RCP PAPER NO.	:	**EMC/RCP/xx/2023/CP93**
SUBJECT	:	**ENHANCEMENT OF DEMAND RESPONSE – CALCULATION OF LOAD CURTAILMENT QUANTITY**
FOR	:	**CONSULTATION**
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DATE OF MEETING	:	**TBC**

Executive Summary

This concept paper discusses a proposed enhancement to Demand Response (DR), particularly with regards to the calculation of Load Curtailment Quantity (LCQ).

LCQ (in terms of MWh) is a calculated benchmark figure, representing the amount of energy that a load facility should be curtailing within a half-hour period. An accurate calculation for LCQ is central to the functioning of the DR scheme. In turn, this requires an accurate calculation for business-as-usual consumption (as represented by OIEC) and scheduled consumption (as represented by SIEC).

However, the current formulae for OIEC and SIEC assume that each load facility can always reach its respective end-period load within the half-hour period. This assumption may not always be true. When this occurs, the calculated LCQ value will likely be inaccurate.

As such, the proposed solution is to more robustly reflect the ramping profile of the load facility, by separating the ramp rates for dispatchable load and non-dispatchable load:

- Dispatchable load is assumed to ramp up/down based on the ramp rate within the energy bid, plateauing thereafter. This is consistent with how ramping constraints are applied to dispatchable load during DR scheduling.
- Non-dispatchable load is assumed to ramp up/down linearly across the half-hour period, and is no longer constrained by any ramp rates. This is also consistent with how ramping constraints are not applied to non-dispatchable load during DR scheduling.

An additional safeguard is also required to resolve the issue of inaccurate OIEC/SIEC. This would apply in extreme scenarios where the Market Clearing Engine is forced to schedule a low value for dispatchable load, even if it violates the downramp constraint, in order to respect DR energy bids.

In such scenarios, when calculating OIEC and SIEC, dispatchable load should also be assumed to ramp down linearly across the half-hour period, and no longer be constrained by indicated ramp rates, similar to the proposed treatment of non-dispatchable load.

EMC is of the view that the proposed enhancements would result in a more robust calculation of LCQ (as well as its underlying components, OIEC and SIEC).

1. Introduction

This concept paper discusses a proposed enhancement to Demand Response (DR), particularly with regards to the calculation of Load Curtailment Quantity (LCQ).

2. Background

2.1 Overview of DR scheme

The DR scheme enables load registered facilities (LRFs) to submit energy bids, indicating willingness to consume energy at different price points. When scheduled to curtail consumption, besides saving on energy costs due to curtailed consumption, there is a further incentive payment to activated LRFs if deemed fully compliant.

As DR activation tends to reduce wholesale electricity prices (and increase consumer surplus), activated LRFs are rewarded with incentive payments representing a share of the increase in consumer surplus due to DR activation.

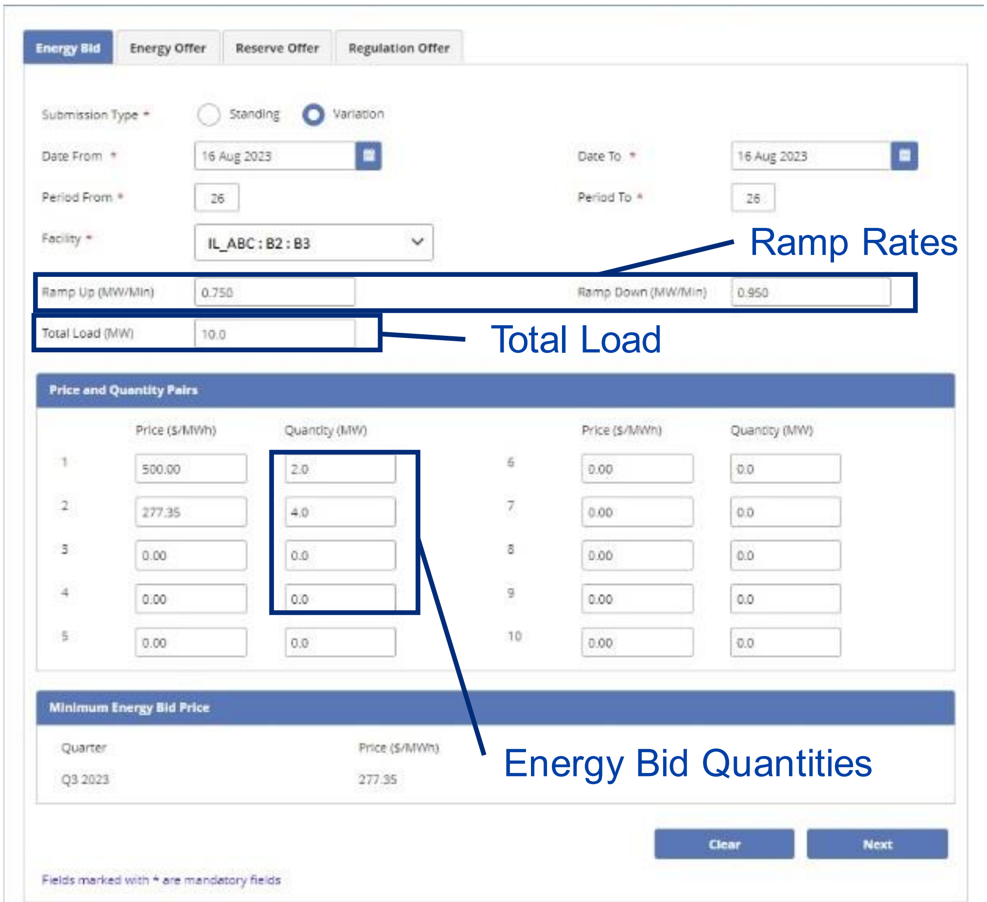
On the flipside, if deemed non-compliant when scheduled to curtail consumption, there is a financial penalty imposed on scheduled LRFs.

