Notice of Market Rules Modification

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This paper assesses the proposal to enable the participation of batteries in the regulation market of the Singapore Wholesale Electricity Market (SWEM).

Currently, only conventional generators that can respond to Automatic Generation Control (AGC) are eligible to provide regulation in the SWEM. However, experience from the U.S. markets has shown that with appropriate dispatch mechanisms, batteries are also capable of providing regulation.

This paper examines the qualities and limitations of batteries as regulation providers and concludes that with dispatch mechanisms approved by the PSO, the proposed participation of batteries in the regulation market will be beneficial to the SWEM. The paper introduces the relevant changes to be made to enable the participation of batteries in the regulation market of the SWEM.

At the 71st RCP meeting, the RCP agreed to consider this proposal only after the PSO approves of the first dispatch mechanism proposed for batteries providing regulation. The paper thus illustrates how this PSO-approved dispatch mechanism works for batteries to provide regulation throughout a dispatch period.

The proposed rule modifications to enable the participation of batteries in the regulation market were presented at the 26th TWG meeting and the 80th RCP meeting. The TWG (unanimously) and the RCP (by majority vote) supported the proposed rule modifications. The RCP also by majority vote recommends that the EMC Board **adopt** the proposed rule modifications as set out in Annex 3.

Date considered by Rules Change Panel:	12 May 2015
Date considered by EMC Board:	31 July 2015
Date considered by Energy Market Authority:	21 August 2015

Proposed rule modification:

See attached paper.

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

Energy Market Company

PAPER NO.	:	**EMC/BD/06/2015/06(a)**
RCP PAPER NO.	:	**EMC/RCP/80/2015/321**
SUBJECT	:	**PROVISION OF REGULATION BY BATTERIES**
FOR	:	**DECISION**
PREPARED BY	:	**JO ONG ZU ER** **ECONOMIST**
REVIEWED BY	:	**PAUL POH LEE KONG** **EVP, MARKET ADMINISTRATION**
DATE OF MEETING	:	**31 JULY 2015**

Executive Summary

Currently, only conventional generators that can respond to Automatic Generation Control (AGC) are eligible to provide regulation in the Singapore Wholesale Electricity Market (SWEM). However, experience from the U.S. markets has shown that with appropriate dispatch mechanisms, batteries are also capable of providing regulation.

This paper examines the qualities and limitations of batteries as regulation providers and concludes that with dispatch mechanisms approved by the PSO, the proposed participation of batteries in the regulation market will be beneficial to the SWEM. The paper thus introduces the relevant changes to be made to enable the participation of batteries in the regulation market of the SWEM.

At the 71st RCP meeting, the RCP agreed to consider this proposal only after the PSO approves of the first dispatch mechanism proposed for batteries providing regulation. This paper thus illustrates how this PSO-approved dispatch mechanism works for batteries to provide regulation throughout a dispatch period.

At the 26th TWG meeting, the TWG considered the proposed rule modifications to enable the participation of batteries in the regulation market and unanimously recommended that the RCP support the proposed rule modifications set out in **Annex 3**.

At the 80th RCP meeting, the RCP by majority vote **supported** the proposed rule modifications and recommends that the EMC Board **adopt** the proposed rule modifications set out in **Annex 3**.

1. Introduction

This paper assesses the rule modification proposal to enable the participation of batteries in the regulation market of the Singapore Wholesale Electricity Market (SWEM).

2. Background

2.1 Purpose of Regulation

Regulation is an ancillary service provided and procured in the SWEM. The objective of regulation is to correct any grid frequency variations of up to 0.2Hz[1] from 50Hz, arising from imbalances between load and the output from generation facilities. Imbalances between load and generation can be attributed to the following factors:

- Inaccuracy in system demand forecast
- Fluctuations in electricity consumption by loads
- Deviation in generators' output from the scheduled amount

2.2 Provision of Regulation by Generation Facilities

Currently, only generation registered facilities (GRFs) which are capable of responding to Automatic Generation Control (AGC)[2] are eligible to provide regulation via the frequent adjustment of their output in the SWEM.

GRFs dispatched or instructed by the Power System Operator (PSO) to provide regulation are placed under the control of the AGC subsystem of the PSO's Energy Management System (EMS). The PSO sends a series of AGC commands from the EMS to the GRFs to automatically increase and decrease their output, correspondingly providing regulation up and down. For the PSO to operate GRFs through AGC, the GRFs' output must be within a certain range. This regulation range is bounded by the RegulationMin and RegulationMax of the GRFs.

To ensure that scheduled GRFs are able to provide regulation throughout the dispatch period, they are expected to maintain unused generation capacity (corresponding to their scheduled regulation quantities) during the dispatch period. In addition, the GRFs' regulation offers are considered for regulation service only when their expected generation levels at the beginning of the dispatch period are within the regulation range.

One limitation of conventional generators as regulation providers is their significant operating costs. This is because the frequent variation of output by generators increases maintenance costs, arising from greater wear and tear of the plants and fuel consumption due to the loss of the plants' efficiency in converting fuel into electricity[3].

2.3 Potential Provision of Regulation by Batteries

Batteries consist of electrochemical cells that are able to store energy by converting electricity into chemical energy for later release. They withdraw electricity from the grid when they store energy (charging) and inject electricity to the grid when they release the stored energy (discharging).

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[1] According to section 8.2.1 of Chapter 8 of the SOM, regulation is responsible for correcting system frequency fluctuations under normal conditions of up to 0.2Hz.

[2] According to Chapter 8 of Market Rules, AGC refers to the process that allows the PSO to centrally adjust the output of GRFs automatically via electronic commands so as to balance generation and load in real-time.

[3] From Frequency Regulation, dated 2013 http://www.beaconpower.com/solutions/frequency-regulation.asp

Batteries can provide regulation via the frequent adjustment of their energy output as well. Their small sizes allow them to change their energy output in very small resolutions. Coupled with their high ramp rates[4], they can respond accurately and rapidly to control signals. Batteries can thus be highly effective and efficient in providing high-quality regulation, which corrects second-by-second imbalances between load and generation.

Global Use of Batteries for Frequency Regulation

The global operational capacity of electrochemical[5] energy storage has indeed been growing steadily over the past decade, from approximately 100MW in 2004 to 520MW in 2014[6]. In fact, as of 1st January 2015, frequency regulation is the top use of electrochemical energy storage worldwide with the U.S. having the largest operational capacity used for frequency regulation at 142MW.

With the use of electrochemical energy storage for frequency regulation growing increasingly widespread globally, experience from other countries has shown that batteries have technical limitations and will require unique dispatch mechanisms to optimise their use in frequency regulation.

Limitations of Batteries

Batteries are not able to provide regulation (in both directions) when they are fully charged or discharged. This is because the output range of a battery, bounded by its maximum rates of charge and discharge, is dependent on its level of stored energy, as measured by its state of charge (SoC). When the battery is empty (i.e. SoC of 0%), its maximum rate of discharge is 0kW as an empty battery has no stored energy to discharge at all if the system requires it to provide up-regulation. When the battery is full (i.e. SoC of 100%), its maximum rate of charge is 0kW as a full battery has no unused capacity to charge at all if the system requires it to provide down-regulation.

Due to the limited storage capacities[7] of batteries, they may not be able to provide regulation continuously throughout a dispatch period. They could easily be fully charged or discharged when providing regulation, especially when the deviations in grid frequency are large, causing the required regulation associated with either direction to be high and for a prolonged period of time.

2.4 Provision of Regulation by Batteries in the U.S. Markets

From our survey of the electricity markets in the U.S., the participation of batteries in their regulation markets is highly encouraged by the following Federal Energy Regulatory Commission (FERC) rulings:

- FERC Order No. 890[8] in 2008 to require the Independent System Operators (ISOs) to allow energy storage like batteries to bid into ancillary services markets
- FERC Order No. 755[9] in 2011 to require the ISOs to modify their compensation mechanism for regulation to incorporate a performance payment, so as to duly reward fast-ramping resources like batteries

[4] Based on the test results of a battery provider, a battery facility of 2MW is able to reach its maximum charge or discharge rate within 200 milliseconds. This translates into a transient ramp rate of 600MW/min.
[5] Electrochemical devices encompass batteries and electrochemical capacitors.
[6] From U.S. Department of Energy's (DOE) Global Energy Storage Database http://www.energystorageexchange.org/
[7] According to typical current international values and ranges, a Li-ion battery has a storage capacity of 5-10kWh. From Electricity Storage, dated 2012 http://www.irena.org/DocumentDownloads/Publications/IRENA-ETSAP%20Tech%20Brief%20E18%20Electricity-Storage.pdf Page 22
[8] 8 For more information on FERC Order No. 890, refer to http://www.ferc.gov/whats-new/comm-meet/2007/021507/E-1.pdf.

These FERC rulings have led to many ISOs re-evaluating and amending their rules to accommodate energy storage resources in their regulation markets. We observe that these ISOs created a separate resource class for such facilities to participate in their regulation markets and implemented performance-based payments for regulation. To enable batteries to provide regulation continuously, the ISOs predominantly use basepoint setting and highpass regulation signals in their dispatch mechanisms (see Table 1).

Table 1: Summary of dispatch mechanisms in U.S. electricity markets

Markets	Resource class for batteries	Dispatch mechanism	
		Highpass signal	Basepoint setting
PJM Interconnection (PJM)	Fast Response Resources (FRR)	Yes	No
New York Independent System Operator (NYISO)	Limited Energy Storage Resources (LESR)	No	Yes
California Independent System Operator (CAISO)	Limited Energy Storage Resources (LESR)	Yes	Yes
Midwest Independent System Operator (MISO)	Stored Energy Resources (SER)	No	Yes

2.4.1 Basepoint Setting

While a conventional generator provides regulation about its then current operating point, a battery provides regulation about its pre-determined basepoint in CAISO, MISO and NYISO. The basepoint of a battery is thus its default output, i.e. whether it charges (negative output), neither charges nor discharges (zero output), or discharges (positive output), when the grid frequency is at its nominal value of 60Hz in these ISOs.

