Notice of Market Rules Modification

Paper No.:	EMC/RCP/139/2024/RC383
Rule Reference:	Chap 6, Sec 5; Appendix 6D, Sec A, B & C; Appendix 6E, Sec E.1; Chap 8
Proposer:	EMC, Market Admin
Date Received by EMC:	15 March 2023
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Status:	Supported by RCP
Effective Date:	NA

This paper proposes to amend the market clearing formulation to more accurately model energy storage systems (ESS), such that dispatch schedules can better reflect the physical capabilities of ESS facilities.

Rule modifications are proposed to:

a) allow ESS to submit energy storage offers to indicate both its willingness to charge and discharge; and

b) introduce new constraints in the market clearing formulation to model ESS' performance, taking into account its fast-ramping capability and ability to provide reserves and regulation when charging.

The RCP discussed these proposals at its 139th meeting and the panel **unanimously supported** the proposed recommendations to amend the market clearing formulation to more accurately model ESS.

Date considered by Rules Change Panel:	13 March 2024
Date considered by EMC Board:	
Date considered by Energy Market Authority:	
Proposed rule modification:	See attached paper

Reasons for rejection/referral back to Rules Change Panel (if applicable):

PAPER NO.	:	**EMC/BD/xx/2024/xx**
RCP PAPER NO.	:	**EMC/RCP/139/2024/RC383**
SUBJECT	:	**MODELLING OF ENERGY STORAGE SYSTEMS** **(ARISING FROM CP86: RESERVE PROVISION BY NON-SPINNING GENERATION FACILITIES)**
FOR	:	**DECISION**
PREPARED BY	:	**LIM CHERN YUEN** **SENIOR ECONOMIST**
REVIEWED BY	:	**POA TIONG SIAW** **SVP, MARKET ADMINISTRATION**
DATE OF MEETING	:	**13th MAR 2024**

Executive Summary

This paper proposes to amend the market clearing formulation to more accurately model energy storage systems (ESS), such that dispatch schedules can better reflect the physical capabilities of ESS facilities.

Rule modifications are proposed to:

a) allow ESS to submit energy storage offers to indicate both its willingness to charge and discharge; and

b) introduce new constraints in the market clearing formulation to model ESS' performance, taking into account its fast-ramping capability and ability to provide reserves and regulation when charging.

At the 139th RCP meeting held on 13th March 2024, the RCP **unanimously supported** EMC's recommendations.

The RCP recommends that the EMC Board:

a) **adopt** the proposed modifications to the Market Rules as set out in Annex 1; and

b) **seek the EMA's approval** of the proposed modifications to the Market Rules as set out in Annex 1.

1. Introduction

This paper proposes to amend the Market Clearing Engine to more accurately model energy storage systems (ESS), such that dispatch schedules can better reflect the physical capabilities of ESS facilities.

2. Background

This paper is a follow-up to *CP86: Reserve Provision by Non-Spinning Generation Facilities*. At the 124th RCP meeting, the RCP tasked EMC to prepare rule modifications to enable ESS participation in reserve markets, primarily through remodeling the reserve envelope.

Having said that, EMC notes that even with the above changes, the current Market Clearing Engine (MCE) model would still not be adequate to model ESS participation in the SWEM, particularly when the ESS is charging. As such, EMC worked with the PSO to develop a more comprehensive ESS model.

3. Analysis

Energy Storage Facilities are considered as generation facilities under the Market Rules as they produce electricity when discharging. ESS facilities with nameplate rating of more than 10 MW will be subject to central dispatch and be registered as Generation Registered Facilities (GRFs).

GRFs are required to submit offers for energy, reserves and/or regulation to indicate their willingness to provide. The MCE will then produce dispatch schedules for GRFs, based on their offer quantities, offer prices and modelled physical capabilities.

Modelling of GRFs under the current market clearing formulation was based on the physical characteristics of large conventional spinning generators. Some of these physical characteristics are not appropriate for ESS, which may result in inefficient clearing outcomes if the same modelling constraints are applied to ESS. Therefore, there is a need to differentiate ESS from conventional generators in the market clearing formulation.

This section presents EMC's analysis of the issues that ESS facilities face with existing GRF modelling, and their proposed solutions.

3.1 Modelling of ESS in the Energy Market

3.1.1 Issues Identified

<u>Energy offers by ESS cannot accurately reflect willingness to charge</u>

Currently, the MCE assumes GRFs are only able to inject energy into the grid, without withdrawing any. However, ESS are able to both inject into and withdraw energy from the grid. Ideally, when ESS are charging, such consumption of energy should be dispatchable, and factored into the market clearing process. Otherwise, the MCE may not be able to schedule enough energy from other dispatchable resources to meet this additional load. It is also possible that under tight supply conditions, the ESS should indeed not be cleared to consume (depending on its willingness to charge). The absence of a mechanism for ESS to reflect its willingness to charge may lead to inaccurate dispatch schedules and distort the price signal.

3.1.2 Proposed Solution

Allow charging to be reflected in ESS offers and schedules

It is proposed for a new type of offer, namely Energy Storage Offers, to be created for ESS. This will then allow ESS to submit both positive and negative quantity offers, to indicate willingness to discharge and charge respectively.

For clearing of ESS energy offers, the following principles should apply:

a. For the same ESS facility, the offer price shall be in ascending order, with offer prices for charging lower than offer prices for discharging

b. For the same ESS facility, the MCE can only clear either charging offers (negative MW) or discharging offers (positive MW) – an ESS facility can never be scheduled to both charge and discharge

c. Price-quantity pairs with negative MW will be cleared only if the offer price is higher than the clearing price

d. Price-quantity pairs with positive MW will be cleared only if the offer price is lower than the clearing price

Below is an illustration on how market clearing would occur, with both positive quantity offers and negative quantity offers submitted by the ESS.

Illustration: ESS submits 3 offers to charge and 2 offers to discharge

Offer	Offer Price	Offer Quantity	Charge/Discharge
(1)	-$200/MWh	-1MW	Charge
(2)	$0/MWh	-1MW	Charge
(3)	$200/MWh	-1MW	Charge
(4)	$400/MWh	1MW	Discharge
(5)	$600/MWh	1MW	Discharge

- If the market clearing price is -$300/MWh, offers (1), (2) and (3) are cleared, and the ESS will be scheduled for -3MW (to charge from the grid)
- If the market clearing price is -$100/MWh, offers (2) and (3) are cleared, and the ESS will be scheduled for -2MW (to charge from the grid)
- If the market clearing price is $100/MWh, offer (3) is cleared, and the ESS will be scheduled for -1MW (to charge from the grid)
- If the market clearing price is $300/MWh, no offers are cleared, and the ESS will be scheduled 0MW (neither charge nor discharge)
- If the market clearing price is $500/MWh, offer (4) is cleared, and the ESS will be scheduled for +1MW (to discharge into the grid)
- If the market clearing price is $800/MWh, offers (4) and (5) are cleared, and the ESS will be scheduled for +2MW (to discharge into the grid)

In addition, a new variable called Energy Storage Transfer, which can be either positive (representing discharging) or negative (representing charging), is proposed to be introduced to represent the energy schedule of ESS in the market clearing formulation[1].

Market Clearing Modelling

Similar to the clearing of energy from conventional GRFs, the following constraints will be introduced to clear energy storage offers from ESS.

a. Energy storage block constraints:

   This is to limit the quantity that can be scheduled from each energy storage offer blocks to the offered quantity in that block – please refer to 6D.15.4 in Annex 1 for more details.

b. Energy storage risk constraint:

   The MCE will calculate the risk of energy storage facilities based on its scheduled energy and reserve[2]. Such risk will subsequently be factored into the reserve requirement calculation – please refer to 6D.17.1.1A. in Annex 1 for more details.

c. Energy Storage Up/Down Ramp Constraint:
   This is to limit ESS' energy schedule within its ramping range – please refer to 6D.19.1.1A and 6D.19.1.2A in Annex 1 for more details.

The following constraints are also required to be adapted to factor in the contribution from ESS.

d. Node Generation Balance Constraint:

   A new item is added to include energy schedule for ESS into the node balance calculation – please refer to 6D.16.1.2 in Annex 1 for more details.

e. Objective function

   New item is added to include cost of scheduling of ESS into the market clearing objective function – please refer to 6D.14.1 in Annex 1 for more details.

Below is an illustration of the market clearing of ESS under three different system demand scenarios.

[1] Currently, variable "Generation" is used to represent energy schedule for GRFs. Generation can only be non-negative.

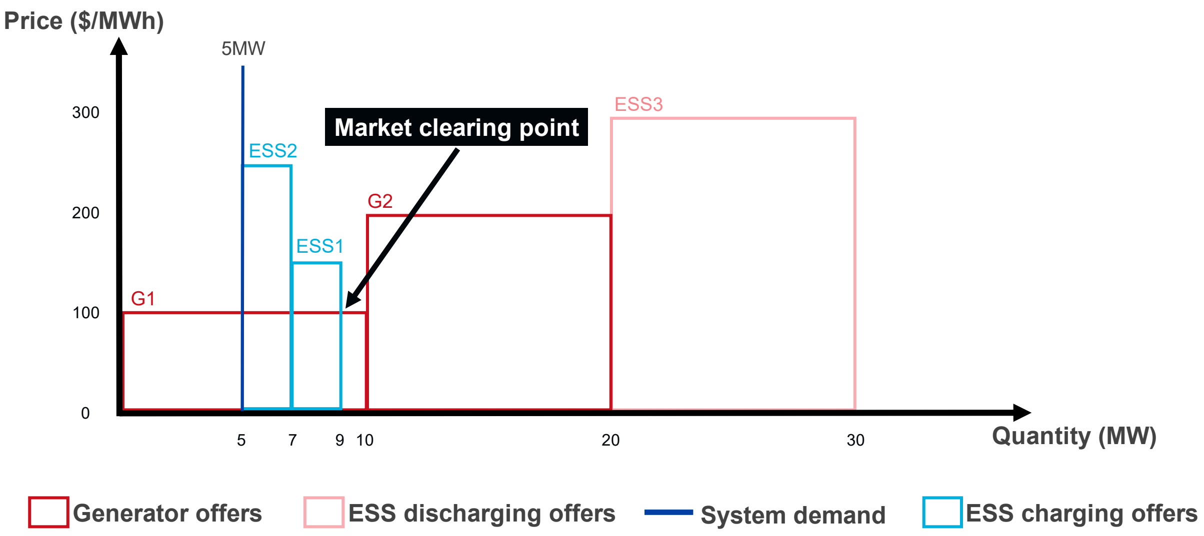
[2] The existing methodology for allocating reserve costs among GRFs (as detailed in Market Rules Appendix 7A) will apply to ESS. Similar to conventional generators, reserve responsibility share of ESS will depend on its probability of failure and scheduled quantity.