The formulae determining incentive payments and financial penalties are elaborated upon in the Section 2.3.

2.2 What do DR energy bids contain?

Figure 1 below highlights key items within DR energy bids submitted by LRFs.

FIGURE 1: Sample of energy bid interface



As shown above, essential bid submission items include ramp rates, Total Load and Energy Bid Quantities (at different price-quantity blocks).

Total Load = Sum of Energy Bid Quantities[1] + Non-Dispatchable Load[2]

➔ Non-Dispatchable Load is inferred as (Total Load – Sum of Energy Bid Quantities)

2.3 What is Load Curtailment Quantity (LCQ) used for?

LCQ (in terms of MWh) is a calculated benchmark figure, representing the amount of energy that the LRF should be curtailing within a half-hour period. LCQ affects various aspects of DR, as explained below.

2.3.1 LCQ is an input to calculating Load Curtailment Price (LCP)

LCP (in $/MWh) is the incentive payment per MWh curtailed. LCQ is used as an input to the calculation of LCP, as shown in the formula below[3]:

$$LCP = \frac{Max(\frac{1}{3} \times \Delta USEP \times Non - Regulatory\ Load, 0)}{Sum\ of\ LCQ\ across\ all\ LRFs}$$

I.e., if LCQ reduces for a particular LRF, the calculated LCP would increase, which affects all LRFs activated for DR.

2.3.1 LCQ is a parameter used for determining compliance

When an LRF is scheduled to curtail, it needs to be compliant before it is eligible for incentive payment:

- If actual curtailment[4] ≥ 100% x LCQ, the LRF is deemed to be compliant
- If actual curtailment < 95% x LCQ, the LRF is deemed to be non-compliant[5]

I.e., reduced LCQ will translate to a more lenient compliance threshold for an activated LRF.

2.3.2 LCQ is a direct input to calculating incentive payments/ financial penalties

When scheduled to curtail:

- If the LRF is deemed to be compliant, it receives an incentive payment of LCP x LCQ
- If the LRF is deemed to be non-compliant, it receives a financial penalty of LCP x LCQ[6]

I.e., reduced LCQ will have a direct impact on reducing incentive payments / financial penalties, but as per Section 2.3.1, will also have a secondary impact on incentive payments / financial penalties, due to its effect on LCP.

LCQ is not used in the scheduling for DR. Having said that, it is clear that an accurate calculation for LCQ is central to the functioning of the DR scheme.

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[1] Energy Bid Quantities represent MW load that is flexible (i.e., can either be consumed or not consumed, depending on DR schedule)

[2] Non-Dispatchable Load refers to MW quantity that is not flexible (i.e., must be consumed)

[3] Market Rules Appendix 6L, Section L.4.1

[4] MWh curtailment is measured indirectly as Offered Implied Energy Consumption (OIEC) – Actual Withdrawal. OIEC represents business-as-usual consumption, further explained in Section 2.4

[5] Under the 2023-2024 Demand Side Management Sandbox, the compliance threshold has been lowered to 80%.

[6] Under the 2023-2024 Demand Side Management Sandbox, the financial penalty has also been reduced.