The basepoint setting mechanism aims to maintain the battery's SoC at approximately 50%, where the battery has as much stored energy as unused capacity, to ensure continuous regulation provision throughout a dispatch period. A battery's basepoint at each SoC is set such that when the grid frequency is at its nominal value of 60Hz, the battery charges when the SoC is low and discharges when the SoC is high. Table 2 explains the mechanism and rationale of basepoint setting.

Table 2: Rationale for basepoint setting

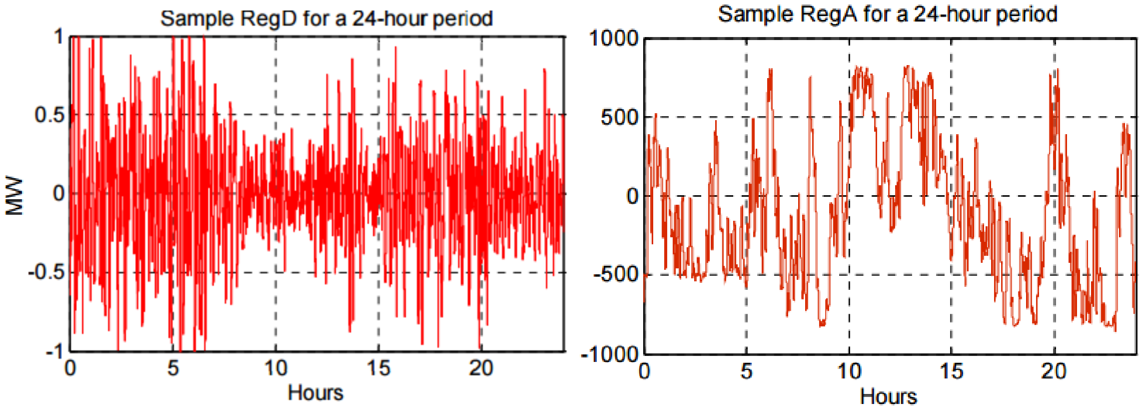
SoC (%)	Basepoint (kW)	Rationale
Low (Almost Empty)	Negative i.e. charging	Increase the battery's SoC and restore its SoC to approximately 50%
Approx. 50 (Half)	Zero i.e. neither charging nor discharging	Maintain the battery's SoC at approximately 50%
High (Almost Full)	Positive i.e. discharging	Decrease the battery's SoC and restore its SoC to approximately 50%

[9] For more information on FERC Order No. 755, refer to http://www.ferc.gov/whats-new/comm-meet/2011/102011/E-28.pdf .

2.4.2 Highpass Regulation Signals

PJM and CAISO send different types of regulation signals to different types of resources. Fast-ramping resources such as batteries and flywheels respond to highpass regulation signals while slow-ramping resources such as the conventional generators respond to lowpass regulation signals. These two types of signals divide required regulation, as indicated by the Area Control Error (ACE[10]) signals, into two components according to frequency. This allows for fast-ramping resources contributing to the high frequency component in response to highpass signals to complement slow-ramping resources contributing to the low frequency component in response to lowpass signals in regulation provision. Figure 1 shows the sample highpass and lowpass signals in PJM.

Figure 1: Sample highpass (RegD) and lowpass (RegA) signals in PJM[11]



Responding to only highpass signals are ideal for batteries because as seen in Figure 1, such signals change direction so frequently that the required energy associated with either direction is limited. This utilises the rapid response capability of batteries and allows them to provide regulation continuously without excess charge or discharge despite their small storage capacities.

The conventional generators benefit as well from responding to only lowpass signals which change direction less frequently and require slower response. Since the grid frequency variations are smoothed by regulation provision by the fast-ramping resources, less maintenance-inducing strain arising from the frequent variation of output is now placed on the slow-ramping resources[12].

In the context of the SWEM where the current regulation providers are largely Combined-Cycle Gas Turbine (CCGT) generators[13], Figures 2A and 2B illustrate that the rapid and accurate response capability of batteries in response to highpass signals is superior to that of a CCGT generator in response to lowpass signals in PJM. In PJM, as high as 16.24% of its average hourly actual cleared MW of regulation is from resources following highpass signals.[14]

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[10] According to PJM's Manual 12 Balancing Operations section 3.1.1 and CAISO's Business Practice Manual for Definitions & Acronyms, ACE is a measure of the imbalance between sources of power and uses of power (in MW) within the respective Regional Transmission Organizations (RTOs).
[11] Source of Figure 1: KERMIT Study Report- To determine the effectiveness of the AGC in controlling fast and conventional resources in the PJM frequency regulation market, dated 2011 http://www.pjm.com/~/media/committees-groups/task-forces/rpstf/postings/pjm-kema-final-study-report.ashx Page F-7
[12] From the Abstract of A Coordinating Algorithm for Dispatching Regulation Services Between Slow and Fast Power Regulating Resources, dated 2013 http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6630129&isnumber=5446437
[13] As of 1 Sep 2014, CCGTs contribute to 80.3% of the total registered regulation capacity (408.5MW) in the SWEM.
[14] From Quarterly State of the Market Report for PJM: January through September 2014, page 353 http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2014/2014q3-som-pjm-sec10.pdf

Figure 2A: Response of batteries to highpass signals in PJM[15]

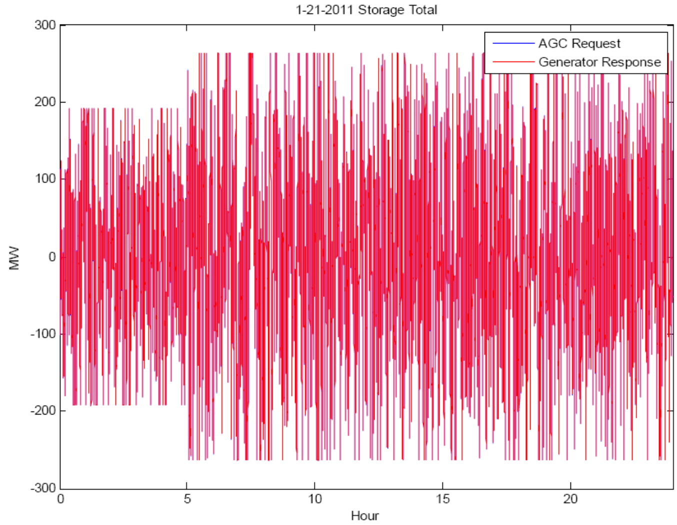
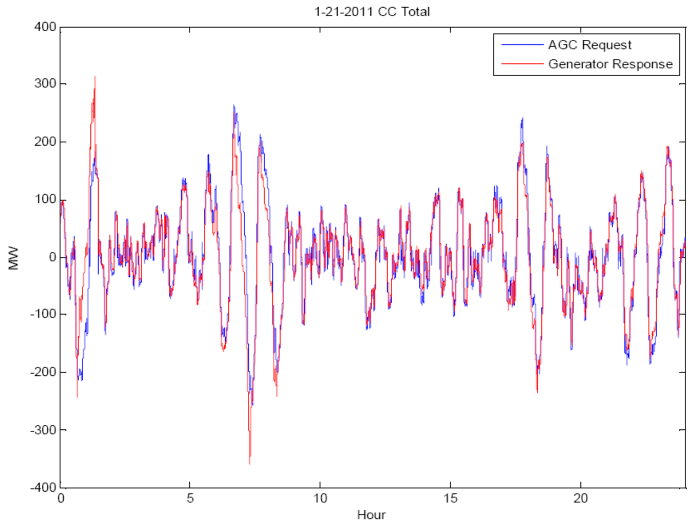


Figure 2B: Response of a CCGT to lowpass signals in PJM



According to a study by KEMA, the introduction of fast regulation resources like batteries to complement conventional generators in providing regulation is expected to reduce the overall regulation requirement or improve the system's performance in frequency regulation.

2.5 Benefits of Proposal

From both the system and market perspectives, the proposed participation of batteries in the regulation market will be beneficial to the SWEM.

The participation of batteries will increase the quantity and quality of regulation available in the market, contributing to improved system security. The rapid response of batteries reinforces the fast ramping capability of CCGTs in suppressing grid frequency fluctuations. With greater competition in the regulation market, market efficiency is likely to increase.

[15] Source of Figures 2A and 2B: KERMIT Study Report- To determine the effectiveness of the AGC in controlling fast and conventional resources in the PJM frequency regulation market, dated 2011
http://www.pjm.com/~/media/committees-groups/task-forces/rpstf/postings/pjm-kema-final-study-report.ashx
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Furthermore, allowing supply of regulation from batteries complements the upcoming increase in deployment of renewable energy sources like solar energy. Due to their dependency on weather, the generation of electricity from renewable resources is intermittent and will require the additional regulation supplied by batteries.

To enable the proposed provision of regulation by batteries, the next section shall establish the various implementation considerations. The dispatch mechanisms used in the U.S. regulation markets will be taken into consideration as well, in order to fully utilise the benefits of batteries as regulation providers complementing conventional generators in the SWEM.

3. Participation of Batteries in the SWEM

3.1 Registration

Batteries will be classified as generation facilities in the SWEM. Their ability to store energy withdrawn from the transmission system and to (later) produce or release that stored energy back into the transmission system as the ancillary service of regulation is seen as "generation"[16]. Since batteries will need to be dispatched to provide regulation, they will have to register with the EMC as Generation Registered Facilities (GRFs). Therefore, we will need to amend the existing Market Rules for GRFs to make them applicable to batteries.

During commissioning of the batteries, the PSO will conduct tests to validate the performance of batteries in regulation provision using the dispatch mechanism proposed by the battery provider. Once the PSO is satisfied with the testing results, the PSO will provide the EMC with the battery's maximum regulation capacity as part of its standing data.

3.2 Scheduling

Identical to existing GRFs, the minimum offer requirement of 0.1MW will apply to batteries in the regulation market of the SWEM. To meet this minimum offer requirement, multiple generating units at the same generating station can register as one facility.

The Market Clearing Engine (MCE) will qualify all offers from batteries, as long as the total offered quantity of each battery do not exceed its maximum regulation capacity approved by the PSO. After which, the MCE will schedule sufficient regulation from batteries and conventional generators based on their offer prices, to jointly meet the regulation requirement.

