RCP PAPER NO. : **EMC/RCP/50/2010/CP22**

SUBJECT : **COMPENSATION FOR EXCESS REGULATION**

FOR : **DECISION**

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DATE OF MEETING : **6 July 2010**

Executive Summary

During the Financial Year 2009/2010 RCP Workplan Consultation exercise, stakeholders raised their concerns that some GRFs were called upon to provide more regulation than what they were scheduled for. They requested introducing a compensation regime to address such situations.

Before considering such a compensation regime, it is necessary to first establish when regulation provision is considered to be in excess of a generator's schedule. This in turn depends on the conditions under which regulation is procured, and how the regulation quantity requirement is determined by the PSO.

The PSO determines the amount of regulation required using the Forecast Demand and Actual System Demand, both of which are calculated on an average basis across the whole period. As such, the derived regulation requirement should be similarly understood to be the <u>average requirement across the whole period, and **not** the maximum instantaneous value within the period.</u>

Based on this, GRFs should only be considered to have over-provided regulation if their actual energy output (sum of their metered IEQ and associated station/auxiliary load) falls outside of the total expected energy output range {defined as ½ [½ (Scheduled Energy in Period T-1 + Scheduled Energy in Period T) ± (Scheduled Regulation in Period T)]}.

There are, however, exceptions whereby the GRFs would **not** be considered to have over-provided regulation, namely, if they were (i) displaying a non-linear ramping pattern, (ii) affected by forced outages where any GRF scheduled to provide more than 10MW of energy tripped or failed to start-up, (iii) operating out of the AGC control range or not on AGC, (iv) generating under the PSO's instruction to maintain generation at a particular level, (v) not scheduled to provide regulation, or (vi) scheduled for energy, but did not generate any output.

At the 46th RCP Meeting held on 3rd November 2009, EMC presented evidence on excess regulation provision using data from MPs that reverted, based on the above methodology. The evidence reflected excess regulation payments amounting to about 25.97% of scheduled regulation payments **or $1,937,559.41** among these MPs, over the period from 1st January 2009 to 30 June 2009.

Following discussion at the meeting, the RCP requested for further analysis to be conducted before deciding whether a compensation regime for the provision of excess regulation should be introduced, specifically:

(a) Evaluate whether there is over-provision of regulation across the whole market
(b) Select some periods for more detailed analysis to better understand the issue.

Using new system-wide SCADA data provided by the PSO, the study found that excess regulation provision on a system-wide level was insignificant. It amounted to $195,139.41 over a six-month period, translating to 0.89% of total regulation payments. As such, there is no strong justification to provide excess regulation compensation to regulation providers as a whole.

However, the following situations were observed:

1. At the individual GRF level, some GRFs were found to be more responsive and correspondingly provided regulation in excess of their schedules. In certain cases, some GRFs provided “free” regulation even when they were not scheduled for any regulation.
2. Some GRFs responded differently from the intended regulation pulses at the system-wide level. For example, while the rest of the system were pulsing up, some GRFs responded by providing less energy output than scheduled.

Thus, EMC proposed adjusting existing regulation payments to GRF in relation to their regulation provision responsiveness by assigning a Regulation Effectiveness Factor (REF) to each GRF, which can be determined based on either:

a. PSO’s **technical assessment** of each individual GRF’s effectiveness in responding to regulation needs, or;
b. a **historical assessment** of each individual GRF’s regulation provision pattern relative to their respective offers.

This REF factor will be applied to the GRF’s scheduled regulation quantity to derive its adjusted regulation quantity, which in turn determines its regulation payments. In other words, the total regulation payment “pie” is fixed based on the scheduled regulation quantity/price, and the payments to individual GRFs will be “sliced” based on their relative REFs and their schedule regulation quantities. This will provide the correct incentives for GRFs to provide responsive regulation when called upon.

At the 48th RCP meeting, the RCP:

a. Decided not to introduce a compensation regime for excess regulation provision as excess regulation provision at a system-wide level was not significant.

b. Considered the REF methodology and requested that EMC compute the proposed REF for each Generation Registered Facility (GRF) using Gross Metering data for 2009

At the 49th RCP Meeting, EMC presented an REF methodology that used historical data to compute a single averaged REF value for each GRF that takes a value of between 0 and 1. Most GRFs were found to take on an REF of between 0.5 to 0.7.

In addition, EMC computed system-wide excess regulation provision data for the period from 1 July 2009 to 31 December 2009. Total excess regulation amounts (Regulation Up and Regulation Down) in dollar terms amounted to $604,261.54 over a six-month period, translating to 1.56% of total regulation payments.

The RCP then requested that PSO revert with more information on how the Automatic Generation Control (AGC) works in relation to regulation provision so as to better understand the situation before deciding if the REF method should be further pursued.