2.3 How is LCQ calculated?

LCQ (how many MWh the LRF should be curtailing) = OIEC – SIEC, where

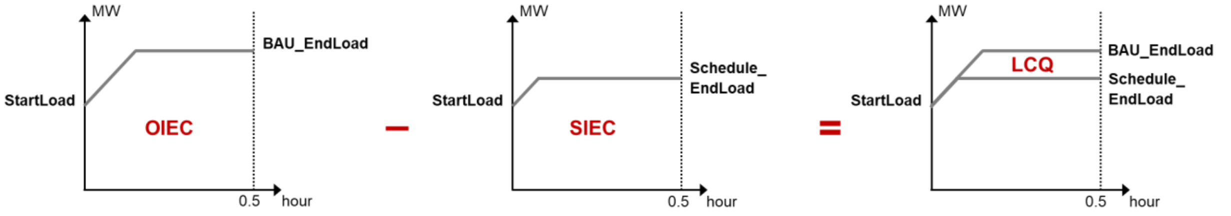
- OIEC is the Offered Implied Energy Consumption, representing business-as-usual consumption and
- SIEC is the Scheduled Implied Energy Consumption, representing scheduled energy consumption, including if the load is scheduled for curtailment.

As illustrated in Figure 2 below, OIEC, SIEC and LCQ are MWh values that can be represented as "areas under the curve", when considering MW load over time.

In essence, when the LRF is scheduled to curtail, LCQ should represent the difference in MWh consumption for the LRF across the half-hour period when not scheduled to curtail (OIEC) vs scheduled to curtail (SIEC).

When the LRF is not scheduled to curtail, OIEC = SIEC ➔ LCQ = 0.

FIGURE 2: Illustration of OIEC – SIEC = LCQ



Ideally, we would expect OIEC ≥ SIEC for all periods for all LRFs, resulting in a non-negative LCQ for each LRF.

However, in a particular period in 2023, an existing LRF was found to have *negative* LCQ for that period (which has no meaningful physical interpretation), when scheduled for curtailment, revealing a limitation of how LCQ is calculated in practice.

3. Identified Issues

3.1 How the current LCQ calculation may not always work as intended

Table 1 below is an illustration of bids submitted by an LRF, which would result in negative LCQ.

TABLE 1: Illustration of bids submitted by LRF

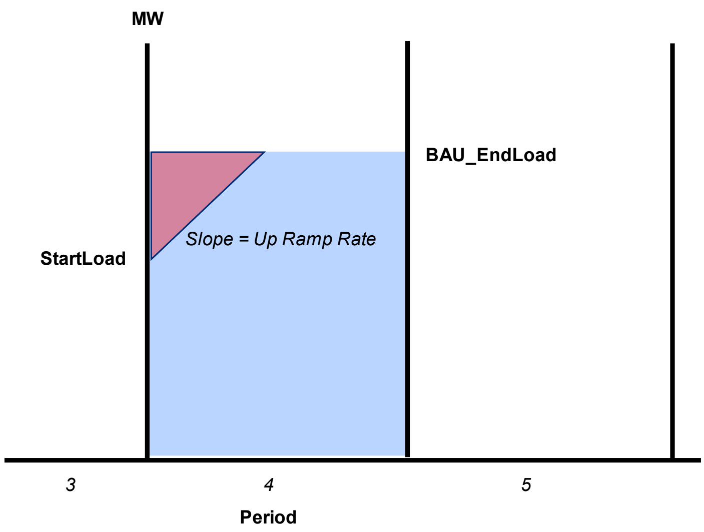
Period	Total Load, MW	Energy Bid Quantity, MW	Curtailed Load, MW	Up-Ramp Rate, MW/min
1	12	3	3	0.2
2	12	3	3	0.2
3	4	3	3	0.2
4	12	3	3	0.2

As shown in Table 1 above, the LRF indicates a low Total Load figure in Period 3. This resulted in knock-on impacts on the calculation of OIEC and SIEC for Period 4, as explained in the subsequent Sections 3.2 and 3.3.