3.3 Compliance Monitoring

Batteries will be required to keep a record of their individual battery units' output and send in 2-second data, at least at the aggregate level. When batteries are deemed unable to provide regulation as scheduled, the PSO is then required to report a non-provision event and no payment will be made.

[16] According to the Electricity Act, "generate" means to produce electricity by means of a generating station for the purpose of giving a supply to any premises or enabling a supply to be so given; and "generating station" means any installation used for, or for purposes connected with, the production of electricity.

3.4 Settlement

Batteries will be similarly paid based on scheduled quantity of regulation in accordance with the Market Rules.

3.5 Dispatching

Batteries will be eligible for regulation provision via dispatch mechanisms approved by the PSO.

Experience in the U.S. markets has shown that to circumvent the limitation of batteries, it is most desirable for batteries to provide regulation about the basepoint in response to highpass regulation signals. However, when such a dispatch mechanism was tested by the PSO and a battery provider in Singapore, it was not acceptable to the PSO when they observed that it may result in reverse behaviour exhibited by the batteries, where the final output of the batteries is opposite to that required by the grid frequency.

One PSO-approved dispatch mechanism is designed to allow batteries to operate continuously without being fully charged or discharged and also eliminate reverse behaviour exhibited by the batteries. It has been tested by the PSO and the battery provider using a 50kW battery system over the period of a week. The testing results, as shown in Table 3, have proven that the various features of the dispatch mechanism are indeed effective in achieving their objectives.

Table 3: Features, objectives and testing results of dispatch mechanism

Features	Objectives	Results
• Output range setting • Basepoint setting • Multiple types of regulation signals	Allowing batteries to operate continuously without being fully charged or discharged.	100% service continuity; 8% to 76% SoC
• Dead-band incorporated in modified highpass signals[17]	Ensuring that the final output of batteries is aligned with the system frequency, i.e. charge and discharge when the grid frequency is above and below 50Hz respectively.	0% reverse behaviour

The following subsections 3.5.1 to 3.5.3 explain the objectives of the dispatch mechanism and how the features work to achieve them. **Annex 1** sets out the related parameters, formulae and explanation for reference.

3.5.1 Service Continuity

Let us recall from section 2.3 that the limitation of batteries in regulation provision lies in their limited storage capacities, causing them to be easily fully discharged or charged and hence unable to provide regulation in the up or down direction respectively. Therefore, to prevent batteries from being fully discharged or charged in order to ensure service continuity by batteries, the approved dispatch mechanism has the following features:

- **Output Range Setting**

The maximum charge and discharge rates of batteries are referred to as their output range. With output range setting, the output range of batteries at each SoC will be pre-determined. A battery's maximum charge rate will be restricted to slow charging when the SoC is high (e.g. above 55%), and its maximum discharge rate will be restricted to slow discharging when the

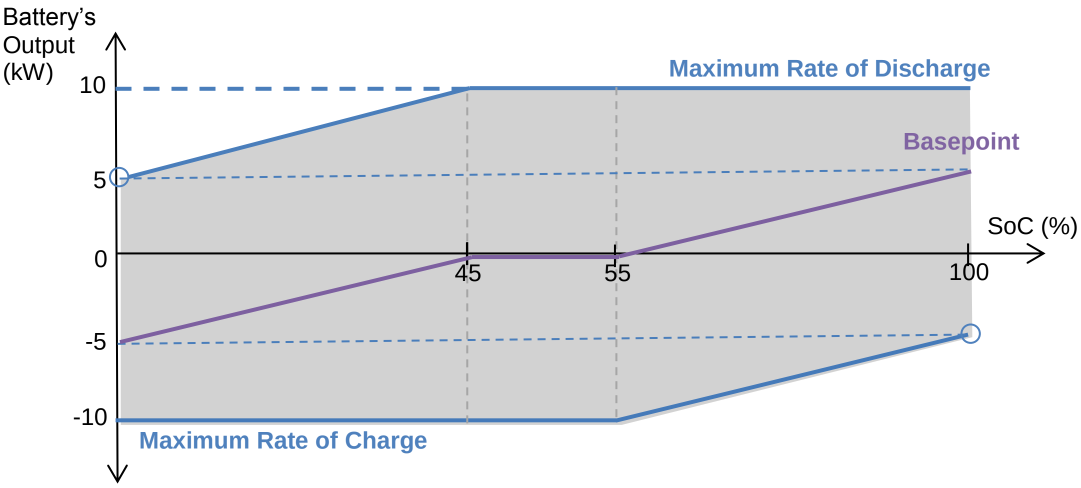
[17] For more information on dead-band, refer to subsection 3.5.2.

SoC is low (e.g. below 45%). This is to prevent the unused capacity or stored energy of the battery from depleting too quickly.

The output range of batteries will be unrestricted[18] at their optimal SoC range (e.g. 45% to 55%). This is because at this SoC range, the battery is approximately half-full and has as much stored energy to discharge as unused capacity to charge. As long as a battery has some stored energy or unused capacity, its maximum rates of discharge or charge respectively could be non-zero (e.g. 5kW), albeit for a limited period of time.

Figure 3 shows how the output range (with its maximum charge and discharge rates represented by the blue lines) of a 10kW battery is set to vary with its SoC.

Figure 3: Variation of output range and basepoint with SoC of a 10kW battery[19]



- **Basepoint Setting**

Emulating the practice in the U.S., the basepoint of the battery is set to be positive (i.e. discharge when the grid frequency is at 50Hz) when the SoC is high (e.g. above 55%) and negative (i.e. charge when the grid frequency is at 50Hz) when the SoC is low (e.g. below 45%). This setting restores the SoC of batteries to their optimal range, hence avoiding full charge or discharge.

Figure 3 shows how the basepoint (represented by the purple line) of a 10kW battery is set to vary with its SoC.

- **Multiple Types of Regulation Signals**

To ensure service continuity, batteries follow different types of regulation signals under different conditions determined by (i) the grid frequency and (ii) their SoC.

[18] When the output range of a battery is unrestricted, the battery is capable of charging or discharging up to a rate of its maximum regulation capacity.
[19] For the formulae for a battery's output range and basepoint at a specific SoC, refer to **Annex 1.2** Steps 1 and 2 respectively.

Table 4: Types of regulation signals under different conditions

<table>
<tr><th colspan="5">Type of Regulation Signal</th></tr>
<tr><th colspan="2" rowspan="2">Conditions</th><th colspan="3">SoC_t (%)</th></tr>
<tr><th>Below 45</th><th>45 to 55</th><th>Above 55</th></tr>
<tr><th rowspan="2">Grid $Freq_t$ (Hz)</th><th>Below 50</th><td>Modified Highpass</td><td rowspan="2">Absolute Frequency Deviation</td><td>Absolute Frequency Deviation (Scenario 1)</td></tr>
<tr><th>Above 50</th><td>Absolute Frequency Deviation</td><td>Modified Highpass (Scenario 2)</td></tr>
</table>

As detailed in Table 4, batteries follow absolute frequency deviation signals i.e. grid frequency – 50Hz only when in the course of restoring the grid frequency back to 50Hz, they can also restore their SoC back to its optimal range. For example in Scenario 1, when (i) the grid frequency is below 50Hz, requiring the battery to discharge, and since (ii) the battery's SoC is above 55%, the battery discharging in response to absolute frequency deviation signals also helps restoring its SoC to, or maintaining its SoC within, the optimal range.

However, for example in Scenario 2, when (i) the grid frequency is above 50Hz, requiring the battery to charge, and since (ii) the battery's SoC is above 55%, if the battery charges in response to absolute frequency deviation signals, the battery may risk being fully charged and thus unable to provide up-regulation. Therefore, the batteries should follow modified highpass signals i.e. grid frequency – $filter_t$[20] when in the course of restoring the grid frequency back to 50Hz, they cannot restore their SoC back to their optimal range. This avoids the risk of batteries being fully discharged or charged, hence ensuring service continuity.

3.5.2 Eliminating Reverse Behaviour by Introducing a Dead-band

Under this dispatch mechanism, the final output of a battery[21] at each second comprises of two components, a) the battery's basepoint and b) its regulation response. The battery's regulation response is proportional to the regulation signal, with its final output restricted by its output range setting.

Batteries are expected to exhibit reverse behaviour when the expected battery output is opposite to that required by the grid frequency. For instance, the expected battery output is negative when the grid frequency requires it to be positive, and vice versa. This arises from the use of basepoint setting and highpass signals. Please refer to **Annex 2** for detailed explanation on why the use of basepoint setting and highpass signals lead to reverse behaviour by batteries.

In order to eliminate reverse behaviour by batteries, the modified highpass signals incorporate a dead-band:

- **Dead-band**

The effect of the dead-band is a final battery output of zero in cases where the battery is expected to exhibit reverse behaviour. This is so that instead of allowing batteries to exhibit reverse behaviour, they will not be providing output at all.

3.5.3 Summary of Dispatch Mechanism

Table 5 overleaf summarises how the key features of the dispatch mechanism work to effect different settings under different SoC (and grid frequency) conditions.

[20] For the formula for modified highpass signal, refer to **Annex 1.2** Step 3B.
[21] For the formula for final battery output, refer to **Annex 1.2** Step 5.

Table 5: Summary of Dispatch Mechanism

<table>
<tr><th colspan="2"></th><th colspan="3">SoC (%)</th></tr>
<tr><th colspan="2"></th><th>Low
(below 45%)
</th><th>Within Optimal Range
(45% to 55%)</th><th>High
(above 55%)
</th></tr>
<tr><td rowspan="2">Output Range</td><td>Max Discharge Rate (kW)</td><td>Restricted</td><td rowspan="2">Unrestricted</td><td>Unrestricted</td></tr>
<tr><td>Max Charge Rate (kW)</td><td>Unrestricted</td><td>Restricted</td></tr>
<tr><td colspan="2">Basepoint (kW)</td><td>Negative</td><td>Zero</td><td>Positive</td></tr>
<tr><td rowspan="2">Type of Regulation Signal to Follow</td><td>Grid Frequency below 50Hz</td><td>Modified Highpass (Battery Output is zero when Expected Battery Output is negative)</td><td rowspan="2">Absolute Frequency Deviation</td><td>Absolute Frequency Deviation</td></tr>
<tr><td>Grid Frequency above 50Hz</td><td>Absolute Frequency Deviation</td><td>Modified Highpass (Battery Output is zero when Expected Battery Output is positive)</td></tr>
</table>

4. Proposed Rule Modifications

The existing rules, which were designed for conventional generators as the only regulation providers, preclude participation by batteries in the regulation market. EMC has drafted the proposed modifications to the market rules, as set out in **Annex 3**, to implement the proposal to enable the participation of batteries in the regulation market as GRFs. Table 6 below summarises the proposed modifications to the market rules.

