Notice of Market Rules Modification

Paper No.:	EMC/RCP/126/2021/370
Rule Reference:	Chap 6, App J.3
Proposer:	EMC, Market Admin
Date Received by EMC:	14 July 2021
Category Allocated:	1
Status:	Not Approved by EMA
Effective Date:	NA

This paper reviews the CVP settings for energy, reserve and regulation in the SWEM. The review was initiated following frequent occurrences of reserve shortfall in 2018-2019, during which the Market Clearing Engine (MCE) did not fully utilise all available resources to meet energy and reserve requirements.

We conclude that the current CVP settings reflect the original intent for reserve deficits, in which non-core reserve requirement is accorded low priority when the overall supply is tight. Nevertheless, we expect going forward that the occurrence of reserve deficits would be alleviated with increased participation of demand-side resources.

EMC proposed for the PSO to consider differentiating between essential reserve requirement and non-essential reserve requirement. After consultation with the PSO, who is of the view that all reserve and regulation requirement is essential to maintain system reliability and security and should be procured as long as there is sufficient resource available, we propose that higher CVPs should be applied to ensure that the MCE will activate more costly resources to fully meet essential requirement.

For non-essential reserve requirement, we propose to consider using an Operating Reserve Demand Curve (ORDC) for the MCE to procure additional reserve if its reliability value so justifies. While the implementation of ORDC would add to the complexity of reserve procurement and cost allocation, it can improve market efficiency by procuring reserves at a more optimal level and should be further studied as a possible long-term solution.

At its 124th meeting, the RCP

a) *unanimously supported* the proposal to adjust CVP settings to secure dispatch for Essential Requirement; and

b) *by majority vote supported* the proposal for EMC to study further how ORDC can be adapted in Singapore's context for procurement of non-essential reserve requirement and its impact on the market outcome.

At its 126th meeting, RCP by majority vote supported the rule modification proposal to give effect to the RCP's decision of a) above.

Date considered by Rules Change Panel: 10 November 2021

Date considered by EMC Board: 19 January 2022

Date considered by Energy Market Authority: 03 March 2022

Proposed rule modification:

See attached paper.

Reasons for EMA's Decision Not to Approve the Rule Change:

This rule change proposal is intended to prevent reserve shortfalls in the SWEM. As noted by the EMC in the proposal, reserve shortfalls may still occur after implementing it. Furthermore, the potential cost to consumers significantly outweighs any potential benefit to the system. EMA has therefore rejected this rule change proposal which unjustly discriminates against consumers and is inconsistent with the function and duty of EMA under section 3(3) of the Electricity Act.

PAPER NO	:	**EMC/BD/01/2022/05a**
RCP PAPER NO.	:	**EMC/RCP/126/2021/370**
SUBJECT	:	**REVIEW OF CONSTRAINT VIOLATION PENALTY**
FOR	:	**DECISION**
PREPARED BY	:	**WANG JING** **AVP, MARKET ADMINISTRATION**
REVIEWED BY	:	**POA TIONG SIAW** **SVP, MARKET ADMINISTRATION**
DATE OF MEETING	:	**8 SEPTEMBER 2021/10 NOVEMBER 2021**

Executive Summary

This paper reviews the CVP settings for energy, reserve and regulation in the SWEM. The review was initiated following frequent occurrences of reserve shortfall in 2018-2019, during which the Market Clearing Engine (MCE) did not fully utilise all available resources to meet energy and reserve requirements.

We conclude that the current CVP settings reflect the original intent for reserve deficits, in which non-core reserve requirement is accorded low priority when the overall supply is tight. Nevertheless, we expect going forward that the occurrence of reserve deficits would be alleviated with increased participation of demand-side resources.

Recognising that declarations of high risk and emergency operating states owing to reserve deficit can create unwarranted uncertainties for MPs, we considered if high risk and emergency operating state should only be activated based on the physical conditions of the system, rather than based entirely on MCE schedule.

We also propose for the PSO to consider differentiating between essential reserve requirement and non-essential reserve requirement. After consultation with the PSO, who is of the view that all reserve and regulation requirement is essential to maintain system reliability and security and should be procured as long as there is sufficient resource available, we propose that higher CVPs should be applied to ensure that the MCE will activate more costly resources to fully meet essential requirement.

For non-essential reserve requirement, we propose to consider using an Operating Reserve Demand Curve (ORDC) for the MCE to procure additional reserve if its reliability value so justifies. While the implementation of ORDC would add to the complexity of reserve procurement and cost allocation, it can improve market efficiency by procuring reserves at a more optimal level and should be further studied as a possible long-term solution.

After taking into feedback received from consultation, we recommend the RCP:

- Support the proposal to adjust CVP settings to secure dispatch for Essential Requirement and task EMC to modify the market rules to give effect to it; and
- Support EMC to study further how ORDC can be adapted in Singapore's context for procurement of non-essential reserve requirement and its impact on the market outcome.

At its 124th meeting, the RCP

a) *unanimously supported* the proposal to adjust CVP settings to secure dispatch for Essential Requirement and tasked EMC to modify the market rules to give effect to it; and

b) *by majority vote supported* the proposal for EMC to study further how ORDC can be adapted in Singapore's context for procurement of non-essential reserve requirement and its impact on the market outcome.

The proposed rule modifications to give effect to RCP's decision of a) above are set out in Annex 2.

At the 126th RCP meeting, the RCP by majority vote supported the rule modification proposal.

1. Introduction

This paper reviews the CVP settings for energy, reserve and regulation in the SWEM. The review was initiated following frequent occurrences of reserve shortfall in 2018-2019, during which the Market Clearing Engine (MCE) did not fully utilise all available resources to meet energy and reserve requirements.

2. Background

The SWEM produces security constrained economic dispatches. The market clearing engine (MCE) is programmed to maximise net system benefit while respecting operational constraints of all facilities and the transmission system.

In some cases, the MCE may not be able to find a feasible solution while satisfying every constraint. It is thus allowed to violate some constraints at the cost of incurring associated penalty values (i.e. constraint violation penalty or CVP) to the objective function.

2.1 Role and structure of the current CVP

The current CVP settings achieve the following objectives:

- to pre-define a priority order for resolving potential dispatch conflicts between different constraints. The higher the CVP price is, the higher the priority the MCE places on the corresponding constraint.
- to ensure the pre-defined violation priority order is maintained by setting sufficient differentiation between CVP prices of different constraint types.

The CVP for deficit energy, meaning the load at any location that cannot be fully served, is set at the Value of Loss Load (VoLL). VoLL reflects the value consumers place on the interruption of electricity supply. Currently the VoLL is set at $5000/MWh.

The CVP for deficit ancillary services (i.e. regulation and reserves), are set at *a fraction of the VoLL*. This considers that ancillary services are less important compared to energy. A stepwise constraint violation structure was introduced for reserves and regulation, in which the CVP value increases in blocks as violation quantity increases.

The setting of CVPs for constraints associated with *operation requirement*, such as transmission line flow constraints, generation facility/load facility ramping constraints, generally reflects /indicate the cost/difficulty in violating these constraints. Typically, these are relatively hard constraints failing which there would be impact on the safe and reliable operation of the grid and plants. The CVPs of such constraints are set at *multiples of VoLL* so that the MCE will choose to dispatch more expensive generation facility/load facilities or even energy deficit over violating them.

Table 1 summarises the current CVP settings. A full list of CVP for all constraint violation variables can be found in the Market Rules (Chapter 6, Appendix 6J).

Table 1 Current CVP Settings

Constraint Violation Variable	Constraint Violation Penalty Prices	Max Violation Quantities
Products (Energy, Reserve and Regulation) Constraints		
Deficit Generation	$5000	10,000MW
Excess Generation	$5000	10,000MW
Deficit Regulation (Block 1)	$305	Regulation Requirement- Minimum Regulation Requirement[1]
Deficit Regulation (Block 2)	$3000	Minimum Regulation Requirement
Deficit Primary Reserve (Block 1)	$310	0.2 x Primary Reserve Requirement[2]
Deficit Primary Reserve (Block 2)	$2550	0.8 x Primary Reserve Requirement – Minimum Primary Reserve Requirement[3]
Deficit Primary Reserve (Block 3/Core Quantity)	$4500	Minimum Primary Reserve Requirement
Deficit Contingency Reserve (Block 1)	$185	0.3 x Contingency Reserve Requirement[4]
Deficit Contingency Reserve (Block 2)	$1950	0.7 x Contingency Reserve Requirement – Minimum Contingency Reserve Requirement[5]
Deficit Contingency Reserve (Block 3/Core Quantity)	$3500	Minimum Contingency Reserve Requirement
Line Constraints		
Excess Line Flow	2.2 x VoLL ($11,000)	10,000MW

[1] Minimum regulation requirement is defined in the SOM. Currently the value is 50MW.

[2] Primary reserve requirement as dynamically determined by MCE for each dispatch period.

[3] Minimum primary reserve requirement is defined in the SOM. Currently the value is 115MW.

[4] Contingency reserve requirement as dynamically determined by MCE for each dispatch period.

[5] Minimum contingency reserve requirement is defined in the SOM. Currently the value is 250MW.

Constraint Violation Variable	Constraint Violation Penalty Prices	Max Violation Quantities
Security Constraint		
Deficit Security	6 x VoLL ($30,000)	10,000MW
Facility Constraints		
1 Ramping Constraints and Combined **Ramping constraints** **2 Constraints on Reserve/Regulation capability at different loading levels** **3 Constraints on Combined generation, reserve and regulation capacity**	20 x VoLL ($100,000)	10,000MW

2.2 Rationale of Current CVP Settings for Reserves

Current CVP settings for ancillary services were based on a study[6] conducted in 2013. The study addressed price anomalies during scarcity periods in which dispatch of ancillary services were prioritised over energy.

The study showed that, when a generating unit offers the same 1MW of capacity for both energy and reserve, the MCE weighs the costs of using this 1MW capacity to provide two classes of reserve (Option 1 in Table 2), against the costs of using this 1MW capacity for energy (Option 2 in Table 2).