3.2 How was OIEC calculated in this case?

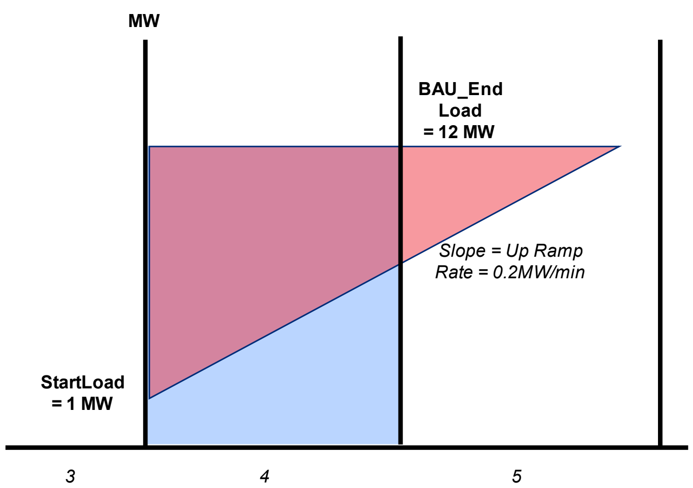
As illustrated in Figure 3 below, when StartLoad < BAU_EndLoad[7], the formula for calculating OIEC is generally based on subtracting the area of a small triangle from a rectangle[8], to calculate business-as-usual consumption MWh during the half-hour period, assuming an up-ramp rate as indicated within the energy bid.

FIGURE 3: Illustration of how OIEC is intended to be calculated



Meanwhile, Figure 4 below illustrates how OIEC (≈0.96 MWh) will actually be calculated in this particular case, represented by a subtracting the area of a large triangle from a rectangle. The triangle extends beyond period 4 as it takes more than 30 minutes for load to ramp up from StartLoad to BAU_EndLoad, based on the indicated up-ramp rate; the calculated OIEC is no longer an accurate reflection of business-as-usual consumption.

FIGURE 4: Illustration of how OIEC ≈ 0.96 MWh will actually be calculated



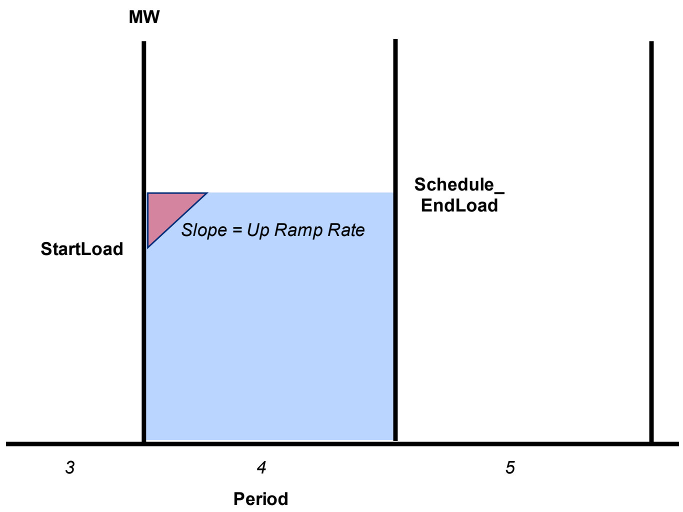
[7] For the purposes of this paper, we are defining the target end-period load when not scheduled to curtail (business-as-usual) as BAU_EndLoad. Within the Market Rules Appendix 6L, Section L.1, this is instead defined as EndPeriodLoad.

[8] Kindly refer to Market Rules Appendix 6L, Section L.2 for the exact calculation methodology for OIEC and SIEC, under different scenarios.

3.3 How was SIEC calculated in this case?

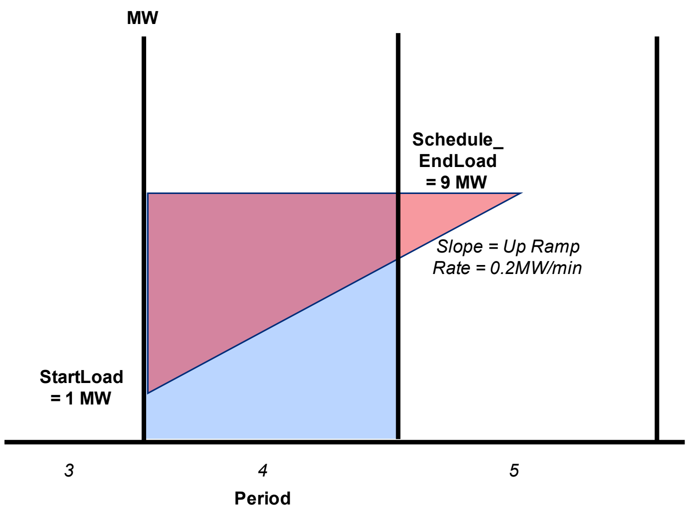
Similarly, as illustrated in Figure 5 below, when StartLoad < Schedule_EndLoad[9], the formula for calculating SIEC is generally based on subtracting the area of a small triangle from a rectangle[10], to calculate scheduled consumption MWh during the half-hour period, assuming an up-ramp rate as indicated within the energy bid.

