Notice of Market Rules Modification

Paper No.:	EMC/RCP/56/2011/303
Rule Reference:	Market Rules/Chapter 6 Appendix D/Section 3 & Section 13A
Proposer:	Energy Market Company
Date Received by EMC:	01 June 2011
Category Allocated:	1
Status:	Approved by EMA
Effective Date:	17 November 2011

Summary of Proposed Rule Modification:

Currently one of the tests to determine whether a generation registered facility's (GRF's) regulation offer is eligible for regulation provision is that the GRF's StartGeneration must be greater than or equal to its RegulationMin and less than or equal to its RegulationMax. The test's objective is to ensure that the GRF's generation is at a level where it would be able to provide regulation throughout a dispatch period – as such, StartGeneration is used in the test as the parameter for the GRF's generation level at the beginning of a dispatch period.

This paper discusses the proposal to revise the test and analyses whether the test should be revised - by replacing the StartGeneration parameter with another parameter - or removed. A study consisting of two simulations, for revising and removing the test, was also carried out to evaluate the impact of doing so on GRFs' regulation provision and system-wide regulation shortfall.

This paper, its study results, and the industry's comments were presented at the 54th RCP meeting. After consideration, the RCP decided to support the implementation of the revised BOP test (Option B). Based on the Panel's decision, the legally reviewed draft of the proposed rule modification required to implement Option B is set out in Annex 3.

The RCP unanimously recommends that the EMC Board adopt this proposal.

Date considered by Rules Change Panel:	12 July 2011
Date considered by EMC Board:	21 July 2011
Date considered by Energy Market Authority:	10 August 2011

Proposed rule modification:

See attached paper.

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

PAPER NO.	:	**EMC/BD/03/2011/07(b)**
RCP PAPER NO.	:	**EMC/RCP/56/2011/303**
SUBJECT	:	**ELIGIBILITY OF REGULATION OFFERS**
FOR	:	**DECISION**
PREPARED BY	:	**MOK XINYING** **SENIOR ECONOMIST**
REVIEWED BY	:	**PAUL POH LEE KONG** **SVP, MARKET ADMINISTRATION**
DATE OF MEETING	:	**21 July 2011**

Executive Summary

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This paper discusses the proposal to revise the test and analyses whether the test should be revised - by replacing the StartGeneration parameter with another parameter - or removed. A study consisting of two simulations, for revising and removing the test, was also carried out to evaluate the impact of doing so on GRFs' regulation provision and system-wide regulation shortfall.

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The RCP unanimously recommends that the EMC Board adopt this proposal.

1. Introduction

The Singapore Wholesale Electricity Market (SWEM) currently uses two tests which check the generation level of a generation registered facility (GRF) before qualifying its regulation offer and scheduling it for regulation provision:

(i) A GRF's StartGeneration must be greater than or equal to its RegulationMin and less than or equal to its RegulationMax[1] for its regulation offer to be qualified for use by the Market Clearing Engine (MCE) – this test is stated in sections D.13A.1.2 and D.13A.1.3 of Appendix 6D of the market rules and shall herein be referred to as the Beginning of Period (BOP) test.

(ii) A GRF's output when providing both scheduled energy and scheduled regulation must be less than or equal to its RegulationMax and greater than or equal to its RegulationMin for the MCE to schedule it for regulation provision – this test is stated in sections D.18.1.3 and D.18.1.4 of Appendix 6D of the market rules and shall herein be referred to as the End of Period (EOP) test.

The objective of these two tests, which is only stated in the explanatory note of section D.13A, is to ensure that a GRF providing regulation has a generation level whereby "regulation can be provided throughout the dispatch period".

When EMC met with industry stakeholders to establish a Rules Change Panel's (RCP's) work plan in 2009/10, one of the proposals raised was to revise the BOP test. The proposer wanted to replace a GRF's StartGeneration, which is used in this test as the parameter for a GRF's generation level at the beginning of a dispatch period, with a GRF's scheduled energy for the prior dispatch period (SE_{T-1}). At the RCP meeting in March 2010 where the RCP's work plan 2010/11 was discussed, the RCP prioritized this proposal to be addressed within the next 12 months.

This paper assesses whether the BOP test should be revised. Section 2 explains the objective of the BOP and EOP tests. Section 3 examines the practices in other electricity markets to ensure regulation providers are able to provide regulation throughout a dispatch period and assesses whether the BOP test should be revised, by replacing the StartGeneration parameter with another parameter, or should be removed – so as to better achieve the objective that a GRF scheduled to provide regulation has a generation level whereby it is able to do so throughout a dispatch period. Our study on the impact of revising or removing the BOP test is set out in Section 4.

2. Regulation Range Constraints in the SWEM

Regulation is the frequent adjustment to a generating unit's output so that any power system frequency variation due to the imbalance between load and generation can be corrected. At the moment, regulation can only be provided by GRFs.

The PSO prompts GRFs to provide regulation through the Automatic Generation Control (AGC) subsystem. For the AGC to be able to control a GRF, the GRF's output must be within a certain range. This regulation range is defined by the RegulationMin and RegulationMax of the GRF i.e. the GRF's output should not be less than the RegulationMin or greater than RegulationMax.

[1] StartGeneration is the forecast generation level of a GRF at the beginning of the dispatch period. RegulationMin and RegulationMax are the minimum output and maximum output, respectively, at which the AGC can operate the GRF to provide regulation.

To qualify a GRF's regulation offer for use by the MCE – a set of regulation constraints, as stated in section D.13A of Appendix 6D of the market rules, are applied:

D.13A REGULATION RANGE CONSTRAINTS

D.13A.1 A valid *regulation offer* shall only be used in the linear program if:

D.13A.1.1 a valid *energy offer* exists for the *GRF* for that *dispatch period* and the sum of the quantities in that *energy offer* is greater than RegulationMin_g for the relevant *GRF*;

D.13A.1.2 the StartGeneration_g of the relevant *GRF* is greater than or equal to the RegulationMin_g for the relevant *GRF*; and

D.13A.1.3 the StartGeneration_g of the relevant *GRF* is less than or equal to the RegulationMax_g for the relevant *GRF*.

The BOP test which is the subject of this proposal is set out in sections D.13A.1.2 and D.13A.1.3. This test means that a GRF's StartGeneration must be greater than or equal to its RegulationMin and less than or equal to its RegulationMax for its regulation offer to be eligible for use in running the MCE.

The BOP test was first introduced in 2002 by Rule Change 57. As stated in that rule change paper (EMC/PTRCP/057/2002), the objective of this test is to ensure that the GRFs scheduled for regulation provision are "likely to be within their regulation range at the start of the dispatch period" and, thus, are able to provide regulation throughout the dispatch period.

It was proposed that a GRF's StartGeneration[2] be used in the BOP test as the reference point for its generation level at the start of the dispatch period. This is because "the data in the network status file reflects actual generation levels and gives a more accurate basis for determining if the GRF will be within its regulation range". Such accuracy is important as "it reduces the likelihood that a GRF will be scheduled for regulation provision when its generation level is outside its regulation range in real-time".

While there have been subsequent Rule Changes[3], the objective of this test and its use of a GRF's StartGeneration as the reference point for its generation level have been unchanged. Indeed, the market rules currently set out this test in an identical way to what was initially recommended by Rule Change 57.

When a GRF satisfies the regulation constraints set out in section D.13A, its regulation offer is qualified for use by the MCE. To determine if such a GRF will be scheduled for regulation provision – the following set of regulation constraints, as stated in sections

[2] Start Generation is usually the data available in the network status file provided by PSO ten minutes prior to the start of the dispatch period.