Arising from the on-going discussions on this issue, the RCP requested for the following from the PSO at the 50th RCP Meeting:

1. Whether PSO could determine the regulation effectiveness of a GRF from a technical perspective
2. For PSO to provide information on how AGC works in relation to regulation provision
3. For PSO to submit "System-wide Actual Online Generation" data to EMC bi-annually for the purposes of monitoring system-wide excess regulation.

At the 50th RCP meeting, taking into consideration PSO's inputs, the RCP concluded that:

1. There are already regular checks by the PSO on whether GRFs provide regulation based on dispatch instructions, which ensures that GRFs can effectively provide regulation when called upon.

2. It is not possible for PSO to conduct a technical assessment of a GRF's regulation effectiveness.

3. Given that it is not possible to use the technical assessment approach, further refinements would have to be made to the proposed REF methodology using historical data. The RCP recognises that this is one of the many approaches and it is hard to assess the accuracy of the methodology.

Given the above considerations, the RCP unanimously agreed **not to pursue** refining the proposed REF methodology.

The PSO also declined to provide the requested data for the purposes of monitoring system-wide excess regulation on grounds that:

a) It would increase cost.

b) Monitoring of the market is under the purview of the Market Surveillance and Compliance Panel (MSCP), and PSO will only provide data on "System-wide Actual Online Generation" if the MSCP includes it as part of the its catalogue of data.

1. Introduction

This paper discusses one of the issues prioritized in the Financial Year 2009/2010 Rule Change Work Plan, "Compensation for Excess Regulation".

Some stakeholders are concerned that there are instances whereby the amount of regulation effectively provided by a generator exceeds its scheduled regulation quantity, and requested that compensation be introduced under these circumstances.

Before considering a compensation regime for the provision of excess regulation, it is necessary to first establish when regulation provision is considered to be in excess of a generator's scheduled regulation. This in turn depends on the conditions under which regulation is procured, and how the regulation quantity requirement is determined by the PSO. Only after all SWEM stakeholders have established an understanding on these key regulation fundamentals can there be a meaningful discussion on the issue of compensation.

Section 2 of this paper examines how PSO determines the regulation requirement, while Section 3 identifies conditions under which generators can be considered to have provided excess regulation. Section 4 recaps these conditions, while section 5 presents the industry's comments and a summary of excess regulation data submitted by generating companies using the proposed methodology. Section 6 reports EMC's recommendations and describes the RCP's request at the 46th RCP meeting for further analysis of the proposed methodology. Sections 7 and 8 presents results gathered arising from the RCP's request. Section 9 introduces the Regulation Effectiveness Factor (REF) concept, while section 10 summarises EMC's recommendations, along with the RCP's discussion at the 48th RCP Meeting. Section 11 introduces the REF computation methodology, while section 12 provides additional system-wide excess regulation provision data as requested by the RCP. Sections 13 and 14 summarise the RCP's discussions and decisions at the 49th and 50th RCP Meeting respectively.

2. Regulation Requirement Determination

2.1 Purpose of Regulation in SWEM

Chapter 8, Section 1.1.208 of the Market Rules defines *regulation* as the frequent adjustment to a generator's output such that any power system frequency variations or imbalances between load and the output from generation facilities can be corrected.

Section 8.2.1 of the System Operation Manual (SOM) further provides a background to the need for regulation in the SWEM. It states that imbalances between load and generation can arise from a variety of factors, such as an inaccurate system demand forecast and fluctuations in electricity consumption by loads, which may in turn result in an unstable power system if the system frequency falls out of the appropriate limits of 49.8Hz to 50.2 Hz.

2.2 Regulation Requirement in the Market Rules

Chapter 5, Section 4.4.1 of the Market Rules states the following:

> <u>Chapter 5, Section 4.4.1</u>
>
> 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*.

The above clause implies that the Power Systems Operator (PSO) determines the regulation requirement for each dispatch period based on the methodology specified in the SOM.

2.3 Regulation Requirement Methodology in the SOM

Section 8.2.1 of the SOM also sets out how PSO determines the regulation requirement for each dispatch period in the SWEM.

Period-Based Regulation Requirement

The regulation requirement is determined by the February[1] of each year, which will apply for the following 12 months. This requirement is calculated as follows:

1. Regulation Required = Forecast Demand – Actual System Demand for each dispatch period of the preceding year

   Computation of Forecast Demand
   The PSO proxies the Forecast Demand using the most updated Very Short Term Load Forecast[2] (VSTLF) forecast for each period[3].

   The VSTLF refines the initial load forecast from the Short Term Load Forecast (STLF) every half-hour, by comparing the deviations between the STLF's forecast with actual system load over the last five hours (A). The STLF itself uses the actual half-hourly system load values over the past 42 days (B) as one of its inputs. Both actual system loads (A) and (B) are sampled at fixed intervals within the period.

   Computation of Actual System Demand
   The Actual System Demand is recorded using the sum of actual online generation of all GRFs scheduled to provide energy for that half-hourly period. This data is sampled at fixed intervals within the period using the Energy Management System (EMS) for all GRFs, and averaged to yield the half-hourly period Actual System Demand.