Table 2 MCE Scheduling during Scarcity periods

	Option 1: Channel 1MW capacity to primary and contingency reserve	Option 2: Channel 1MW capacity to energy
Procurement cost	Marginal (Pri & Con) reserve offer prices	Marginal energy offer price
Cost for Constraint Violation (Deficit CVP)	Deficit Energy CVP (i.e. VoLL)	Deficit (Pri & Con) Reserve CVP

[6] https://www.emcsg.com/f1136,82775/EMC317-EMA-LL.pdf

In order for the MCE to choose to serve energy instead of ancillary services, the following condition must be met:

Cost of Option 1 > Cost of Option 2

- ➔ Marginal Reserves Offer Price + Deficit Energy CVP > Marginal Energy Offer Price + Deficit Reserves CVP
- ➔ Deficit Reserves CVP < Deficit Energy CVP - (Marginal Energy Offer Price – Marginal Reserves offer Price) (**Condition 1**)

With a) Deficit Energy CVP set at VoLL (i.e. $5000), b) highest possible Energy Offer Price at the price cap of $4500 and c) lowest possible Reserves Offer Price at $0, the Deficit Reserves CVP will have to be lower than $500 to *guarantee* that the capacity will be channelled to provide energy instead of reserves. Therefore, the CVP value for the lowest CVP block of Deficit Primary Reserve and Deficit Contingency Reserve were set at $310 and $185 respectively to meet this condition.

In addition, considering the *core requirement*, which is the minimum requirement set in the SOM, for ancillary services plays a critical role in ensuring system stability and the need for the sufficient reserve to be procured to cover the loss of generation from the largest online unit, a high CVP will be incurred for failure to procure the core requirement and N-1 requirement.

2.3 Proposals Received

In recent years, contingency reserve shortfalls have occurred relatively frequently. This was considered abnormal given that there is usually sufficient capacity in the market to meet both energy and reserve requirements. There were concerns that the CVP for contingency reserve is set too low, resulting in the MCE not scheduling sufficient reserve.

A review of CVPs was proposed to finetune its settings with the aim to reducing occurrences of reserve deficit and improve system reliability. The proposer suggested considering the following:

a) Reduce quantity for CVP Block 1 for contingency reserve deficit;

   The current quantity for CVP Block 1 for contingency reserve is set at 30% of the reserve requirement, which is the same as the limit set for reserve provided by Interruptible Load (IL). It is proposed that the sum of the reserves provided by ILs and the CVP Block 1 quantity ought to be less than 30% of the total contingency reserve requirement, so that there will be sufficient reserves scheduled from online generation registered facilities (GRFs) to cover the loss of generation from the largest online GRF.

b) Re-allocate the proportion of Block 1 violation penalty price for contingency reserve deficit;

   It is proposed to increase the Block 1 CVP price for contingency reserve deficit and decrease that for primary reserve deficit to reduce the frequency of contingency reserve shortfalls as primary reserve shortfall hardly occurs except during periods when the intertie is not synchronised.

c) General review of the CVP structure

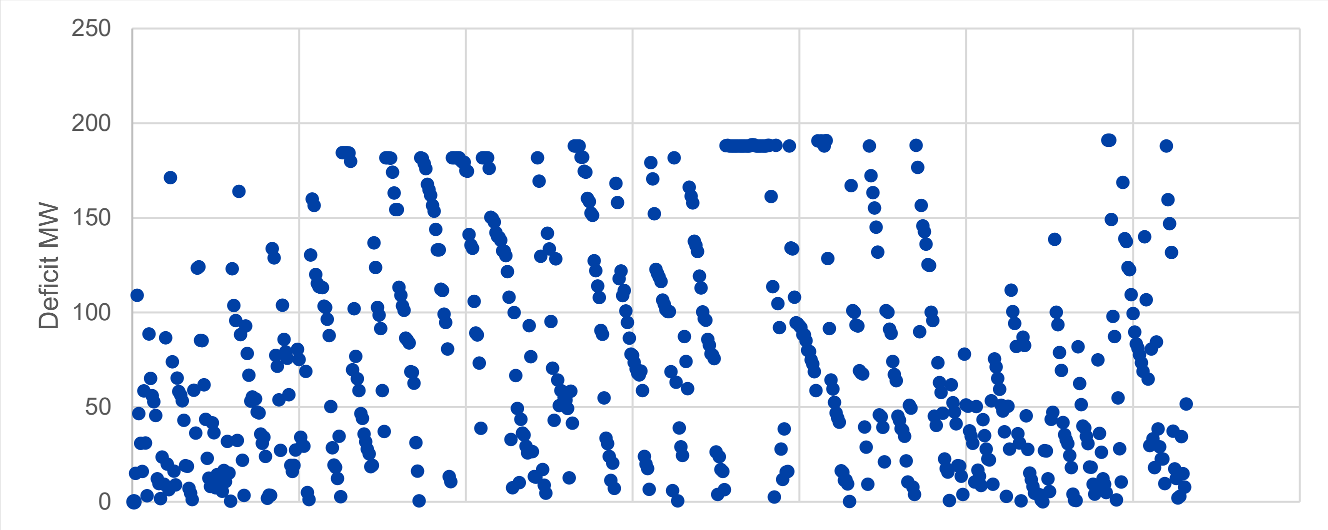
   At the 105th RCP meeting, while discussing instances of prolonged IL interruption due to contingency reserve shortfalls, the Panel showed concern if the current CVP was set at an optimal level. It proposed to enhance CVP settings to address abnormal instances of contingency reserve shortfall.

3. Analysis

3.1 *Overview of past reserve shortfall incidents and Impact to the system and market*

In 2018 and 2019, a total of 262 and 368 periods of reserve deficit were observed respectively, with the deficit quantity ranging from 0.081MW to 191.1MW, with a median value of 69MW. This is substantially higher than the preceding years[7] after stepwise CVP was introduced in 2014.

Figure 1 Contingency Reserve Deficits in 2018-2019



Notably, in 2018 and 2019, on average the supply cushion was above 25%[8]. It is expected in most periods, there should have been sufficient energy and reserve offers to meet both energy and reserve requirement. Such frequent reserve shortfalls are therefore considered to be abnormal and raised the question of whether the market clearing formulation is effective in optimising available resources to meet the system's need.

When reserve deficit occurs, PSO *may* declare a high-risk operating state, potentially escalating to an emergency operating state if the deficit continues for more than 30 minutes[9].

Declaration of a high-risk or emergency operating state will be announced to the market where market participants will be allowed to revise their offers within gate closure to contribute positively to reduce such shortfalls. In addition, the PSO can take measures including overriding schedules in order to maintain system security. Such measures include directing GRFs to change its output level and directing load registered facilities that have been curtailed to provide reserve to postpone restoration of consumption.

3.2 *Why reserve deficit despite sufficient generation capacity for both energy and reserve*

Reserve deficit can be scheduled despite there being sufficient capacity in the market to provide reserve and energy. In this section, we explain the logic behind such MCE scheduling.

[7] In 2016 and 2017, there were only 80 and 35 reserve deficits.

[8] MSCP market watch.

[9] Section 11.4.2 of System Operation Manual

When overall supply is tight and a unit/reserve provider is competing in both the energy and reserve market, the MCE will weigh the overall savings/benefit to the system when determining if this unit should be scheduled for energy or reserves/ancillary services. This is the logic behind the MCE's co-optimisation. Table 3 below illustrates how the MCE schedules in a tight supply scenario.

Table 3 Illustration of MCE Scheduling Logic during Reserve Deficit

	Unit 1/Reserve Provider (Generation Capacity = 200MW)		Unit 2/Non-Reserve Provider (Generation Capacity = 110MW)		Remark
Energy: Demand = 180MW					
	Offer: 150MW @ $90/MWh 50MW @ $200/MWh	Schedule: 180MW	Offer: 110MW@ $300/MWh	Schedule: 0MW	
Reserve: Requirement = 40MW					
	Offer: 20MW @ $10/MWh 20 MW@ @ $100/MWh	Schedule: 20MW	-	-	Reserve deficit of 20MW

In this example, the total capacity of the two units is enough to meet total energy and reserve requirement. However, the optimal schedule is for the MCE to incur a reserve deficit instead of procuring higher cost energy from Unit 2. This is because when the MCE considers whether 20MW more of reserve should be scheduled from Unit 1 and 20MW of energy scheduled from Unit 2, the MCE will compare the costs of the following two options:

Table 4 MCE Scheduling during tight supply periods

	Option 1: Channel 1MW capacity of Unit 1 to reserve	Option 2: Channel 1MW capacity of Unit 1 to energy and incur reserve deficit
Procurement cost	Unit 1 Reserve offer price: $100 Unit 2 Energy offer price: $300	Unit 1 Energy offer price: $200
Cost for Constraint Violation (Deficit CVP)	Nil	Deficit Reserve CVP: $185
Total Cost	$400	$385

By incurring a reserve deficit instead of scheduling more costly energy from Unit 2, Option 2 will incurs a lower cost to the system and thus makes a more optimal solution.

This example shows that in order to *guarantee* no reserve deficit when enough generation capacity is available in the system, the following condition must be met:

Cost of Option 1 < Cost of Option 2

- ➔ Marginal Unit (i.e. Unit 1) Reserves Offer Price + Replacement (i.e. Unit 2) Energy Offer Price < Marginal Unit Energy Offer Price + Deficit Reserves CVP
- ➔ Deficit Reserves CVP > Marginal Unit Reserves Offer Price + (Replacement Energy Offer Price - Marginal Unit Energy Offer Price) **(Condition 2)**

Condition 2 means that in order to prioritise reserve dispatch over reserve deficit, deficit reserve CVP should be set at greater than the sum of

a) Marginal unit's reserve offer price; and

b) the energy price difference between the marginal unit's energy offer and the next least expensive energy offer ("*trade-off cost*").

The problem is, both items a) and b) can be higher than the current reserve deficit CVP of the lowest CVP block (i.e. $185) in a tight supply situation.

Contingency reserve cost/offer price higher than $185

In Singapore, the marginal units in the system for both energy and reserve are typically CCGTs. For CCGTs, the difference in the costs of providing reserve and energy is mainly fuel cost, which typically hovers around $100. This price difference is substantially lower than the price difference between energy and reserve that we observe in tight supply situations.

In other words, when the system is in a tight supply situation where energy price increases (or expected to increase) above deficit reserve CVP (which is usually considered as the price cap for contingency reserve) plus the fuel cost, the (opportunity) cost to provide reserve as perceived by the sellers, would be much higher than $185. Gencos would choose either to offer into energy market instead of reserve market, or to offer into reserve market at prices higher $185[10]. With insufficient reserve offers below $185 to meet reserve requirement, reserve deficit is expected.

