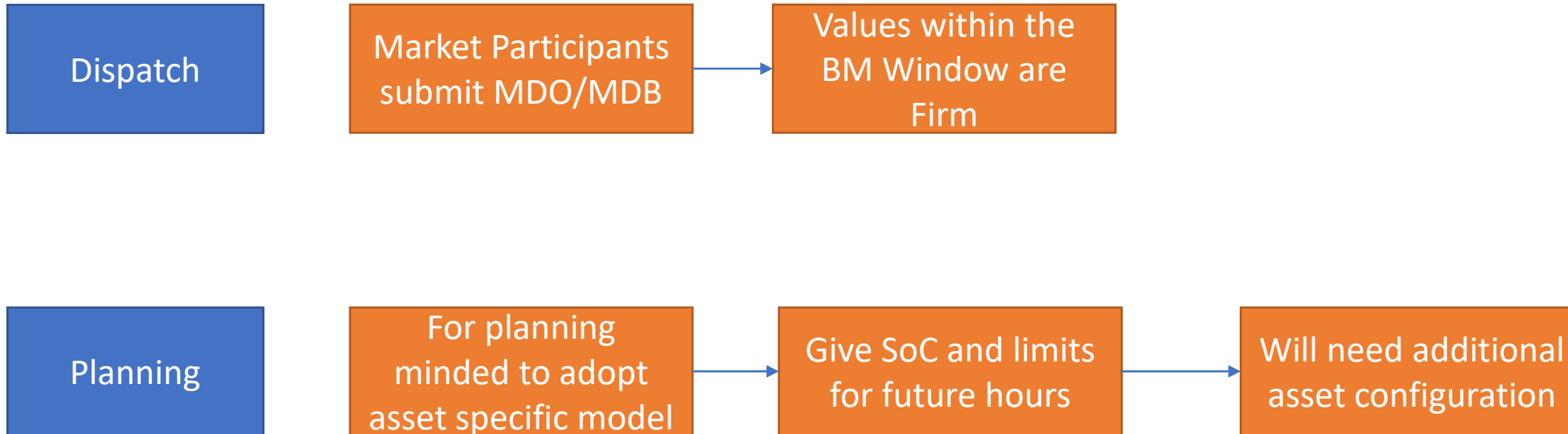
Could use MDB/MDO to indicate participation in other markets and energy not available in BM



Recommendation

Recommendation

Following discussions with Work Group members we are looking to have different solutions for Dispatch and Planning





Open Questions & Next Steps

Open questions & Next Steps

Want to check how these new parameters work with existing services such as DC/DM/DR and mandatory frequency response (MFR)

Still to consider how new LDA parameters co-exist with new market services – new parameters for Quick and Slow Reserve, both BMU and non-BMU

Data formats – need to find way to reduce redeclarations but still handle multiple cases

Initiate BSC changes

Section Q
2.1.2 The Dynamic Data Set shall comprise the following data items (in each case, as defined in the Grid Code) (the "Dynamic Data Set"):

- (a) Run-Up Rate;
- (b) Run-Down Rate;
- (c) Notice to Deviate from Zero;
- (d) Notice to Deliver Offers;
- (e) Notice to Deliver Bids;
- (f) Minimum Zero Time;
- (g) Minimum Non-Zero Time;
- (h) Maximum Delivery Volume and associated Maximum Delivery Period;
- (i) Stable Export Limit;
- (j) Stable Import Limit.