   Since both Forecast Demand and Actual System Demand are calculated on an average basis across the whole period (using sampling at fixed intervals within the period), the Regulation Required amount should similarly be understood to be the average requirement across the whole period.

2. Determine the 99% Confidence Interval[4] for each of the 48 periods that will apply for respective dispatch periods throughout the following year (for example, the regulation requirement calculated using the 99% CI for Period 1 will apply for all Period 1s in the following year).

   99% Confidence Interval for the Regulation Requirement
   $= \mu \pm 2.58^*\sigma$

   Where: μ is the historical regulation mean
   σ is the standard deviation

   This is calculated based on data from the same dispatch period in all days of the year before (i.e. there will be 365 data sets from the previous year, spanning 1 January to 31 December, to compute the 99% Confidence Interval for Period 1.)

3. Calculate the derived period-based regulation reserve.

[1] For example, using historical data from 01 Jan 2008 to 31 Dec 2008, the PSO will determine in Jan 2009, the regulation requirements that will apply from 01 Feb 2009 to 31 Jan 2010.
[2] The methodology use to determine the VSTLF is set out in section 4 of the SOM.
[3] For example, the VSTLFs computed in Periods 1 to 14 will all contain the forecast schedule of Period 15 (e.g. the VSTLF available in Period 1 will forecast from Periods 2 to 15, while that in Period 14 will forecast from Periods 15 to 28). PSO will use the forecast for Period 15 from the VSTLF available in Period 14, since it will be the most updated value.
[4] A 99% confidence interval implies that 99% of the time, the value of the regulation should fall within this range.

$$\text{Derived period-based regulation} = \text{Max}\left(\left|\mu - 2.58*\sigma\right|, \left|\mu + 2.58*\sigma\right|\right)$$

4. The derived period-based regulation reserve calculated from Step 3 is further capped at a maximum of 100 MW.

2.4 Regulation Requirement Determination in Other Jurisdictions

Annex 1 summarises the regulation requirement determination methodologies in selected overseas electricity markets.

The US electricity markets reviewed largely employs the generic method of using a percentage of the forecast demand for the applicable period to determine the regulation requirement, although the system operator may periodically adjust this. In addition, the requirements determined in these US jurisdictions will have to meet the standards set out at regional and national level.

A more specific regulation requirement methodology is that employed by the Australian Energy Market Operator (AEMO), which uses a tolerance level depending on the system frequency. Similar to the SWEM, the AEMO also imposes a regulation requirement cap.

3. Basis for Over-Provision of Regulation

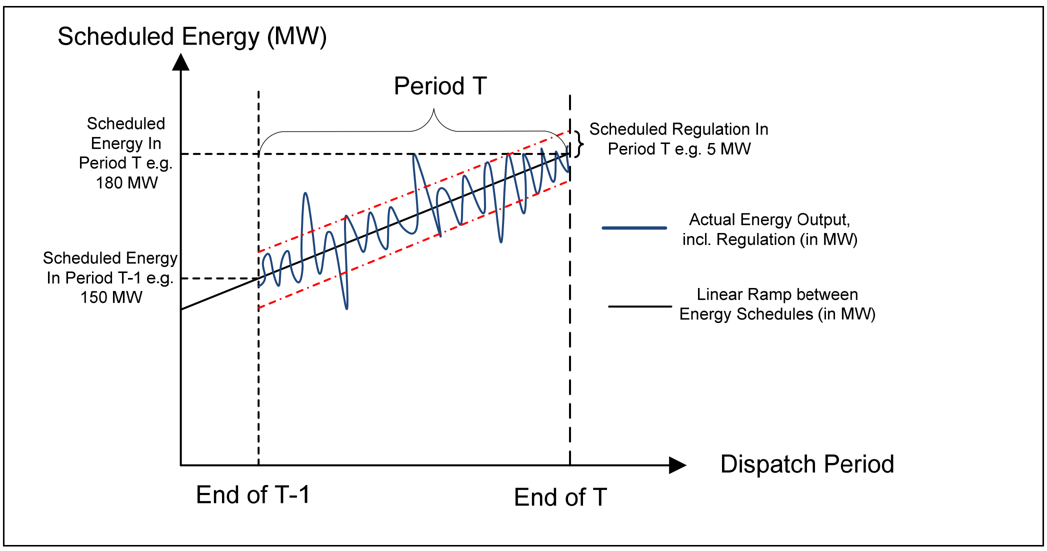
3.1 When a GRF would be Deemed to Have Over-Provided Regulation

As established in the earlier section, both Forecast Demand and Actual System Demand are calculated on an average basis across the whole period (using sampling at fixed intervals within the period). Since the Regulation Required amount is directly derived from both terms, it should similarly be understood to be the average requirement across the whole period, **not** the maximum instantaneous value within the period.