Steep Energy Supply Curve and Limited Demand Response

Energy cost differs across generation technologies. For CCGTs, the long run marginal cost is less than $200/MWh. For OCGTs, the energy offer price can be as high as $500 if considering the start-up cost. When supply is tight, it is not surprising to see price difference of $200 to $600 between energy offer stacks, which substantially increase the trade-off cost if the MCE has to procure more expensive energy to avoid reserve deficit.

On the other hand, we expect more demand response participating in the market to help counter the effects of a steep supply curve. In 2020, we observed that periods of reserve deficit dropped to 68 from 368 in 2019, coinciding with more frequent activation of demand response[11].

3.3 Must N -1.5 Requirement always be fulfilled/procured regardless of the price?

From preceding section, we understand that a reserve deficit may be scheduled even if there is sufficient capacity available in the system. This is largely the result of changes in reserve and energy offer price in a tight supply situation, where the cost (due to either reserve offer price

[10] Reserve providers can offer reserve at prices higher than the reserve CVP. For primary reserve, the offer price cap is at $4250 for primary reserve and $3250 for contingency reserve.

[11] In 2019 December, an LRF with demand response capacity of 35 MW started to participate in the market.

change or MCE co-optimisation) to procure reserve could increase substantially above the current CVP ($185) for Block 1 reserve deficit.

MCE's scheduling of reserve deficit is consistent with original design intent

In the 2013 study, simulation results showed that reserve deficits could occur during peak or tight periods where energy prices were relatively high[12]. Nevertheless, the RCP decided to implement stepwise CVP for ancillary services.

Despite the relatively frequent occurrences of reserve deficit in 2018-2019, it is worth noting that the deficits were only in the cheapest CVP block, i.e. the safety margin of 50% of reserve requirement ("N-1.5 requirement"). The MCE still procured sufficient reserves to meet the N-1 requirement to cover the largest single online GRF's risk[13]. This scheduling outcome is in line with the design intent contemplated in the 2013 study, where the objective was to "procure at least the core ancillary services requirements, while minimising energy deficits."

If we consider it unacceptable to schedule reserve deficit when there is enough generation capacity to meet both energy and reserve requirement, we then have to ask if the market should always procure enough reserve to meet the N-1.5 requirement, regardless of the price.

What is the right price/reliability value of 50% reserve requirement margin?

As stated in the SOM[14], the purpose of having a safety margin of 50% of reserve requirement is to provide for the system's ability to "*survive a subsequent contingency for the next 4 to 10 hours*". Based on the probability of failure of all generation units registered in the system, we have estimated that by having a buffer of 50% more of contingency reserve (approximately 200MW), the expected loss of load prevented would be 0.409 MW[15]. Using the existing VoLL of $5000, the value of each MW of reserve is about $10.24/MWh.

Considering the low likelihood of a subsequent contingency event following a generator forced outage, we are of the view that the N-1.5 reserve requirement need not always be binding. The current lowest CVP for contingency reserve deficit ($185) provides sufficient price signal to recognise the risk and associated cost of "subsequent contingency events". It may be more effective for the PSO to intervene on a subsequent contingency event using out-of-market measures.

Concluding Summary of the Issue

We consider the occurrence of a reserve deficit a valid scheduling outcome in which the MCE chooses not to incur high reserve cost to meet an additional 50% safety margin of reserve requirement. Instead, it chooses to channel the efficient/competitive generation resources to serve energy when the overall supply is tight.

Admittedly, it is not intuitive that reserve requirement is not fully met when system clearly has sufficient resources on offer to meet both energy and reserve requirements. However, we would like to point out that the amount of reserve deficit incurred had only been for the additional 50% reserve requirement margin, whose reliability value does not justify the market paying a price higher than $185.

---

[12] Please refer to RC317, Annex 10 of the simulation results under option 6. Simulation results showed contingency reserve shortfall would occur when USEP rise to the range of $300 ~$600.

[13] During the 2018-2019 reserve shortfall cases, only the cheapest constraint violation block is violated. Even during the 18 Sep 2018 load shedding case, sufficient reserve is still procured to cover the largest online GRF.

[14] Section 12.2.1 of SOM

[15] Sum of PoF multiplied by the max generation capacity (capped at 200MW) of all units. A relatively conservative estimate of expected loss of load.

Nevertheless, we acknowledge that frequent declarations of high-risk and emergency operating state do create uncertainties to the dispatch coordinators of the generation and load facilities, because their dispatch schedules can potentially be overridden during such times.

4 Potential Solutions Explored

4.1 Proposed Measures to Address Uncertainties to MPs due to High-risk and Emergency Operation State

As provided for under section 11.4.2 of System Operation Manual, when reserve deficit occurs, PSO may declare a high-risk operating state, potentially escalating to an emergency operating state if the deficit persists.

Activation of high-risk or emergency operation state due to reserve deficit could have an unintended impact to the market. For example, load registered facilities could be prevented from restoring their consumption. MPs are also allowed to revise their offers within gate closure. Frequent declarations of high-risk and emergency operating state may misinform stakeholders of the system condition.

To address this, we can consider to exclude an MCE forecasted *reserve deficit from the criteria to issue high-risk and emergency operating state*. The activation criteria can be based on the system's physical conditions (e.g. reserve capacity that is physically available from online units) instead.

4.2 Adjustment to CVP settings to guarantee dispatch for Essential Requirement

In section 3.3 of this paper, we established that reserve deficits were the correct scheduling outcome when supply is tight, where MCE chose to not procure the amount of reserve that is deemed to be not essential to system reliability during tight supply situation.

If the N -1.5 Requirement (or any other reserve quantity that PSO may determine) is essential to maintain system reliability and should always be fulfilled as long as there is sufficient capacity available for both energy and reserve, regardless the price, then we need to look into revising CVP settings to achieve this objective.

The amount of reserve, which shall always be procured as long as there is sufficient capacity to meet both energy and reserve demand, is termed as "Essential Requirement" in subsequent sections of this paper.

With fulfilling the Essential Requirement of Reserve to be of high priority, there will be these two, sometimes contradicting, objectives for the MCE to meet:

- When there is *insufficient capacity* to meet both energy and reserve requirement, energy scheduling should be prioritised over reserve scheduling. This implies reserve provision should be of relatively low priority.
- When there is *sufficient capacity* for both reserve and energy, energy and essential requirement of reserve should be met before incurring any reserve or energy deficit. This implies reserve provision should be of relative high priority.

The priority of reserve provision, as reflected by the reserve deficit CVP, is further quantified under these two conditions, as derived in section 2 and 3 of this paper:

Condition 1:

Deficit Reserves CVP < Deficit Energy CVP - (Marginal Energy Offer Price – Marginal Reserves offer Price)

Condition 2:

Deficit Reserves CVP > Marginal Unit Reserves Offer Price + (Replacement Energy Offer Price - Marginal Unit Energy Offer Price)

The Right Hand Side (RHS) of Condition 1 and Condition 2 forms the upper and lower bound of Deficit Reserve CVP. With the current setting of Deficit Energy CVP ($5000/MWh), reserve offer price cap ($3250/MWh) and floor ($0/MWh) and Energy offer price cap ($4500/MWh) and floor ($-4500/MWh). It is not possible to find a value for deficit reserve CVP that is able to always satisfy both conditions under all scenarios.[16]

Therefore, in order to meet both objectives, one or more of these three parameters a) deficit energy CVP, b) energy offer price cap, and c) reserve offer price cap must be changed.

Increase Deficit Energy CVPs /VoLL to above current Energy Price Cap and Increase Deficit Reserve CVP

We are of the view that the current setting of VoLL at $5000 could be an underestimate of the cost of load shedding. VoLL, which was derived from annual GDP and annual electricity consumption[17], reflects the value of energy at the *national average* level. In reality, when *unplanned load shedding* actually occurs, the cost to the consumers could be higher than this average value, due to the following reasons:

- Load shedding usually occurs in blocks, which is typically greater than the exact MW of energy deficit that is scheduled/predicted by the MCE;
- Lead-time required to resume operation, which means some load may not be able to resume production immediately after the electricity supply is restored and thus longer disruption duration than that is scheduled/predicted by the MCE; and
- Other costs or damages associated with disruption of supply, such as waste of products/raw material, damage to equipment and additional labour required to restart the production process

Therefore, the price the system is willing to pay to avoid any load shed, which should be reflected in VoLL and consequently deficit energy CVP, could be higher.

From our jurisdiction scan, it is normal for violation penalty for energy and even ancillary services to be set above their administered energy price cap level in order to achieve the desired dispatch outcome.

[16] RHS of Condition 1, which is the upper bound of deficit reserve, could be as low as $500 (range from $500 to $5000). RHS of Condition 2, which is the lower bound of deficit reserve, can be as high as $12500(the range from 0 to $12250.) or even higher if we take into account other trade-off with regulation and transmission constraints.

[17] Based on 2019 and 2020 GDP (S$510.7 bil and S$469.1bil) and energy consumption (51.6TWh and 50.7TWh) of Singapore, the updated VoLL would be $9897/MWh and $9252/MWh respectively.

	NEM[18]	IESO
Price Cap	Market Price Cap (MPC) at $12,500	$2,000
Energy Deficit CVP	150 x MPC	$30,000
Deficit CVP for Ancillary services	4 ~10 x MPC	$6,000~$10,000

With a deficit energy price increase, the upper bound of reserves deficit CVP for primary and contingency reserve can be increased from the current $500.

We propose for the following options to be considered (**Proposed Solution 1**)

a. Minimally, energy deficit CVP should increase to $10,000 or above. This value is also consistent with the current level of electricity consumption and GDP in Singapore;

   With deficit energy CVP increased to $10,000, it would allow a higher upper bound for reserve deficit of $5000 ~ $5500. This would allow the MCE to assign a higher reserve deficit CVP while not incurring energy deficit before reserve deficit is incurred.

b. Reserves deficit CVP for Essential Requirement be increased to a level that should be at least high enough to cover the sum of a) potential trade-off costs and b) reserve offer price in a typical tight supply scenario.

   In theory, this value should be higher than the sum of the reserve and energy price caps.[19] In reality, it is unlikely for the marginal unit's reserve offer price to exceed its energy offer price significantly. As a result, the RHS of condition 2 is unlikely to exceed the marginal energy price.

   We retrieved the historical USEP over the past 10 years in the table 5, which shows that only about 0.013% of the time (23 periods) energy prices reached $2000 or above. Therefore, we propose to extend the current Block 2 CVP price (i.e. $2550 for Primary and $1950 for contingency) to the Essential Requirement for reserve, which will place a high enough priority to channel capacity (albeit higher cost) to meet Essential Reserve requirement.