[3] Rule Change 189 and Rule Change 263 – see rule change papers EMC/PTRCP/189/2002 and EMC/RCP/29/2006/263 for details.

D.18.1.3 and D.18.1.4 of Appendix 6D of the market rules, are applied to it in running the MCE.

D.18.1.3 Regulation Max Constraint:

$Generation_g + Regulation - ExcessRegGen \leq RegulationMax_g$

D.18.1.4 Regulation Min Constraint:

$Generation_g - Regulation + DeficitRegGen \geq RegulationMin_g$

These constraints – herein referred to as the EOP test – mean that a GRF will be scheduled for regulation provision only if its output, when providing both scheduled energy and scheduled regulation, is within its regulation range where it can be controlled by the AGC. The EOP test thus ensures that the output of each GRF scheduled for regulation provision is within its regulation range, as such, it is able to respond readily to the AGC to provide regulation.

Given the regulation constraints applied by the BOP and EOP tests to check that a GRF's generation level / output is within its regulation range, respectively, at the beginning and end of the dispatch period – both tests aim to ensure that the market rules' objective, i.e. a GRF scheduled for regulation provision is able to provide regulation throughout the dispatch period[4], is achieved.

3. Analysis

3.1 Practices in Electricity Markets

From our survey of electricity markets where regulation offers are bidded into, and regulation provision is scheduled by, the market – we observed that there are no similar tests written in the rules to qualify regulation offers or schedule regulation providers based on checks that the generation facilities are able to provide regulation throughout the dispatch period. However, all the markets have a general rule that generation facilities which are eligible for regulation provision should be capable of AGC control or responding to AGC signals. The paragraphs below describe this general rule and other relevant rules in these electricity markets.

ISO NE and PJM markets[5]: it is a rule that regulation offers may be submitted only if a generating unit is capable of AGC control and able to receive AGC signals – in this sense, a generating unit is principally responsible for checking its own ability to provide regulation prior to submitting offers.

[4] As stated in the explanatory note of Section D.13A of Appendix 6D of the market rules – "the current rules…are designed so that regulation can be provided throughout the dispatch period".

[5] The relevant rules on "Regulation Market Eligibility" are attached in Annex 1, for reference.

In addition, new regulation resources need to pass an initial performance test (PJM) and regulation resources must exhibit satisfactory performance during ongoing audits (PJM and ISO NE).

It is worth noting that a generating unit in the ISO NE market is eligible for regulation assignment in the upcoming hour even if, at the start of the previous hour when regulation is initially assigned, its generation level is outside its regulation range – so long as the generating unit is able to achieve a generation level within its regulation range in the next 20 minutes[6].

Australia NEM: it is a rule that "an ancillary service provider that submits a market ancillary service offer must ensure that (the generating unit) is at all times capable of responding in the manner contemplated by the market ancillary service specification"[7].

Alberta ESO market: upon receipt of a dispatch to provide regulating reserve, it is a rule that "the generator shall, within 15 minutes, position the regulating reserve resource within the offered regulation range and be able to accept control signals from the AGC master controller"[8]. It is also worth noting that the Alberta ESO market, like the ISO NE market, allows time for generators – which are assigned to provide regulation before the beginning of the dispatch period – to ramp into their regulation range.

3.2 Rule Change Proposal to Revise BOP Test

3.2.1 Proposal to Replace StartGeneration with Scheduled Energy

This proposal is to revise the BOP test by replacing a GRF's StartGeneration, which is used in this test as the parameter for a GRF's generation level at the beginning of the dispatch period, with a GRF's scheduled energy for the prior dispatch period (SE_{T-1}).

The proposer noted that StartGeneration is supposed to be the parameter for a GRF's generation level at the beginning of the dispatch period. However, in practice, StartGeneration values are obtained from a network status file, provided by the PSO, which captures GRFs' generation levels at 10 minutes before the beginning of a dispatch period. As such the StartGeneration value can deviate from a GRF's actual generation level at the beginning of a dispatch period, especially when a GRF was ramping up or down. This could result in disqualifying the regulation offer of a GRF which was – at 10 minutes before the beginning of a dispatch period – ramping into its regulation range and was able to reach its regulation range at the beginning of the dispatch period. Thus, the proposer felt that the current BOP test is too conservative as it could disqualify the regulation offers of such GRFs which were actually capable of providing regulation at the beginning of the dispatch period.

In addition, we note that using StartGeneration as a parameter in the BOP test could result in qualifying the regulation offer of a GRF which was actually unable to provide

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[6] ISO New England Manual for Market Operations – Regulation Market, section 3.2.1(10)(e) states that "if the Generator's current generation is outside of the range (i.e. its regulation range), the Generator must be capable of achieving an output level within this range within a duration specified by the ISO (e.g. 20minutes)".

[7] National Electricity Rules – Market Rules, section 3.8.7A(k).

[8] Operating Reserves – Technical Requirements for Provision of Regulating Reserves, section 2.1.8.

regulation at the beginning of a dispatch period. This is because a GRF's generation level – at 10 minutes before the beginning of a dispatch period – could be within its regulation range but, if that GRF was ramping out of this range, its generation level may no longer be within this range at the beginning of that dispatch period.

3.2.2 EMC's Analysis of the Proposal

Under section D.3 "Parameters" of Appendix 6D of the market rules, StartGeneration is defined as "the forecast beginning of dispatch period generation level of the GRF". Subsequently section D.12.1 sets out that, in general, "the values of StartGeneration for each GRF in the applicable dispatch period…shall be the values received from the PSO in accordance with Appendix 6G section G.3.1" – which requests for "the PSO's expectation of the MW energy output level of each generation unit as at the beginning of the upcoming dispatch period".

PSO provides a network status file which captures GRFs' generation levels at 10 minutes before the beginning of the applicable dispatch period. As StartGeneration values are obtained from this file, we agree with the proposer that StartGeneration may not be an accurate proxy for a GRF's generation level at the beginning of the dispatch period.

Since a GRF's SE_{T-1} represents the energy output that it is expected to reach at the end of a dispatch period (T-1) – **in principle, we agree with the proposer that SE_{T-1} is a suitable parameter for the GRF's generation level at the beginning of a dispatch period T.**

3.2.3 EMC's Suggested Revision to the Proposed BOP Test

While we agree that SE_{T-1} is a suitable parameter for the GRF's generation level at the beginning of the dispatch period, we think there would be two issues if the BOP test is revised by simply replacing StartGeneration with SE_{T-1} i.e. if the BOP test is revised to $SE_{T-1} \geq$ RegMin and $SE_{T-1} \leq$ RegMax :

(i) While a GRF's SE_{T-1} represents the energy output that it is expected to reach at the end of that dispatch period (T-1), there could be situations where it is unable to do (e.g. if the GRF is on forced outage from tripping or failure to synchronise) – in these situations, simply checking $SE_{T-1} \geq$ RegMin and $SE_{T-1} \leq$ RegMax would be inaccurate as its SE_{T-1} is no longer a good proxy for its generation level at the beginning of the dispatch period T (e.g. if the GRF is on forced outage with zero energy output, its regulation offer would be qualified so long as its SE_{T-1} is within its regulation range).

(ii) Nevertheless, in situations where the GRF is unable to reach its SE_{T-1} at the end of that dispatch period (T-1), there could be a subset of situations where the GRF is within its regulation range at that time – in this subset, the GRF is able to provide regulation at the beginning of the dispatch period T and its regulation offers should be qualified – simply checking $SE_{T-1} \geq$ RegMin and $SE_{T-1} \leq$ RegMax would not make us aware of this subset of GRFs and we would omit qualifying regulation offers from these GRFs.