An Illustration: Calculation of the Energy Output Range

Figure 1 shows a GRF scheduled to provide 150MW of energy in period T-1, and 180 MW of energy and 5 MW of regulation for period T.

Figure 1: Actual Energy Output for a GRF in a Given Period



At the beginning of period T, the GRF's energy output should be within the range of 145 MW and 155 MW, as represented in the equation below:

Energy output at the beginning of period T = Scheduled Energy in Period T-1 ± Regulation
= 150 MW ± 5 MW

Similarly, the GRF's energy output at the end of period T should be within the range of 175 MW and 185 MW, as represented in the equation below:

Energy output at the end of period T = Scheduled Energy in Period T ± Regulation
= 180 MW ± 5 MW

Assuming that this GRF did not provide any reserve in dispatch period T, then the expected range of energy output, given its energy and regulation schedule, is between 80MWh and 85MWh. This is elaborated in the calculations below:

For a given GRF in a trading period:

Expected Energy Output + Regulation Up

$$= \left[\frac{(\text{Scheduled Energy}_{T-1} + \text{Scheduled Regulation}_{T})}{2} + \frac{(\text{Scheduled Energy}_{T} + \text{Scheduled Regulation}_{T})}{2} \right] \times \frac{1}{2}\text{h}$$

$$= \frac{(150 + 5) + (180 + 5)}{2}\text{MW} \times \frac{1}{2}\text{h}$$

= 85MWh

Expected Energy Output - Regulation Down

$$= \left[\frac{(\text{Scheduled Energy}_{T-1} - \text{Scheduled Regulation}_{T})}{2} + \frac{(\text{Scheduled Energy}_{T} - \text{Scheduled Regulation}_{T})}{2} \right] \times \frac{1}{2}\text{h}$$

$$= \frac{(150 - 5) + (180 - 5)}{2}\text{MW} \times \frac{1}{2}\text{h}$$

= 80 MWh

Total Expected Energy Output Range = (80MWh to 85MWh)

The Total Expected Energy Output Range (TEEOR), which is the energy output range that the GRF can reasonably expect to produce given their scheduled regulation, is therefore between 80 to 85MWh.

Criteria for Over-Provision[5] of Regulation

Following from the example above, the GRF can be considered to have over-provided regulation if its Total Actual Energy Output (TAEO)[6], as represented by the area under the blue line in Figure 1, falls outside the expected range of 80MWh to 85MWh. This is represented in the equation below:

[5] As regulation can fluctuate up or down, over-provision would imply that the GRF has generated above or below its scheduled range.

[6] This is measured by the sum of the GRF's IEQ and any station/auxiliary load. IEQ measures a GRF's net injection into grid, while a GRF's scheduled energy includes its station/auxiliary load. For actual total energy output to be comparable with total expected energy output station/auxiliary load has to be added to IEQ.

For a given period, the GRF would be considered to have over-provided regulation if:

(TAEO = IEQ + Auxiliary Load) ≥ (Expected Energy Output + Regulation Up) (e.g. 85MWh), or

(TAEO = IEQ + Auxiliary Load) ≤ (Expected Energy Output - Regulation Down) (e.g. 80MWh)

However, the above guideline is subject to the exceptions described in the following section.

3.2 When a GRF Would NOT be Deemed to Have Over-Provided Regulation

A GRF would not be considered to have over-provided regulation so long as its TAEO falls within the TEEOR of 80-85MWh, even if its energy output instantaneously exceeds the red lines in Figure 1. This is explained from the fact that the required regulation quantity is determined and procured on an average basis across the whole period.

In addition, given the definition and intent of regulation, there are certain conditions under which GRFs would not be considered to have over-provided regulation (and hence not entitled to any form of compensation), even if the TAEO falls out of the TEEOR. The following describe conditions when distortion occurs.

a. Exclude non-linear ramping effects
The example in Figure 1 presents a constant linear ramp between the scheduled energy outputs of 2 adjacent dispatch periods. There are however instances whereby GRFs could deviate from such a linear ramp pattern, in which case their energy output could fall out of the TEEOR. However, it is difficult to distinguish if a GRF is falling outside of the TEEOR because of its non-linear energy ramp, or that it was called upon to provide regulation beyond its scheduled level. Since there is no clear-cut case of over-provision of regulation, we will not consider such cases eligible for compensation.

b. Exclude dispatch periods affected by forced outages, where any GRFs scheduled to provide more than 10MW of energy tripped or failed to start-up
All GRFs should not be compensated for excess regulation in dispatch periods where there is a forced outage from any GRF. This is because the increase in the generators' actual energy output may be due to reserve activation, rather than an over-provision of regulation. However, this exclusion shall only apply to periods whereby GRFs that tripped/failed to start-up were scheduled to provide energy of more than 10MW. This is because any outages below and including 10MW would not trigger reserve activation, but are instead covered by regulation.