Table 5 Historical High USEP price

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Max USEP	$4500 [20]	$4500 [21]	$2788 [22]	$936	$1328	$1232	$903	$1355	$1355	$1254

[18] https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Congestion-Information/2016/Schedule-of-Constraint-Violation-Penalty-factors.pdf

[19] This refers to a quite extreme scenario where the unit is offering energy at zero price and offering reserve at price cap. And the replacement energy offer is at price cap.

[20] USEP prices were higher than $2000 in 9 periods.

[21] USEP prices were higher than $2000 in 13 periods.

[22] USEP prices were higher than $2000 in 1 period.

It is also worth noting that like reserve, provision of regulation takes up a generation unit's generation capacity. When the overall supply is tight, a trade-off could also happen between energy provision and regulation provision. Currently, the lowest CVP for regulation is set at higher ($305) than the lowest CVP for contingency reserve. If the N-1.5 reserve requirement is to be considered as Essential Requirement, we may want to consider the order of priority between regulation requirement and Essential Requirement for reserve. For regulation requirement that is deemed essential to maintain system reliability, a CVP level that is higher/comparable to energy offers should be assigned to secure its dispatch. To this, we propose to extend the CVP ($3000) for the regulation core requirement to regulation essential requirement.

Simulation Results

Simulations were conducted to verify whether the revised CVP setting for reserve, regulation and energy proposed in this section would achieve the above desired dispatch priority.

Simulations were conducted for 68 periods of 7 days in 2018 and 2019 where reserve and regulation deficit occurred. They were conducted by assuming current regulation requirement and reserve requirement (N-1.5) are all Essential Requirement, where CVPs of $2550, $1950 and $3000 were respectively assigned to CVP Block 1 of primary reserve, contingency reserve and regulation.

The results are summarised in the table below. It can be seen that with the proposed stepwise CVP, reserve and regulation deficits were eliminated except for 4 periods on 18 Sep 2018[23].

	No. of Periods with Reserve Deficit		
	Primary Reserve	Contingency Reserve	Regulation
Current Stepwise CVP	3	68	31
Proposed Stepwise CVP	1	4	0

With energy deficit CVP increased and all reserve/regulation deficit CVP increase to $1950 and above, the MCE is more likely to procure reserves and regulation from more costly offers. It is therefore expected that prices will be increased across the board. If we compare the reserve deficit reduced with the additional energy payment that load needs to pay, it translates into an average cost of **$46,958 for each MW of reserve deficit reduced**.

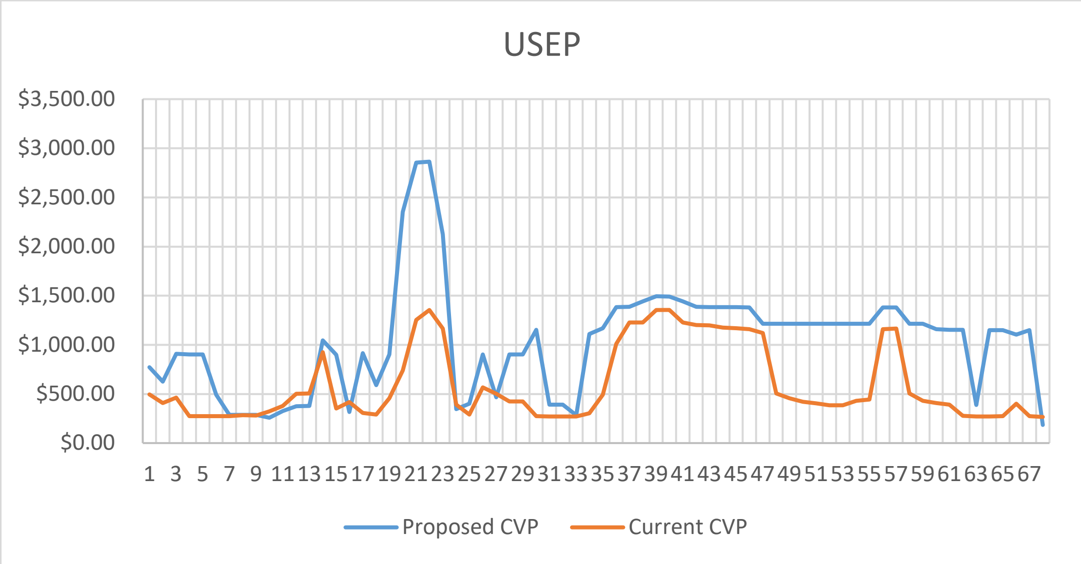
Table 6 Summary of Simulation Results

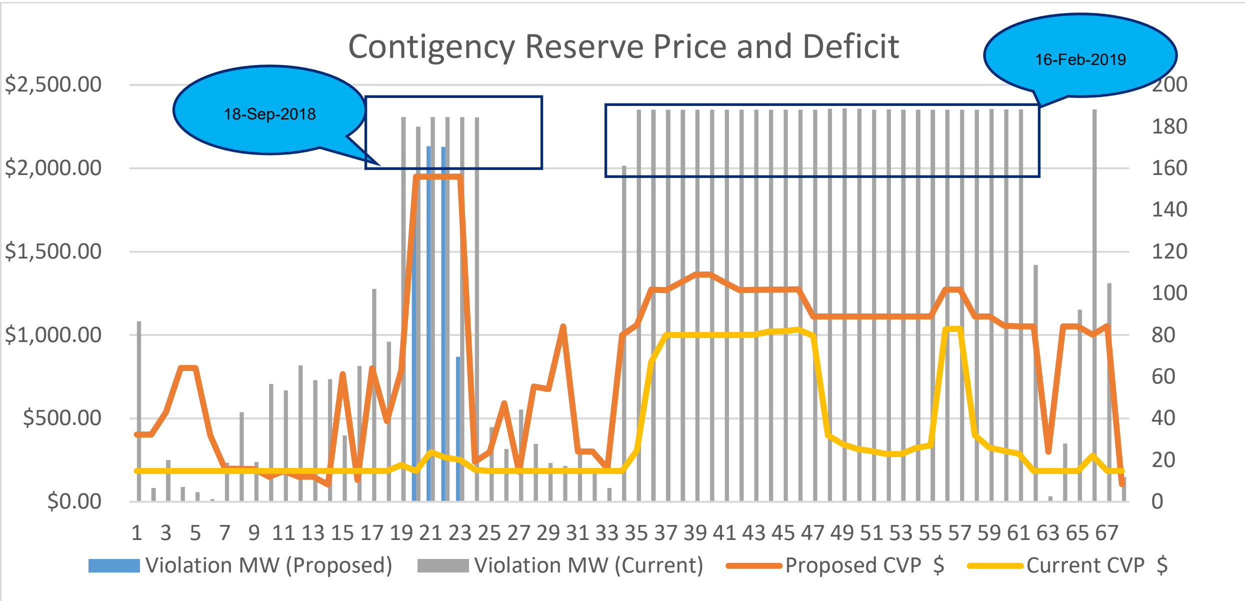
	Max Increase	Min Increase	Average Increase
Energy Payment	$5,503,984	-$377,558	$1,353,851
USEP	$1613	-$126	$440
Primary Reserve	$599	-$45	$56
Contingency Reserve	$1765	-$81	$479
Regulation[24]	$117	-$82	$30.22

[23] In these four periods, the offered capacity is not sufficient to meet the energy (including loss) and contingency reserve requirement.

[24] Price cap of $300 is assumed to continue.

Figure 2 Changes to USEP and Reserve Deficit with Proposed CVP





Cap Energy Offer prices

Lowering the energy offer price cap would increase the upper bound of the RHS of Condition 1 and decrease the lower bound of the RHS of Condition 2. It increases the solution space for deficit reserve CVPs to achieve the two objectives.

On the other hand, historical USEP prices hardly reach $2000. Even with the proposed revised CVP, based on our simulation results, USEP did not exceed $2000 except for the 4 periods of 18 Sep 2018.

Offer prices indicate sellers' willingness to sell. Wherever possible, we should refrain from setting further limits on offer prices so as not to arbitrarily exclude any resource able to provide energy at prices below VoLL.

Nevertheless, we would like to seek industry's view on implementing an energy price cap of $2000. (**Proposed Solution 2)**

With an energy offer cap of $2000 in place, the potential trade-off cost for scheduling a reserve provider to provide reserve instead of energy will be much reduced. There will be more certainty for MCE to channel available resources to meet energy and reserve requirement instead of incurring any deficit.

With the Proposed Solution 1 and 2 in place, the priority of dispatch will be as below, from highest to lowest:

1. Meeting **Core Reserve Requirement**
2. Meeting Energy Demand/**No energy deficit**
3. Meeting **Essential Reserve Requirement**
4. Activate all resources offered /**incur high cost** (with energy price capped at $2000)
5. Procuring Non-Essential Reserve Requirement (if any[25])

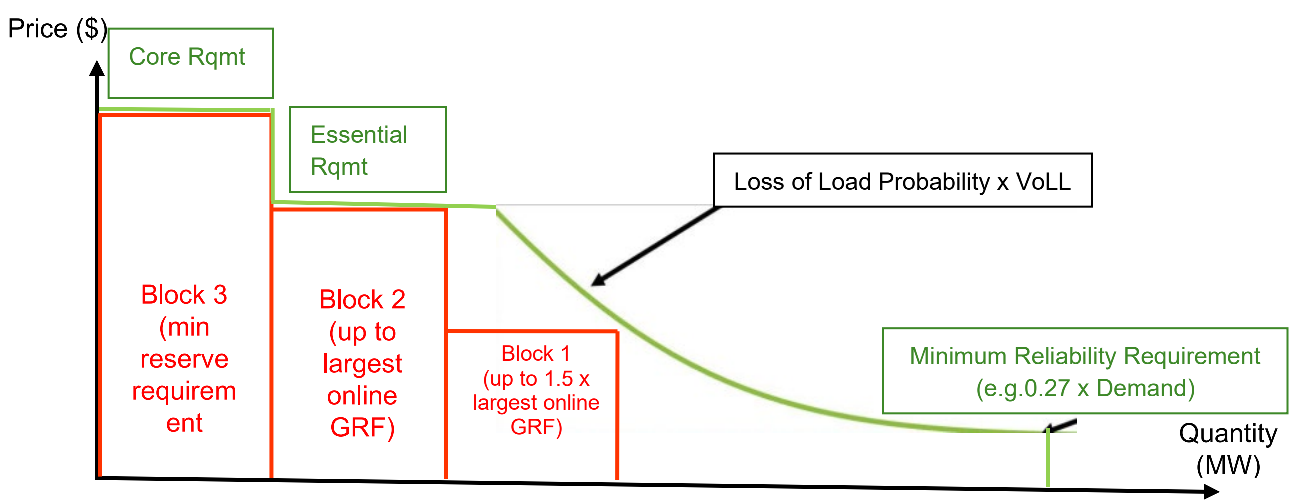
We would like to point out that if Proposed Solution 1 (i.e. increase energy deficit CVP) is adopted *without* Proposed Solution 2 (i.e. lower price limit), there is the possibility that Essential Requirement would still not be fully procured even when resources (whose offer prices are above $2000) are available and not utilised. Historical prices suggest that such probability is less than 0.1%.