FIGURE 5: Illustration of how SIEC is intended to be calculated



Meanwhile, Figure 6 below illustrates how SIEC (≈1.83 MWh) will actually be calculated in this particular case, represented by subtracting the area of large triangle from a rectangle. The triangle similarly extends beyond period 4 as it takes more than 30 minutes for load to ramp up from StartLoad to Schedule_EndLoad, based on the indicated up-ramp rate; the calculated SIEC is no longer an accurate reflection of scheduled energy consumption.

FIGURE 6: Illustration of how SIEC ≈ 1.83 MWh will actually be calculated



[9] For the purposes of this paper, we are defining the target end-period load when scheduled to curtail as Schedule_EndLoad. Within the Market Rules Appendix 6L, Section L.1, this is instead defined as ReferenceEnergyWithdrawal.

[10] Kindly refer to Market Rules Appendix 6L, Section L.2 for the exact calculation methodology for OIEC and SIEC, under different scenarios

Referring to Figures 2-6 above, the calculation of OIEC and SIEC involve StartLoad for the period as an input. In turn, StartLoad for Period T is assumed to be Schedule_EndLoad for Period T-1.

In the case shown in Table 1,

- StartLoad for Period 4 = Schedule_EndLoad for Period 3 = 4 – 3 = 1MW

Meanwhile, referring to the above figures, the (upward) slope of the curves are determined by the (up) ramp rate indicated within the LRF energy bids.

As illustrated in Figures 4 and 6, OIEC<SIEC, leading to a calculated LCQ of approximately -0.88 MWh (which has no meaningful physical interpretation).

4. Analysis

4.1 Why wasn't the intended LCQ calculated?

The formulae for OIEC and SIEC are established by assuming that the facility can always reach BAU_EndLoad and Schedule_EndLoad respectively, at the specified ramp rates within the half-hour period.

However, for this incident, the assumptions behind the formulae do not hold – the ramp rate was insufficient for StartLoad to increase to BAU_EndLoad and Schedule_EndLoad within the half-hour period.

Such scenarios can occur due to the inconsistency in the use of ramp rates when scheduling DR quantities, versus calculating OIEC/SIEC.

(1) When scheduling DR quantities, ramp rates act as constraints that apply only to *dispatchable load*, i.e., $DispLoad_T$ is limited by $DispLoad_{T-1}$ ± RampRate x 30 mins.

(2) However, when calculating OIEC (or SIEC), ramp rates are instead applied to BAU_EndLoad (or Schedule_EndLoad), which consists of dispatchable load plus non-dispatchable load, e.g., $BAU\_EndLoad_T$ is assumed to be within $StartLoad_T$ ± RampRate x 30 mins, which may not always be true.

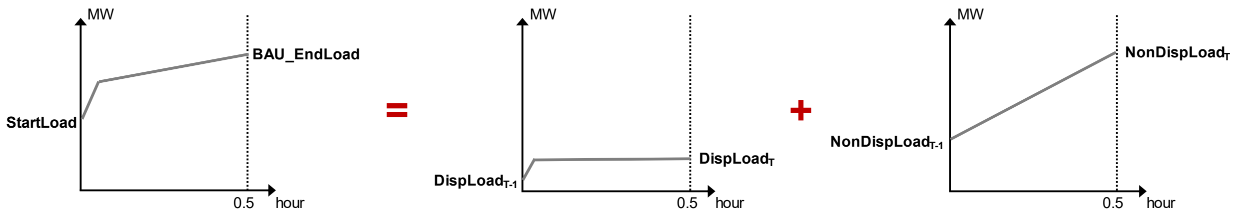
In order to resolve this issue, the application of ramping rates to the calculation of OIEC and SIEC in (2) above need to be aligned with the application of ramping constraints to DR scheduling in (1) above.

4.2 Proposed solution: separate ramp rates for dispatchable and non-dispatchable load

As discussed in Section 4.1 above, under the status quo, dispatchable load + non-dispatchable load is constrained by a single ramp rate.

The proposed solution involves applying different ramp rates to dispatchable and non-dispatchable load, thus calculating the consumption (MWh) for dispatchable and non-dispatchable portions separately, as illustrated in Figure 7 below.

FIGURE 7: Illustration of separate ramp rates for dispatchable and non-dispatchable load when calculating OIEC



As shown in Figure 7 above, dispatchable load is assumed to ramp up/down based on the ramp rate as indicated in the energy bid, plateauing thereafter. This is consistent with how ramping constraints are applied to dispatchable load during DR scheduling.