   In addition, GRFs that tripped or failed to start-up in a dispatch period clearly have not met their regulation provision obligations and should not be compensated.

c. Exclude GRFs operating out of the AGC control range or not on AGC
When a GRF's is operating out of the AGC control range or not on AGC, then its actual energy output is due to the facility operating under its own station control. Since the over-provision of energy is due to its own action rather than PSO's control, it should not be eligible for compensation

d. Exclude GRFs whose market schedules are overridden by PSO
When PSO overrides a GRF's schedule, then the GRF's actual energy output reflects PSO's instruction to maintain its generation at a particular level, rather than the GRF market schedule. The GRF should not be compensated for any excess regulation provision, since it is already entitled to separate compensation for following PSO's instructions.

e. Exclude GRFs that were not scheduled for regulation

GRFs that were not scheduled for regulation are excluded from compensation consideration, as these units could have requested to be taken their units off AGC, such that they will not be called upon to provide regulation.

f. Exclude GRFs that were scheduled for energy, but did not generate any output
GRFs that were scheduled for energy in a particular dispatch period but did not generate any energy output should be excluded from being compensated for excess regulation. This is because in this situation, the GRF would have significantly provided below the TEEOR because it failed to meet its energy schedule, rather than over-provided regulation.

4. Conclusion

In SWEM, the regulation requirement is determined based on the difference between the Forecast Demand and Actual System Demand, both of which are calculated on an average basis across the whole period. As such, the regulation requirement should similarly be understood to be the average requirement across the whole period, **not** the maximum instantaneous value within the period.

Based on this principle, GRFs should only be considered to have over-provided regulation if their total actual energy output (sum of their metered IEQ and associated station/auxiliary load) falls outside of the total expected energy output range in a given dispatch period. The exceptions to this are periods whereby the GRFs were:

(i) displaying a non-linear ramping pattern

(ii) affected by forced outages where there are any GRFs who tripped or failed to start-up but was scheduled to provide energy of more than 10MW

(iii) operating out of the AGC control range or not on AGC;

(iv) generating under the PSO's instruction to maintain generation at a particular level

(v) not scheduled to provide regulation; and

(vi) who were scheduled for energy, but did not generate any output

5. Consultation

On 16 September 2009, EMC published the above methodology for feedback as well as sought the Market Participants' views on whether they consider that they have materially over-provided regulation in any dispatch period, along with the supporting evidence. It was also conveyed during the publication that EMC would only consider a compensation methodology for this over-provision, if relevant evidence of over-provision of regulation were received.

Section 5.1 presents the feedback on the proposed methodology coupled with EMC's response to them, while section 5.2. presents a summary of supporting evidence of overprovision of regulation submitted by some MPs.

5.1 Industry Feedback

Table 1 compiles various comments received from the industry along with EMC's response to each comment.

Table 1: Industry feedback

	Feedback	**EMC's Response**
PSO	It is stated in **EMC/RCP/33/2007/CP15** on equity between generators and interruptible loads in reserve provision, under Section 3.3, that reserve providers receive payment for being **scheduled** to provide reserve. When scheduled to provide reserve, a reserve provider will receive payment even if it is not activated, and it will not receive any extra payment for being activated. This proposal, if adopted, would move away from the above philosophy i.e. giving additional payment for provision of Regulation Reserve. By suggesting to pay compensation for excess regulation, the proposal fails to distinguish the difference between energy and reserves when reserves, in effect, are capacity set aside for Regulation of system frequency and Contingency events.	The concept paper quoted dealt with the issue of payment for activation versus non-activation, rather than payment for excess reserve provided beyond their scheduled amount. As such, that paper does not imply that reserve providers are disallowed from seeking compensation in the event they provide reserve beyond their scheduled amounts following activation of reserve if the following conditions hold: • The Market Rules allow for compensation • Compensation is justifiable • Quantum of compensation can be determined • Costs of determining compensation is justified by the quantum of compensation.
	The proposal also contradicts the notes stated in the EMC Monitoring List under Payment to Reserve/ Regulation Providers who failed to provide, which states that: *Paying reserve/regulation providers for services not rendered is undesirable. However, to change the current settlement setup to eliminate such payments entails costs. Hence, the RCP's decision is to consider taking action when the combined reserve/regulation payment (on a rolling 12-month basis) exceeds $600,000.*	We have taken a similar stance on this issue of "Compensation for Over-provision of Regulation, contrary to the comment that this proposal contradicts the approach taken for the "Payment to Reserve/Regulation Providers Who Failed to Provide" issue. In the concept paper put up for comments, it was stated that a compensation regime would only be considered if there were evidence that there has indeed been an overprovision of regulation. The evidence submitted is evaluated in section 5.2.
	This proposal, if adopted, would need changes to the current settlement system incurring additional cost that would be borne by consumers.	We recognize that additional costs may be incurred should this proposal be adopted. However, this will only be evaluated in the event that the RCP agrees to adopt a compensation regime for this over-provision of regulation.