4.3 Operating Reserve Demand Curve for Non-Essential Reserve Requirement

In addition to changes to the setting of deficit CVPs, we can further improve the current reserve procurement by introducing the Operating Reserve Demand Curve (ORDC) for the *Non-Essential reserve* quantity.

Similar to the stepwise CVP, ORDC is a downward sloping curve which represents decreased risk of load shed with increasing amount of reserve. Figure 3 below illustrates the difference between stepwise CVP and ORDC, where the red line represents the current constraint violation blocks and the green line represents the proposed CVP structure with ORDC.

Figure 3 Illustration of Operating Reserve Demand Curve



[25] Please refer to section 4.3 for the proposed mechanism for procurement of non-essential reserve.

Compared with the current CVP structure where reserve beyond the reserve requirement has no value, the ORDC *recognises the reliability value of reserve beyond the reserve requirement level*.

The price of ORDC can be derived from the Loss of Load Probability multiplied by the VoLL at the respective reserve margin level. For example, we can take reference from the required reserve margin of 27 % to meet LOLH3 reliability requirement[26] set by the EMA. With LOLH of 3 hours, the probability of occurrence of load shed would be about 0.034%[27], which translates into an estimated price of $3.4/MWh[28] at the reserve margin of 27%.

Setting the reserve deficit CVP based on the economic value of reserve allows the MCE to procure a higher optimal reserve quantity when the supply is sufficient and a lower optimal reserve quantity when the supply is tight. Correspondingly, capacity that is available when supply is tight will be compensated at a higher price.

We propose for the current reserve procurement to be enhanced by *applying an ORDC to non-essentia*l reserve quantities to better represent the reliability value of reserve capacity beyond the essential requirement. (**Proposed Solution 3)**

If the industry supports the use of an ORDC, EMC will study the following, in consultation with the PSO, and propose the design parameters to give effect to the proposal:

a. Set the maximum quantity to be procured under ORDC in the real-time market.

   Theoretically, the maximum quantity should be set at the point where the LOLP is zero. Practically, it also can be considered that the maximum quantity should be set at the minimum reserve margin required to meet the reliability requirement set by EMA.

b. Establish Loss of Load Probability profiles under different scenarios and determine prices of the ORDC

   Currently, reserve requirement is set based on the largest single online generation unit's scheduled energy. In practice, contingency events other than tripping of generation units, such as fluctuation in output of solar generators or consumption by large (discrete) loads, can also affect system reliability and contribute to the LOLP. This may suggest different LOLP profiles (and consequently a different ORDC) may apply on different days or different times of the day.

c. Study the feasibility of allowing a new type of reserve (non-spinning reserve) to fulfil Non-Essential reserve requirement.

   Currently only online generation units and interruptible load facilities can provide reserve, giving them reliability value. Nevertheless, it would be beneficial to acknowledge the reliability value that can be provided by offline generation units, especially generation units with fast start capabilities. Currently, such generation units are only compensated for energy during severe contingency events leading to price spikes, or when directed by the PSO to run up. Such events do not generate a predictable revenue stream.

   If offline generation units with fast start capabilities can provide reserve under ORDC, they can be compensated for providing additional standby capacity to the market. Participating in the reserve market offers some revenue certainty.

[26] Infosheet on RRM and EDF.pdf (ema.gov.sg)

[27] Estimated with 3 hours divided by (24 hours/day x 365 days)

[28] Assuming VoLL of $10000 is adopted.

4.4 Assessment of Original Proposals

We also assessed the following two proposals raised by the original proposer.

a) Reduce quantity for CVP Block 1 for contingency reserve deficit

The proposer proposed that the sum of the reserves provided by ILs and the CVP Block 1 quantity ought to be less than 30% of the total contingency reserve requirement.

We consider that the quantity of CVP Block 1 (Non-Essential Requirement) of reserve should be determined based on how essential it is to maintain system security.

We have proposed the concept of Essential Requirement for reserve, for which the MCE will place a high priority on procuring. If this Essential Requirement is higher than the N-1 requirement, then the quantity of Block 1 will naturally be reduced.

If the PSO also considers that IL reserve is less reliable and that Essential Requirement should be fully procured from on-line generation facilities, then the CVP setting can be further adjusted to reflect such a requirement.

b) Re-allocate the proportion of Block 1 CVP between primary and contingency reserve deficit

It is proposed for the Block1 CVP to decrease for primary reserve and increase for contingency reserve, such that the sum of the two is still below $500 while the contingency reserve deficit can be reduced.

Based on our analysis in section 3.3 of the paper, the reliability value of the 50% safety margin for contingency reserve does not seem to justify further increase of the CVP. In addition, our simulation study showed that even if the CVP for deficit contingency reserve is doubled to $370, the number of deficit reserve is not significantly reduced[29].

We consider that our proposed solutions in section 4 of this paper is more effective in ensuring that the amount of reserve that is essential to maintain system security is procured.

5. Consultation

We published the concept paper for consultation on 8 June 2021. Comments were received from Tuas Power Generation, Keppel Merlimau Cogen, Senoko, YTL PowerSeraya, PacificLight Power and the PSO.

Comments received from consultation and EMC's response is summarised in Table 7 below. Please refer to Annex 1 for EMC's full response to each comment.

[29] For the simulated periods, number of reserve deficit is reduced by 14%.

Table 7 Comments Received and EMC's response

S/N	Comments received	EMC's response
Proposed Solution 1 (Increase CVP settings for Energy and Essential Requirement of Reserves/Regulation)		
1	PSO is of the view that all the reserves and regulation requirements are essential requirements that need to be procured by the MCE.	We note PSO's view that all reserve and regulation requirement is essential requirement. As such, Block 1 CVP for primary and contingency reserve will be increased to \$2550 and \$1950 (i.e. the same as Block 2). The Block 1 CVP for regulation will be increased to \$3000 (i.e. the same as Block 2)
2	In general, MPs support the proposal that the CVP of energy and ancillary service should be increased to secure procurement of essential requirement. PacificLight has also recommended delinking the Deficit Energy CVP from VOLL and set it as \$10,000/MWh.	We note the industry's support for proposal 1. We agree with increase of Deficit Energy CVP to \$10,000/MWh.
Proposed Solution 2 (Lower price cap for energy)		
3	Most MPs do not support lowering the energy price cap to \$2000. In their view, an energy-only-market as SWEM should allow energy prices to rise significantly during scarcity periods to provide opportunities for investors to recover the costs of new and existing capacity resource investments. Setting energy price cap at a level much lower than VoLL does not provide the correct investment signal for new planting and will severely compromise our system security.	A price limit of \$2000 is proposed to allow for sufficient differentiation between (a) the cost (including trade-off cost) to provide ancillary services and (b) the deficit ancillary services CVP, in order to guarantee that all available resources can be dispatched to meet the essential requirement. We note the industry's view and agree that in an energy-only market, generally the energy price cap should be set high enough to allow Gencos to recover fixed costs during scarcity periods. We would also like to point out that if the price limit remains at \$4500, it will be possible that reserve deficit still occurs even when there is sufficient available capacity (offered at a high price) in the market.

S/N	**Comments received**	**EMC's response**
4	MPs additionally propose for the price cap for energy (currently at $4,500/MWh) and ancillary services to be increased relative to the increase of VOLL.	While we have proposed for deficit energy CVP to be increased to reflect the current GDP level, we are of the view that the price limit does not have to be pegged to Deficit Energy CVP. Sufficient differentiation between price cap and deficit energy CVP will allow MCE to maintain the desired dispatch priority (i.e. incur reserve deficit before incurring energy deficit). In addition, price limit serves as a regulatory tool to curb potential exercise of market power. We are of the view that there is no compelling reason to increase the price limit at this juncture.
Proposed Solution 3 (Procurement of non-essential reserve via ORDC)		
5	PSO is of the view that with all reserve and regulation requirement classified as Essential Requirement, there is no need to procure additional/non-essential reserve/regulation.	We note PSO's view that all reserve and regulation requirement is essential requirement.
6	MPs are generally not supportive of proposal 3 and raised concern on the uncertainty in the reserve quantity that can be procured under ORDC and consequently the uncertainty in reserve cost that will be allocated to generation facilities.	We would like to point out that by establishing an ORDC, it allows MCE to discover and incorporate the reliability value of reserves into the market clearing process and procure a more optimal level of reserve. We agree that ORDC would introduce uncertainty in the estimation of reserve cost. We are open to consider supplementary measures to address such concern, including evaluating if reserve cost allocation should be improved such that all causers (potentially including large load and/or solar) that contribute to reserve need should bear its fair share of reserve cost.

S/N	Comments received	EMC's response
Proposal for high risk and emergency operating state be activated based on the physical conditions of the system		
7	PSO is of the view that if the Real-Time Dispatch schedule is able to eliminate most of inaccurate MCE shortfall based on offer prices submitted after stepwise CVP revision, then system high-risk and emergency operating states will still be based on MCE outcomes. Furthermore, that shortfall in Pre-Dispatch and Short-Term schedule by EMC help to avoid further shortfall during Real-Time Dispatch Schedule. The MCE outcome should reflect the physically available resources in the system. The high-risk and emergency operating states declaration by PSO during shortfall in Real-Time Dispatch schedule is necessary to inform and prepare MPs that there is an actual shortage based on schedule, and to be ready to ramp up above its scheduled capacity (MW) when required by the PSO.	We note PSO's view that all reserve and regulation requirement are essential requirements, which MCE will assign a high priority to. In this case, it is most likely that when the MCE forecasts/schedules a shortfall in ancillary services, there is not enough resources to meet ancillary services requirement. With that understanding, we agree that MCE' schedule outcome (post implementation of proposed solution 1) should be generally reflective of the system condition and can be used as the trigger for high risk and emergency operating state. We would also like to point out that MCE outcomes may not always reflect actual available resources in the system, especially when the generators' offers do not correctly reflect their physical condition (e.g. offers not removed from units on forced outage or available resources are offered at price above CVP). Therefore on their own, MCE schedule outcomes may not be the most effective indicator of system condition for the purpose of determining high risk or emergency operating states.