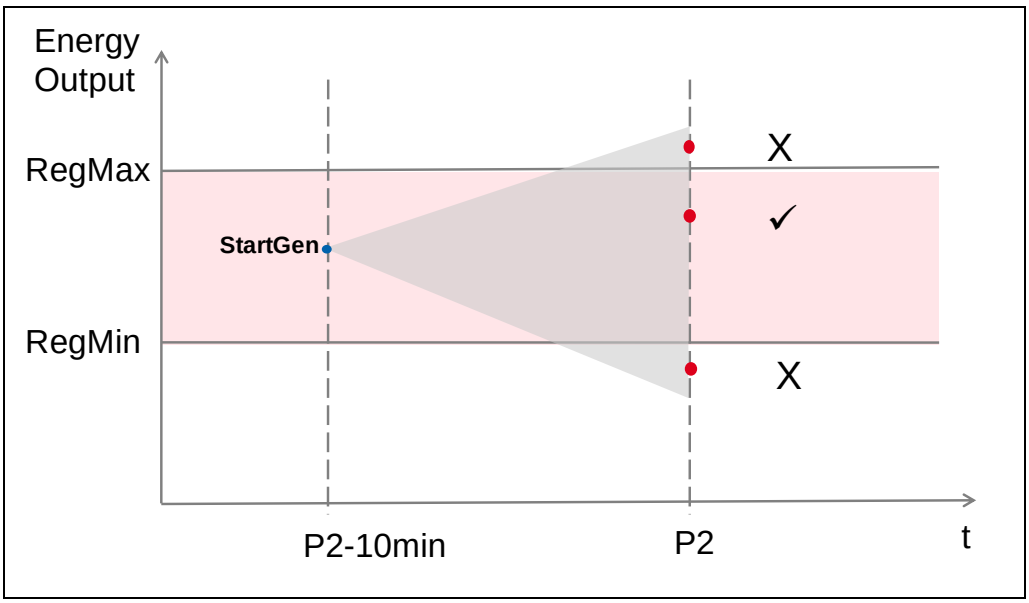
To resolve the two issues, we suggest a two-part BOP test:

(i) For a GRF which is able to reach its SE_{T-1} **i.e. (StartGen – SE_{T-1})/RampingTime**[9] **≤ DownRampRate** AND **(SE_{T-1}-StartGen)/RampingTime ≤ UpRampRate**, check whether its SE_{T-1} falls within its regulation range:

When RegMin≤SE_{T-1}≤RegMax is true, then qualify.

This can be illustrated by Figure 1 below.

Figure 1 GRFs which are able to reach SE_{T-1}



The grey shaded area represents a GRF's maximum and minimum energy output level given its StartGeneration value and its offered Up/Down ramp rate. If a GRF's SE_{T-1}(as represented by the red dots) falls within this range, it would be able to reach its SE_{T-1}. Since a GRF is obligated to (and able to) comply with its SE_{T-1}, it is then expected that the GRF's output at the beginning of Period 2 would be at SE_{T-1}. SE_{T-1} is then compared against RegulationMin/RegulationMax to determine if this GRF is eligible to provide regulation for Period 2.

(ii) For a GRF which is unable to reach its SE_{T-1} i.e. (StartGen – SE_{T-1})/RampingTime > DownRampRate AND (SE_{T-1}-StartGen)/RampingTime > UpRampRate, it is assumed that the GRF would try to reach its scheduled energy by ramping up or down at its maximum rate. In this case, we would check whether it can enter into its regulation range when it is ramping up/down to meet its SE_{T-1}:

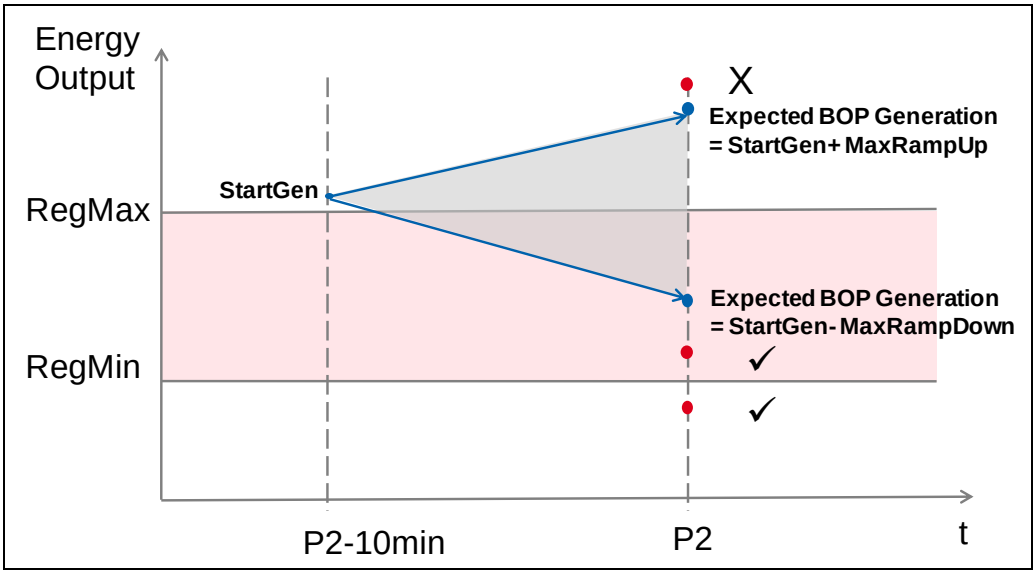
When StartGen>SE_{T-1} AND **RegMin≤ StartGen-DownRampRate x Ramping time ≤RegMax** is true, then qualify.

[9] As StartGeneration (StartGen) values are captured at 10 minutes before the beginning of a dispatch period, our suggested BOP test uses a RampingTime of 10 minutes so as to proxy a GRF's generation level at the beginning of a dispatch period.

When StartGen<SE_{T-1} AND **RegMin≤ StartGen+UpRampRate x Ramping time ≤RegMax** is true, then qualify.

Figure 2 below illustrates how this test works when the SE_{T-1} is not reachable. As shown in the diagram, if the GRF is ramping up at maximum rate to meet its scheduled energy, its expected generation level at the beginning of P2 would be *StartGen+UpRampRate x RampingTime*. We will then check if this value is within the regulation range to determine if this GRF is qualified to provide regulation. Similarly, if a GRF is ramping down, its expected generation level at the beginning of P2 would be *StartGen-DownRampRate x Ramping time.* The value is then checked to ascertain if it is within the regulation range, in order to qualify this GRF for regulation provision.

Figure 2 GRFs which are not able to reach SE_{T-1}



In summary, the proposed two-part BOP test would project a GRF's generation level at the beginning of a dispatch period taking into account of its schedule ($SE_{(T-1)}$) and its physical constraints (i.e.StartGeneration and ramp rates) instead of relying only on its StartGeneration which captures the GRF's generation level at 10 minutes before the beginning of a dispatch period. When such physical constraints allow the GRF to meet its $SE_{(T-1)}$, $SE_{(T-1)}$ would be the expected generation level at the beginning of a dispatch period and be used to test if the GRF is within the regulation range. When these physical constraints do not allow the GRF to meet its $SE_{(T-1)}$, then the expected generation level at the beginning of a dispatch period is determined with its StartGeneation with maximum ramp up/down rate.