	Feedback	EMC's Response
PSO	Agreeing to pay for excess regulation demonstrates a lack of natural justice and tends to bias towards the party, who provided additional Regulation reserve (assuming this is indeed the case). This approach is clearly skewed, seeking to incentivise the Gencos unnecessarily, as the "compensation" would be on top of what has already been paid for Regulation reserve scheduled.	It is only fair to pay stakeholders for a service that they have provided, i.e. compensating these GRFs for any regulation provided beyond their scheduled amounts.
	The purpose of regulation reserve, in short, is to balance demand and supply. This is a zero-sum game. If a GRF has indeed over-provided regulation reserve, conversely, it means that some other GRFs have under-provided their share of regulation reserve. Just rewarding the GRF that over-provides and not penalizing the GRFs that under-provide would send a wrong signal to the market that it is acceptable to under-perform. Is it fair to the consumers who are paying most of the regulation charges? Therefore, to protect the interests of the consumers, PSO proposed that EMC in making the settlement system changes, should include both (payment for) over and (deduction for) under provision of Regulation reserve and it should be computed for all dispatch periods.	We agree that it is possible that the existence of some GRFs over-providing regulation may imply other GRFs under-providing regulation. To facilitate the evaluation on whether there is no over-provision in total i.e. under-provided of regulation by some GRFs are compensated through over-provision by other GRFs, we request for PSO to provide us with system-wide Actual Online Generation recorded in the SCADA data by dispatch period for the period of 1st January 2009 to 30 June 2009. Using SCADA[7] to compare against scheduled generation and regulation is more appropriate as VSTLF used in determining scheduled energy requirements is also derived from inputs that use SCADA measurements. We would consider if it is appropriate to make deductions for under-provision as part of the compensation regime.
	Lastly, from technical perspective, the output of a GRF at any point in time does not depend on AGC command alone as its governor control mechanism would also respond to system frequency fluctuations. Therefore, using IEQ or average output to assess whether there is over (or under) provision of Regulation reserve fails to recognize that the GRF governor has also contributed to its output deviation.	We would consider other alternative measures to isolate regulation provision from GRFs if they are available. IEQ or average output, however, would be the best proxy in the absence of better measures.

[7] In the 2005 Load forecast accuracy study, the TWG compare scheduled gross generation with actual SCADA gross generation data instead of metering data to avoid measuring errors between SCADA & meters.

	Feedback	EMC's Response
Sembcorp Cogen Pte Ltd	Will the compensation scheme be built into the EMC settlement process? TAEO (Total Actual Energy Output) = IEQ + Auxiliary Load How is auxiliary load determined? Perhaps EMC can consider asking MSSL to provide the Gross Unit Generated since MSSL is already reading the gross UG and Auxiliary Load in the computation of IEQ.	These suggestions will be assessed in the event the Rule Change Panel (RCP) decides that a compensation regime be introduced for the over-provision of regulation.
	How do you determine if the ramping is non-linear unless plotting a per second chart? Even the GRFs are on non-linear ramping due to AGC control. Since there is no clear-cut way to determine if the ramping is non-linear, why would you want to exclude it?	We will consider obtaining "per-second" data and assess ramping patterns if the RCP decides that there should indeed be compensation for the over-provision of regulation.
	<u>Periods whereby dispatch periods are affected by forced outage will not be considered</u> Is it only the periods where the tripped GRF is not entitled for compensation?	No. The compensation would not be constrained to only the tripped GRF, but instead, to all GRFs in that dispatch period. A dispatch period that is marked by any tripped GRF that was scheduled to provide more than 10MW of energy would be considered as a dispatch period with a forced outage. As discussed in the paper, this exclusion is because the increase in generators' actual energy output in these periods of forced outages may be due to reserve activation, rather than an over-provision of regulation.
	<u>Periods whereby GRFs whose market schedules are overridden by PSO will not be considered</u> There are no written instruction issued by PSO, therefore it is difficult to determine duration where PSO overrides a GRF's schedule.	Section 9.1.2.1 of Chapter 5 of the Market Rules states that a real-time dispatch schedule released by the EMC shall be deemed to be the dispatch instructions issued by the PSO for that GRF and dispatch period unless and until the PSO issues subsequent dispatch instructions to override this dispatch schedule. We understand that these dispatch instructions may be issued verbally. Therefore, this concern will be addressed should the RCP agree that a compensation regime should be introduced for the over-provision of regulation.

	Feedback	EMC's Response
Island Power	The proposed method of determining whether a genco has over-provided regulation only if TAEO fell outside of TEEOR is not equitable as it smears the effect of sharp response that a genco provides to ensure a stable system frequency. Moreover, the ramp response of AGC would have to be tested before a genco is certified capable of providing regulation. This rule out the possibility of non-linear ramping. Using the example provided in the paper, as long as the load drops below 145MW or goes above 185MW at any instant between T-1 and T, the genco concerned should be considered to have over-provided regulation.	As discussed in Sections 2 and 3 of this paper, both Forecast Demand and Actual System Demand are calculated on an average basis across the whole period (using sampling at fixed intervals within the period). Since the Regulation Required amount is directly derived from both terms, it should be taken as the average requirement across the whole period, **not** the maximum instantaneous value within the period.