6. Conclusion and Recommendations

This paper reviews the CVP settings for energy, reserve and regulation in the SWEM. The review was initiated following frequent occurrences of reserve shortfall in 2018-2019, where the MCE did not fully utilise all available resources to meet energy and reserve requirements.

We conclude that the current CVP settings reflect the original intent of reserve deficit CVP setting, in which non-core reserve requirement is accorded low priority when the overall supply is tight. Nevertheless, we expect going forward that occurrence of reserve deficits would be further alleviated with increased participation of demand-side resources.

After consultation with the PSO, who is of the view that all reserve and regulation requirement is essential to maintain system reliability and security and should be procured as long as there is sufficient resource available, we propose that higher CVPs should be applied to ensure that the MCE will activate more costly resources to fully meet essential requirement.

While we have further proposed to lower the price limit for energy and ancillary service to eliminate the instances of deficit of ancillary services, we recognise that in an energy-only market, prices should be allowed to rise to reflect the value of energy during scarcity periods, and should not be arbitrarily reduced to achieve preconceived desirable dispatch outcome. Therefore, we do not recommend lowering the price limit at this juncture.

For non-essential reserve requirement, we propose to consider using an ORDC for the MCE to procure additional reserve if its reliability value so justifies. ORDC recognises the reliability value of reserve beyond the essential reserve requirement and allows for flexibility to incorporate new contingency events (other than generator's forced outages) into reserve procurement. While the implementation of ORDC would add to the complexity of reserve procurement and cost allocation, it can improve market efficiency by procuring reserves at a more optimal level and should be further studied as a possible long-term solution.

We recommend the RCP

a) Support Proposed Solution 1 to adjust CVP settings to secure dispatch for Essential Requirement and task EMC to modify the market rules to give effect to it; and

b) Support EMC to further study how ORDC can be adapted to Singapore's context for procurement of non-essential reserve requirement and its impact on the market outcome.

7. Decision at the 124th RCP Meeting

The concept paper was discussed at the 124th RCP meeting.

The panel unanimously supported, in-principle, the proposed solution 1 to adjust CVP settings to secure dispatch for Essential Requirement and task EMC to modify the market rules to give effect to it. The panel has further tasked EMC to review the proposed CVP revisions and fine-tune them to retain the dispatch priority contemplated in the current CVP setting.

The panel by majority vote supported the proposal for EMC to continue to study how ORDC can be adapted to Singapore's context for procurement of non-essential reserve requirement.

The following RCP members supported the proposal:

1. Mr. Tony Tan (Representative of Generation Licensee)
2. Mr. Teo Chin Hau (Representative of Generation Licensee)
3. Mr. Sean Chan (Representative of Retail Electricity Licensee)
4. Mr. Cheong Zhen Siong (Representative of Wholesale Electricity Trader)
5. Mr. Fong Yeng Keong (Representative of Consumers of Electricity in Singapore)
6. Ms. Ho Yin Shan (Representative of the Market Support Services Licensee)
7. Ms. Carol Tan (Representative of the Transmission Licensee)

The following RCP members did not support the proposal:

1. Mr. Soh Yap Choon (Representative of the PSO)
2. Mr. Calvin Quek (Representative of Generation Licensee)

The following RCP members abstained from voting:

1. Mr. Henry Gan (Representative of EMC)
2. Mr. Terence Ang (Representative of the Retail Electricity Licensee)

8. Further Study Conducted following the 124th RCP Meeting

At the 124th RCP meeting, the RCP tasked EMC to further review the proposed CVP values for regulation, reserves and energy, such that the current procurement prioritization of products is preserved.

As contemplated in the original design of the CVP setting, which was established before market start, procurement of regulation is of lower priority than that of primary and contingency reserves. This is reflected in the CVP values for primary reserve, contingency reserve and regulation, which were set at 0.9x VoLL, 0.7 x VoLL and 0.6 x VoLL respectively.

During stepwise CVP was introduced in 2013, the CVP of the first CVP block of regulation was intended to be set at lower level ($112) than the first block of contingency reserve CVP. The intention was to preserve the relative priority between regulation and reserves. However, doing that would have resulted in frequent regulation deficits based on the simulation conducted at that time. In order to reduce regulation deficit, the CVP for regulation was therefore increased to $305, above the regulation price cap.

After consultation with PSO, we are of the view that the relative priority between regulation and reserves should be retained as much as possible. With the CVP for the first block of primary and contingency reserve increased to $2550 and $1950 respectively, we propose for the CVP for the first block of regulation to be increased to $1700 (instead of $3000 as previously proposed in Solution 1). Based on the simulation results of the 68 cases in 2018-2019, a regulation CVP price of $1700 is high enough for the MCE to schedule offered resources to avoid regulation deficit.[30]

In summary, our proposed CVP settings for energy, primary reserve, contingency reserve and regulation is shown in Table 8 below.

Table 8 Proposed CVP Setting

Product	**Block 1**		**Block 2**		**Block 3**	
	CVP	Qty	**CVP**	Qty	**CVP**	Qty
Energy	**2x VoLL ($10000)** [31]	10000	N.A.	N.A.	N.A.	N.A.
Primary Reserve	**0.51 x VoLL ($2550)** [32]	0.2 x Requirement	0.51 x VoLL ($2550)	0.8 x Requirement - Minimum requirement	0.9 x VoLL ($4500)	Minimum Requirement
Contingency Reserve	**0.39 x VoLL**	0.3 x Requirement	0.39 x VoLL ($1950)	0.7 x Requirement -	0.7 x VoLL	Minimum Requirement

[30] Based on the simulation results, the highest market clearing price for regulation is $1400 and there is no regulation deficit was incurred.

[31] Increased from current CVP of $5000

[32] Increased from current CVP of $315

Product	Block 1		Block 2		Block 3	
	($1950)[33]			Minimum requirement	($3500)	
Regulation	**0.34 x VoLL** **($1700)**[34]	Requirement – Minimum requirement	0.6 x VoLL ($3000)	Minimum Requirement	N.A.	N.A.

As shown in Table 8, we propose to retain the current CVP structure with 3 CVP blocks for primary and contingency reserves, however with block 1 and block 2 assigned the same CVP value. Compared with removing 1 CVP block for primary and contingency reserve, retaining the current 3-block structure provide more flexibility. With it, the MCE can perform more complex simulations in the future if further revision to the CVP settings is required. Keeping the current structure would also reduce implementation cost and time[35].

Implementation effort estimate

A summary of the implementation effort estimate is provided below.

Effort Estimates	
Cost Estimate	
EMC Internal Manpower	$22,000
Time Estimate	
User Acceptance Test	8 Calendar Weeks

9. Proposed Rule Modifications

EMC has drafted rule modifications to give effect to the changes to CVP settings as set out in Table 8. Please refer to Annex 2 for details of the proposed rule modifications.

Table 9 Summary of Proposed Rule Modifications

S/N	Chapter/ Section	Proposed Changes	Reasons for Changes
1	Chapter 6 Appendix 6J	•To change violation penalty price for energy to 2 times VoLL; •To change violation penalty block 1 prices for regulation to 0.34 times VoLL; •To change violation penalty block 1 prices for primary reserve to 0.51 times VoLL; •To change violation penalty block 1 prices for contingency reserve to 0.39 times VoLL;	To change the CVP for energy, regulation, primary reserve and contingency reserve.

[33] Increased from current CVP of $185.

[34] Increased from current CVP of $305.

[35] Based on EMC's estimate, change from current CVP structure from 3 CVP blocks to 2 CVP blocks would mean an implementation timeline of 26 calendar weeks and implementation cost of $88,000 (including $66,000 internal manpower cost and $22,000 of external audit cost).

10. Consultation (Rule Modification)

EMC published the rule modification on 16 August 2021 for industry consultation. Comments were received from PacificLight Power and iSwitch.

Table 10 Industry Comments and EMC's response

S/N	Comments Received	EMC's Response
Comments Received from PacificLight Power		
1	We are supportive of EMC's proposal to increase the CVP price settings for Energy, Block 1 Primary Reserve and Block 1 Contingency Reserve. Timing-wise, we would appreciate that changes are implemented in the Market Clearing Engine as soon as practicable.	We note that PacificLight Power is supportive of the proposal and prefers the proposal to be implemented as soon as possible. We have recommended the implementation approach with the shortest implementation timeline.
Comments Received from iSwitch		
2	Is the lack of reserves provision despite having sufficient capacity a function of lack of price incentive or is it an exercise of market power to raise wholesale prices? a. The recent volatility events raise significant issues regarding the possibility and ability of the gencos to exercise market power and raise prices to extreme levels at the detriment to the Singaporean consumers. b. This raises the concern that despite the increase in CVP, capacity will still not be offered into the reserves market and the potential end result will be that consumers end up paying higher	The objective of this review is to find solutions for MCE to procure enough ancillary services when there is sufficient capacity offered. Assessment of whether there is exercise of market power is not within the scope of EMC. Based on our observation of the energy and reserve prices during deficit periods, we are of the view that the current CVP for reserve ($185) is not high enough to reflect the value of generation capacity during those periods. We are of the view that recent price volatility is not related to CVP settings in the MCE. We are of the view that the revised CVP should be able to provide sufficient price signals to incentivize reserve providers to offer capacity into the reserve market. The impact of the proposed change on market prices have been covered in the paper. The proposed change is to allow the MCE to meet the reserve requirement

S/N	Comments Received	EMC's Response
	electricity prices without any reliability increase.	in order to maintain system reliability, which will benefit consumers.
3	Should this change be implemented, we recommend that a review be conducted every 6 months for the first 2 years to review the intended targets of change and if this has been achieved. If there has been no material improvements, then we should consider rolling back on the change as we will be exposing Singaporean consumers to higher energy prices and volatility for no material reliability benefit.	We agree that we should monitor the effectiveness of the proposal after its implementation.
4	How do we communicate to the consumers that the proposed changes are the optimal solution and is not the electricity industry looking for alternative ways of raising prices. a. Has any 3rd party study / consultation been done on alternative solutions to the current problem? What about on the effectiveness of the proposed changes? b. Having conducted such exercises will allow the industry to better convince the public and Singaporean businesses that the proposed change is indeed the optimal choice for the entire community and not just rule drawing within the industry participants with vested interest to raise prices.	We would like to reiterate that the objective of the review is to ensure the MCE is able to procure sufficient reserves in order to maintain system reliability. At no point in our analysis and formulating of solution has price outcomes been a consideration. Based on EMC's simulation results, the proposed solution (increased CVP setting) should be effective to resolve the reserve deficit issue. Actual effectiveness will have to be observed after the proposal is implemented.
5	Is installation of additional new capacity a better solution rather than raising prices for Reserves with potential spill over to Energy to the benefit of generation companies and at the expense of Singaporean consumers.	In EMC's opinion, additional new capacity invariably creates more competition on the supply side and therefore benefit consumers. However, the economics of adding new capacity will be specific to the investor.