3.3 Is the EOP test alone sufficient?

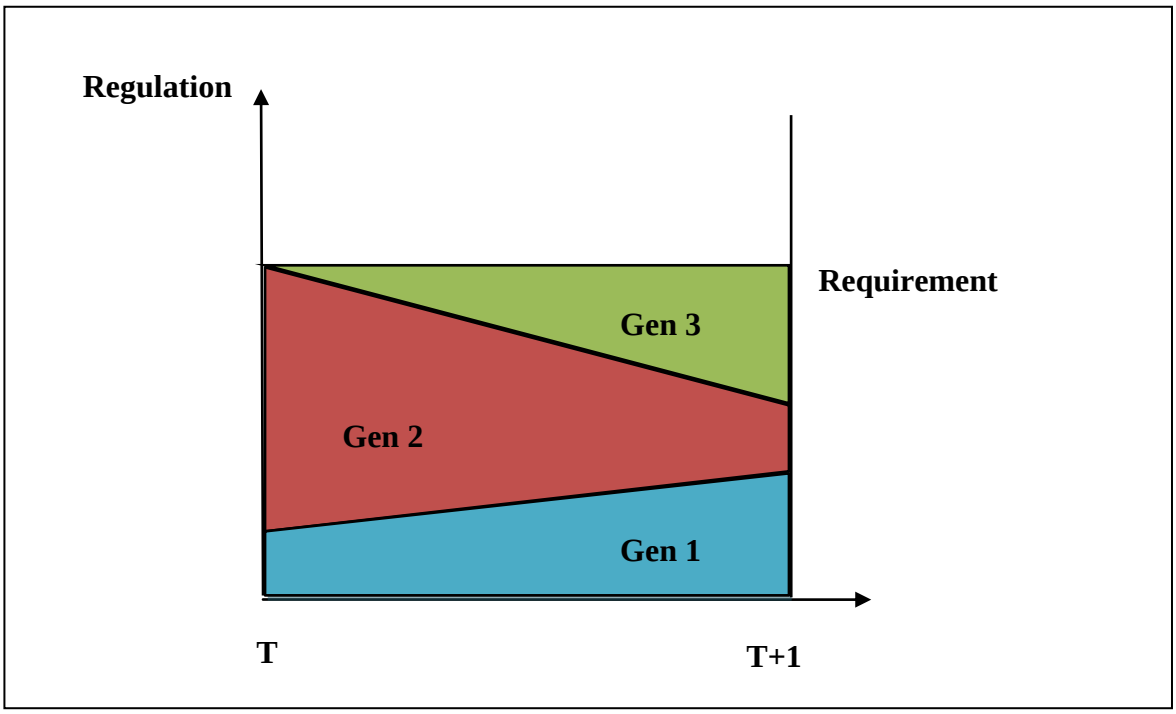
As an alternative to revising the BOP test, we also considered whether it could be justified to remove the BOP test i.e. is the EOP test alone sufficient to ensure that GRFs scheduled to provide regulation are able to do so throughout the dispatch period?

It can be argued that EOP feasibility is all that is required for ancillary service provision to be maintained throughout each dispatch period. Using only EOP feasibility test is consistent with the dispatch philosophy which sets EOP targets for dispatch variables and rests on the observations that:
- unless there was an unexpected event, such as a forced outage, the previous period's MCE run should ensure that the BOP position is possible; and
- linear ramping between the BOP position and the EOP position should ensure feasibility throughout the period.

We agree that this argument is valid, on condition that GRFs remains within the range which they can provide the ancillary service throughout the dispatch period i.e. in the case of regulation provision, the GRFs should be within its regulation range from the beginning to the end of the dispatch period.

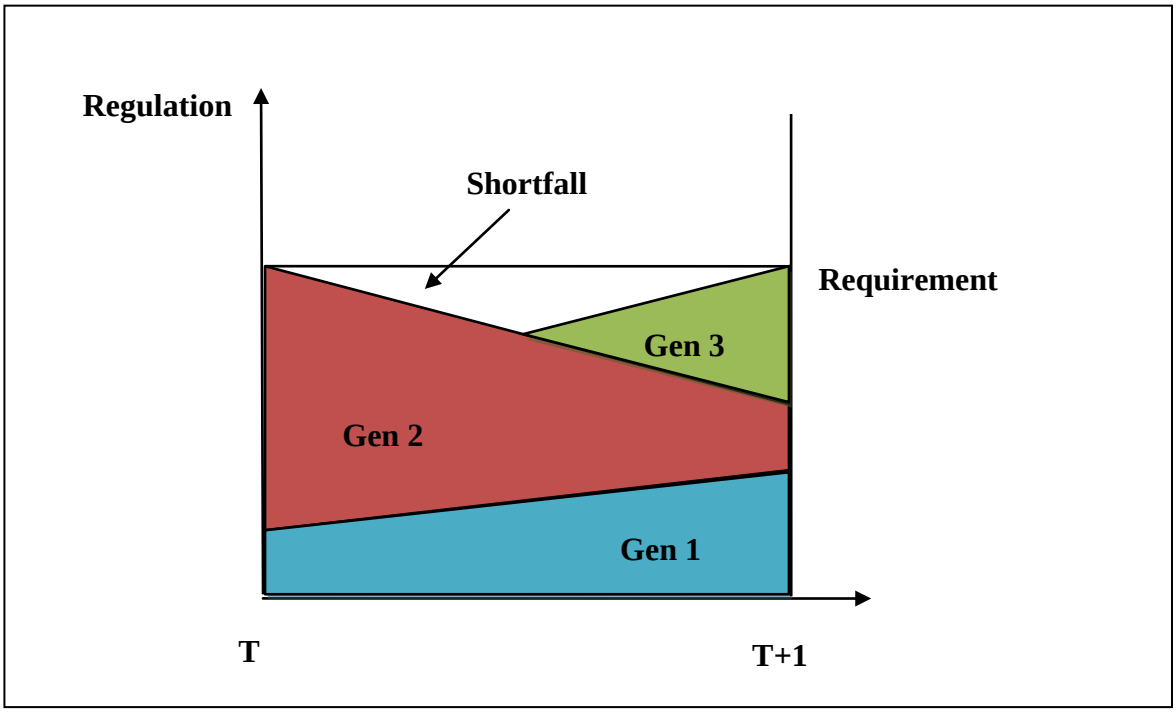
This is because, when we look at the whole set of GRFs providing regulation, the GRFs' aggregate regulation contribution will sum to the total regulation requirement at the end of each dispatch period – so long as the GRFs' are all able to ramp linearly AND provide regulation throughout the dispatch period, with some GRFs ramping down just as other GRFs are ramping up regulation contribution, there will be no shortfall in regulation provision for that dispatch period. This is illustrated by Figure 3 below.

Figure 3: No Shortfall in Regulation Provision



Conversely, if during the dispatch period, some GRFs are ramping into their regulation range or other GRFs are ramping out of their regulation range – these GRFs are not able to provide regulation for parts of that period and a shortfall in regulation provision could be created for that period. This is illustrated by Figure 4 below.

Figure 4: Shortfall in Regulation Provision



Our study in section 4 evaluates the results of removing the BOP test, i.e. only the EOP test is applied, on regulation provision by GRFs and system-wide regulation shortfall. This will let us observe whether the EOP test alone is sufficient to ensure that GRFs scheduled to provide regulation are able to do so throughout a dispatch period.

4. Study Results and Suggested Revision

In view of the rule change proposal to revise the BOP test by replacing the parameter for a GRF's generation level at the beginning of the dispatch period – from its StartGeneration to its scheduled energy for the prior dispatch period (SE_{T-1}) – we conducted a study to examine the effectiveness of current BOP test versus revised BOP test with EMC's suggested changes, as proposed in section 3.2.3.

In addition, we also presented the "effectiveness" when no BOP test is applied i.e. only the EOP test is applied (see section 3.3).