Illustration: market clearing outcomes under different system demand scenarios[3]

We assume that there is a conventional generator and an ESS offering in the following price-quantity pairs.

- G1 = ($100/MWh,10MW)
- G2 = ($200/MWh,10MW)
- ESS1 = ($150/MWh, -2MW)
- ESS2 = ($250/MWh, -2MW)
- ESS3 = ($300/MWh, 10MW)[4]

Scenario 1: System Demand = 5MW



Clearing price = $100/MWh

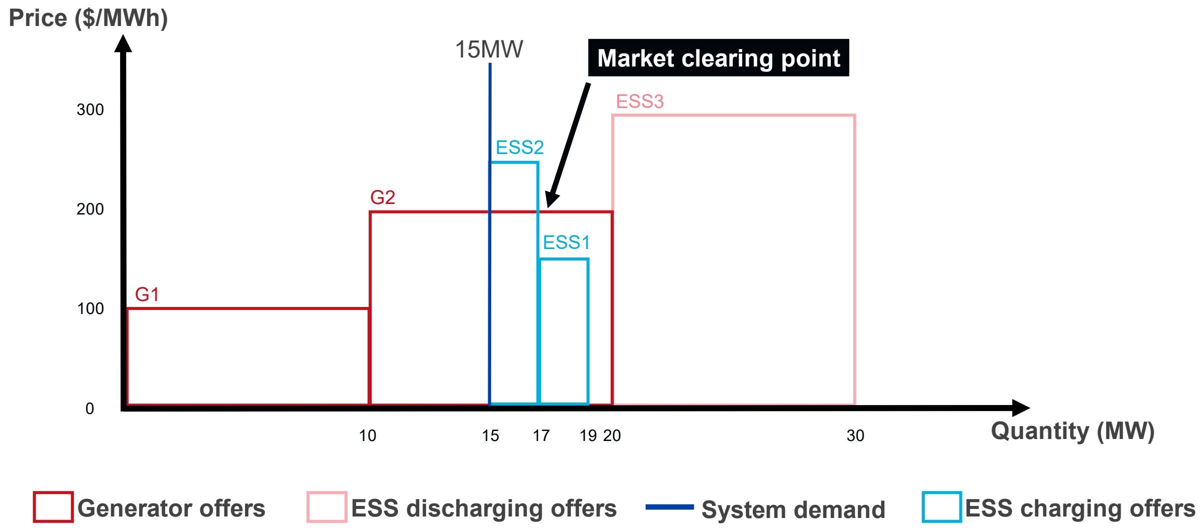
G1 is scheduled up to 9MW

ESS1 and ESS2 are scheduled fully (-2MW each, -4MW total)

[3] This illustration is meant to briefly show what the clearing price and scheduled quantities will be under different illustrative scenarios. This is not fully reflective of how market clearing works in practice. In particular, ESS charging offers are drawn here as an extension to the demand curve, but the intent of proposed rule changes in this paper is not for “energy storage offers” when the ESS is charging to be interpreted as “demand bids”.

[4] As mentioned earlier in Section 3.1.2, for the same ESS facility, the offer price shall be in ascending order, with offer prices for charging lower than offer prices for discharging.

Scenario 2: System Demand = 15MW



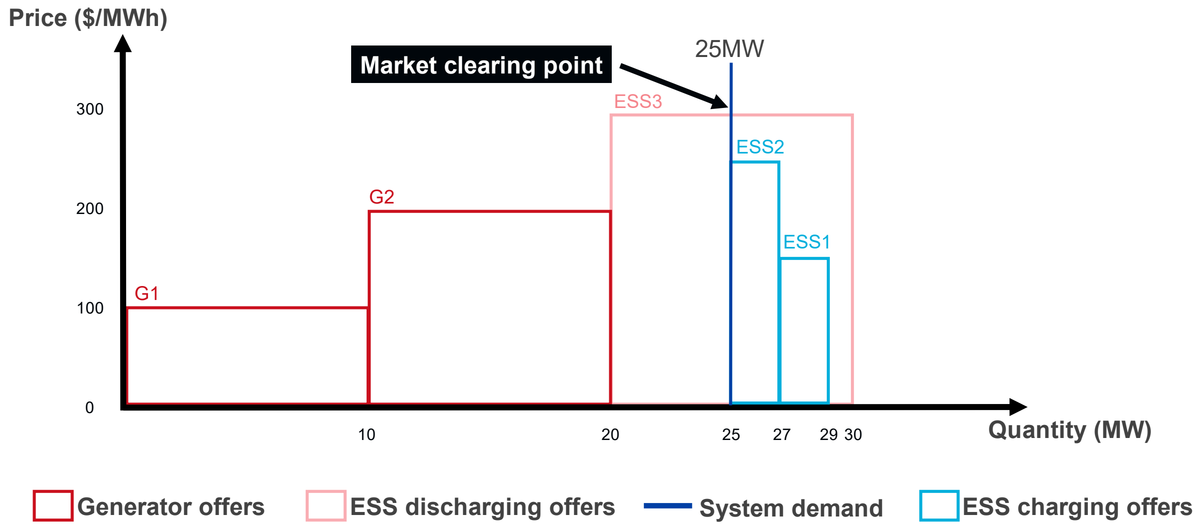
Clearing price = $200/MWh

G1 is scheduled fully at 10MW

G2 is scheduled up to 7MW

ESS2 is scheduled fully at -2MW

Scenario 3: System Demand = 25MW



Clearing price = $300/MWh

G1 and G2 are scheduled fully at 10MW each (20MW total)

ESS3 is scheduled up to 5MW

3.2 Modelling of ESS in the Reserve Market

3.2.1 Issues Identified

Issue 1: Reserve provision is unduly restricted for ESS due to ReserveProportion constraint and Reserve Envelope constraints

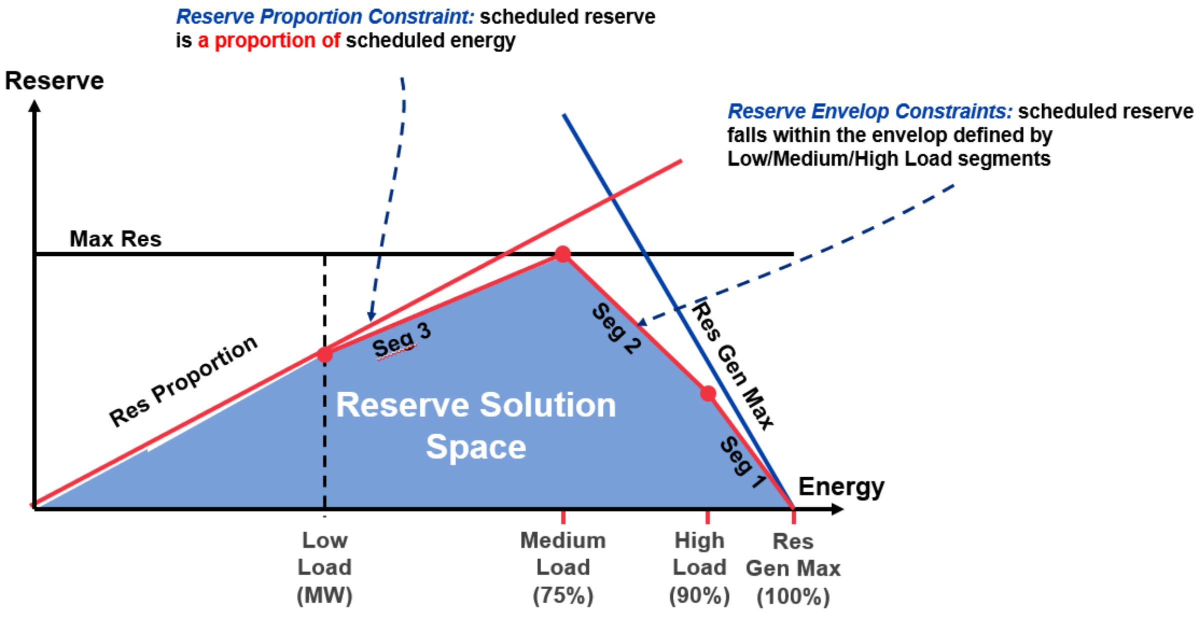
Currently, when providing reserves, all GRFs are bound by a ReserveProportion constraint, which means that the maximum reserve scheduled is directly proportional to the energy scheduled. For example:

- If ReserveProportion is 10 and energy schedule is 10MW, the maximum reserve schedule is 100MW
- Similarly, if ReserveProportion is 10 and energy schedule is 0MW (or negative MW), the maximum reserve schedule is 0MW

In other words, ESS currently need to be scheduled for some energy before they can provide any reserves. However, as noted previously by the RCP and Technical Working Group, ESS are capable of providing reserves even when energy schedule is zero or negative.

In addition, the current modeling of the reserve envelope, which is defined based on GRFs' reserve capability at HighLoad/MediumLoad/LowLoad points, are not applicable to ESS either. With ESS fast ramping capability, its reserve capability should only be restricted by its maximum discharge and charge limits.

Illustration: Reserve Solution space under current modeling



Issue 2: Reserve provision is unduly restricted for ESS to rated capacity when charging

Currently, GRFs are only able to provide reserve up to the rated capacity of the facility. However, for a ESS that is charging at maximum capacity, it is possible to provide reserves of up to twice its rated capacity. For example, for a 10MW rated ESS, ramping from -10MW (charging) to +10MW (discharging) essentially provides 20MW of reserve.