Table 6: Summary of Proposed Rule Changes

Section	Proposed Changes	Reasons for Change
Chapter 2 Section 5.3.5	Add “if determined by the PSO to be required” before “include”.	To provide that the detailed commissioning test plans shall include information set out in sections 5.3.5.1 to 5.3.5.4, but only if determined by the PSO to be required.
	Italicise “energy”.	To italicise terms defined in Chapter 8 of the Market Rules.
	Amend “reactive output” to “reactive power output”.	To amend the expression to “reactive power output”.
	Delete “generating”.	To correct a typographical error.
	Redraft/rearrange the section.	To improve clarity.
Chapter 5 Section 4.4.1	Introduce new section as section 4.4.1, preceding existing section	For sequential and drafting consistency with section 4.5 of

Section	Proposed Changes	Reasons for Change
	4.4.1. Specify in new section that regulation may be provided by registered facilities when certain requirements are met. To clarify that specifically in the case of load facilities in future, they may register to provide regulation when the relevant notice is published by the EMC.	Chapter 5.
Chapter 5 Section 4.4.1A	Re-number existing section 4.4.1 as section 4.4.1A. Delete “the PSO shall determine”.	To make a consequential amendment to reflect the introduction of the new section 4.4.1 above. For drafting consistency with section 4.5.3 of Chapter 5.
Chapter 5 Section 4.4.4	Change “section 4.4.1” to “section 4.4.1A”.	To correct the cross-reference to the existing section 4.4.1 to reflect its new section number.
Chapter 5 Section 4.4.6	Replace “set forth” with “referred to”. Add “, where applicable” after reference to performance standards in section A.1 of Appendix 5A and the System Operation Manual.	For drafting consistency with section 4.5.10 of Chapter 5. To clarify that registered regulation providers shall meet the applicable performance standards.
Chapter 5 Section 7.1.1	Italicise “outage”.	To italicise a term defined in Chapter 8 of the Market Rules.
Chapter 5 Section 9.4.1 & 9.4.2 Appendix 6D Section D.3 Appendix 6E Sections E.1.1.9 & E.1.1.10	Add “or other signals acceptable to the PSO” after “AGC signals” or “AGC”.	To provide that regulation can be provided in response to not only AGC signals, but also other signals acceptable to the PSO.
Chapter 5 Section 9.4.1	Replace “generation facility” with “registered facility”.	To use the term ‘registered facility’ for consistency with this section.
Chapter 5 Sections 11.2.2 & 11.3.1	Add “’s” and replace “for” with “to”. Amend the condition for synchronisation request to be issued late. Stipulate the advance notice required for desychronisation	To correct grammatical errors. To provide for late issuance of synchronisation or desynchronisation requests if the requests are associated with fast start service or regulation.

Section	Proposed Changes	Reasons for Change
	requests, and the condition for desynchronisation request to be issued late.	
Chapter 5 Section 11.3.8	Redraft the section.	To improve clarity.
Appendix 5A Section A.1.2	Add "(if the registered facility is registered as having AGC capability)" before "selected to be on AGC".	To provide that telemetering between the PSO's EMS and a registered regulation provider does not require indication of AGC if the registered facility is not registered as having AGC capability.
Chapter 6 Sections 3.1.3 & 3.1.4	Replace "," with "and". Redraft these sections.	To correct a grammatical error. To improve clarity.
Chapter 6 Section 5.3.7.1	Replace "facility" with "facility's".	To correct a typographical error.
Appendix 6D Section D.3	Italicise "AGC".	To italicise a term defined in Chapter 8 of the Market Rules.
Appendix 6E Sections E.1.1.9 & E.1.1.10	Add "to provide regulation capability" and "energy".	For consistency across both sections.
Chapter 8 Section 1.1.109	Italicise "generating station".	To italicise a term defined in Chapter 8 of the Market Rules.
Chapter 8 Section 1.1.215	Replace "generating unit" with "generation registered facility".	To amend existing reference of "generating unit" to "generation registered facility".

5. Implementation Process

The breakdown of the estimated implementation time and costs are set out in Table 7 below.

Table 7: Estimated Implementation Time and Costs

Time Estimates	**Effort Estimates (man-weeks)**	**Lapse time (calendar-weeks)**
1) Requirement Scoping and Analysis	0.5	1
2) System (including Standing Data and MCE) Development and Testing	6	3
3) User Acceptance Testing	2	4
4) Parallel MCE/Settlement Runs	0.5	1
Total Time Required	**9**	**9**
Cost Estimates		
1) Power Systems Consultant Resource/ EMC Manpower	$47,085	
2) External resource to support the project	N.A.	
Total Cost	**$47,085**	

Update: The proposed system changes to the MCE will be made together with the roll-out of the Demand Response Program (DR) project. The system changes were originally recommended to be implemented in December 2015. However, the implementation date of the DR project is now postponed to 28 April 2016.

6. Conclusion

In conclusion, the participation of batteries contributes to the quantity and quality of regulation providers, enhancing competition and efficiency in the SWEM. This paper proposes rule amendments to enable the participation of batteries in the regulation market, and shares the first PSO-approved dispatch mechanism for batteries to contribute to frequency regulation.

7. Industry Consultation

The rule change paper was published for industry consultation on 26 March 2015, and the following comments were received from CPvT Energy Asia, Tuas Power Generation and Senoko Energy.

<u>Comments from CPvT Energy Asia</u>

a) *Registration: Class of Licence*

Will the Regulation Services provider using battery storage solutions need to secure the "Generation Class Licence" separately even if such provider already holds the "Electricity Retail Licence" considering that batteries will be classified as generation facilities in the SWEM?

<u>EMC's Response</u>

The existing licensing requirements still apply. The Electricity Generation Licence is only required for persons with generating units with name-plate ratings of 10MW or more.

Persons with generating units with name-plate ratings of 1MW or more but less than 10MW are exempted from the licence to generate but require at least the licence to trade i.e. the Electricity Wholesaler or Retailer Licence. Otherwise, persons with generating units with name-plate ratings less than 1MW are exempted from holding an electricity licence. The minimum licencing requirement and applicable exemption orders for generating units of different name-plate ratings are summarised below:

Name-plate ratings of Generating Units	Minimum Licensing Requirement	Applicable Exemption Order
10MW or more	• Electricity Generation Licence	NA
1MW or more but less than 10MW	• Electricity Wholesaler Licence • Electricity Retailer Licence	• Electricity (Electricity Generation Licence) (Exemption) (No. 2) Order
Less than 1MW	NA	• Electricity (Electricity Generation Licence) (Exemption) (No. 2) Order • Electricity (Electricity Trading Licence) (Exemption) Order 2010

b) Registration: Location / Siting

Will SP PowerGrid, the Transmission Licensee, facilitate the siting of batteries, up to 1MW, within its sub-station premises for inter-connection to the transmission system?

If not, does it mean that the provider needs to find a private location suitable for transmission inter-connection?

Are there any specific considerations for battery siting and inter-connection to the NEMS transmission system like voltage level and the zones?

Will the provider be free to choose any industrial or commercial establishment that has a sub-station and space to house the battery for providing the regulation service?

EMC's Response

This is not within the jurisdiction of the wholesale market. Battery providers may liaise directly with SP PowerGrid or EMA for more information.

c) Scheduling: Priority

Will the batteries receive higher priority in scheduling considering their fast responsiveness compared to regulation services provided by generators?

EMC's Response

No, scheduling is still merit-order based on offer prices and co-optimisation.

d) Compliance Monitoring: Non-performance Penalty

Are there any penalties for non-performance under the "non-provision event" or just loss of payments?

EMC's Response

Non-providers will not be paid if identified by the PSO within 5 business days. In addition, they may be referred by the PSO to the Market Surveillance Compliance Panel (MSCP) for non-compliance to dispatch instructions. Please refer to Chapter 3 Section 7.2.8 of the Market Rules for the enforcement actions the MSCP may take.

Comments from Tuas Power Generation

a) *Settlement*

The paper only mentioned that batteries will be similarly paid based on scheduled quantity of regulation in accordance with the Market Rules. It is silent on the settlement of energy produced when the batteries are discharging and energy withdrawn from the grid when the batteries are charging.

Just as conventional generators have to factor in the loss of the plant's efficiency in converting fuel into electricity when they compete in the market, the cost of energy loss in the charge/discharge cycle should be properly accounted for in the market. Given that conventional generators are paid for the additional energy delivered beyond the scheduled quantities through prevailing energy prices, batteries-based regulation providers should similarly be paid for energy delivered into the grid at the prevailing MNN prices as well as be charged for the energy consumed so that players are competing on a level playing field. Energy metering requirements as per prevailing codes should also be applicable.

EMC's Response

A battery can choose to settle its energy portion in the retail or wholesale market. A battery settling its energy in the retail market shall secure its energy procurement in line with the requirements in the retail market as per other consumers. A battery settling its energy in the wholesale market will do so based on gross treatment as per the current market design, unless exemption is granted by the EMA for batteries to settle based on net injection or withdrawal.

b) *Energy Limitations of Batteries*

The diagram on page 9 purportedly shows a 10"kW" battery. Based on the diagram, could EMC confirm that to provide/offer 10kW of regulation service for the entire duration of the half hour settlement period adopted for Singapore, the battery rating would have to be at least 11kWh (0.5hr @ 10kW discharge / 0.45 [assuming @45% SoC])?

With a minimum offer requirement of 0.1MW, what would be minimum installation capacity (in kWh) for the "single" facility?

EMC's Response

There is no minimum storage capacity requirement for batteries. The PSO will determine during commissioning and the approval of standing capability data that the commissioning battery can deliver its regulation capability using its proposed dispatch mechanism, regardless of its storage capacity.