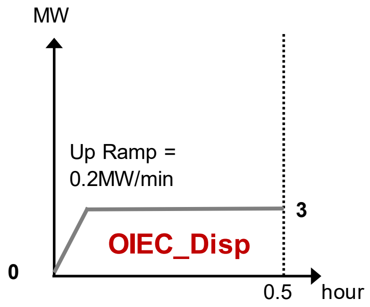
Furthermore, non-dispatchable load is assumed to ramp up/down linearly across the half-hour period, and is no longer constrained by indicated ramp rates. This is also consistent with how ramping constraints are not applied to non-dispatchable load during DR scheduling.

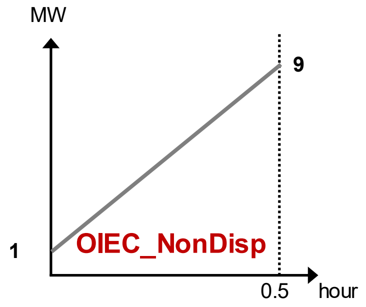
4.2.2 Numerical worked example

Applying this methodology to the scenario in Table 1 earlier, OIEC and SIEC for period 4 in particular will be calculated as below:

$OIEC_{P4}$

= BAU consumption due to dispatchable load + BAU consumption due to non-dispatchable load



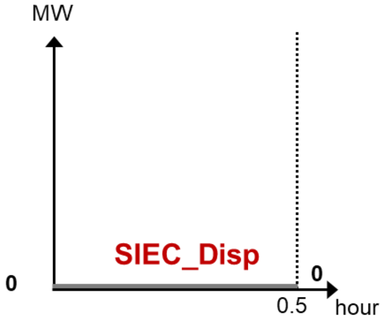


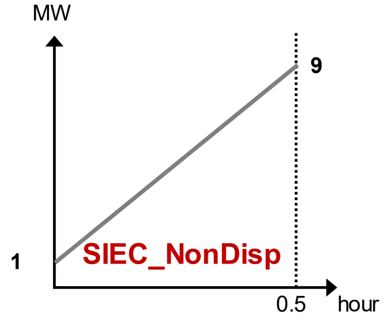
= 1.125 + 2.5

= 3.625 MWh

$SIEC_{P4}$

= Scheduled consumption due to dispatchable load + Scheduled consumption due to non-dispatchable load





= 0 + 2.5

= 2.5 MWh

LCQ = OIEC – SIEC = 1.125 MWh > 0

4.2.2 Key assumptions

1. No matter how much non-dispatchable load indicated within energy bids differs from period-to-period, it is always possible for the facility to ramp up/down its non-dispatchable load within the half-hour period.

   This is in line with the “self-commitment principle”, where bids and offers are expected to reflect actual physical capability.

2. Non-dispatchable load ramps up/down across the period in a linear fashion (as opposed to for example, rapid ramping up/down from $NonDispLoad_{T-1}$ to $NonDispLoad_{T}$ within a few minutes).

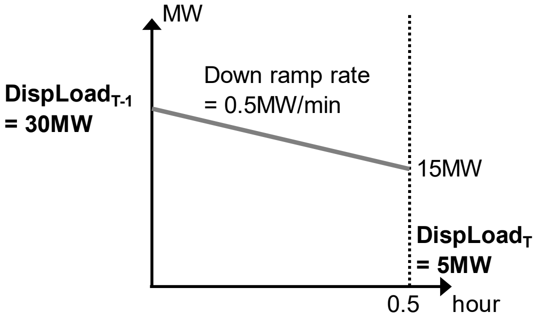
   As a specific ramping profile across the half-hour period for non-dispatchable load is not indicated by LRFs, this seems like a reasonable assumption, subject to industry feedback.

4.2.2 An additional safeguard to the proposed solution

Having said that, there is an extreme scenario where the above proposed solution might still not fully resolve the issue of inaccurate OIEC/SIEC, requiring an additional layer of safeguards.

While MCE will consider the ramp rate of an LRF when scheduling the dispatchable load, there might still be scenarios where the MCE scheduled dispachable load may not be achievable based on the declared ramp rate. As illustrated in Figure 8 below, in the scenario where the sum of energy bid quantities in period T is much lower than $DispLoad_{T-1}$, but not equal to zero[11], the Market Clearing Engine will respect the bid quantity[12] and be forced to schedule the load to consume at $DispLoad_{T}$ (in this case, the sum of energy bids in period T) at the end of the period, even if it violates the downramp constraint.

FIGURE 8: Illustration of why an additional safeguard is required



Such instances only occur because the indicated ramp rate and energy bid quantities submitted by market participants are inconsistent, and unlikely to reflect actual physical capability. These instances may be referred to the MSCP for further investigation; EMC strongly encourages market participants to submit bids that accurately reflect actual physical capability.