3.2.2 Proposed Solutions

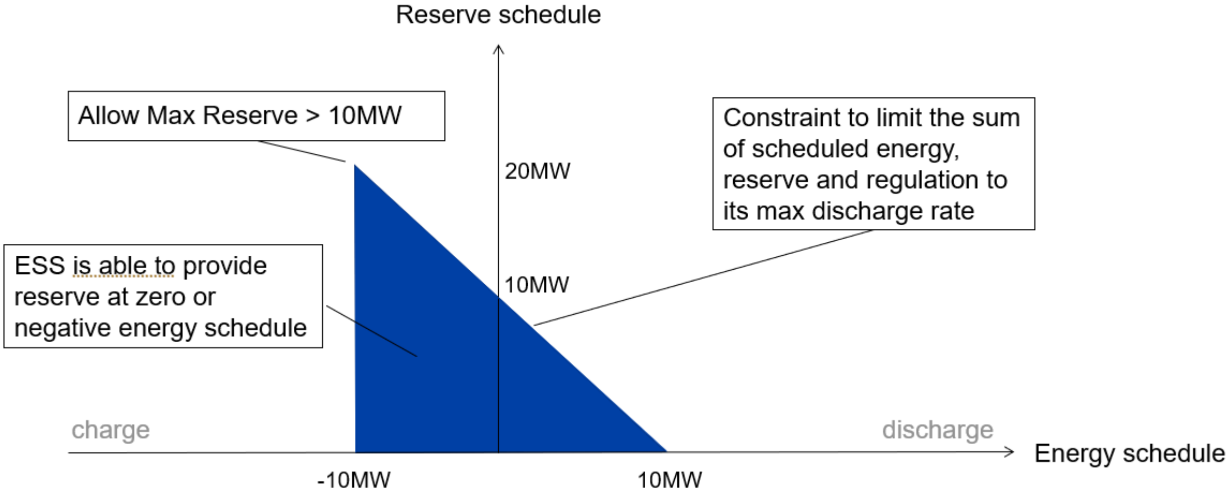
Different solution space for ESS reserve provision

The ReserveProportion constraint and Reserve Envelope constraint should be removed for ESS.

Furthermore, the maximum reserve capability for ESS should be allowed to exceed ESS rated capacity (but still subject to PSO approval for standing capability data).

An illustration of the proposed reserve envelope for a 10MW ESS is provided below.

Illustration: Proposed reserve solution space for a 10MW ESS



Market Clearing Modeling

In order to reflect the proposed solution illustrated above, the following constraint needs to be introduced for the modelling of reserve from ESS.

a. Energy Storage Reserve Max Constraint

   This is to limit total schedule of energy (can be either positive or negative), reserve and regulation from ESS to its maximum capacity – please refer to 6D.17.2.4A in Annex 1 for more details.

3.3 Modelling of ESS in Regulation Market

3.3.1 Issues Identified

Mixed Integer Program (MIP)-based regulation constraint is not required for ESS

Currently, when providing regulation, a conventional generation facility needs to operate within its regulation range, which is defined by its RegulationMin and RegulationMax parameters. For conventional generation facilities, if its energy schedule is outside the regulation range, it will not be able to provide any regulation at all. As such, a set of MIP-based regulation constraints[5] were put in place to model the provision of regulation from conventional generation facilities.

ESS, with its fast response capability, is able to provide regulation throughout its operating range. Therefore, the only constraint required for the modelling of regulation provision from ESS is to

[5] Please refer to section D.18.1.3-5 of Appendix 6D of Market Rules.

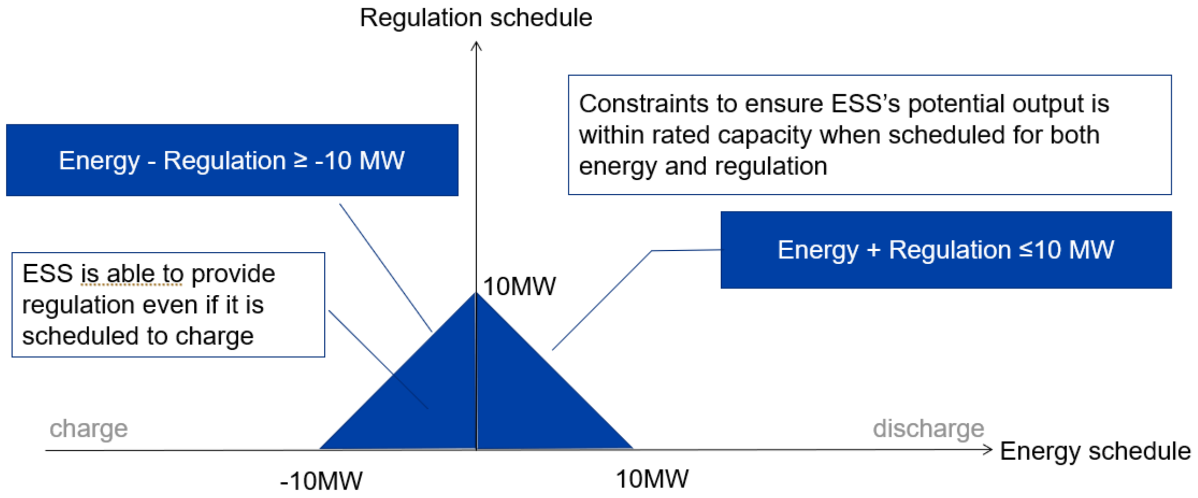
limit the ESS' output (when providing both energy and regulation) to be within its maximum discharge and charge limits.

3.3.2 Proposed solutions

<u>Different solution space for ESS regulation provision</u>

An illustration of the proposed regulation envelope for a 10MW ESS is provided below. For ESS, its maximum regulation capability will typically be the same as its maximum capacity – when its energy schedule is zero.

Illustration: Proposed regulation solution space for a 10MW ESS



<u>Market Clearing Modeling</u>

In order to reflect the proposed solution illustrated above, the following constraints need to be introduced for the modelling of regulation from ESS.

a. Energy Storage Regulation Max and Min Constraint

   This is to limit the energy storage facilities' output to its regulation range when providing both energy and regulation – please refer to 6D.18.1.6 and 6D.18.1.7 in Annex 1 for more details.

4. Rule Modifications Required

In incorporate all the above proposed solutions, it is proposed to treat the ESS as a separate type of Generation Registered Facility which can have "energy storage offers" (as opposed to "energy offers" currently). Furthermore, there is a need to introduce a distinct set of constraints (and associated parameters, variables and functions which are used in these constraints) to model ESS in the market clearing formulation. Various other enabling rule modifications are also proposed.

Table 1 below provides a summary of the proposed modifications to the market rules. The detailed modifications are set out in Annex 1.

TABLE 1: Summary of Proposed Modifications

S/N	Chapter/ Section	Proposed Modifications	Reasons for Modifications
1	Chapter 6, Section 5	Introduce a new type of offer – "energy storage offer" – for energy provision from ESS	Such energy storage offers allow ESS to submit offers for both positive energy quantity (to indicate willingness to discharge) and negative energy quantity (to indicate willingness to charge)
2	Appendix 6D, Section A: Definitions	Introduce new parameters, variables and functions	To facilitate the changes made in Appendix 6D, Section C
3	Appendix 6D, Section B: Pre-processing	Augment existing sections (inc. adding new sections)	To clarify if certain pre-processing processes should apply to ESS
4	Appendix 6D, Section C: Linear Program	Introduce a selected set of constraints to model ESS in the market clearing formulation, including: • Energy storage block constraints to limit the quantity that can be scheduled from each energy storage offer blocks to the offered quantity in that block (D15.4) • Energy storage risk constraint to calculate the risk of energy storage facilities, so that such risk will be factored into the reserve requirement calculation (D.17.1.1A) • Energy Storage Reserve Max Constraint to limit total schedule of energy, reserve and regulation to its maximum capacity (D.17.2.4A) • Energy Storage Regulation Max and Min Constraint such that the energy storage facilities' output will remain within regulation range when providing both energy and regulation (D.18.1.6, D.18.1.7) • Energy Storage Up/Down Ramp Constraint to limit ESS' energy schedule within its ramping range (D.19.1.1A, D.19.1.2A) • Violation Constraints and Tie Breaking Constraints for ESS (D.20A, D.21)	To more accurately model ESS' physical constraints within the MCE

S/N	Chapter/ Section	Proposed Modifications	Reasons for Modifications
5	Appendix 6D, Section C: Linear Program	Include ESS contribution into objective function (D.14.1), Node Generation balance constraint (D.16.1), MEP calculation (D.24.1) and estimated HEUR calculation (D.25.1.13)	To align ESS contribution with other generators' contribution to these calculations
6	Appendix 6E, Section E.1	Introduce a new section to specify the standing capability data required for ESS facilities	ESS facilities have different physical capabilities compared to conventional generators
7	Chapter 8	Introduce new definitions pertaining to ESS, and update all other relevant definitions	To define new terms used, and clarify existing terms

5. Other Considerations – State of Charge (SoC)

The SoC of ESS represents the amount of energy stored in the ESS, which is potentially useful for the MCE to assess ESS' ability to provide energy and ancillary services (especially contingency reserve). However, this requires PSO and EMC to acquire accurate, reliable and up-to-date SoC data, to be fed into the MCE.

At the 133rd Rules Change Panel (RCP) meeting in March 2023, the RCP had the following concerns if SoC is not incorporated into market clearing:

- The proposed modelling of ESS would not accurately reflect ESS' physical capability
- ESS operators would face difficulties in making offers reflective of ESS' capabilities within gate closure

As a follow-up, the RCP tasked the Technical Working Group (TWG) to examine:

(a) The feasibility of incorporating SoC in the MCE, the impact of doing so on the implementation timeline, and the system changes required

(b) The feasibility of alternative solutions (e.g., allow gate closure breach for ESS operators) to maintain self-commitment and allow for accurate MCE modelling of ESS

With TWG's endorsement, EMC's proposal to incorporate SoC in the MCE is detailed in *RC386: Incorporation of State-of-Charge in MCE modelling of ESS*[6]*.*

6. Consultation

The proposed modifications were published for consultation on 1 March 2023, and we have received comments from EMC Markets and Operations, Senoko Energy, PacificLight Power, Keppel and the PSO.