Comments from Senoko Energy

a) *Section 3.4 should be further elaborated to articulate the wholesale settlement flows for a battery GRF. While it is clear that a battery GRF would receive revenue for its scheduled regulation, we would like to confirm our understanding that the facility would pay for any withdrawn energy needed to charge the battery and not receive payment for energy that is discharged. If the forgoing is correct, it is difficult to see how a battery GRF could be economically viable because the energy price (for charging) is typically higher than the regulation price that would be received.*

EMC's Response

Please refer to EMC's response to part a) comments from Tuas Power Generation above. The commercial viability of batteries' participation in the SWEM is to be assessed by the potential investors in batteries. This proposal aims to make the market accessible by new technologies at the minimum cost to the market.

b) *At the 71st RCP meeting, it was highlighted that the proposed rules should not be tailored for a single provider of battery sourced regulation. It would be useful for the EMC to note the number of parties they are aware of that are actively looking to establish such facilities in Singapore.*

EMC's Response

The proposed rule changes are to allow batteries in general to adhere only to the requirements applicable to them. These changes are generic and not specific to any single battery provider or type of battery.

8. Legal Sign-Off

The text of the rule modifications in Annex 3 has been vetted by EMC's external legal counsel, whose opinion is that the modifications reflect the intent of the rule modification proposal as expressed in the third column of the table in Annex 3.

9. TWG's Decision at the 26th TWG Meeting

The TWG unanimously **supported** the proposed rule modifications set out in **Annex 3**.

10. RCP's Decision at the 80th RCP Meeting

At the 80th RCP meeting, the RCP by majority vote **supported** the proposed rule modifications set out in **Annex 3**. The details of the votes are as follows:

The RCP members who voted to support:

1.	Mr Toh Seong Wah	Representative of EMC
2.	Mr Soh Yap Choon	Representative of PSO
3.	Ms Priscilla Chua	Representative of Generation Licensees
4.	Mr Marcus Tan	Representative of Generation Licensees
5.	Mr Lim Han Kwang	Representative of Transmission Licensee
6.	Mr Sean Chan	Representative of Retail Electricity Licensees
7.	Mr Daniel Lee	Representative of Retail Electricity Licensees
8.	Mr Phillip Tan	Person experienced in Financial Matters in Singapore

The RCP members who voted to abstain:

1.	Ms Grace Chiam	Representative of Generation Licensees
2.	Mr Luke Peacocke	Representative of Retail Electricity Licensees
3.	Mr Lawrence Lee	Representative of Market Support Services Licensee

11. Recommendations

The RCP by majority vote recommends that the EMC Board:

a) **adopt** the proposed rule modifications as set out in **Annex 3**;

b) **seek** the EMA's approval of the proposed rule modifications as set out in **Annex 3**; and

c) **recommend** that the proposed rule modifications come into force in **December 2015**.

Annex 1: Dispatch Mechanism for Regulation Provision by Batteries

Annex 1.1 – Parameters

Fixed Parameters

Battery – Max Reg Cap[22] (kW), Optimal SoC Range (%) (e.g. 45 to 55%)
System – Nominal Grid Freq (Hz)

Variable Parameters

At time t (second),
Battery – SoC_t (%)
System – Grid $Freq_t$ (Hz), $Filter_{t-1}$ (Hz)

[22] This refers to the battery's maximum regulation capacity approved by the PSO for standing data. The maximum regulation capacity is the maximum charge or discharge rate of a battery when its SoC is within its optimal range.

Annex 1.2 – Formulae

In the dispatch period where the battery is scheduled to provide regulation, its final battery output at each second will be computed step-by-step using the parameters in **Annex 1.1** and the following formulae:

Step	Formulae
1	<u>**Output Range**</u>

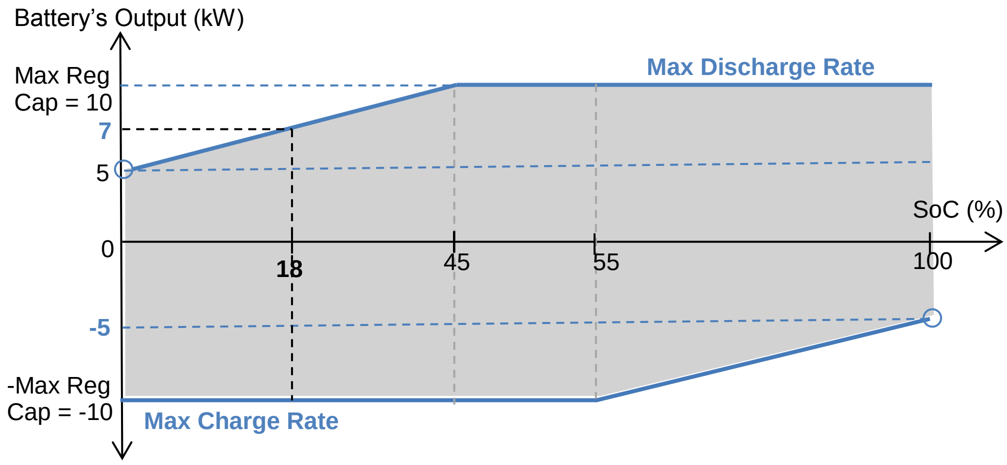
$$\boldsymbol{Max\ Discharge\ Rate_t\ (kW)} = \begin{cases} \dfrac{(SoC_t(\%) + 45\%)}{90\%} \times Max\ Reg\ Cap\ (kW) & SoC_t < 45\% \\ Max\ Reg\ Cap\ (kW) & SoC_t \geq 45\% \end{cases}$$

$$\boldsymbol{Max\ Charge\ Rate_t\ (kW)} = \begin{cases} -Max\ Reg\ Cap\ (kW) & SoC_t < 55\% \\ \dfrac{(SoC_t(\%) - 145\%)}{90\%} \times Max\ Reg\ Cap\ (kW) & SoC_t \geq 55\% \end{cases}$$

Example:

Given that Max Reg Cap = 10kW, Figure 5 illustrates the output range of the battery at each SoC.

<u>**Figure 5: Output Range of Battery**</u>



When $SoC_t = 18\%$,

$$\boldsymbol{Max\ Discharge\ Rate_t} = \frac{(18\% + 45\%)}{90\%} \times 10kW = 7kW$$

$$\boldsymbol{Max\ Charge\ Rate_t} = -10kW$$

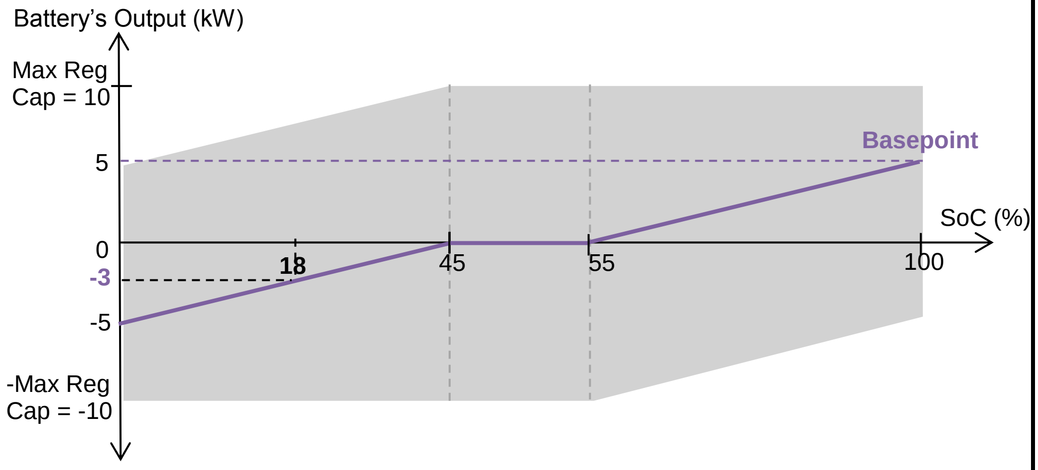
Step	Formulae
2	**<u>Basepoint</u>**

$$\boldsymbol{Basepoint_t\ (kW)} = \begin{cases} \dfrac{(SoC_t(\%) - 45\%)}{90\%} \times Max\ Reg\ Cap\ (kW) & SoC < 45\% \\ 0kW & 45\% \leq SoC \leq 55\% \\ \dfrac{(SoC_t(\%) - 55\%)}{90\%} \times Max\ Reg\ Cap\ (kW) & SoC > 55\% \end{cases}$$

Example:

Figure 6 illustrates the basepoint of the battery at each SoC.

<u>Figure 6: Basepoint of Battery</u>



Given that Max Reg Cap = 10kW, when SoC_t = 18%,

$\boldsymbol{Basepoint_t} = \frac{(18\%\text{-}45\%)}{90\%} \times 10kW = -3kW$ (i.e. battery output will be -3kW if grid frequency is 50Hz)

<table>
<tr><th>Step</th><th>Formulae</th></tr>
<tr><td>3</td><td>

<u>Regulation Signal</u>

Table 8 shows the type of regulation signal to be followed by the battery under different conditions determined by (i) Grid $Freq_t$ and (ii) SoC_t (as explained in section 3.5.1 of the paper).