5.2 Data submitted by stakeholders

Table 2: Summary of Selected GRFs with Excess Regulation

GRF	No. of Periods with Excess Regulation from 1st Jan to 30 June	Total Excess Regulation (in $)*	Regulation Payment Received (in $)**	% of Amount Payable to Regulation Paid Based on Scheduled Regulation
G1	2946	$477,111.71	$1,348,191.78	35.39%
G2	2175	$10,020.07	$37,895.53	26.44%
G3	1948	$126,784.83	$756,381.26	16.76%
G4	1831	$190,436.20	$854,375.30	22.29%
G5	632	$120,626.02	$736,085.80	16.39%
G6	324	$377,332.94	$120,207.94	33.73%
G7	324	$167,110.13	$465,702.96	35.88%
G8	200	$224,619.01	$583,920.43	38.47%
G9	938	$288,771.49	$1,198,007.99	24.10%
G10	1154	$211,872.01	$1,123,831.75	18.85%
Total	**-**	**$1,937,559.41**	**$7,460,760.18**	**25.97%**
Average (per GRF)	**-**	**$193,755.94**	**$746,076.02**	**25.97%**

*Total Excess Regulation = Excess Regulation (in MWh) x Regulation Price for period t
**Regulation Payment Received = Scheduled Regulation (in MWh) X Regulation Price for period t

A few generating companies returned with evidence that their GRFs have indeed provided excess regulation based on the proposed methodology described in sections 2 and 3. These are summarised in Table 2 above.

Results

The impact is significant in terms of regulation payment. Table 2 shows that the percentage of excess regulation payment to scheduled regulation payment for the corresponding dispatch period ranges from 16.39% to 38.47%.

On average, excess regulation payment amounted to 25.97% of scheduled regulation payments. If we assume this 25.97% ratio to apply to all other generators, this translates to about $5.71 million (25.97% of the $21.988 million in total regulation payments from 1st January 2009 to 30th June 2009) in excess regulation provision over the corresponding period.

Limitations

The data collated in Table 2 applies for the dispatch periods from 1st January 2009 to 30 June 2009. It includes all criteria described in section 3.2 of the paper, except for the “Non-linear ramping pattern” and the “AGC control range” criteria. It is currently hard to distinguish between “non-linear ramping patterns” and “linear ramping patterns” as this would require the “second-on-second” generation output data for each GRF. A suitable methodology to distinguish between these 2 ramping patterns would be established in the event that the RCP decides to proceed with introducing a compensation regime for excess regulation. Also, not all GRFs that are operating out of the AGC control range are excluded in the analysis.

In addition, as not all the generating companies submitted evidence during the feedback exercise, it is hard to ascertain if this data is a true reflection of the state of over-provision of regulation in the SWEM.

Given the above limitations, it is necessary to point out that the data above gives a rough estimation regulation over-provision in the SWEM and might be over-stated given that the “non-linear ramping” effect is not excluded from the data.

6. EMC’s Recommendations and Consideration by the RCP at the 46th RCP Meeting

Evidence submitted by the generating companies suggests that excess regulation provision is indeed a cause for concern in the SWEM. The estimated excess regulation payment amounts are rather significant relative to existing scheduled regulation payments. Nevertheless, it must be noted that these are merely estimates.

Given the evidence above, at the 46th RCP Meeting, EMC requested that if the RCP decides that a compensation regime should be investigated, EMC would proceed with the following:

a) Conduct further analysis to determine if, as suggested by PSO, the shortfall through under-provision by some GRFs is compensated through over-provision by other GRFs. However, PSO would need to provide the system-wide Actual Online Generation recorded in the SCADA data by dispatch period required for this analysis.

b) Consider the results of the analysis followed by a recommendation on how to address concerns on provision of excess regulation.

Following discussion of the above methodology and evidence of excess regulation provision from an individual GRF’s perspective, the RCP requested further analysis to be conducted before deciding whether a compensation regime for the provision of excess regulation should be introduced, specifically:

(a) Evaluating whether there is over-provision of regulation across the whole market (i.e. whether the over-provision of regulation by some GRFs is matched by the under-provision by other GRFs).

(b) Select some periods for more detailed analysis to better understand the issue.

These requests, reflected in Sections 7 to 9 below, were presented at the 48th RCP Meeting.

7. Over-provision of Regulation on a System-wide Basis

This section presents the results of whether over-provision of regulation on a system-wide basis is significant.