A summary of industry comments, as well as EMC responses are provided below in Table 2.

[6] Rule Change Paper EMC/RCP/139/2024/RC386

TABLE 2: Summary of Industry Comments

<table>
<tr><th>S/N</th><th>Comment</th><th>EMC Response</th></tr>
<tr><td colspan="3">Comments received from: EMC Markets and Operations</td></tr>
<tr><td>1</td><td>As the market operator, EMC Markets and Operations team recognises the benefits of this rule change to achieve greater modelling accuracy for ESS's capabilities in the Market Clearing Engine (MCE), which in turn leads to more reflective price signals.

Considering the good synergy in saving implementation cost, we would like to propose to implement another pure MCE-related proposed rule change on robustly handling StartGeneration together with this rule change. It will improve the MCE resiliency even further and minimise the key service disruptions to PSO and MPs.</td><td>EMC notes the comments received and proposes to the RCP for this issue on robustly handling StartGeneration[7] to be addressed together during implementation of ESS modelling changes. This will likely save on overall implementation costs, while further improving MCE resilience.</td></tr>
<tr><td colspan="3">Comments received from: Senoko Energy</td></tr>
<tr><td>2</td><td><u>Section 3.1.2 – Modelling of ESS in the Energy Market: Proposed Solution</u>

The methodology of using a negative offer to net off a positive offer will understate the actual system demand at any point in time when battery systems are charging. In the long run, this will reduce demand forecast accuracy and hence, we are proposing for battery charging scenarios to be captured with corresponding increases in demand.</td><td>It may not be desirable to include ESS charging offers within system demand as this may consistently overstate system demand, as long as any charging offer is not fully scheduled.

Also, including ESS charging offers within system demand will result in increased modelled load at all offtake nodes. Technically, ESS charging should only be modelled at its actual node, in order to produce accurate dispatch schedules.</td></tr>
<tr><td>3</td><td><u>Section 3.2.1 – Modelling of ESS in Reserve Market: Issues Identified</u>

While we agree that ESS are capable of providing reserves when the energy schedule is zero, the same principles can be applied for fast-ramping Gas Turbines in relation to the provision of contingency reserves.

Hence, we are hoping for EMC / PSO to revisit this topic.</td><td>As noted in the 124th RCP meeting (Matters Arising from the 120th RCP Meeting), "TWG members unanimously endorsed the statement that it is not technically and economically viable for OCGTs / CEs to operate between 0MW (not inclusive) and MSL."

The RCP has accepted the TWG's assessment. EMC is not aware that any new information on the matter has emerged to warrant revisiting the topic.</td></tr>
</table>

[7] Issue no. 18 within the RCP Workplan Prioritisation 2023 exercise

S/N	Comment	EMC Response
4	<u>Section 3.2.1 – Modelling of ESS in Reserve Market: Issues Identified</u> While we agree with the fundamental principles behind this, the State of Charge ("SoC") needs to be accurately monitored to ensure that such additional reserve capability is not overstated. Hence, our view is that this proposal should only be in place **once SoC is captured in an automated and accurate fashion**.	EMC recognises the benefits of including SoC in MCE modelling. Nevertheless, a robust mechanism will be required to implement this. EMC will endeavour its best to work with the PSO to design a sufficiently accurate, reliable and up-to-date mechanism. In the meantime, we also note that ESS will remain subject to the same compliance requirements as conventional GRFs. For example, energy output deviations remain subject to AFPS; reserve non-provision will result in non-payment for each instance, and contributing to a non-compliant ESS being assigned to a lower Reserve Provider Group, leading to lower payment for scheduled reserve. Therefore, the proposed modelling changes should be introduced, to presently enhance accuracy of MCE scheduling and pricing.
5	<u>Section 5 – Other Considerations</u> By solely relying on participants' self-commitment, it presents an opportunity for ESS to offer energy or reserves when they physically are unable to do so because of the MCE's inability to track the SoC. Such situations would occur due to human error and / or potential gaming behaviour, where MPs with ESS capabilities would find themselves with an added advantage over MPs with traditional GRFs. To prevent such **potential gaming behaviour**: 1. We strongly suggest that **SoC is captured in the MCE independently**, in an automated and accurate manner. 2. Taking reference from AFPS for GRFs, a **penalty framework** should also be in place for **non-compliant ESS offers** (where SoC is insufficient for corresponding offers).	Please see comment above. Existing mechanisms (e.g., AFPS, reserve non-payment, Reserve Provider Group) are in place to deter potential gaming behaviour.
Comments received from: PacificLight Power		
6	PLP supports the proposal to amend the Market Clearing Engine formulation to more accurately model energy storage systems (ESS) such that	EMC agrees that amendments to allow ESS to offer into the energy market (when both charging and discharging) are critical and

S/N	Comment	EMC Response
	dispatch schedules can better reflect the physical capabilities of ESS. We strongly believe that understanding the characteristics and working principles of the ESS is key in designing an appropriate scheme. We would therefore propose EMC appoints an external technical consultant to assist EMC in designing the scheme. Broadly, the proposal introduces two amendments, one is to allow ESS facilities to participate in the energy market, and the other is to allow ESS to participate in the reserves and regulation market. PLP would propose to implement the amendments in two phases: <u>Phase 1: Amend to allow ESS to participate in the Energy Market</u> i. This amendment is critical and urgent as it will reflect real-time supply and demand and will facilitate balancing. ii. We believe PSO is receiving real-time charging and discharging rates from ESS which would allow them to monitor and ensure that any ESS is compliant with the dispatch, even in the absence of other critical information like State-of-Charge (SoC) of the ESS. iii. Nonetheless, we would like to point out that the charge and discharge quantity would still depend on the real-time SoC before the dispatch period. Given that the gate closure is 65 minutes prior to the dispatch period, there is no certainty on the SoC when the ESS provider bids, as it is still contingent upon the clearing schedule of the previous two periods and the potential pulsing during the 65 minutes. iv. We therefore propose to implement this amendment first. <u>Phase 2: Amend to allow ESS to participate in the Reserve and Regulation market.</u> i. This amendment requires a more detailed study by the proposed technical consultant to establish the information needed to be incorporated into the MCE to reflect the real-time capability of ESS in providing reserve and/or regulation. ii. At the very minimum, the SoC data must be incorporated into the MCE for deriving the	urgent, thus should be implemented in a timely manner. Based on experience in overseas jurisdictions, ESS is mostly valued for its ability to provide ancillary services (instead of conducting energy arbitrage). Considering that there are existing mechanisms (e.g., AGC control, reserve non-payment, Reserve Provider Group) in place to enforce compliance for ancillary

S/N	Comment	EMC Response
	real-time capability of ESS. Currently, the proposed formula allows for a theoretical provision of reserve up to twice the rated capacity, ignoring the SoC, which is risky from a security of supply perspective as the ESS may fail to respond during an emergency event. iii. One of the possible ways is to capture the SoC five minutes prior to the dispatch period and use it as an input to derive the effective capability of ESS for the following period. The formula that derives the capability of providing reserve could then be updated as follows: a. If ESS is scheduled for charging, the max reserve capability shall be equal to: |Scheduled charge| + Min (SoC (MWh) ÷ 0.5h, Power Rating (MW)) b. If ESS is discharging, the max reserve capability shall be equal to: Min (SoC (MWh) ÷ 0.5h - Scheduled Discharge (MW), Power Rating (MW) –Scheduled discharge (MW)) iv. The technical study should also include a review of the reserve effectiveness i.e., response time of ESS, as it is likely different from a CCGT, and appropriately incorporate it as part of the design. For example, with more supply from solar, we observe an increased number of occasions where frequency dips due to intermittency issues. Fast response time is therefore key to balance the grid under these circumstances.	services, it seems reasonable at this juncture to facilitate ESS participation in reserve and regulation markets. Having said that, EMC will engage with the PSO to design a sufficiently accurate, reliable and up-to-date mechanism to incorporate SoC into the MCE, to more closely reflect the physical capabilities of ESS in real time. Lastly, EMC will consult with PSO on whether there is a need to introduce “fast response” reserve/regulation as a separate product in the SWEM, in view of intermittency issues due to increased solar penetration.
Comments received from: Keppel		
7	Keppel has no objections to the proposed modelling of ESS in the MCE. However, we would like EMC to provide the estimated cost of implementation as well the estimated additional costs to model the SoC of the ESS into the MCE to better reflect the actual capability of the facility.	An estimate of implementation costs is provided below in Section 7. Costs to include SoC modelling within the MCE will be provided in future, when the extent of system changes required becomes clear.
Comments received from: PSO		
8	<u>Section 3.1.2 – Modelling of ESS in the Energy Market: Proposed Solution</u> Referring to the Energy Storage Risk Constraint, can the MCE also calculate the risk of solar PV, to factor into reserve requirement calculation?	We note that there may be benefits in doing so. However, this is beyond the scope of this rule change paper.

S/N	Comment	EMC Response
9	Section 3.2.2 – Modelling of ESS in the Reserve Market: Proposed Solution Upon facility registration, commissioning tests will be conducted to validate ESS capacity. However, during daily real time operations, ESS operators will need to ensure that there is available capacity prior to offering into the NEMS. ESS operators are obliged to comply with dispatch schedules under the Market Rules.	EMC agrees that the obligations to ensure that there is available capacity and comply with dispatch schedules lies with the MPs.
10	Section 5 – Other Considerations When providing regulation reserves, it will be challenging for the MCE to assess ESS' ability to provide energy and ancillary services in the dispatch period. This is a self-commitment market. Similar to current gencos, ESS operators should offer into the market according to its capability, in line with the Market Rules' compliance breach framework that is imposed on all licensees.	EMC will continue to engage with the PSO to explore the possibility of modelling SoC, taking into account these considerations.

7. Implementation Effort Estimate

A summary of the implementation effort estimate is provided in Table 3 below. The total cost is estimated to be **$300,344** and the total lead time required is estimated to be **35 calendar weeks**.