Table 8: Types of Regulation Signals under Different Conditions

<table>
<tr><th colspan="5">Type of Regulation Signal</th></tr>
<tr><th colspan="2" rowspan="2">Conditions</th><th colspan="3">SoC_t (%)</th></tr>
<tr><th>< 45</th><th>45 ≤ SoC_t ≤ 55</th><th>> 55</th></tr>
<tr><th rowspan="2">Grid $Freq_t$ (Hz)</th><th>< 50</th><td>Modified Highpass</td><td rowspan="2">Absolute Frequency Deviation</td><td>Absolute Frequency Deviation</td></tr>
<tr><th>> 50</th><td>Absolute Frequency Deviation</td><td>Modified Highpass</td></tr>
</table>

$\boldsymbol{Reg\ Signal_t\ (Hz)} = Absolute\ Frequency\ Deviation\ Signal_t\ (Hz)$ (Proceed to **Step 3A**)
$or\ Modified\ Highpass\ Signal_t\ (Hz)$ (Proceed to **Step 3B**)

Example:

When Grid $Freq_t$ = 49.9Hz and SoC_t = 18%,

$\boldsymbol{Reg\ Signal_t} = Modified\ Highpass\ Signal_t$

</td></tr>
<tr><td>3A</td><td>

<u>Regulation Signal – Absolute Frequency Deviation Signal</u>

$\boldsymbol{Absolute\ Freq\ Deviation\ Signal_t(Hz)} = Grid\ Freq_t(Hz) - Nominal\ Grid\ Freq\ (Hz)$

</td></tr>
</table>

Step	Formulae
3B	**Regulation Signal – Modified Highpass Signal**

$$Expected\ Battery\ Output_t(Hz) = Basepoint_t\ (kW) + Expected\ Reg\ Response_t(kW)$$

Where:

$$Expected\ Reg\ Response_t(kW) = Max\ Reg\ Cap\ (kW) \times \frac{Expected\ Reg\ Signal_t\ (Hz)}{-0.2Hz}$$

$$Expected\ Reg\ Signal_t(Hz) = Grid\ Freq_t(Hz) - Filter_{t-1}{}^{23}\ (Hz)$$

Table 9 shows the values of $Filter_t$ under different conditions determined by (i) Grid $Freq_t$ and (ii) Expected Battery $Output_t$ (as explained in **Annex 1.3**).

Table 9: $Filter_t$ under Different Conditions

Conditions		$\boldsymbol{Filter_t\ (Hz)}$
$\boldsymbol{Grid\ Freq_t(Hz)}$	$\boldsymbol{Expected\ Battery\ Output_t\ (Hz)}$	
< 50	> 0	$Filter_{t-1}(Hz) - \frac{0.02}{60}Hz$
	⩽ 0 (reverse behaviour expected)	$Grid\ Freq_t\ (Hz) - (0.2Hz \times \frac{Basepoint_t\ (kW)}{Max\ Reg\ Cap\ (kW)})$
> 50	< 0	$Filter_{t-1}(Hz) + \frac{0.02}{60}Hz$
	⩾ 0 (reverse behaviour expected)	$Grid\ Freq_t\ (Hz) - (0.2Hz \times \frac{Basepoint_t\ (kW)}{Max\ Reg\ Cap\ (kW)})$

$$\boldsymbol{Modified\ Highpass\ Signal_t\ (Hz)} = Grid\ Freq_t\ (Hz) - Filter_t\ (Hz)$$

Example:

Given that Max Reg Cap = 10kW, when Grid $Freq_t$ = 49.9Hz, $Filter_{t-1}$ = 49.93Hz and $Basepoint_t$ = -3kW (from Step 2),

$Expected\ Reg\ Signal_t = 49.9Hz - 49.93Hz = -0.03Hz$

$Expected\ Reg\ Response_t = 10kW \times \frac{-0.03Hz}{-0.2Hz} = 1.5kW$

$Expected\ Battery\ Output_t = -3kW + 1.5kW = -1.5kW$ (negative when grid frequency being less than 50Hz requires it to be positive, hence reverse behaviour expected)

$Filter_t = 49.9Hz - (0.2Hz \times \frac{-3kW}{10kW}) = 49.96Hz$ (filter takes on value which results in zero battery output in Step 5)

$\boldsymbol{Modified\ Highpass\ Signal_t} = 49.9Hz - 49.96Hz = -0.06Hz$

[23] When $Filter_{t-1}$ does not exist due to (a) the modified highpass signal being first used in second t after absolute frequency deviation signal was used in the prior second t-1 and (b) the current second t being the first second in the dispatch period, $Filter_{t-1}$ will take on the value of 50Hz.

<table>
<tr><th>Step</th><th>Formulae</th></tr>
<tr><td rowspan="2">4</td><td><u>Regulation Response</u>

$\boldsymbol{Reg\ Response_t(kW)} = Max\ Reg\ Cap\ (kW) \times \frac{Reg\ Signal_t\ (Hz)}{-0.2Hz}$</td></tr>
<tr><td>Example:

Given that Max Reg Cap = 10kW and Reg Signal$_t$ = -0.06Hz (from Steps 3 and 3B),

$\boldsymbol{Reg\ Response_t} = 10kW \times \frac{-0.06Hz}{-0.2Hz} = 3kW$</td></tr>
<tr><td rowspan="2">5</td><td><u>Battery Output</u>

$\boldsymbol{Battery\ Output_t\ (kW)} = Basepoint_t\ (kW) + Reg\ Response_t(kW)$

$\{Max\ Charge\ Rate_t(kW) \leq Battery\ Output_t\ (kW) \leq Max\ Discharge\ Rate_t(kW)\}$</td></tr>
<tr><td>Example:

Given that Max Charge Rate$_t$ = -10kW(from Step 1), Max Discharge Rate$_t$ = 7kW (from Step 1), Basepoint$_t$ = -3kW (from Step 2) and Reg Response$_t$ = 3kW (from Step 4),

$\boldsymbol{Battery\ Output_t} = -3kW + 3kW = 0kW$ (Zero battery output due to expected reverse behaviour from battery)

{-10$kW \leq Battery\ Output_t \leq 7kW$}</td></tr>
</table>

Annex 1.3 – Filter for Modified Highpass Signal

In the computation of the modified highpass signal value (Step 3B), the filter value $Filter_t$ depends on:

(i) Whether the grid frequency is below or above 50Hz (requiring positive or negative battery output respectively); and

(ii) Whether the expected battery output, computed using the filter value of the prior second $Filter_{t-1}$, is positive or negative.

If the direction of the required output based on grid frequency (in point (i) above) contradicts that of the expected output (in point (ii) above), reverse behaviour is expected. Under such situations, the final battery output should be set to zero.

To result in a final battery output of zero, $Filter_t$ has to take on the following value:

Set Battery Output to be zero:

$$Battery\ Output = Basepoint + Max\ Reg\ Capacity \times \frac{(Grid\ Frequency - Filter)}{-0.2} = 0$$

Rearrange equation and make Filter the subject:

$$Grid\ Frequency - Filter = 0.2\ \times \frac{Basepoint}{Max\ Reg\ Capacity}$$

$$\boldsymbol{Filter} = Grid\ Frequency - (0.2\ \times \frac{Basepoint}{Max\ Reg\ Capacity})$$

Therefore, as shown in Table 10 below,

- When reverse behaviour is expected from the batteries i.e. expected battery output contradicts required battery output, $Filter_t$ takes on the value derived above to result in a final battery output of zero.
- When no reverse behaviour is expected from the batteries i.e. expected battery output agrees with required battery output, $Filter_t$ takes on the value of $Filter_{t-1} \pm 0.02/60$[24] to result in a final battery output that will arise from following approximated highpass signals.

Table 10: Final Battery Output Arising from $Filter_t$ under Different Conditions

Conditions			$\boldsymbol{Filter_t\ (Hz)}$	Final Battery Output
Grid $Freq_t$ (Hz)	**Required Battery Output**	**Expected Battery Output**		
Below 50	Positive	Positive	$Filter_{t-1}(Hz) - \frac{0.02}{60}Hz$	Positive
		Zero or Negative (i.e. reverse behaviour)	$Grid\ Frequency_t\ (Hz) - (0.2Hz \times \frac{Basepoint_t\ (kW)}{Max\ Reg\ Cap\ (kW)})$	Zero
Above 50	Negative	Negative	$Filter_{t-1}(Hz) + \frac{0.02}{60}Hz$	Negative

24 The movement of the filter follows that of a 5-minute moving average of the grid frequency at 0.02/60Hz per second. This is empirically derived by Panasonic from the observed movement of the moving average of the grid frequency by 0.02Hz per minute.

Conditions			$Filter_t\ (Hz)$	Final Battery Output
Grid Freq$_t$ (Hz)	**Required Battery Output**	**Expected Battery Output**		
		Zero or Positive (i.e. reverse behaviour)	$Grid\ Frequency_t\ (Hz) - (0.2Hz \times \frac{Basepoint_t\ (kW)}{Max\ Reg\ Cap\ (kW)})$	Zero

Annex 2: Causes of Reverse Behaviour by Batteries

1. Basepoint Setting

With a non-zero basepoint, expected regulation response in the correct direction but of too small a magnitude, would cause the expected battery output to be contradictory to what the grid frequency requires of it.

Example:

Without Basepoint Setting	With Basepoint Setting
SoC = 18% → Basepoint = **0kW** Grid Frequency < 50Hz (requires positive battery output) Expected Regulation Response = 2kW Expected Battery Output = 0kW + 2kW = **2kW** (positive output)	SoC = 18% → Basepoint = **-3kW** Grid Frequency < 50Hz (requires positive battery output) Expected Regulation Response = 2kW (positive but too small in magnitude due to negative basepoint) Expected Battery Output = -3kW + 2kW = **-1kW** (negative output) Hence, this is a scenario of reverse behaviour by the battery since grid frequency requires positive output.

2. Use of Highpass Signals

With the use of highpass signals instead of absolute frequency deviation signals, expected regulation response may be in the wrong direction due to the volatility of the filter, causing the expected battery output to be contradictory to what the grid frequency requires of it.

Example:

Using Absolute Frequency Deviation Signals	Using Highpass Signals
Assuming no basepoint setting, Grid Frequency = 50.1Hz (requires negative battery output) Expected Regulation Signal = 50.1Hz – **50Hz** *(nominal grid frequency)* = 0.1Hz Regulation Response = 10kW x (0.1/-0.2) = -5KW (negative) Expected Battery Output = 0kW – 5kW = **-5kW** (negative output)	Assuming no basepoint setting, Grid Frequency = 50.1Hz (requires negative battery output) Expected Regulation Signal = 50.1Hz – **50.2Hz** *(filter)* = -0.1Hz Regulation Response = 10kW x (-0.1/-0.2) = 5KW (positive due to large filter value) Expected Battery Output = 0kW + 5kW = **5kW** (positive output) Hence, this is a scenario of reverse behaviour by the battery since grid frequency requires negative output.