11. Legal sign off

The text of the proposed rule modifications as set out in Annex 2 has been vetted by EMC's internal legal counsel, whose opinion is that the modifications reflect the intent of the market manual modification proposal as expressed in the third column of the table in Annex 2.

12. Recommendation (Rule Modification)

EMC recommend RCP to:

a) **support** the rule modification proposal as set out in the Annex 2;

b) **recommend** that the EMC's Board adopt the rule modification proposal; and

c) **recommend** that the rule modification proposal come into force **8 weeks** after the date on which the approval of the Authority is published by the EMC.

13. Decision at the 126th RCP Meeting

The Panel discussed the rule modification proposal at its 125th and 126th RCP meeting.

At the 126th RCP meeting, the Panel by majority vote supported the proposed rule modification set out in Annex 2.

The following RCP members supported the proposal:

1. Mr. Calvin Quek (Representative of Generation Licensee)
2. Mr. Tony Tan (Representative of Generation Licensee)
3. Mr. Teo Chin Hau (Representative of Generation Licensee)
4. Mr. Sean Chan (Representative of Retail Electricity Licensee)
5. Ms. Ho Yin Shan (Representative of the Market Support Services Licensee)
6. Ms. Carol Tan (Representative of the Transmission Licensee)

The following RCP members did not support the proposal:

1. Ms. Nerine Teo (Representative of the Retail Electricity Licensee)
2. Mr. Cheong Zhen Siong (Representative of Wholesale Electricity Trader)
3. Mr. Fong Yeng Keong (Representative of Consumers of Electricity in Singapore)
4. Mr. Henry Gan (Representative of EMC)
5. Mr. Tan Chian Khong (Person experienced in financial matters in Singapore)

The following RCP members abstained from voting:

1. Mr. Soh Yap Choon (Representative of the PSO)

Energy Market Company

Annex 1 Comments received from Industry and EMC's response

S/N	**Comments received**	**EMC's response**
Comments received from PacificLight		
1	Section 12.2.1 of the System Operation Manual (SOM) expressly provides that having a safety margin of 50% of reserve requirement (i.e., N-1.5 reserve requirement) is to support the system's ability to "survive a subsequent contingency for the next 4 to 10 hours". Accordingly, the Essential Requirement, as broadly defined in the paper, should be similarly set at N-1.5 requirements. Doing so would mean that if there is sufficient capacity to meet both energy and reserve demand, the market should procure the full requirement. Currently, it is constrained by the low CVP set for Block 1.	We note PacificLight's view that the essential requirement should be set at N-1.5 requirement, which is in line with PSO's view. Please refer to our response to comment 1 in Table 7.
2	PacificLight is supportive of the implementation of Proposed Solution 1 along with some modifications, but has reservations over Proposed Solutions 2 and 3 as further outlined below: • We support the adoption of Proposal 1 put forth by EMC, which involves the following steps, as it will eliminate more than 99% of the occurrence of reserve shortfalls: a) Revising up the Deficit Generation CVP; and b) Extending the Block 2 CVP price to the Essential Requirement. However, instead of increasing the Deficit Energy CVP through the VOLL review, which may take time given its implications on other parameters on MCE, we recommend delinking the Deficit Energy CVP from VOLL and set it as $10,000/MWh.	We note PacificLight's support of proposal 1. Please refer to our response to comment 2 in Table 7.
3	We do not support the implementation of Proposed Solution 2 as it only removes the residual risk of 0.1% occurrence of reserve shortfalls. Moreover, it is counterintuitive that on one hand the increase of VOLL over time as economic growth is recognised but on the other hand energy price cap is proposed to be lowered to $2,000.	Please refer to our response to comment 3 in Table 7.

S/N	Comments received	EMC's response
4	While Proposal 3 on adoption of ORDC seems feasible, we need more clarity on the structure and impact of LOLP on CVP price. As further studies need to be done, we believe it is more cost and time efficient to go ahead with Proposal 1 (i.e., changing a parameter) as opposed to implementing a new structure as per Proposal 3.	We agree that Proposed Solution 1 can be implemented before further study is carried out for Proposed Solution 3.
5	Furthermore, we are unable to agree with EMC's other proposals that suggest for ad-hoc interventions such as: 1. PSO intervening on subsequent contingency events using out-of-market measures than procuring the full N-1.5 requirements, and 2. PSO deciding and declaring high-risk and emergency operating states based on the physical conditions of the system rather than relying on reserve deficit as a criteria for activation.	We are of the view that PSO should be allowed to intervene when the market schedule is not feasible or unable to maintain system reliability. Current market rules provide for it. Declaration of high-risk and emergency operating state may result in out-of-market intervention by PSO and should be used only when the physical system is in high risk/emergency. Hence we are of the view it should be declared based on physical condition.
Comments received from Senoko		
6	Supply cushion is determined based on total demand vs total supply with valid market offers in the system. As offline (unscheduled) units are unable to provide reserves, the comparison of reserve shortfall instances against supply cushion is invalid.	We agree that there are various factors that could contribute to reserve shortfall while supply cushion is healthy as analysed in section 3 of the paper.
7	We are in agreeance of the view that High-risk operating states should only be declared solely based on the system's physical conditions. Should the operating state change from 'high-risk' to 'emergency', we can expect out-of-market solutions such as Fast-start machines coming online which will distort market prices and signals.	We note that Senoko agrees with the proposal and the impact to Gencos when an emergency operating state is declared.
8	With Singapore rapidly moving towards automation and gearing towards being a data centre hub, we agree that the current VOLL of	Please refer to our response to comment 4 in Table 7.

S/N	Comments received	EMC's response
	$5,000/MWh is potentially underestimated and support the increase of VOLL to $10,000/MWh. Our view is that the current energy price cap of $4,500/MWh should also be increased relative to the increase of VOLL.	
9	Subject to PSO's quantification of "Essential Reserves", we are agreeable to the proposed increase of Reserve products across the board. As we have previously estimated that VOLL should be closer to $10,000/MWh, reserve products act as an insurance against the VOLL prices / scarcity pricing to become binding.	Please refer to our response to comment 4 in Table 7.
10	As per the paper's estimation, VOLL should be closer to or higher than $10,000/MWh, it also implies that the market offer price cap should be revised to reflect VOLL. Comparing NEMS to other energy-only markets, Australia has a price cap of $15,000/MWh and New Zealand has an energy price cap of $20,000/MWh whereas we have a price cap of $4,500/MWh. Although the chance of scarcity pricing occurring is low, these rare occasions provide essential renumeration towards units that are in the system but usually not within the merit-order of dispatch due to higher variable / operating costs. Hence, we are strongly against the proposal to reduce the energy offer price cap to $2,000/MWh and instead propose to increase the energy offer price cap to a number closer to $10,000/MWh.	Please refer to our response to comment 3 and 4 in Table 7.
11	With current practice, Gencos are already operating with limited data and hence having the need to make informed deductions on their own RRS requirements. These deductions are often off-the-mark which in turn encourages Gencos in general to over-offer reserve products. Offering the optimal amount of reserve products is key to reflecting the true cost of generation, which will	Please refer to our response to comment 6 in Table 7.

S/N	Comments received	EMC's response
	help alleviate the currently depressed energy market. Adding another layer of complexity as per proposal 3 will further increase the difficulty for Gencos to calculate their RRS requirements. Hence, we are not supportive of proposal 3 due to the complexity involved with little benefit to the system.	
12	We are supportive to allow non-spinning fast-start units to participate in the Reserves market. Our view is that they should be able to participate in the "Essential Reserves" market albeit with a MW cap on reserve provision. Contingency Reserve requirement = 10 minutes response time, able to hold output for 30 minutes. MW Cap = {[10 Mins – Unit preparation time * Ramp Rate}	We note Senoko's view. The PSO has in a separate work stream shared that offline units are not eligible to provide contingency reserve. Hence EMC is exploring the possibility for offline units to provide non-essential reserve.
Comments from Tuas		
13	We agree with Proposal 1 to adjust VoLL upwards as the current VoLL is clearly not reflective of the true valuation. In the 60th RCP meeting on the review of the value of lost load, "EMC recommends to hold the proposal to raise VoLL in abeyance until such time when there is (1) a lower level of market concentration which can be signalled by the EMA's removal of vesting contracts imposed for market power control, (2) more demand response initiatives, and/or (3) better risk management". Hence, we would like to request for EMC to conduct a valuation of VoLL with or without Proposal 1 being adopted, given that the vesting contract has been rolled back with LNG vesting contract ending in 1H 2023 and that market has undergone significant changes with the introduction of electricity futures market, demand response and the new dynamics of the post pandemic world	We note Tuas is supportive of Proposed Solution 1 and the request for review of VOLL to be conducted.

S/N	Comments received	EMC's response
14	We do not agree with Proposal 2 to lower the energy price cap from $4,500/MWh to $2,000/MWh. The current NEMS design is that of an Energy-only-Market ("EOM"), with energy and ancillary service markets, and the main revenue streams are from the EOM. To support sufficient investment to maintain resource adequacy (to ensure system security), EOM designs must allow energy prices to rise significantly when resources are in short supply, i.e. "scarcity" event, to provide opportunities for investors to recover the costs of new and existing capacity resource investments. Setting energy price cap at a level much lower than VoLL does not align with the principles of an Energy-on-Market and does not provide the correct investment signal for new planting and will severely compromise our system security.	Please refer to our response to comment 4 in Table 7.
15	We do not agree with Proposal 3 as implementation of ORDC would bring about uncertainty in the estimation of reserve responsibility share leading to less efficient outcome	Please refer to our response to comment 6 in Table 7.
Comments from Keppel Merlimau Cogen		
16	Keppel supports EMC's proposal for an upward revision to the VoLL to reflect the increased electricity consumption and GDP in Singapore since the time the VoLL was last set. Keppel recommends EMC to further analyse the optimal CVP settings to ensure sufficient resources are procured to meet both energy and reserve requirements.	We note that Keppel supports the increase of energy deficit CVP. Our analysis and the proposed solutions to ensure sufficient resources are procured to meet both energy and reserve requirements are set out in section 4 of this paper.
17	Keppel does not support lowering the energy offer price cap. As the current energy price cap is pegged to be close to VoLL (0.9 x VoLL), can EMC share the justifications the removal of the peg between VoLL and the energy price cap? A low historical frequency of the market at such price levels does not imply that the cost of shortage has decreased. On the contrary, the higher electricity demand and GDP in Singapore	Please refer to our response to comment 3 in Table 7.