TABLE 3: Implementation Effort Estimate

Time Estimate		
Task	**Man Weeks**	**Elapsed Time in Calendar Weeks**
Change Requirement Scoping and Analysis	4	4
System Development / Testing / Project Management	26	19
User Acceptance Testing (UAT)	6	6
Security Testing / CII	6	2
Audit (overlapping with UAT for two weeks)	4	4
Total Effort Required	**46**	**35**
Cost Estimate		
Internal EMC Manpower		$223,344
External Resource to Support (Vendor)		$17,000
Audit		$60,000
Total Cost		**$300,344**

8. Conclusion

This paper proposes to amend the Market Clearing Engine to more accurately model ESS. These changes are timely, considering that the already sizable registered ESS capacity in the SWEM, and the likelihood of such capacity increasing over time.

By better reflecting ESS' physical capabilities in the market clearing process, the MCE will produce more optimal dispatch schedules and more accurate price signals.

9. RCP's Decision at the 139th RCP Meeting

At the 139th meeting, the RCP **unanimously supported** the proposed modifications as set out in Annex 1.

10. Recommendation

The RCP recommends that the EMC Board:

a) **adopt** the proposed modifications to the Market Rules as set out in Annex 1; and

b) **seek the EMA's approval** of the proposed modifications to the Market Rules as set out in Annex 1.

ANNEX 1: Proposed Modifications to Market Rules

Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
Chapter 6	
5 OFFERS AND BIDS	
5.2 <u>FORM OF ENERGY OFFERS</u> 5.2.1 Each *energy offer* is an *offer* to provide *energy* to the relevant *real-time market* by a *generation registered facility* <u>that is not an *energy storage facility*,</u> or an *import registered facility* at its *market network node* in a *dispatch period*.	To include a new type of offers for energy storage facilities to indicate its willingness to charge and discharge.

<table>
<tr>
<td>

5.2B FORM OF ENERGY STORAGE OFFERS

5.2B.1 Each *energy storage offer* is an offer to provide *energy* to, or withdraw *energy* from, the *real-time market* by a *generation registered facility* that is an *energy storage facility* at its *market network node* in a *dispatch period*.

5.2B.2 Each *energy storage offer* shall state:

5.2B.2.1 the identity of the *energy storage facility* that the *energy storage offer* is for;

5.2B.2.2 if it is a *standing offer* or an *offer variation*;

5.2B.2.3 the *dispatch period* that the *energy storage offer* is for;

5.2B.2.4 between 1 to 10 *price-quantity pairs* stated in increasing order of price where;

a) *price-quantity pairs* in the range 1-5 represent offers to withdraw *energy* from the *transmission system* for the purpose of charging the *energy storage facility*. The quantity in each of these *price-quantity pairs* shall not be more than 0.0 MW;

b) *price-quantity pairs* in the range 6-10 represent offers to provide energy to the *transmission system* by means of discharging the *energy storage facility*. The quantity in each of these *price quantity pairs* shall not be less than 0.0 MW;

5.2B.2.5 the maximum combined transfer limit of the *energy storage facility* for *energy*, *reserve* and *regulation* for the *dispatch period*;

5.2B.2.6 the *energy* ramp-up rate and the *energy* ramp-down rate, which respectively imply the allowable change in the output or withdrawal of the *energy storage facility* during the *dispatch period*.

5.2B.3 The price in each *price-quantity pair* of an *energy storage offer* shall:

5.2B.3.1 be expressed in $/MWh to two decimal places;

5.2B.3.2 not exceed the upper price limit specified in Appendix 6J; and

5.2B.3.3 not be less than the lower price limit specified in Appendix 6J.

</td>
<td>To include a new type of offers for energy storage facilities to indicate its willingness to charge and discharge.</td>
</tr>
</table>

Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)	**Reasons for Modification**
5.2B.4 If the quantity in a *price-quantity pair* of an *energy storage offer* is 0.0 MW, the corresponding price shall be $0.00/MWh. 5.2B.5 The total of the absolute value of the quantities in all negative-quantity *price quantity pairs* of an *energy storage offer* for a *dispatch period* shall not exceed: 5.2B.5.1 the maximum charge limit, indicated in the relevant *energy storage facility*'s *standing capability data* for that *dispatch period*; or 5.2B.5.2 the maximum charging quantity that can be delivered in that *dispatch period* as reasonably estimated by its *dispatch coordinator*. 5.2B.6 The total of the quantities in all the positive-quantity *price-quantity pairs* of an *energy storage offer* for a *dispatch period* shall not exceed: 5.2B.6.1 the maximum discharge limit, indicated in the relevant *energy storage facility's standing capability data* for that *dispatch period*; or 5.2B.6.2 the maximum discharging quantity that can be delivered in that *dispatch period* as reasonably estimated by its *dispatch coordinator*.	
APPENDIX 6D MARKET CLEARING FORMULATION	
SECTION A: DEFINITIONS	
D.2 SETS	

<table>
<tr><th>Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)</th><th>Reasons for Modification</th></tr>
<tr><td>D.2.1 Unless otherwise stated, a reference to a generation registered facility in this D.2 does not include a reference to a generation registered facility that is an energy storage facility.</td><td>To exclude “energy storage facility” from the reference to “generation registered facility” for the purpose of section D.2.</td></tr>
<tr><td>
<table>
<tr><td>ENERGYSTORAGEOFFERS</td><td>The set, indexed by es, comprising all energy storage offers from dispatch coordinators of energy storage facilities</td></tr>
<tr><td>ENERGYSTORAGEOFFERS$_n$</td><td>The set of all energy storage offers associated with node n. A subset of ENERGYSTORAGEOFFERS</td></tr>
<tr><td>GENREGULATIONOFFERS</td><td>The subset of REGULATIONOFFERS that have been submitted by the dispatch coordinators for generation registered facilities</td></tr>
<tr><td>STORAGEREGULATIONOFFERS</td><td>The subset of REGULATIONOFFERS that have been submitted by the dispatch coordinators for energy storage facilities.</td></tr>
<tr><td>VIOLATIONGROUPBLOCKSFAC$_{y(es)}$</td><td>The set of violation penalty blocks for violation of violation constraint group y(es) which consists of violations associated with energy storage facilities. Indexed by j.</td></tr>
</table>
</td><td>To introduce new sets to differentiate energy and regulation offers for energy storage facilities.</td></tr>
</table>

Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
D.3 PARAMETERS	
D.3.1 Unless otherwise stated, a reference to a *generation registered facility* in this D.3 does not include a reference to a *generation registered facility* that is an *energy storage facility*.	To exclude "energy storage facility" from the reference to "generation registered facility" for the purpose of section D.3.

DownRampRate$_{g}$ or DownRampRate$_{es}$ or DownRampRate$_{p}$	The maximum ramp-down rate of the *generation registered facility* that the *energy offer g* is for, the *energy storage facility* that the *energy storage offer es* is for, or the *LRF with REB* that the *energy bid p* is for, in MW/minute. Set from the values stated in valid *energy offers* referred to in section 5.2.2.6 of Chapter 6, in valid *energy storage offers* referred to in section 5.2B.2.8 of Chapter 6, or in valid *restricted energy bids* referred to in section 5.2A.2.6 of Chapter 6.
EnergyStorageBlockLimit$_{es,j}$	The limit on the MW which can be scheduled from block *j* of ENERGYSTORAGEOFFERBLOCKS$_{es}$ for *energy storage offer es* in the set ENERGYSTORAGEOFFERS. Determined by the *price-quantity pairs* for valid *energy storage offers*. For the offers referred to in section 5.2B.2.4 of Chapter 6 for *charging* the *energy storage facility* this limit will be negative, and for the offers referred to in section 5.2B.2.5 of Chapter 6 for *discharging* the *energy storage facility* this limit will be positive.
MaximumChargeLimit$_{es}$	The maximum rate, in MW, at which *an energy storage facility* can withdraw electrical *energy* from the *transmission system*. Received from the *PSO* in accordance with Appendix 6E section E.1A.1.2.
MaximumDischargeLimit$_{es}$	The maximum discharge limit representing the maximum rate, in MW, at which, an *energy storage facility* can inject electrical *energy* into the *transmission system*. Received from the *PSO* in accordance with Appendix 6E section E.1A.1.3.
OfferedCapacity$_{es}$	The maximum combined energy storage transfer level of the *energy storage facility* for *energy*, *reserve* and *regulation* stated in *energy storage offer es* under section 5.2B.2.7 of Chapter 6.
RegulationMax$_{es}$	The maximum *energy* transfer level at which *automatic generator control* (*AGC*) or other signals acceptable to the *PSO* can operate the *energy storage*

To introduce new parameters for energy storage facilities.

Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)		Reasons for Modification
	facility associated with *energy storage offer es* to provide *regulation* capability. Calculated in accordance with section D.9A.8A.	
RegulationMin$_{es}$	The minimum *energy* transfer level at which *automatic generator control* (*AGC*) or other signals acceptable to the *PSO* can operate the *energy storage facility* associated with *energy offer es* to provide *regulation* capability. Set from the *standing capability data* referred to in Appendix 6E section E.1A.1.10.	
StartGeneration$_{es}$	The forecast generation level at the beginning of a given *dispatch period* of a *generation registered facility* associated with *energy storage offer es* for that *dispatch period*. Received from the *PSO* in accordance with section G.3.1 of Appendix 6G.	
UpRampRate$_{g}$, UpRampRate$_{es}$ or UpRampRate$_{p}$	The maximum ramp-up rate of the *generation registered facility* that the *energy offer g* is for, the *energy storage facility* that the *energy storage offer es* is for, or the *LRF with REB* that the *energy bid p* is for, in MW/minute. Set from the values stated in valid *energy offers* referred to in section 5.2.2.6 of Chapter 6, in valid *energy storage offers* referred to in section 5.2B.2.8 of Chapter 6, or in valid *restricted energy bids* referred to in section 5.2A.2.6 of Chapter 6.	
D.4 VARIABLES		

Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
<table><tr><td>ExcessDownRamp_g ExcessDownRamp_{es} or ExcessDownRamp_p</td><td>The MW amount by which the maximum down ramp of the generation registered facility associated with energy offer g, the energy storage facility associated with energy storage offer es, or the LRF with REB associated with energy bid p, is exceeded.</td></tr><tr><td>EnergyStorageBlock_{es}</td><td>The MW scheduled in block j of energy storage offer es.</td></tr><tr><td>EnergyStorageTransfer_{es}</td><td>The total MW transfer scheduled for energy storage offer es. This variable can be positive or negative, with a positive values indicating discharging and a negative transfer indicating charging.</td></tr><tr><td>ExcessUpRamp_g ExcessUpRamp_{es} or ExcessUpRamp_p</td><td>The MW amount by which the maximum up ramp of the generation registered facility associated with energy offer g, the energy storage facility associated with energy storage offer es, or the LRF with REB associated with energy bid p, is exceeded.</td></tr><tr><td>FacilityRampViolation_{es}</td><td>The total MW violation of the ramping constraints associated with the energy storage facility that energy storage offer es is for.</td></tr></table>	To introduce new variables for energy storage facilities.

Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
D.4.3 Unless otherwise stated, a reference to a *generation registered facility* in this D.4 does not include a reference to a *generation registered facility* that is an *energy storage facility*.	To exclude "energy storage facility" from the reference to "generation registered facility" for the purpose of section D.4.
D.5 FUNCTIONS	
D.5.1 Unless otherwise stated, a reference to a *generation registered facility* in this D.5 does not include a reference to a *generation registered facility* that is an *energy storage facility*.	To exclude "energy storage facility" from the reference to "generation registered facility" for the purpose of section D.3.

<table>
<tr><th>Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)</th><th>Reasons for Modification</th></tr>
<tr><td>
<table>
<tr><td>es(l)</td><td>References the energy storage offer es that has the same associated generation registered facility that is an energy storage facility as the regulation offer l</td></tr>
<tr><td>es(r)</td><td>References the energy storage offer es that has the same associated generation registered facility that is an energy storage facility as the reserve offer r</td></tr>
<tr><td>l(es)</td><td>References the regulation offer l that has the same associated energy storage facility as the energy storage offer es.</td></tr>
<tr><td>r(g,c), r(h,c), r(es,c)</td><td>References the reserve offer r that has the same associated generation registered facility as the energy offer g or h, or the same energy storage facility as the energy storage offer es, and applies to reserve class c.</td></tr>
<tr><td>y(k), y(c), y(es), y(g), y(p), y(s), y(regulation)</td><td>References the violation constraint group associated with line k, the reserve requirement for reserve class c, the energy storage facility associated with energy storage offer es, the generation registered facility associated with energy offer g, the LRF with REB associated with energy bid p, the security constraint s, the multi-unit constraint s, or the regulation requirement, respectively.</td></tr>
</table>
</td><td>To introduce new variables for energy storage facilities.</td></tr>
<tr><td>SECTION B: PRE-PROCESSING</td><td></td></tr>
<tr><td>D.6 DISPATCH NETWORK DERIVATION
…
D.6.7 For the avoidance of doubt, a reference to a generation registered facility in this section D.6 shall include a reference to a generation registered facility that is an energy storage facility.</td><td>To clarify that section D.6 apply to energy storage facilities.</td></tr>
</table>

Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
D.7 MARKET NETWORK NODES … D.7.10 For the avoidance of doubt, a reference to a *generation registered facility* in this section D.7 shall include a reference to a *generation registered facility* that is an *energy storage facility*.	To clarify that section D.7 apply to energy storage facilities.
D.8 REPRESENTATION OF MULTI-UNIT FACILITIES … D.8.10 Unless otherwise stated, a reference to a *generation registered facility* in this D.8 does not include a reference to a *generation registered facility* that is an *energy storage facility.*	To exclude "energy storage facility" from the reference to "generation registered facility" for the purpose of section D.8.

D.9A ENERGY BIDS AND OFFERS D.9A.1A The set ENERGYSTORAGEOFFERS shall comprise all valid *energy storage offers* for the *dispatch period* received by the *EMC.* D.9A.7 The parameter ReserveGenerationMax$_r$ associated with each *reserve offer* associated with a *generation registered facility* shall equal the smaller of: D.9A.7.1 the *standing capability data* referred to in section E.1.1.6 of Appendix 6E for the associated *generation registered facility* for the appropriate *reserve class*; and D.9A.7.2 OfferedCapacity$_{g(r)}$. D.9A.7A The parameter ReserveGenerationMax$_r$ associated with each *reserve offer* associated with an *energy storage facility* shall equal the smaller of: D.9A.7A.1 the *standing capability data* referred to in section E.1A.1.7 of Appendix 6E for the associated *energy storage facility* for the appropriate *reserve class*; and D.9A.7A.2 OfferedCapacity$_{es(r)}$. D.9A.8 The parameter RegulationMax$_{g(l)}$ associated with each *regulation offer* associated with a *generation registered facility* shall equal the smaller of: D.9A.8.1 the *standing capability data* referred to in section E.1.1.9 of Appendix 6E for the associated *generation registered facility*; and D.9A.8.2 OfferedCapacity$_{g(l)}$. D.9A.8A The parameter RegulationMax$_{es(l)}$ associated with each *regulation offer* associated with an *energy storage facility* shall equal the smaller of: D.9A.8A.1 the *standing capability data* referred to in section E.1A.1.9 of Appendix 6E for the associated *energy storage facility*; and	To introduce rules for determination of parameter ReserveGenerationMax and RegulationMax for energy storage facilities

Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
D.9A.8A.2 OfferedCapacity $_{es(l)}$. D.9A.9 Unless otherwise stated, a reference to a *generation registered facility* in this D.9A does not include a reference to a *generation registered facility* that is an *energy storage facility*.	

D.9C **TIED OFFERS**

D.9C.5 If a *price-quantity pair (g,j)* of $\text{GENERATIONOFFERBLOCKS}_g$ and a *price-quantity pair (es',j')* of $\text{ENERGYSTORAGEOFFERBLOCKS}_{es'}$ meet the following condition, they shall be assigned to a set, $\text{TIEDENERGYOFFERBLOCKPAIR}_o$:

$$\text{GenerationOfferPrice}_{(g(o),j(o))} = \text{EnergyStorageOfferPrice}_{(es'(o),j'(o))}$$

$\{g(o)=g, \in \text{ENERGYOFFERS}$
$es'(o)=es' \neq es, \in \text{ENERGYTORAGEOFFERS}$
$j(o)=j, \in \text{GENERATIONOFFERBLOCKS}_{g(o)}$ and
$j'(o)=j', \in \text{ENERGYSTORAGEOFFERBLOCKS}_{es'(o)}\}$ where $\text{EnergyStorageBlockLimit}_{es,j'} \geq 0\}$

D.9C.6 If a *price-quantity pair (es,j)* of $\text{ENERGYSTORAGEOFFERBLOCKS}_{es}$ and a *price-quantity pair (es',j')* of $\text{ENERGYSTORAGEOFFERBLOCKS}_{es'}$ meet the following condition, they shall be assigned to a set, $\text{TIEDENERGYOFFERBLOCKPAIR}_o$:

$$\text{EnergyStorageOfferPrice}_{(es(o),j(o))} = \text{EnergyStorageOfferPrice}_{(es'(o),j'(o))}$$

$\{es(o)=es, \text{ENERGYSTORAGEOFFERS},$
$es'(o)=es' \neq es, \in \text{ENERGYTORAGEOFFERS},$
$j(o)=j, \in \text{ENERGYSTORAGEOFFERBLOCKS}_{g(o)}$ where $\text{EnergyStorageBlockLimit}_{es,j} \geq 0$, and
$j'(o)=j', \in \text{ENERGYSTORAGEOFFERBLOCKS}_{es'(o)}$ where $\text{EnergyStorageBlockLimit}_{es,j'} \geq 0\}$

D.9C.7 If a *price-quantity pair (es,j)* of $\text{ENERGYSTORAGEOFFERBLOCKS}_{es}$ and a *price-quantity pair (es',j')* of $\text{ENERGYSTORAGEOFFERBLOCKS}_{es'}$ meet the following condition, they shall be assigned to a set, $\text{TIEDENERGYOFFERBLOCKPAIR}_o$:

$$\text{EnergyStorageOfferPrice}_{(es(o),j(o))} = \text{EnergyStorageOfferPrice}_{(es'(o),j'(o))}$$

$\{es(o)=es, \in \text{ENERGYSTORAGEOFFERS}$
$es'(o)=es' \neq es, \in \text{ENERGYTORAGEOFFERS}$
$j(o)=j, \in \text{ENERGYSTORAGEOFFERBLOCKS}_{g(o)}$ where $\text{EnergyStorageBlockLimit}_{es,j} \leq 0$ and
$j'(o)=j', \in \text{ENERGYSTORAGEOFFERBLOCKS}_{es'(o)}$ where $\text{EnergyStorageBlockLimit}_{es,j'} \leq 0\}$

To introduce rules for establishing tied offers between energy storage facilities and generation facilities.

Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
D.11 ESTIMATED RESERVE EFFECTIVENESS D.11.2 $EstReserveEffectiveness_{r(es,c)} = Effectiveness_{x(es,c),1}$ $\{es,c \mid es \in ENERGYSTORAGEOFFERS,\ c \in RESERVECLASSES\}$	To introduce rules for determination of EstReserveEffectiveness for energy storage facilities
D.12 RAMPING CONSTRAINTS … D.12.11 Unless otherwise stated, a reference to a *generation registered facility* in this D.12 does not include a reference to a *generation registered facility* that is an *energy storage facility*.	To introduce a new section on determination of StartGeneration and the ramping range for energy storage facilities.

D.12A RAMPING CONSTRAINTS FOR ENERGY STORAGE FACILITY

D.12A.1 In the case where a *real-time dispatch schedule* is being produced, or where the *dispatch period* is the first *dispatch period* of the multiple *dispatch periods* involved in the calculation of a *short-term schedule*, then the values of $StartGeneration_{es}$ for each *energy storage facility* in the applicable *dispatch period* shall be the values received from the *PSO* in accordance with section G.3.1 of Appendix 6G.