Annex 3: Proposed Rule Changes

Existing Market Rules (1 Apr 2015)	**Proposed Rules Changes** (Deletions represented by strikethrough text and additions represented by double underlined text)	**Reasons for rule change**
CHAPTER 2	**CHAPTER 2**	
5.3 REGISTRATION OF COMMISSIONING GENERATION FACILITIES …	**5.3 REGISTRATION OF COMMISSIONING GENERATION FACILITIES** …	
5.3.5 The detailed commissioning test plans referred to in section 5.3.4.2 shall be submitted to the *PSO* for approval and the tests referred to in such plans as are approved by the *PSO* and shall be scheduled in accordance with the procedures applicable to the *outage* coordination process described in section 7 of Chapter 5, with any applicable *market manual* and with the *system operation manual* and shall include:	5.3.5 The detailed commissioning test plans referred to in section 5.3.4.2 shall be submitted to the *PSO* for approval ~~and the tests referred to in such plans as are approved by the *PSO* and shall be scheduled in accordance with the procedures applicable to the *outage* coordination process described in section 7 of Chapter 5, with any applicable *market manual* and with the *system operation manual*~~ and shall, if determined by the *PSO* to be required, include:	To provide that the detailed commissioning test plans shall include the information / subject matter set out in sections 5.3.5.1 to 5.3.5.4, but only if determined by the PSO to be required.
5.3.5.1 the time required for the *commissioning generation facility* to *synchronise* to and *desynchronise* from the *PSO controlled grid*;	5.3.5.1 the time required for the *commissioning generation facility* to *synchronise* to and *desynchronise* from the *PSO controlled grid*;	
5.3.5.2 energy and reactive output levels;	5.3.5.2 ~~energy~~*energy* and reactive power output levels;	To amend the existing references of "reactive output" to "reactive power output".
5.3.5.3 the timing of and ramp rates associated with changes in energy and reactive output levels; and	5.3.5.3 the timing of and ramp rates associated with changes in ~~energy~~*energy* and reactive power output levels; and	To italicise terms

Existing Market Rules (1 Apr 2015)	**Proposed Rules Changes** (Deletions represented by strikethrough text and additions represented by double underlined text)	**Reasons for rule change**
5.3.5.4 run-back or trip tests for the *commissioning generating generation facility*. …	5.3.5.4 run-back or trip tests for the *commissioning* ~~*generating*~~ *generation facility*. The tests referred to in such plans, as may be approved by the *PSO*, shall be scheduled in accordance with the procedures applicable to the *outage* coordination process described in section 7 of Chapter 5, with any applicable *market manual* and with the *system operation manual*. …	which are defined in Chapter 8. To correct a typographical error. To redraft/rearrange this section to improve clarity.
CHAPTER 5	**CHAPTER 5**	
4.4 REGULATION [New section]	**4.4 REGULATION** 4.4.1 *Regulation* may be provided by *registered facilities* to the extent that each meets the applicable requirements to be a *registered facility* and have been so registered. Notwithstanding the foregoing, *regulation* may not be provided by a *load facility* until the date on which the *EMC* publishes a notice pursuant to section 5.1.2.2 of Chapter 2 to the effect that *load facilities* may be registered as *registered facilities* for the purpose of providing *regulation*.	To establish that regulation may be provided by registered facilities when certain requirements are met (and, in addition in the case of load facilities, when the relevant notice is published by the EMC), for consistency with section 4.5.1 of Chapter 5.

Existing Market Rules (1 Apr 2015)	**Proposed Rules Changes** (Deletions represented by strikethrough text and additions represented by double underlined text)	**Reasons for rule change**
		To introduce this new section as section 4.4.1, preceding the existing section 4.4.1, for sequential consistency with the existing section 4.5 of Chapter 5.
4.4.1 The *PSO* shall establish and include in the *system operation manual* the methodology by which the *PSO* shall determine the amount of *regulation* required in any *dispatch period* to meet all applicable *reliability standards.*	4.4.1A The *PSO* shall establish and include in the *system operation manual* the methodology by which ~~the *PSO* shall determine~~ the amount of *regulation* required in any *dispatch period* to meet all applicable *reliability standards* is determined.	To amend for drafting consistency with section 4.5.3 of Chapter 5. To re-number the existing section 4.4.1 as section 4.4.1A, given the introduction of the new section 4.4.1 above.
4.4.4 The *PSO* shall, in accordance with the methodology described in section 4.4.1, determine the quantity of *regulation* required for each *dispatch period* of the *market outlook horizon* to satisfy the requirements of section 2.1.4 of Chapter 6.	4.4.4 The *PSO* shall, in accordance with the methodology described in section 4.4.1A, determine the quantity of *regulation* required for each *dispatch period* of the *market outlook horizon* to satisfy the requirements of section 2.1.4 of Chapter 6.	To change the cross-reference to the existing section 4.4.1 to reflect its new section number.

Existing Market Rules (1 Apr 2015)	Proposed Rules Changes (Deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for rule change
4.4.6 A *registered facility* providing *regulation* shall meet the performance standards set forth in section A.1 of Appendix 5A and in the *system operation manual*.	4.4.6 A *registered facility* providing *regulation* shall meet the performance standards ~~set forth~~ <u>referred to</u> in section A.1 of Appendix 5A and in the *system operation manual*<u>, where applicable</u>.	To amend for drafting consistency with section 4.5.10 of Chapter 5. To clarify that registered facilities providing regulation shall meet certain performance standards where applicable.
7.1 <u>INTRODUCTION</u> 7.1.1 The objectives of this section 7 are to enable the *PSO* to review and assess the impact of outage schedules on the fulfilment by the *PSO* of its *reliability*-related responsibilities under the <u>*Electricity Act*</u> and the *market rules*, to require *market participants* to obtain the approval of the *PSO* in respect of *planned outage* schedules, to permit the *PSO* to reject, defer and recall *outages* that may have an impact on the *reliability* of the *PSO controlled system* and to provide for certain consequences following the cancellation of *outages*.	**7.1 <u>INTRODUCTION</u>** 7.1.1 The objectives of this section 7 are to enable the *PSO* to review and assess the impact of ~~outage~~ <u>*outage*</u> schedules on the fulfilment by the *PSO* of its *reliability*-related responsibilities under the <u>*Electricity Act*</u> and the *market rules*, to require *market participants* to obtain the approval of the *PSO* in respect of *planned outage* schedules, to permit the *PSO* to reject, defer and recall *outages* that may have an impact on the *reliability* of the *PSO controlled system* and to provide for certain consequences following the cancellation of *outages*.	To italicise a term defined in Chapter 8 of the Market Rules.

Existing Market Rules (1 Apr 2015)	Proposed Rules Changes (Deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for rule change
…	…	
9.4 DISPATCH OF REGULATION 9.4.1 The *dispatch instructions* for *regulation* issued to each applicable *dispatch coordinator* for or within a given *dispatch period*, as the case may be, shall indicate the amount of *regulation*, expressed as a MW range about its then current operating point, that a *generation facility* is to provide in response to *AGC* signals. 9.4.2 Each *registered facility* providing *regulation* shall maintain unused *generation capacity* during the applicable *dispatch period* consistent with the *dispatch instructions* issued to it, so as to be able to increase or decrease *energy* production in response to *AGC* signals.	**9.4 DISPATCH OF REGULATION** 9.4.1 The *dispatch instructions* for *regulation* issued to each applicable *dispatch coordinator* for or within a given *dispatch period*, as the case may be, shall indicate the amount of *regulation*, expressed as a MW range about its then current operating point, that a ~~*generation*~~ *registered facility* is to provide in response to *AGC* signals or other signals acceptable to the *PSO*. 9.4.2 Each *registered facility* providing *regulation* shall maintain unused *generation capacity* during the applicable *dispatch period* consistent with the *dispatch instructions* issued to it, so as to be able to increase or decrease *energy* production in response to *AGC* signals or other signals acceptable to the *PSO*.	To change the existing reference to "generation facility" in section 9.4.1 to "registered facility". To allow regulation to be provided in response to not only AGC signals, but also other signals acceptable to the PSO.
11.2 PROCESS FOR SELF-COMMITMENT … 11.2.2 The *dispatch coordinator* request issued pursuant to section 11.2.1 shall, having regard for the time taken to complete *synchronisation* of the *generation registered facility* on earlier occasions, be issued to the *PSO* in sufficient time to enable:	**11.2 PROCESS FOR SELF-COMMITMENT** … 11.2.2 The *dispatch coordinator's* request issued pursuant to section 11.2.1 shall, having regard ~~for~~to the time taken to complete *synchronisation* of the *generation registered facility* on earlier occasions, be issued to the *PSO* in sufficient time to enable:	To correct grammatical errors.

Existing Market Rules (1 Apr 2015)	**Proposed Rules Changes** (Deletions represented by strikethrough text and additions represented by double underlined text)	**Reasons for rule change**
11.2.2.1 the *PSO* to approve and, where necessary, participate in the *synchronisation* of the *generation registered facility*; and 11.2.2.2 the *dispatch coordinator* to obtain approval of *synchronisation* in time to allow it to comply with any applicable *dispatch instruction* or call to provide *ancillary services*, and in no event shall such request be issued less than 30 minutes in advance of the anticipated time of *synchronisation*, unless the request is associated with operations under an *ancillary services contract* for *fast start service.* …	11.2.2.1 the *PSO* to approve and, where necessary, participate in the *synchronisation* of the *generation registered facility*; and 11.2.2.2 the *dispatch coordinator* to obtain approval of *synchronisation* in time to allow it to comply with any applicable *dispatch instruction* or call to provide *ancillary services*, and in no event shall such request be issued less than 30 minutes in advance of the anticipated time of *synchronisation,* unless the request is associated with operations ~~under an *ancillary services contract* for~~ relating to the provision of *fast start service* or *regulation*. …	To allow a request for PSO's approval for synchronisation to be issued late also when the request is associated with regulation provision and to remove the reference to ancillary services contract.
11.3 <u>PROCESS FOR DE-COMMITMENT</u> 11.3.1 A *dispatch coordinator* responsible for a *generation registered facility* that is *synchronised* to the *transmission system* and that, having regard to any valid and outstanding *offers* that may have been submitted in respect of the *generation registered facility* and to the provisions of any	**11.3 <u>PROCESS FOR DE-COMMITMENT</u>** 11.3.1 A *dispatch coordinator* responsible for a *generation registered facility* that is *synchronised* to the *transmission system* and that, having regard to any valid and outstanding *offers* that may have been submitted in respect of the *generation registered facility* and to the provisions of any	To provide that a request for PSO's approval to desynchronise must be given at least 30 minute in advance