Having said that, under such a scenario, the calculation of OIEC and SIEC may face similar inaccuracies that the proposed solution in Section 4.2 above does not cover[13], thus requiring immediate remedy if they occur.

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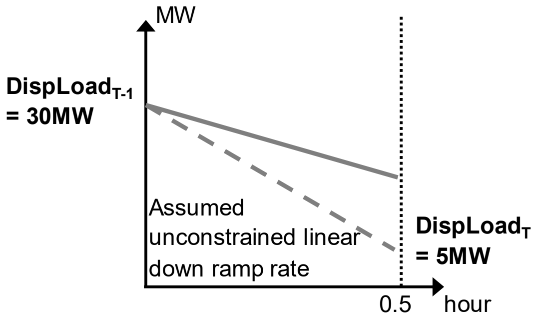
[11] If there are no energy bids in period T (sum of bid quantities equal zero), the calculation for OIEC and SIEC will likely be inaccurate. However, as there are no energy bids, it also means that the LRF is not subject to compliance checks for the period. Furthermore, if $DispLoad_{T}$ equals to zero, OIEC = SIEC ➔ LCQ = 0, which is an accurate reflection of how many MWh the LRF should be curtailing.

[12] Within the Market Clearing Engine, bid quantity constraints are hard constraints that cannot be violated, while ramping constraints are soft constraints that may sometimes be violated, incurring constraint violation penalties.

[13] In the scenario where the sum of energy bid quantities is instead much higher than $DispLoad_{T-1}$, such that the upramp constraint is binding, the MCE will simply not schedule such a high $DispLoad_{T}$. This does not violate any bid quantity constraints, and does not incur constraint violation penalties. The resulting OIEC and SIEC will be accurate, and an additional safeguard will not be required.

As such, another safeguard is required to account for such extreme scenarios – in such scenarios, when calculating OIEC and SIEC, dispatchable load should also be assumed to ramp down linearly across the half-hour period, and no longer be constrained by indicated ramp rates, similar to the proposed treatment of non-dispatchable load. This safeguard mechanism is illustrated in Figure 9 below.

FIGURE 9: Illustration of additional safeguard mechanism



4.3 Alternative solutions considered

Besides the solution proposed in Section 4.2 above (which affects OIEC and SIEC calculation for all instances of DR participation), alternative solutions were also considered, which affect OIEC and SIEC calculation only for exceptional instances where ramp rates are insufficient ("exception handling"). Two such alternative solutions are included in Appendix 1:

(1) For exceptional cases, $StartLoad_T$ is based on $NonDispLoad_T$ instead of $NonDispLoad_{T-1}$

(2) Extend existing exception handling for zero ramp rate scenarios

However, as these other solutions do not address the root problem – that there is inconsistent application of ramp rates to scheduling of DR versus calculation of OIEC/SIEC – these other solutions are ultimately not recommended.

5. Summary

As discussed in Section 2.3, an accurate calculation of LCQ is central to the functioning of the DR scheme. In turn, this requires an accurate calculation of MWh quantities OIEC and SIEC.

However, the current formulae for OIEC and SIEC assume that the facility can always reach their respective end-period loads[14] within the half-hour period. This assumption may not always be true, as there is an inconsistency between the application of ramp rates when scheduling DR quantities, versus calculating OIEC/SIEC. In other words, it is possible for DR quantities to be scheduled that are not accurately reflected when calculating OIEC/SIEC.

As such, the proposed solution is to separate the ramp rates for dispatchable load and non-dispatchable load:

- Dispatchable load is assumed to ramp up/down based on the indicated ramp rate, plateauing thereafter. This is consistent with how ramping constraints are applied to dispatchable load during DR scheduling.
- Non-dispatchable load is assumed to ramp up/down linearly across the half-hour dispatch period, and is no longer constrained by indicated ramp rates. This is also consistent with how ramping constraints are not applied to non-dispatchable load during DR scheduling.

[14] BAU_EndLoad and Schedule_EndLoad respectively

Furthermore, as detailed in Section 4.2.2, an additional safeguard is required to resolve the issue of inaccurate OIEC/SIEC. This would apply in extreme scenarios where the Market Clearing Engine is forced to schedule the load to consume at a low DispLoad, even if it violates the downramp constraint, in order to respect LRF bids.

In such scenarios, when calculating OIEC and SIEC, dispatchable load should also be assumed to ramp down linearly across the half-hour period, and no longer be constrained by indicated ramp rates, similar to the proposed treatment of non-dispatchable load.

EMC is of the view that the proposed enhancements would result in a more robust calculation of LCQ (as well as its underlying components, OIEC and SIEC).