The objective of our study is to understand the effectiveness of the three Options:

Option A – the current BOP test where StartGeneration is used as the parameter; GRF's energy output at BOP is StartGeneration and at EOP is $SE_{T.}$

Option B – the revised BOP test, as proposed in section 3.2.3; GRF's energy output
- at BOP is either SE_{T-1} (if SE_{T-1} can be reached) or
StartGen-DownRampRate x Ramping time or StartGen+UpRampRate x Ramping time
(if SE_{T-1} cannot be reached, respectively, for StartGen > SE or StartGen < SE) and
- at EOP is $SE_{T.}$

Option C – no BOP test; GRF's energy output at BOP is SE_{T-1} and at EOP is $SE_{T.}$

Using a 15-day period (18 Oct - 1 Nov 2010), our study uses these assumptions:

- GRF's energy output at BOP and at EOP, for the three Options, are as stated above.
- GRFs are ramping linearly between BOP and EOP positions.
- GRF's regulation provision throughout the dispatch period is sufficiently represented by its regulation provision at each minute of the dispatch period (i.e. in the study, for every dispatch period, a GRF's regulation provision is calculated at 1-min intervals).

Given Option A is status quo i.e. the current BOP and EOP tests were applied to GRFs, our study consists of two simulations for Options B and C – with the revised BOP test applied and the BOP test removed, respectively. As part of the post-processing for each run/rerun of the real time dispatch schedules for the three Options, the following were calculated for each minute of a dispatch period:

- Calculate the regulation capability at each minute, $RegCap_{g,t}$[10], with respect to the linearly pro-rated energy level of each GRF which was scheduled to provide regulation.
- Calculate the system-wide regulation capability at each minute, $SystemRegCap_t$ [11], which is the sum of all the $RegCap_{g,t}$ figures at that same minute.
- Calculate the system-wide regulation shortfall at each minute, $ShortfallReg_t$[12], in relation to regulation requirement for the dispatch period.

The formula $RegCap_{g,t} = Min(RegMinCap_{g,t}, RegMaxCap_{g,t}, OfferedRegCap_g)$ is used to calculate $RegCap_{g,t}$. As illustrated by the following diagram, the regulation capability of a generator, at different energy output levels, is determined by the minimum of:

(a) its *RegMinCap* or "lower AGC margin" (as shown by the blue line);

(b) its *RegMaxCap* or "upper AGC margin" (as shown by the green line); and

(c) its maximum regulation capability as declared in its regulation offer quantity (*OfferedRegCap*).

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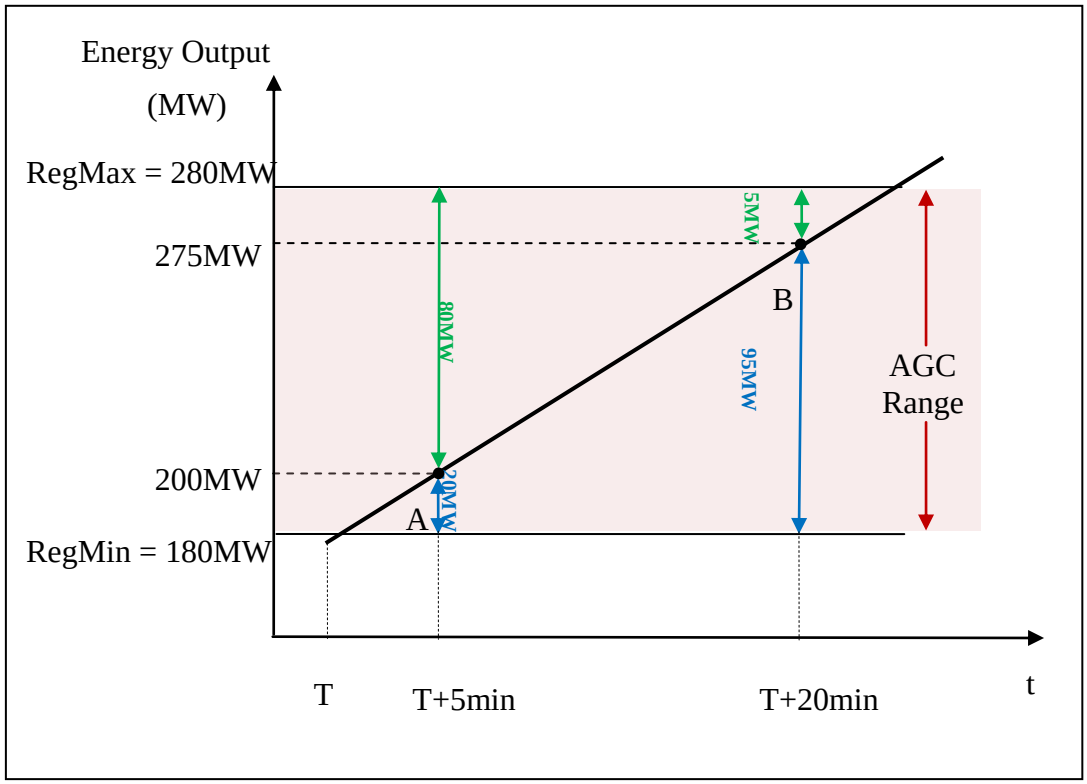
[10] $RegCap_{g,t} = Min(RegMinCap_{g,t}, RegMaxCap_{g,t}, OfferedRegCap_g)$
where $RegMinCap_{g,t} = Max[Energy_{g,t} - RegMin_g, 0]$ and $RegMaxCap_{g,t} = Max[RegMax_g - Energy_{g,t}, 0]$

[11] $SystemRegCap_t = \sum RegCap_{g,t}$

[12] $ShortfallReg_t = SystemRegCap_t - RegulationRequirement$

Figure 5: Illustration of Regulation Capability at Different Energy Output Level



For example, for a generator with a regulation offer of 10 MW:

At point A, its regulation capability is 10MW (the minimum of *RegMinCap* of 20MW, *RegMaxCap* of 80MW, and *OfferedRegCap* of 10MW).

At point B, its regulation capability is 5MW (the minimum of *RegMinCap* of 95MW, *RegMaxCap* of 5MW, and *OfferedRegCap* of 10MW).

The results of $RegCap_{g,t}$, $SystemRegCap_t$ and $ShortfallReg_t$ calculations allow us to measure the effectiveness of the three Options by examining, under each Option, whether the GRFs scheduled to provide regulation are able to do so throughout the dispatch period and the amount of regulation shortfall experienced by the system.

Details of the results, including the range (maximum - minimum values) of the average number of qualified regulation providers in each period and the average MW amount of system-wide regulation shortfall, are presented in Table 1.

Table 1: Results

	Option A (current BOP test)	Option B (revised BOP test)	Option C (no BOP test)
1. Average number of qualified regulation providers in each dispatch period (Max – Min number)	14.17 (17 – 11)	14.30 (18 – 11)	15.57 (19 – 11)
2. % of time, in the 15-day period, where there was system-wide regulation shortfall	1.023%	0	0.060%
3. Average MW amount of shortfall in all 1-min intervals with system-wide regulation shortfall (Max – Min MW amount)	7.53 MW (22.69 – 0.061 MW)	0	6.84 MW (12.99 – 0.970 MW)
4. GRF's average % of "under-performing" time[13], for the GRFs scheduled to provide regulation	7.84%	1.93%	5.79%
5. GRF's average MW amount of shortfall[14], for the GRFs scheduled to provide regulation	1.67 MW	1.86 MW	1.28 MW

From Table 1, it is observed that Option B (revised BOP test was applied) gives the best results with zero system-wide regulation shortfall.