Existing Market Rules (1 Apr 2015)	Proposed Rules Changes (Deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for rule change
ancillary service contract, wishes to *desynchronise* from the *transmission system*, shall request approval from the *PSO* to *desynchronise* that *generation registered facility*. …	*ancillary service contract*, wishes to *desynchronise* from the *transmission system*, shall request approval from the *PSO* to *desynchronise* that *generation registered facility*~~.~~, and in no event shall such request be issued less than 30 minutes in advance of the anticipated time of *desynchronisation*, unless the request is associated with operations relating to the cessation of provision of *fast start service* or *regulation.* …	of the anticipated time of desynchronisation. To allow a request for PSO's approval to desynchronise to be issued late when the request is associated with operations relating to cessation of provision of fast start service or regulation.
11.3.8 Each *dispatch coordinator* for a *generation registered facility* shall promptly notify the *PSO* if it is unable to comply with: 11.3.8.1 a properly given direction by the *PSO* to *desynchronise* the *generation registered facility* pursuant to section 11.3.2; or 11.3.8.2 in accordance with the approval of the *PSO* given pursuant to section 11.3.4. upon receipt of such notice, the *PSO* shall re-assess accordingly any direction to, or approval for, the	11.3.8 Each *dispatch coordinator* for a *generation registered facility* shall promptly notify the *PSO* if it is unable to comply with: 11.3.8.1 a properly given direction by the *PSO* to *desynchronise* the *generation registered facility* pursuant to section 11.3.2; or 11.3.8.2 ~~in accordance with~~ the approval of the *PSO* for *desynchronisation* given pursuant to section 11.3.4. ~~upon~~Upon receipt of such notice, the *PSO* shall re-	To redraft this section to improve clarity.

Existing Market Rules (1 Apr 2015)	**Proposed Rules Changes** (Deletions represented by strikethrough text and additions represented by double underlined text)	**Reasons for rule change**
dispatch coordinator to *desynchronise* its *generation registered facility*.	assess accordingly any direction to, or approval for, the *dispatch coordinator* to *desynchronise* ~~its~~such *generation registered facility*.	
APPENDIX 5A	**APPENDIX 5A**	
A.1 REGULATION … A.1.2 The telemetering between the *PSO's* Energy Management System and a *registered facility* providing *regulation* shall indicate the gross power output of the *registered facility* and whether the *generating unit(s)* within the *registered facility* are: A.1.2.1 *synchronised* with the *transmission system*; and A.1.2.2 selected to be on *AGC*.	**A.1 REGULATION** … A.1.2 The telemetering between the *PSO's* Energy Management System and a *registered facility* providing *regulation* shall indicate the gross power output of the *registered facility* and whether the *generating unit(s)* within the *registered facility* are: A.1.2.1 *synchronised* with the *transmission system*; and A.1.2.2 (if the *registered facility* is registered as having *AGC* capability) selected to be on *AGC*.	 To provide that the telemetering between the PSO's Energy Management System and a registered facility (if registered as having AGC capability) shall indicate whether the generating unit(s) of the facility is/are selected to be on AGC.
CHAPTER 6	**CHAPTER 6**	
3.1 MARKET NETWORK NODES …	**3.1 MARKET NETWORK NODES** …	

Existing Market Rules (1 Apr 2015)	**Proposed Rules Changes** (Deletions represented by strikethrough text and additions represented by double underlined text)	**Reasons for rule change**
3.1.3 The *EMC* shall, prior to the *market commencement* date: 3.1.3.1 establish the necessary parameters for relating *dispatch network nodes* and *market network nodes* to all *generation registered facilities* and *generation settlement facilities* in accordance with section D.7 of Appendix 6D; 3.1.3.2 develop software and procedures to perform the price transformations described in sections D.7 and D.24 of Appendix 6D; and 3.1.3.3 *publish* the names of the *market network nodes*, the identity of the *revenue quality meter* assigned to each *market network node*;	3.1.3 The *EMC* shall, prior to the *market commencement* date: 3.1.3.1 establish the necessary parameters for relating *dispatch network nodes* and *market network nodes* to all *generation registered facilities* and *generation settlement facilities* in accordance with section D.7 of Appendix 6D; 3.1.3.2 develop software and procedures to perform the price transformations described in sections D.7 and D.24 of Appendix 6D; and 3.1.3.3 *publish* the names of the *market network nodes*~~,~~ and the identity of the *revenue quality meter* assigned to each *market network node*~~;~~.	To redraft this section to improve clarity. To correct a grammatical error.
3.1.4 and shall thereafter maintain and update as required the elements described in this section 3.1.3, including *publishing* changes to any information *published* pursuant to section 3.1.3.3.	3.1.4 ~~and~~The *EMC* shall ~~thereafter~~ maintain and update as required the elements described in ~~this~~ section 3.1.3, including *publishing* changes to any information previously *published* pursuant to section 3.1.3.3.	To redraft this section to improve clarity.
5.3 FORM OF RESERVE OFFERS …	**5.3 FORM OF RESERVE OFFERS** …	

Existing Market Rules (1 Apr 2015)	**Proposed Rules Changes** (Deletions represented by strikethrough text and additions represented by double underlined text)	**Reasons for rule change**
5.3.7 The total of the quantities in all the *price-quantity pairs* of a *reserve offer* of a *dispatch period* shall not exceed: 5.3.7.1 the maximum *reserve* capacity for that *reserve class*, indicated in the relevant *generation registered facility* or *load registered facility*'s *standing capability data* for that *dispatch period*; or …	5.3.7 The total of the quantities in all the *price-quantity pairs* of a *reserve offer* of a *dispatch period* shall not exceed: 5.3.7.1 the maximum *reserve* capacity for that *reserve class*, indicated in the relevant *generation registered facility*'s or *load registered facility*'s *standing capability data* for that *dispatch period*; or …	To correct a typographical error.
APPENDIX 6D	**APPENDIX 6D**	
D.3 PARAMETERS RegulationMax$_g$ — The maximum output for which *automatic generator control* (AGC) can operate the *generation registered facility* associated with *energy offer g* to provide *regulation* capability. Calculated in accordance with section D.9A.8. RegulationMin$_g$ — The minimum output for which *automatic generator control* (AGC) can operate the *generation registered facility* associated with *energy offer g* to provide *regulation* capability. Set from the *standing capability data* referred to in Appendix 6E section	**D.3 PARAMETERS** RegulationMax$_g$ — The maximum output for which *automatic generator control* (~~AGC~~*AGC*) or other signals acceptable to the *PSO* can operate the *generation registered facility* associated with *energy offer g* to provide *regulation* capability. Calculated in accordance with section D.9A.8. RegulationMin$_g$ — The minimum output for which *automatic generator control* (~~AGC~~*AGC*) or other signals acceptable to the *PSO* can operate the *generation registered facility*	To italicise terms which are defined in Chapter 8. To allow for regulation to be provided in response to not only AGC signals, but also other signals acceptable to the PSO.

Existing Market Rules **(1 Apr 2015)**	**Proposed Rules Changes** (Deletions represented by strikethrough text and additions represented by double underlined text)	**Reasons for rule change**
E.1.1.10.	associated with *energy offer g* to provide *regulation* capability. Set from the *standing capability data* referred to in Appendix 6E section E.1.1.10.	
APPENDIX 6E	**APPENDIX 6E**	
E.1 GENERATION FACILITY DATA E.1.1 The *standing capability data* pertaining to a *generation facility* shall include: … E.1.1.9 the maximum *energy* output at which *automatic generator control* or *AGC* can operate the *generation facility* if the *generation facility* is or seeks to be registered to provide *regulation*; E.1.1.10 the minimum output at which *automatic generator control* or *AGC* can operate the *generation facility* to provide *regulation* capability if the *generation facility* is or seeks to be registered to provide *regulation*; …	**E.1 GENERATION FACILITY DATA** E.1.1 The *standing capability data* pertaining to a *generation facility* shall include: … E.1.1.9 the maximum *energy* output at which *automatic generator control* ~~or~~ (*AGC*) or other signals acceptable to the *PSO* can operate the *generation facility* to provide *regulation* capability if the *generation facility* is or seeks to be registered to provide *regulation*; E.1.1.10 the minimum *energy* output at which *automatic generator control* ~~or~~ (*AGC*) or other signals acceptable to the *PSO* can operate the *generation facility* to provide *regulation* capability if the *generation facility* is or seeks to be registered to provide *regulation*; …	To allow for regulation to be provided in response to not only AGC signals, but also other signals acceptable to the PSO. To add the words "to provide regulation capability" in section E.1.1.9 for consistency with section E.1.1.10.

Existing Market Rules (1 Apr 2015)	**Proposed Rules Changes** (Deletions represented by strikethrough text and additions represented by double underlined text)	**Reasons for rule change**
CHAPTER 8	**CHAPTER 8**	
1 DEFINITIONS 1.1 In the *market rules*: … 1.1.109 *generate* means to produce *electricity* by means of a generating station for the purpose of giving a *supply* to any premises or enabling a *supply* to be so given; …	**1 DEFINITIONS** 1.1 In the *market rules*: … 1.1.109 *generate* means to produce *electricity* by means of a ~~generating station~~ *generating station* for the purpose of giving a *supply* to any premises or enabling a *supply* to be so given; …	To italicise a term defined in Chapter 8 of the Market Rules.
1.1.215 *regulation* means, in relation to a *generating unit*, the frequent adjustment to its output so that any *power system* frequency variations or imbalances between *load* and the output from *generation facilities* can be corrected;	1.1.215 *regulation* means, in relation to a ~~*generating unit*~~ *generation registered facility*, the frequent adjustment to its ~~ ~~output so that any *power system* frequency variations or imbalances between *load* and the output from *generation facilities* can be corrected;	To amend the existing reference of "generating unit" to "generation registered facility". To remove an extra space.