6. Consultation

EMC would like to seek industry views on the proposed enhancement of Demand Response via more robust calculations of LCQ, particularly by separating the ramp rates for dispatchable and non-dispatchable load when calculating OIEC and SIEC.

We appreciate receiving comments by 7 September 2023.

Appendix 1: Alternative solutions considered

(1) For exceptional cases, $StartLoad_T$ is based on $NonDispLoad_T$ instead of $NonDispLoad_{T-1}$

Under the status quo:

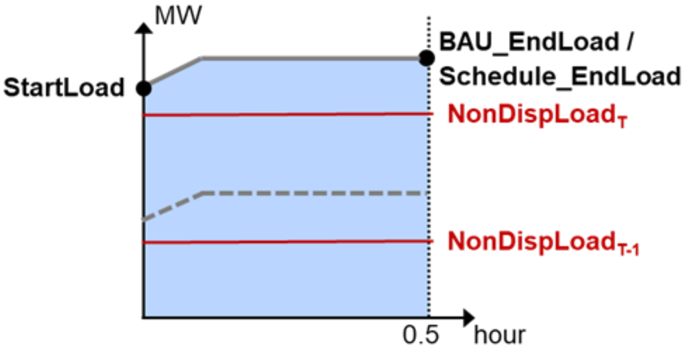
$$StartLoad_T = NonDispLoad_{T-1} + DispLoad_{T-1}$$

In the scenario where the ramp rate is insufficient to achieve BAU_EndLoad (for calculation of OIEC) or Schedule_EndLoad (for calculation of SIEC) within the half-hour period, a potential solution is to then assume that:

$$StartLoad_T = NonDispLoad_T + DispLoad_{T-1}$$

This is illustrated in Figure 10 below.

FIGURE 10: Illustration of alternative solution (1)



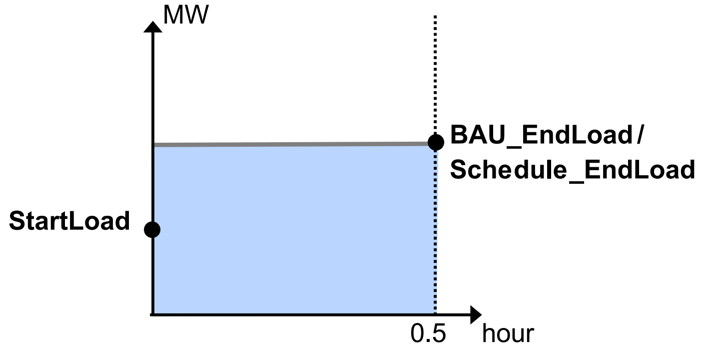
Doing so would adjust StartLoad to be closer to BAU_EndLoad and Schedule_EndLoad, ensuring that BAU_EndLoad and Schedule_EndLoad can now be achieved while respecting the ramp rate indicated within the energy bid.

However, if this solution were to be adopted, we would be assuming that in such scenarios where the ramp rate is insufficient, that in reality the ramp rate is actually very high, such that the LRF can ramp from $NonDispLoad_{T-1}$ to $NonDispLoad_T$ in a very short period of time.

(2) Extend existing exception handling for zero ramp rate scenarios

Under the status quo, when indicated ramp rate is zero (e.g., when energy bids are removed), OIEC and SIEC are by default, calculated as simple rectangular areas based on BAU_EndLoad and Schedule_EndLoad respectively[15]. This is to ensure that there is always a feasibly calculated value for OIEC and SIEC, illustrated below in Figure 11.

FIGURE 11: Illustration of alternative solution (2)



A potential scenario is to expand this existing exception handling mechanism – as long as the ramp rate is insufficient to achieve BAU_EndLoad or Schedule_EndLoad (including when ramp rate is zero), it is assumed that load is constant across the period.

However, if this solution were to be adopted, we would either be:

- making inconsistent assumptions about StartLoad when calculating OIEC (assumes StartLoad = BAU_EndLoad) versus SIEC (assumes StartLoad = ScheduleEndLoad), or
- assuming that in such scenarios where the ramp rate is insufficient, that in reality the LRF can ramp to the desired MW level (either BAU_EndLoad or Schedule_EndLoad) within a very short period of time, upon receiving dispatch instructions.

For the two alternative options considered above, as they require making strong assumptions, and also do not resolve the underlying inconsistency in application of ramp rates to scheduling of DR versus calculation of OIEC/SIEC, they are ultimately not recommended.

[15] Kindly refer to Market Rules Appendix 6L, Sections L.2.2 and L.2.3 for calculation of OIEC and SIEC when UpRampRate = 0 or DownRampRate = 0.