In comparison: Option A (current BOP test was applied) had the highest percentage of time where there was system-wide regulation shortfall (1.023%) – with shortfall at 221 1-min intervals, spread over 23 dispatch periods, during the 15-days – and the highest average MW amount of shortfall (7.53 MW). Under Option A, a GRF's average percentage of "under-performing" time was also the highest.

[13] % of "under-performing" time for a scheduled GRF = the number of 1-min intervals where the GRF is unable to provide its scheduled quantity of regulation divided by the total number of its scheduled 1-min intervals (i.e. the number of periods it is scheduled to provide regulation x 30)

[14] Average MW amount of shortfall for a scheduled GRF = the total amount of regulation the GRF is unable to provide (i.e. the sum of shortfall amount experienced in each of its scheduled 1-min intervals) divided by the total number of its scheduled 1-min intervals (i.e. the number of periods it is scheduled to provide regulation x 30) .

Option C (no BOP test was applied) had 0.060% of time where there was system-wide regulation shortfall – with shortfall at 13 1-min intervals, spread over 3 dispatch periods, during the 15-days – and an average of 6.84 MW of shortfall. Compared with Option A: Removing the BOP test reduced the time where there was system-wide regulation shortfall by about 94% and the average MW amount of shortfall by about 9%. A GRF's average percentage of "under-performing" time and average MW amount of shortfall were also reduced by about 26% and 23%, respectively.

Lastly, it is worth noting that Option C had the highest average number of regulation providers qualified in each period (15.57). Option B qualified, on average, 14.30 regulation providers in each period. The lowest average number of 14.17 was under Option A.

As reference – for the individual GRFs which were scheduled for regulation provision under the three Options – we have included in Annex 2 these individual GRFs' % of "under-performing" time and average MW amount of shortfall in each Option.

Table 2 shows the impact Options B and C, when compared with "status quo" Option A, have on net benefit and prices (USEP, regulation, and the three classes of reserve). Option C has the highest net benefit - followed by Option B then Option A. Conversely, USEP and Regulation Price (RegPrice) are the highest in Option A - followed by Option B then Option C.

Table 2: Net Benefit and Prices

	Option A (current BOP test)	Option B (revised BOP test)		Option C (no BOP test)	
			Change from option A to B		Change from option B to C
Net Benefit	256,335,202	256,335,253	+51.149	256,335,307	+54.111
USEP (S$)	162.43	162.41	-0.026	162.11	-0.300
RegPrice (S$)	87.96	85.90	-2.057	84.03	-1.866
PriResPrice (S$)	0.21	0.21	-0.003	0.24	+0.023
SecResPrice (S$)	2.71	2.74	+0.029	2.95	+0.212
ConResPrice (S$)	6.62	6.57	-0.047	6.52	-0.147

5. Implementation

EMC Market Operations team estimates the cost of implementing Option B (revised BOP test) and Option C (no BOP test, i.e. the current BOP test will be removed) to be identical. The implementation cost, including UAT and testing, of either Option B or Option C is estimated to be S$56000 with an effort of 72 man days, which is covered under EMC's budget.

6. Consultation

EMC published this paper for consultation on 31 January 2011. We received comments from Power Seraya, Senoko Energy, SembCorp Cogen and the PSO. The comments and our response are detailed below:

Power Seraya's comments

Power Seraya's view is that for the provision of regulation, in the interests of system security and reliability, it is good and proper for there to be checks as to ability to provide. Option C with the proposal of no BOP test would be a step in the wrong direction.

EMC's response

Power Seraya's view is noted. However we would like to point out that while Option C does not apply the BOP test, this does not necessarily mean it is a step in the wrong direction.
For Option C, the EOP test is still in place. As explained in Section 3.3 – on condition that GRFs are within regulation range throughout the dispatch period – the EOP test should be able to ensure the provision of regulation service is sufficient, assuming there is no unexpected event (e.g. forced outage) and there is linear ramping between EOP and BOP positions. The simulation results of Option C also shows an improvement from the status quo – there is system-wide regulation shortfall for only 0.060% of the time (i.e. 99.94 % of the time there is sufficient regulation), with an average shortfall amount of 6.84MW.

Senoko Energy's comments

The proposed solution (Option B) is an improvement over the current method. We support EMC's proposal.

EMC's response

Senoko Energy's view is noted.

Sembcorp Cogen's comments

To simplify the proposed Option B, and to take into account a GRF which tripped during the prior dispatch period (T-1) and did not revise its offer submission during the first 20 minutes of that period (T-1), SembCorp Cogen's counterproposal for Option B is:

If StartGen = 0, then disqualify; else (i.e. StartGen > 0) if $SE_{T-1} \geq$ RegMin, then qualify.

The "Recovery and Refund of Reserve and Regulation Payments" will take care of the actual eligibility of GRFs during dispatch periods.

EMC's response

The revised BOP test (Option B) already takes into account cases where a GRF had tripped in the prior dispatch period as it checks whether a GRF is indeed able to reach its scheduled energy target at the end of that period i.e. (StartGen – SE)/RampingTime <= DownRampRate AND (SE-StartGen)/RampingTime <= UpRampRate.

In proposing the revised BOP test, Section 3.2.3 also discusses two issues which would arise if the BOP test is revised by simply replacing StartGen with SE_{T-1} i.e. if the BOP test is revised to $SE_{T-1} \geq$ RegMin and $SE_{T-1} \leq$ RegMax:

(i) In situations where a GRF is unable to reach its scheduled energy target, simply checking $SE_{T-1} \geq$ RegMin and $SE_{T-1} \leq$ RegMax would be inaccurate as its SE_{T-1} is no longer a good proxy for its generation level at the beginning of the dispatch period T.

(ii) In situations where a GRF is unable to reach its scheduled energy target at the end of dispatch period T-1, there could be a subset of GRFs which are within its regulation range at that time – simply checking $SE_{T-1} \geq$ RegMin and $SE_{T-1} \leq$ RegMax would not make us aware of this subset and we would omit qualifying regulation offers from these GRFs.

"Recovery and Refund of Reserve and Regulation Payments" deals only with payment for the provision of ancillary services, there could still be system-wide regulation shortfall if GRFs' regulation offers are not accurately qualified and scheduled for the provision of regulation.

PSO's comments

Please extend studies to review if a similar BOP test (Option B) is applicable to the scheduling of reserve and energy.

Option C (EOP test without BOP test) alone is not sufficient. As pointed out in this paper an unexpected event, such as forced outage, could result in a GRF being scheduled but not being able to provide regulation.

EMC's response

The scope of this rule change is on the qualification of regulation offers, as such it is sufficient for this paper's study to examine Options A, B and C as applied to regulation offers only.
For qualification of reserve and energy offers, we welcome PSO to propose this as a separate study at the RCP workplan prioritisation exercise at the upcoming RCP meeting.

We note PSO's view that Option C is not sufficient. However the study results show that for Option C, there is system-wide regulation shortfall for only 0.060% of the time (i.e. 99.94 % of the time there is sufficient regulation), with an average shortfall amount of 6.84MW.

7. RCP Deliberation

At the 54th RCP meeting, EMC's study results and conclusions were presented for the Panel's consideration:

(i) As proposed in Section 3.2.3, the revised BOP test is a good alternative for qualifying the regulation offers of GRFs which can provide regulation at the beginning of a dispatch period. From the study results, it is observed that the revised BOP test is the most effective – compared with the current BOP test and no BOP test – as it had the least, i.e. zero, time and MW amount of system-wide regulation shortfall during the 15-day period. Therefore, based on our analysis and study results, we recommend for the revised BOP test (Option B) to be implemented.