S/N	Comments received	EMC's response
	should mean that the absolute cost of an energy shortfall in Singapore has increased.	
18	Keppel recommends to re-visit the proposal to introduce an Operating Reserve Demand Curve (ORDC) for the Non-Essential reserve quantity together with EMA and the larger industry in detail. As there are ongoing developments in FCM and Fast Start service which have yet to be finalised, making significant changes to the procurement of reserves in the wholesale market should be deliberated further.	We note Keppel's recommendation and will endeavour to engage EMA when we further study Proposed Solution 3.
Comments from YTL PowerSeraya (YTLPS)		
19	Amongst various measures that can address the frequent violation of the contingency reserve requirements, YTLPS thinks the first step would be to examine the value and criticality of the last 30% of the contingency reserve requirements (Block 1). This review may take into consideration, with the introduction of the Fast Start Ancillary Service, how this would affect the contingency reserve requirements and the application of the step-wise CVP. If the Block 1 reserves are deemed to be non-critical (or non-essential) as described in the consultation paper, YTLPS thinks that: (1) a supply shortfall for this block should not trigger advisory notices that the system is in a high-risk or emergency operation state. This means fast-start units will not be activated for Block 1 violation instances. (2) It warrants a review on the cost allocation for this block of reserve; whether the procurement cost should be recovered via the MEUC, like the Black Start and Fast Start Ancillary costs, instead of being borne by the dispatch GRFs.	EMC's analysis of the 30% of the contingency reserve is set out in section 3 the paper. EMC has consulted PSO on the criticality of the 30% reserve requirement, who is of the view that the 30% reserve requirement is also essential to system security. Please refer to PSO' comment (comment 7) in Table 7 and our response to it. Given the reserve requirement is currently set based on the scheduled energy of the largest online GRF, there does not seem to be reason to change the reserve cost allocation mechanism.
20	If the Block 1 reserves are deemed to be critical for the system's safety operation, the value differential between this product and energy should be reduced to provide the correct price signals that both products are equally or near-equally important. To this, YTLPS agrees with	We note YTLPS agrees with Proposed Solution 1.

S/N	Comments received	EMC's response
	EMC's Proposed Solution 1, to raise the CVPs assigned to Block 1 of primary reserve, contingency reserve and regulation to $2550, $1950 and $3000 respectively and increase of deficit energy CVP to $10,000 and above. Apart from raising the CVP price for reserve and regulation, the maximum offer price for reserve and regulation should also be lifted above this level – to create the intended outcome of reducing the market distortion created by different maximum value(s) the unit of generation capacity can receive by offering into that product.	
21	YTLPS disagrees with EMC's Proposed Solution 2 of lowering the energy price cap to $2,000/MWh. The comparison with IESO is inappropriate because NEMS is a real-time only, and energy-only market. The NEMS market design creates a high level of revenue and dispatch uncertainty for dispatch unit owners. The ERCOT market (with a price cap of US$9,000/MWh) is more appropriate for comparison, where higher maximum energy prices are used to provide price signals for generation asset owners to commit their supply into the market if there are tight supply situations	Please refer to our response to comment 3 in Table 7.
22	While YTLPS agrees with the discussion of reclassifying essential and non-essential reserves, we do not support the ORDC as illustrated in Proposal Solution 3. Firstly, we think that the cost of procuring non-essential reserves should be recovered via the MEUC instead of the dispatched GRFs. If this is not accepted, the concept of having varying ODRC at different times will lead to further complication how the GRF owners prioritise their generation capacity for different products and create unintended consequences. If the concept of procuring and non-essential reserves through the real-time market, recovered via the MEUC is accepted, we suggest to have a new product type for this (i.e. on top of the primary, contingency and regulation products) and not to clear the requirements together in the same contingency reserve product.	Please refer to our response to comment 6 in Table 7. We note YTLPS's suggestion to create a new product for non-essential reserve and will take it into consideration when we further study Proposed Solution 3.

S/N	Comments received	EMC's response
Comments from PSO		
23	[With regard to the proposal for the declaration of high-risk and emergency operating states (pertaining to sufficiency of reserve and regulation) to be assessed based on physically available resources in the system instead of MCE outcomes.] The shortfall from Market Clearing Engine (MCE) will reflect the generation unit conditions based on the offer prices submitted, if the Real-Time Dispatch schedule able to eliminate most of inaccurate MCE shortfall based on offer prices submitted after stepwise CVP revision, then system high-risk and emergency operating states will still be based on MCE outcomes. Furthermore, that shortfall in Pre-Dispatch and Short-Term schedule by EMC help to avoid further shortfall during Real-Time Dispatch Schedule. The MCE outcome should reflect the physically available resources in the system. The high-risk and emergency operating states declaration by PSO during shortfall in Real-Time Dispatch schedule is necessary to inform and prepare MPs that there is an actual shortage based on schedule, and to be ready to ramp up above its scheduled capacity (MW) when required by the PSO.	Please refer to our response to comment 7 in Table 7.
24	[With regard to the amount of contingency reserve that should be procured under Essential Requirement and if a similar concept should be extended to regulation requirement.] All the reserves and regulation are essential requirements that need to be procured in the Market Clearing Engine (MCE). The change is to reduce a 3 block CVP to 2 block CVP so as to reduce the possibility of shortfall amid tight offer situation. Therefore, it will also affect the corresponding CVP quantity which EMC did not consider in their simulation. For PSO, all the blocks are essential requirement to meet system needs.	We note that all reserve and regulation requirement is essential and should be procured as long as there is resource available to meet the requirement. We would like to clarify that in our simulation, we have assumed the most conservative case where all reserve and regulation requirement are essential requirement, which is in line with the PSO's definition of essential requirement.

Annex 2: Proposed Rule Modification

<table>
<tr>
<th>Existing Market Rules
(1 July 2021)</th>
<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>CHAPTER 6, APPENDIX J

J.3 MAPPING OF VIOLATION PENALTIES TO VARIABLES USED IN THE MARKET CLEARING ENGINE FORMULATION</td>
<td>CHAPTER 6, APPENDIX J

J.3 MAPPING OF VIOLATION PENALTIES TO VARIABLES USED IN THE MARKET CLEARING ENGINE FORMULATION</td>
<td></td>
</tr>
<tr>
<td>
<table>
<tr><th>Variable used in MCE formulation</th><th>j</th><th>Violation Penalty Block Prices</th><th>Violation Penalty Block Quantities</th></tr>
<tr><td>DeficitGeneration Blockn,j</td><td></td><td>DeficitGenerationPenalty$_{n,j}$

VoLL</td><td>DeficitGenerationBlockMax$_{n,j}$

10,000 MW</td></tr>
</table>
</td>
<td>
<table>
<tr><th>Variable used in MCE formulation</th><th>j</th><th>Violation Penalty Block Prices</th><th>Violation Penalty Block Quantities</th></tr>
<tr><td>DeficitGeneration Blockn,j
…</td><td></td><td>DeficitGenerationPenalty$_{n,j}$

2 *VoLL</td><td>DeficitGenerationBlockMax$_{n,j}$

10,000 MW</td></tr>
</table>
</td>
<td>To change violation penalty price for energy to 2 times VoLL.</td>
</tr>
</table>

Energy Market Company

<table>
<tr><th>Existing Market Rules
(1 July 2021)</th><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><th>Variable used in MCE formulation</th><th>j</th><th>Violation Penalty Block Prices</th><th>Violation Penalty Block Quantities</th></tr>
<tr><td>DeficitRegulation</td><td>1

2</td><td>0.061 * VoLL

0.6 * VoLL</td><td>2,000 MW

2,000 MW</td></tr>
<tr><td>DeficitReserve$_c$</td><td>

1

2

3</td><td>9 Second Class (Primary Reserve):
0.062 * VoLL

0.51 * VoLL

0.9 * VoLL</td><td>

2,000 MW

2,000 MW

2,000 MW</td></tr>
</table>
</td><td>
<table>
<tr><th>Variable used in MCE formulation</th><th>j</th><th>Violation Penalty Block Prices</th><th>Violation Penalty Block Quantities</th></tr>
<tr><td>DeficitRegulation</td><td>1

2</td><td>~~0.061~~ <u>0.34</u>* VoLL

0.6 * VoLL</td><td>2,000 MW
2,000 MW</td></tr>
<tr><td>DeficitReserve$_c$</td><td>

1

2

3</td><td>9 Second Class (Primary Reserve):
~~0.062~~ <u>0.51</u> * VoLL

0.51 * VoLL

0.9 * VoLL</td><td>

2,000 MW

2,000 MW

2,000 MW</td></tr>
</table>
</td><td>To change violation penalty block 1 price for regulation to 0.34 times VoLL.

To change violation penalty block 1 price for primary reserve to 0.51 times VoLL</td></tr>
</table>

Existing Market Rules (1 July 2021)	Proposed Rule Changes (Deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
See table A below	See table B below	To change violation penalty block 1 price for contingency reserve to 0.39 times VoLL

A. Existing Market Rules (1 July 2021)

Variable used in MCE formulation	*j*	Violation Penalty Block Prices	Violation Penalty Block Quantities
		10 Minute Class (Contingency Reserve):	
	1	0.037 * VoLL	2,000 MW
	2	0.39 * VoLL	2,000 MW
	3	0.7 * VoLL	2,000 MW

B. Proposed Rule Changes

Variable used in MCE formulation	*j*	Violation Penalty Block Prices	Violation Penalty Block Quantities
		10 Minute Class (Contingency Reserve):	
	1	~~0.037~~ 0.39* VoLL	2,000 MW
	2	0.39 * VoLL	2,000 MW
	3	0.7 * VoLL	2,000 MW