D.12A.1.1 In the event that a value of $StartGeneration_{es}$ for any *energy storage facility* is not updated by the *PSO* or provided to the *EMC* during the *dispatch period* for the time being when the calculation of the *real-time dispatch schedule* or the first *dispatch period* of the multiple *dispatch periods* involved in the calculation of a *short-term schedule* commences, the value of $StartGeneration_{es}$ for the *energy storage facility* shall be the same as the corresponding value of $EnergyStorageTransfer_{es}$ for the same *energy storage facility* in the *real-time dispatch schedule* for the *dispatch period* with respect to the time when the calculation of the *real-time dispatch schedule* commences. In the event that no such *real-time dispatch schedule* is available, then the *EMC* shall use a value of zero for $StartGeneration_{es}$ for the *energy storage facility*.

D.12A.2 In the case where the *dispatch period* is the first *dispatch period* of the multiple *dispatch periods* involved in the calculation of the *pre-dispatch schedule*, then the values of $StartGeneration_{es}$ for each *energy storage facility* shall be the corresponding values of $EnergyStorageTransfer_{es}$ in the *real-time dispatch schedule* for the *dispatch period* current at the time when the calculation of the *pre-dispatch schedule* commences, or, if this *real-time dispatch schedule* is not available, the *real-time dispatch schedule* for the *dispatch period* immediately preceding that which is current at the time when the calculation of the *pre-dispatch schedule* commences.

D.12A.3 In the case where the *dispatch period* is the first *dispatch period* of the multiple *dispatch periods* involved in the calculation of the *market outlook scenario*, the values of $StartGeneration_{g}$ for each *energy storage facility* shall be the same as the corresponding values $EnergyStorageTransfer_{es}$ for the same *energy storage facility* in the most recently released *pre-dispatch schedule* with a *nodal load forecast* corresponding to the *market outlook scenario* being calculated, and shall be taken from the *dispatch period* in such *pre-dispatch schedule* immediately preceding the first *dispatch period* required in the calculation of the *market outlook scenario*, provided that such *pre-dispatch schedule* contains the appropriate *dispatch period*. If such *pre-dispatch schedule* does not contain the appropriate *dispatch period*, then initial generation levels the values of $StartGeneration_{es}$ for such *energy storage facilities* shall be zero.

D.12A.4 In the case where the *dispatch period* is involved in the calculation of a *short-term schedule*, a *pre-dispatch schedule* or a *market outlook scenario*, and is not the *first dispatch period* of the multiple *dispatch periods*

Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
involved in the calculation of the *short-term schedule*, *pre-dispatch schedule* or a *market outlook scenario*, the values of $StartGeneration_{es}$ for each *energy storage facility* shall be the corresponding values of $EnergyStorageTransfer_{es}$ for the immediately preceding *dispatch period* in the *short-term schedule*, *pre-dispatch schedule* or *market outlook scenario* respectively. D.12A.5 $EnergyTransferEndMax_{es} = StartGeneration_{es} + (UpRampRate_{es} / 60 \times RemainingTime)$ $\{es \in ENERGYSTORAGEOFFERS\}$ D.12A.6 $EnergyTransferEndMin_{es} = StartGenerationes_{es} - (DownRampRate_{es} / 60 \times RemainingTime)$ $\{es \in ENERGYSTORAGEOFFERS\}$	
SECTION C: LINEAR PROGRAM	

D.14 OBJECTIVE FUNCTION

D.14.1 The NetBenefit is maximised, where:

NetBenefit =

$$\sum_{\substack{\{j,p|j\in \text{PURCHASEBIDBLOCKS}_p \\ \text{where } p\in \text{BIDS}\}}} \text{PurchaseBidPrice}_{p,j} \times \text{PurchaseBlock}_{p,j}$$

$$- \sum_{\substack{\{j,g|j\in \text{GENERATIONOFFERBLOCKS}_g \\ \text{where } g\in \text{OFFERS}\}}} \text{GenerationOfferPrice}_{g,j} \times \text{GenerationBlock}_{g,j}$$

~~$- \sum_{\{j,es|j\in \text{ENERGYSTORAGEOFFERBLOCKS}_{es} \text{ where } es\in \text{ENERGYSTORAGEOFFERS}\}} \text{EnergyStorageOfferPrice}_{es,j} \times \text{EnergyStorageBlock}_{es,j}$~~

$$- \sum_{\substack{\{j,r|j\in \text{RAWRESERVEBLOCKS}_r \\ \text{where } r\in \text{RAWRESERVEOFFERS}\}}} \text{ReserveOfferPrice}_{r,j} \times \text{RawReserveBlock}_{r,j}$$

$$- \sum_{\substack{\{j,l|j\in \text{REGULATIONOFFERBLOCKS}_l \\ \text{where } l\in REGULATIONOFFERS\}}} \text{RegulationOfferPrice}_{l,j} \times \text{RegulationBlock}_{l,j}$$

$$- \sum_{\substack{\{j,n|j\in \text{EXCESSGENERATIONBLOCKS}_n \\ \text{where } n\in \text{NODES}\}}} \text{ExcessGenerationPenalty}_{n,j} \times \text{ExcessGenerationBlock}_{n,j}$$

$$- \sum_{\substack{\{j,n|j\in \text{DEFICITGENERATIONBLOCKS}_n \\ \text{where } n\in \text{NODES}\}}} \text{DeficitGenerationPenalty}_{n,j} \times \text{DeficitGenerationBlock}_{n,j}$$

To include cost of scheduling energy storage facilities into the objective function.

Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
– ViolationPenalties – TieBreakingPenalties	

D.15 CONSTRAINTS ON ENERGY GENERATION AND PURCHASES D.15.4 Energy Storage Constraints D.15.4.1 Energy Storage Block Constraint for Discharging $0 \leq \text{EnergyStorageBlock}_{es,j} \leq \text{EnergyStorageBlockLimit}_{es,j}$ $\{j,es \mid j \in \text{ENERGYSTORAGEOFFERBLOCKS}_{es} \text{ where EnergyStorageBlockLimit}_{es,j} \geq 0\}$ D.15.4.2 Energy Storage Block Constraint for Charging $\text{EnergyStorageBlockLimit}_{es,j} \leq \text{EnergyStorageBlock}_{es,j} \leq 0$ $\{j,es \mid j \in \text{ENERGYSTORAGEOFFERBLOCKS}_{es} \text{ where EnergyStorageBlockLimit}_{es,j} \leq 0\}$ D.15.4.3 Energy Storage Summation Constraint $\text{EnergyStorageTransfer}_{es} = \sum_{j \in \text{ENERGYSTORAGEOFFERBLOCKS}} \text{EnergyStorageBlock}_{es,j}$ $\{es \in \text{ENERGYSTORAGEOFFERS}\}$	To include energy storage constraints to limit the energy scheduled from the energy storage facilities to its offered quantity.

Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
D.16 TRANSMISSION D.16.1 Node Balance D16.1.2 Node Balance Generation Constraint: $\text{NodeNetInjection}_{n} = \sum_{g \in \text{OFFERS}_n} \text{Generation}_g \underline{\underline{+ \sum_{es \in \text{ENERGYSTORAGEOFFERS}_n} \text{EnergyStorageTransfer}_{es}}} - \sum_{p \in \text{ENERGYBIDS}_n} \text{Purchase}_p - \sum_{p \in \text{RESTRICTEDENERGYBIDS}_n} \text{Purchase}_p + \sum_{j \in \text{DEFICITGENERATIONBLOCKS}_n} \text{DeficitGenerationBlock}_{n,j} - \sum_{j \in \text{EXCESSGENERATIONBLOCKS}_n} \text{ExcessGenerationBlock}_{n,j}$ $\{n \in \text{NODES}\}$	To include energy storage transfer (i.e., either injection or withdrawal) by energy storage facilities into Node Balance Generation Constraint

Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
D.17 RISK AND OPERATING RESERVE D.17.1 Risk D.17.1.1A Energy Storage Risk Constraint: $Risk_c \geq RiskAdjustmentFactor_c \times RawCalculatedRisk_{es,c}$ Where: $RawCalculatedRisk_c = EnergyStorageTransfer_{es} - PowerSystemResponse_c + EstReserveEffectiveness_{r(es,c)} \times RawReserve_{r(es,c)}$ and $PowerSystemResponse_c = EstIntertieContribution \times AcceptableFreqDeviation_c \times EstLoadDamping_c - EstGTOutputDamping_c \times \sum_{i \in DAMPINGGENERATORS} Generation_i$ $\{es,c \mid es \in ENERGYSTORAGEOFFERS,\ c \in RESERVECLASSES\}$	To include a constraint to calculate the risk of energy storage facilities such that such risk will be factored into the reserve requirement calculation.

Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
D.17.2 Supply of Contingency Reserve D.17.2.4A Energy Storage Reserve Max Constraint: $EnergyStorageTransfer_{es(r)} + RawReserve_r + Regulation_{l(r)} - ExcessResGen_r \leq ReserveGenerationMax_r$ $\{ r \in STORAGERESERVEOFFERS\}$	To introduce constraint to limit the provision of energy, reserve, regulation by energy storage facilities to its maximum capacity.
D.18 REGULATION D.18.1.6 Energy Storage Regulation Max Constraint: $EnergyStorageTransfer_{es(l)} + Regulation_l - ExcessRegGen_l \leq RegulationMax_{es(l)}$ $\{ l \in STORAGEREGULATIONOFFERS\}$ D.18.1.7 Energy Storage Regulation Min Constraint: $EnergyStorageTransfer_{es(l)} - Regulation_l - DeficitRegGen_l \geq RegulationMin_{es(l)}$ $\{ l \in STORAGEREGULATIONOFFERS\}$	To introduce Regulation Max and Regulation Min constraints for energy storage facilities

Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
D.19 RAMPING D.19.1 Energy Ramping Constraints D.19.1.1 Up Ramp Constraint: $Generation_g - ExcessUpRamp_g \leq GenerationEndMax_g$ $\{g \in ENERGYOFFERS, g \notin INTERTIEENERGYOFFERS\}$ D.19.1.1A Energy Storage Up Ramp Constraint: $EnergyStorageTransfer_{es} - ExcessUpRamp_{es} \leq EnergyTransferEndMax_{es}$ $\{es \in ENERGYSTORAGEOFFERS\}$ D.19.1.2 Down Ramp Constraint: $Generation_g + ExcessDownRamp_g \geq EnergyTransferEndMin_g$ $\{g \in ENERGYOFFERS, g \notin INTERTIEENERGYOFFERS\}$ D.19.1.2A Energy Storage Down Ramp Constraint: $EnergyStorageTransfer_{es} + ExcessDownRamp_{es} \leq EnergyTransferEndMin_{es}$ $\{es \in ENERGYSTORAGEOFFERS\}$	To introduce ramping constraints for energy storage facilities.