(ii) In addition, it is worth noting that when no BOP test was applied (Option C):

- there is system-wide regulation shortfall only 0.060% of the time (i.e. there is no shortfall 99.94% of the time) – with shortfall at 13 1-min intervals, spread over 3 dispatch periods, during the 15-days.
- regulation price is the lowest of the three Options – with a reduction of S$1.866 from Option B.

Thus, the feasibility of removing the BOP test should also be considered.

Following a discussion of the concept paper and the options presented, the Panel decided to support the implementation of the revised BOP test (Option B).

8. Proposed Modification to Market Rules

The two-part BOP test as explained in section 3.2.3 above would require changes to the regulation qualification rules stated in section D13A of Appendix D of Chapter 6 of the market rules. Under the existing rule of this section, only one parameter (i.e.StartGeneration) of a generation registered facility is compared against the RegulationMin and RegulationMax in the BOP test. In the proposed two-part BOP test, depending on whether the generator is able to meet its scheduled energy, RegulationMin/Max will be compared against either a) $SE_{T-1,}$ (under part i of the test); or b) the expected generation at the BOP, i.e.StartGen±Up/DownRampRate x Ramping time (under part ii of the test).

To give effect to the suggested two-part BOP test, the following changes to the market rules are proposed:

(1) Define a new parameter "ExpectedStartGeneration". This new parameter shall replace the StartGeneration in the existing BOP test under section D13A of App 6D. Its value is determined as explained in the table below:

	ExpectedStartGeneration
When the generator is ramping down (i.e. SE_{T-1}< StartGeneration)	ExpectedStartGeneration is the higher of: a) StartGeneration - DownRampRate x RampingTime; and b) SE_{T-1}.

When the generator is ramping up (i.e. SE_{T-1}>StartGeneration)	ExpectedStartGeneration is the lower of: a) StartGeneration+ UpRampRate x RampingTime; and b) SE_{T-1}.
When SE_{T-1}=StartGeneration	ExpectedStartGeneration is SE_{T-1}

(2) Define new parameters (i.e. Ramping Time and SE_{T-1} [15]) that are used to derive "ExpectedStartGeneration".

Please refer to Annex 3 for details of the proposed modification to the Market Rules.

9. Legal sign off

EMC's external legal counsel has indicated that because of the technical nature of this rule modification proposal he is not able to provide a legal signoff.

10. Deliberation by the RCP

At the 56th RCP meeting, the RCP considered the proposed rule modifications and **unanimously supported the proposed rule modifications**.

11. Recommendations

The RCP unanimously recommends that the EMC Board

a. **adopt** the rule modification proposal as set out in Annex 3;

b. **seek EMA's approval of** the rule modification proposal; and

c. **recommend** that the rule modification proposal comes into force 3 months after the date on which the approval of the Authority is published by the EMC.

[15] SE_{T-1} is represented by parameter "PriorScheduledEnergy" in the proposed new rules.

Annex 1

ISO New England Manual for Market Operations – Regulation Market

3.2.1 Regulation Market Eligibility

(1) Regulation offers may be submitted only for those units electrically connected within the New England Control Area.

(2) The following unit criteria must be met:

(a) Unit must meet the minimum technical requirements for Generators (as described in the Operating Procedures i.e. OP-18 and OP-14).

(b) Unit must be capable of Regulation control.

(c) Unit must be able to receive an AGC Setpoint signal.

(d) Unit must demonstrate minimum performance standards in accordance with the Regulation Testing and Auditing Procedures specified within this Section of the Manual or will be limited in the amount of Regulation MW offered based on the performance test results.

PJM Manual 11: Scheduling Operations – Overview of the PJM Regulation Market

3.2.1 Regulation Market Eligibility

(1) Regulation offers may be submitted only for those resources electrically within the PJM RTO.

(2) The following resources criteria must be met:

(a) Generation resources must have a governor capable of AGC control.

(b) Resources must be able to receive an AGC signal.

(c) Resources must demonstrate minimum performance standards, as set forth in the PJM Manuals.

(d) New resources must pass an initial performance test (minimum 75% compliance required). PJM will rely on owner's data for initial qualification.

(e) Resources must exhibit satisfactory performance on dynamic evaluations.

(f) Resources MW output must be telemetered to the PJM control center in a manner determined to be acceptable by PJM.

Annex 2

Table A2-1 Option A (current BOP test)

GRF	No. of dispatch periods GRF is scheduled to provide regulation	No. of 1-min intervals GRF provides less than its scheduled quantity of regulation	GRF's % of "under-performing" time (when it is scheduled)	GRF's ave MW amount of shortfall (in a 1-min interval)
GRF 1	258	818	10.23%	3.03
GRF 2	29	93	10.34%	0.49
GRF 3	630	1499	7.68%	4.24
GRF 4	711	2850	12.93%	2.00
GRF 5	715	1692	7.63%	2.66
GRF 6	489	182	1.20%	1.00
GRF 7	716	96	0.43%	0.86
GRF 8	496	1645	10.70%	1.01
GRF 9	588	1774	9.73%	1.05
GRF 10	464	1224	8.51%	0.84
GRF 11	139	132	3.06%	0.25
GRF 12	119	160	4.34%	0.16
GRF 13	36	113	10.13%	0.24
GRF 14	697	2352	10.89%	2.29
GRF 15	697	1983	9.18%	2.16
GRF 16	686	2674	12.57%	2.73
GRF 17	107	497	14.98%	0.51
GRF 18	86	198	7.43%	0.35
GRF 19	120	394	10.59%	0.95
GRF 20	716	454	2.05%	3.65
GRF 21	718	860	3.86%	5.25
GRF 22	710	880	4.00%	1.12

Table A2-2 Option B (revised BOP test)

GRF	No. of dispatch periods GRF is scheduled to provide regulation	No. of 1-min intervals GRF provides less than its scheduled quantity of regulation	GRF's % of "under-performing" time (when it is scheduled)	GRF's ave MW amount of shortfall (in a 1-min interval)
GRF 1	251	279	3.59%	3.57
GRF 2	87	7	0.26%	0.14

Table A2-3 Option C (no BOP test)

GRF	No. of dispatch periods GRF is scheduled to provide regulation	No. of 1-min intervals GRF provides less than its scheduled quantity of regulation	GRF's % of "under-performing" time (when it is scheduled)	GRF's ave MW amount of shortfall (in a 1-min interval)
GRF 1	272	1661	19.70%	1.10
GRF 2	34	248	23.53%	0.28
GRF 3	633	539	2.75%	5.29
GRF 4	718	228	1.02%	3.89
GRF 5	718	148	0.66%	2.88
GRF 6	497	80	0.52%	0.60
GRF 7	718	40	0.18%	1.43
GRF 8	516	858	5.36%	0.36
GRF 9	595	832	4.51%	0.36
GRF 10	466	942	6.52%	0.23
GRF 11	145	340	7.56%	0.12
GRF 12	121	236	6.29%	0.11
GRF 13	36	103	9.23%	0.14
GRF 14	703	576	2.64%	0.72
GRF 15	708	726	3.31%	1.68
GRF 16	695	855	3.97%	1.92
GRF 17	116	381	10.60%	0.17
GRF 18	87	261	9.68%	0.09
GRF 19	128	273	6.88%	0.15
GRF 20	716	170	0.77%	2.23
GRF 21	718	82	0.37%	2.59
GRF 22	718	285	1.28%	1.87

Annex 3 Proposed Rules Changes

Current Market Rules (1 January 2011)	Proposed Rules Changes (Deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Rule Change
APPENDIX 6D MARKET CLEARING FORMULATION	**APPENDIX 6D MARKET CLEARING FORMULATION**	
D.13A REGULATION RANGE CONSTRAINTS	**D.13A REGULATION RANGE CONSTRAINTS**	
D.13A.1 A valid *regulation offer* shall only be used in the linear program if:	D.13A.1 A valid *regulation offer* for a *generation registered facility* for a *dispatch period* shall only be used in the linear program if:	To make clear that this regulation offer relates to a particular GRF and a particular dispatch period.
D.13A.1.1 a valid *energy offer* exists for the *generation registered facility* for that *dispatch period* and the sum of the quantities in that *energy offer* is greater than the RegulationMin_g for the relevant *generation registered facility*;	D.13A.1.1 a valid *energy offer* (hereinafter referred to in this section D.13A as *energy offer g*) exists for ~~the~~that *generation registered facility* for that *dispatch period* and the sum of the quantities in that *energy offer g* is greater than the ~~RegulationMin_g~~ RegulationMin_g for ~~the relevant~~ that *generation registered facility*;	To make clear that the calculation of $\text{ExpectedStartGeneration}_g$ (see D.13A.2 below) relates to a given energy offer g and to the given dispatch period to which this energy offer *g* relates. To italicise the subscript *g* in RegulationMin_g.

Current Market Rules **(1 January 2011)**	**Proposed Rules Changes** (Deletions represented by strikethrough text and additions represented by double underlined text)	**Reasons for Rule Change**
D.13A.1.2 the $StartGeneration_g$ of the relevant *generation registered facility* is greater than or equal to $RegulationMin_g$ for the relevant *generation registered facility*; and	D.13A.1.2 the ~~$StartGeneration_g$~~ $ExpectedStartGeneration_g$ of ~~the relevant~~ that *generation registered facility* is greater than or equal to ~~$RegulationMin_g$~~ $RegulationMin_g$ for ~~the relevant~~ that *generation registered facility*; and	To revise sections D.13A.1.2 and D.13A.1.3 to set out the revised BOP test to qualify regulation offers for use in the linear program. To italicise the subscripts *g* in $RegulationMin_g$ and $RegulationMax_g$.
D.13A.1.3 the $StartGeneration_g$ of the relevant *generation registered facility* is less than or equal to $RegulationMax_g$ for the relevant *generation registered facility*.	D.13A.1.3 the ~~$StartGeneration_g$~~ $ExpectedStartGeneration_g$ of ~~the relevant~~ that *generation registered facility* is less than or equal to ~~$RegulationMax_g$~~ $RegulationMax_g$ for ~~the relevant~~ that *generation registered facility*.	
	D.13A.2 $ExpectedStartGeneration_g$ of a *generation registered facility* associated with an *energy offer g* shall be determined in accordance with the following table: When the *generation registered facility's* $StartGeneration_g$ is greater than its	To introduce a new section to set out how $ExpectedStartGeneration_g$ is to be determined.

Current Market Rules (1 January 2011)	Proposed Rules Changes (Deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Rule Change
	PriorScheduledGeneration$_g$, ExpectedStartGeneration$_g$ shall be the higher of: a) StartGeneration$_g$ – DownRampRate$_g$ x RampingTime; and b) PriorScheduledGeneration$_g$. When the *generation registered facility's* StartGeneration$_g$ is less than its PriorScheduledGeneration$_g$, ExpectedStartGeneration$_g$ shall be the lower of: a) StartGeneration$_g$ + UpRampRate$_g$ x RampingTime; and b) PriorScheduledGeneration$_g$. When the *generation registered facility's*	

Current Market Rules **(1 January 2011)**	**Proposed Rules Changes** (Deletions represented by strikethrough text and additions represented by double underlined text)	**Reasons for Rule Change**
	$\underline{\text{StartGeneration}_g}$ $\underline{\text{is equal to its PriorScheduledGeneration}_g}$, $\underline{\text{its ExpectedStartGeneration}_g}$ $\underline{\text{shall be its PriorScheduledGeneration}_g}$.	
Explanatory Note: Alternative tests could have been StartGeneration_g + UpRampRate_g x RemainingTime > RegulationMin_g, and StartGeneration_g - DownRampRate_g x RemainingTime < RegulationMax_g which would ensure that the facility could provide the regulation at the end of the dispatch period. However, the current rules are more conservative, and are designed so that regulation can be provided throughout the dispatch period.	~~**Explanatory Note: Alternative tests could have been StartGeneration_g + UpRampRate_g x RemainingTime > RegulationMin_g, and StartGeneration_g – DownRampRate_g x RemainingTime < RegulationMax_g which would ensure that the facility could provide the regulation at the end of the dispatch period. However, the current rules are more conservative, and are designed so that regulation can be provided throughout the dispatch period.**~~	To delete the existing explanatory note.
D.3 PARAMETERS	**D.3 PARAMETERS** $\underline{\text{RampingTime}}$ | $\underline{\text{10 minutes, or such other time period as may be determined by the } \textit{EMC}}$	To define new parameters used in the revised BOP test.

Current Market Rules (1 January 2011)	Proposed Rules Changes (Deletions represented by strikethrough text and additions represented by double underlined text)		Reasons for Rule Change
		in consultation with the *PSO*.	
	PriorScheduledGeneration$_g$	In respect of a *generation registered facility* associated with an *energy offer g* for a given *dispatch period*, either: (a) the scheduled *energy* in the *real-time dispatch schedule* for that *generation registered facility* for the prior *dispatch period*, or (b) in the event that such *real-time dispatch schedule* is not available, that *generation registered facility's* StartGeneration$_g$.	

<table>
<tr><th>Current Market Rules
(1 January 2011)</th><th colspan="2">Proposed Rules Changes
(Deletions represented by strikethrough text and additions represented by double underlined text)</th><th>Reasons for Rule Change</th></tr>
<tr><td></td><td></td><td>ExpectedStartGeneration$_g$</td><td>The forecast generation level at the beginning of a given dispatch period of a generation registered facility associated with energy offer g for that dispatch period, which shall be determined in accordance with section D.13A.2.</td><td></td></tr>
<tr><td>StartGeneration$_g$</td><td>The forecast beginning of dispatch period generation level of the generation registered facility associated with energy offer g. For multi-unit facilities, this is calculated in accordance with sections D.8.3 to D.8.6. For other generation registered facilities this is calculated in accordance with sections</td><td>StartGeneration$_g$</td><td>The forecast ~~beginning of dispatch period~~ generation level at the beginning of a given dispatch period of ~~the~~ a generation registered facility associated with energy offer g for that dispatch period. For multi-unit facilities, this is calculated in accordance with sections</td><td>To align the definition of StartGeneration$_g$ with the proposed new definition of ExpectedStartGeneration$_g$.</td></tr>
</table>

Current Market Rules (1 January 2011)		**Proposed Rules Changes** (Deletions represented by strikethrough text and additions represented by double underlined text)		**Reasons for Rule Change**
	D.12.1 to D.12.4.		D.8.3 to D.8.6. For other *generation registered facilities* this is calculated in accordance with sections D.12.1 to D.12.4.	
StartGeneration$_u$	The forecast beginning of *dispatch period* generation level of generation unit *u*. Received from the *PSO* in accordance with Appendix 6G section G.3.1.	StartGeneration$_u$	The forecast ~~beginning of *dispatch period*~~ generation level at the beginning of a given *dispatch period* of ~~the generation unit~~ *generation unit* *u*. Received from the *PSO* in accordance with Appendix 6G section G.3.1.	To align the definition of StartGeneration$_u$ with the proposed new definition of ExpectedStartGeneration$_g$. To italicise the expression "generation unit".