D.20A TIE-BREAKING CONSTRAINTS

D.20A.1 Energy Tie-Breaking Constraints:

$$\frac{\text{GenerationBlock}_{(g(o),j(o))}}{\text{GenerationBlockMax}_{(g(o),j(o))}} - \frac{\text{GenerationBlock}_{(g'(o),j'(o))}}{\text{GenerationBlockMax}_{(g'(o),j'(o))}}$$

$$= \text{EnergyTieBreakSlack1}_o - \text{EnergyTieBreakSlack2}_o$$

$\{o \in \text{TIEDENERGYOFFERBLOCKPAIRS, where } g(o),\ g'(o) \in \text{ENERGYOFFERS}\}$

$$\frac{\text{GenerationBlock}_{g(o),j(o))}}{\text{GenerationBlockMax}_{(g(o),j(o))}} - \frac{\text{Energy StorageBlock}_{(es'(o),j'(o))}}{\text{EnergyStorageBlockLimit}_{(es'^{(o)},j'(o))}}$$

$$= \text{EnergyTieBreakSlack1}_o \text{ - } \text{EnergyTieBreakSlack2}_o$$

$\{o \epsilon TIEDENERGYOFFERBLOCKPAIRS, \text{where}$

$g(o) \epsilon ENERGYOFFERS, es'(o) \epsilon ENERGYSTORAGEOFFERS, \text{EnergyStorageBlockLimit}_{es'} \geq 0\}$

$$\frac{\text{Energy StorageBlock}_{es(o),j(o))}}{\text{EnergyStorageBlockLimit}_{(es(o),j(o))}} - \frac{\text{Energy StorageBlock}_{(es'(o),j'(o))}}{\text{EnergyStorageBlockLimit}_{(es'^{(o)},j'(o))}}$$

$$= \text{EnergyTieBreakSlack1}_o \text{ - } \text{EnergyTieBreakSlack2}_o$$

$\{o \epsilon TIEDENERGYOFFERBLOCKPAIRS$

$\text{where } es(o) \epsilon ENERGYSTORAGEOFFERS, es'(o) \epsilon ENERGYSTORAGEOFFER\}$

To introduce new tie-breaking constraints for a) tie breaking between energy storage facilities with positive offer blocks and generation facilities and b) tie breaking between different energy storage facilities.

Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
D.21 VIOLATION GROUP CONSTRAINTS D.21.5B Energy Storage Facility Constraint: $\sum_{j \in VIOLATIONGROUPBLOCKSFAC_{y(es)}} ViolationGroupBlock_{y(es),j} \geq FacilityRampViolation_{es} + FacilityReserveViolation_{es} + FacilityRegulationViolation_{es}$ $\{es \in ENERGYSTORAGEOFFERS\}$ D.21.5B.1 Energy Storage Facility Ramp Constraint: $FacilityRampViolation_{es} = ExcessUpRamp_{es} + ExcessDownRamp_{es}$ $\{es \in ENERGYSTORAGE\ OFFERS\}$ D.21.5B.2 Energy Storage Facility Reserve Constraint $FacilityReserveViolation_{es} = \sum_{c \in RESERVECLASSES} ExcessReserveGen_{r(es,c)}$ $\{es \in ENERGYSTORAGEOFFERS\}$ D.21.5B.3 Energy Storage Facility Regulation Constraint $FacilityRegulationViolation_{es} = ExcessRegGen_{l(es)} + DeficitRegGen_{l(es)}$ $\{es \in ENERGYSTORAGEOFFERS\}$	To introduce violation group facility constraint for energy storage facilities, which shall include constraint violation penalties for ramp constraint, reserve cosntratin and regulation constraint for energy storage facilities

Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
<u>D.24 PRICE FORMATION</u> D.24.1 The *market energy price* or *MEP* for each *market network node* shall be calculated as follows: For *generation registered facilities* that are not *multi-unit facilities*, and for *generation settlement facilities* that are not *pseudo generation settlement facilities*, represented as *synchronised* in the *dispatch network data* or connected to the dispatch network in accordance with section D.6.5 in the *dispatch period*, and for *generation registered facilities* that are *energy storage facilities* with $\text{EnergyStorageTransfer}_{es} > 0$, the *market energy price* shall be calculated as follows: $MEP^{m(g)}$ <u>or $MEP^{m(es)}$</u>$= \text{EnergyPrice}_{n(m)}$ where: $\text{EnergyPrice}_{n(m)}$ is the dual variable corresponding to constraint D.16.1.2 for the *dispatch network node n* corresponding to the *market network node m* The price MEP^{m} shall then be further modified in accordance with section D.24.5.	To include the reference to a Market Clearing Price for a generation registered facility that is an energy storage facility.

Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
D.25 ADDITIONAL OUTPUTS D.25.1.13 the estimated hourly *energy* uplift rebate (HEUR) in accordance with the following formula: Estimated HEUR = $\frac{\left[\sum_{g\in ENERGYOFFERS}(MEP^{m(g)} \times \text{Generation}_g \times {}^1/_2) + \sum_{es\in ENERGYSTORAGEOFFERS}(MEP^{m(es)} \times \text{EnergyStorageTransfer}_{es} \times {}^1/_2) - (USEP \times \sum_{p\in ENERGYBIDS,\ p\notin INTERTIEENERGYBIDS} \text{Purchase}_p \times {}^1/_2)\right]}{\sum_{p\in ENERGYBIDS,\ p\notin INTERTIEENERGYBIDS} Purchase_p \times {}^1/_2}$ **Explanatory Note: The estimated hourly energy uplift rebate produced by the market clearing engine for each dispatch period is meant only to serve as an indicative figure of the hourly energy uplift rebate and will not be used for settlement.**	To include the energy settlement for ESS into the formula.
APPENDIX 6E– STANDING CAPABILITY DATA	
E.1 GENERATION FACILITY DATA … E.1.3 Unless otherwise stated, a reference to a *generation facility* or *generation registered facility* in this section E.1.1 does not include a reference to an *energy storage facility*.	To carve out energy storage facilities from existing provisions under Section E.1 of Appendix 6E.

Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)	**Reasons for Modification**
E.1A ENERGY STORAGE FACILITY DATA E.1A.1 The *standing capability data* pertaining to an *energy storage facility* shall include: E.1A.1.1 information sufficient to indicate the *energy storage facility* to which the *standing capability data* pertains; E.1A.1.2 the maximum charge limit representing the maximum rate, in MW, at which an *energy storage facility* can withdraw electrical *energy* from the *transmission system;* E.1A.1.3 the maximum discharge limit representing the maximum rate, in MW, at which, an *energy storage facility* can inject electrical *energy* into the *transmission system;* E.1A.1.4 the maximum ramp-up rate for the *energy storage facility* in MW/minute; E.1A.1.5 the maximum ramp-down rate for the *energy storage facility* in MW/minute; E.1A.1.6 the maximum *reserve* quantity of the *energy storage facility* for each *reserve class* which the *energy storage facility* is or seeks to be registered to provide; E.1A.1.7 the maximum combined *generation* quantity and *reserve* quantity for each *reserve class* for which the *energy storage facility* is or seeks to be registered to provide; E.1A.1.8the maximum *regulation* quantity of the *energy storage facility* if the *energy storage facility* is or seeks to be registered to provide *regulation*; E.1A.1.9 the maximum *energy* transfer level at which *automatic generator control* (*AGC*) or other signals acceptable to the *PSO* can operate the *energy storage facility* to provide *regulation* capability if the *energy storage facility* is or seeks to be registered to provide *regulation*; E.1A.1.10 the minimum *energy* transfer level at which *automatic generator control* (*AGC*) or other signals acceptable to the *PSO* can operate the *energy storage facility* to provide *regulation* capability if the *energy storage facility* is or seeks to be registered to provide *regulation*; E.1A.1.11 the maximum *energy* storage capacity, in MWh, of the *energy storage facility*.	To introduce a new section to set out the standing capability data required for energy storage facilities.

Proposed Rule Changes (deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
Chapter 8 Definitions	
1.1.xxx *energy offer* means a *standing offer* or an *offer variation* submitted to the *EMC* for a *generation registered facility* that is not an *energy storage facility* or *import registered facility* to provide *energy* to the *real-time market* for *energy*;	To clarify that energy offer does not include offers submitted by energy storage facilities.
1.1.xxx *energy storage offer* means a *standing offer* or an *offer variation* submitted to the *EMC* for a *generation registered facility* that is an *energy storage facility* to provide *energy* to, or withdraw *energy* from, the *real-time market* for *energy*;	To define energy storage offer.
1.1.xxx *energy storage facility* means a facility that can withdraw *energy* from the *transmission system* and store it for production of *electricity* and inject onto the *transmission system* at a later time;	To define energy storage facility.
*1.1.*xxx *intermittent generation facility* means any *generation facility* whose power output, in the course of its ordinary and proper operation, cannot be predicted or be directly or indirectly controlled or varied at will. For the avoidance of doubt, a *generation facility* that is integrated with one or more ~~energy storage facilities~~ *energy storage facilities* which render the output of the *generation facility* dispatchable shall not be considered to be an *intermittent generation facility*.	To clarify the requirement for a generation facility to be considered as an intermittent generation facility.
1.1.xxx *offer* means an *energy offer*, *an energy storage offer,* a *reserve offer* or a *regulation offer;*	To include energy storage offer within the definition of offer.