The preliminary analysis discussed in Section 5 used data submitted by MPs, which offers an insight into the average excess regulation amounts that each generating unit provides. However, studying the regulation provision at a system-wide basis would provide a more holistic picture, by analysing if the over-provision of regulation by some GRFs is matched by the under-provision by other GRFs.

7.1 Methodology

Table 3 overleaf summarises the excess regulation data on a system-wide basis for the period of 1st January 2009 to 30 June 2009. The results are compiled using the methodology described in section 3, except for 2 differences as follows:

a. Measurement of TAEO (IEQ+Auxiliary Load) is replaced with system wide Actual Online Generation data, which is derived from SCADA, provided by PSO.

   Replacing IEQ+Auxiliary Load with system wide Actual Online Generation ensures that comparison between TAEO and TEEOR[8] are aligned, since both use data derived from SCADA.

b. The methodology is applied to the **system-wide generation** for each dispatch period, instead of each individual generating unit.

Given the above differences, a given dispatch period would be considered to demonstrate the existence of excess regulation if:

(Total System-wide Actual Online System Generation) ≥ (Total System-wide Expected Energy Output[9] + Total System-wide Scheduled Regulation Up[10]), or

(Total System-wide Actual Online System Generation) ≤ (Total System-wide Expected Energy Output – Total System-wide Scheduled Regulation Down[11])

[8] TEEOR is determined from the system-wide total scheduled energy which is derived from VSTLF that uses inputs derived from SCADA
[9] This is calculated using the sum of scheduled energy of all generators (including non-frequency responsive generators) for a given dispatch period.
[10] This is calculated using the regulation requirement for each dispatch period as submitted by PSO.
[11] See footnote 9.

Table 3: Summary of System-Wide Excess Regulation Provision for 1st January 2009 to 30 June 2009

No.	Data Type	Excess Regulation Down	Excess Regulation Up	Total (Regulation Up and Regulation Down)
1	**No of Periods with Excess Regulation**	191	163	354
2	**Total Number of Periods with Outages that has excess regulation**	1	2	3
3	**No of Periods with Excess Regulation (excl. Outages)**	190	161	351
4	**Total Number of Dispatch Periods (excl. Periods with outages)**	8685	8685	8685
5	**System Wide Excess Regulation Periods (%)**	2.19%	1.85%	4.04%
6	**Average Excess Regulation Amount (in MW) as a % of Regulation Requirement**	34.87%	25.52%	30.83%
7	**Total Regulation Payments**			$21,988,000.00
8	**Total Excess Regulation Compensation**	$127,860.00	$63,930.00	$195,139.41
9	**Total Excess Regulation Compensation (as a % of Total Regulation Payments)**	0.60%	0.29%	0.89%

7.2 Results

Table 3 presents system-wide excess regulation in terms of both Regulation Down and Regulation Up pulses, with the combined effects of both in the last column.

There were a total of 351 dispatch periods (excl. periods with outages) with excess regulation provision on a system-wide basis, with marginally more excess Regulation Down instances (190 periods) compared to Regulation Up instances (161 periods). Relative to the total number of dispatch periods, the number of periods whereby excess regulation was provided at a system-wide level was small at only 4.04%.

Among cases where there is excess regulation at a system-wide level, the amount of excess regulation is quite significant at 30.83%. This percentage is more pronounced for Regulation Down instances at 34.87%, as compared to Regulation Up instances at 25.52%. These high percentages were because of the 351 excess regulation dispatch periods, 53 periods (or 15%) had excess regulation amounts of more than 50MW.

However the total excess regulation amounts (Regulation Up and Regulation Down) in dollar terms was $195,139.41 over a six month period, which represented a small percentage (only 0.89%) of the total regulation payments.

8. Analysis of Regulation Provision in Selected Periods

This section analyses in detail the excess regulation provision at the individual GRF level for selected periods in April 2009.

8.1 Methodology

Table 4 summarises the regulation provision patterns of GRFs for 3 dispatch periods for the month of April 2009. The same methodology discussed in Section 3 was applied to data on these individual GRFs, except for TAEO which now uses actual online generation data of individual GRFs as submitted by PSO.

The 3 periods were selected to reflect the following characteristics:

1. Excess Regulation Up Provision on a System-Wide Basis (18 April 2009 Period 46)
2. Excess Regulation Down Provision on a System-Wide Basis (23 April 2009 Period 1)
3. No Excess Regulation Provision on a System-wide Basis (28 April 2009 Period 16)

A comprehensive regulation provision pattern breakdown of each GRF with its respective scheduled generation, scheduled regulation and actual generation based on SCADA data for these 3 dispatch periods is provided in Annex 2.

8.2 Discussion

Table 4: Summary of Regulation Provision Patterns for GRFs

Dispatch Period	System-wide Excess Regulation*	GRFs Scheduled For Regulation with Excess Regulation Up		GRFs Scheduled For Regulation with Excess Regulation Down		No of GRFs Not Scheduled For Regulation with Excess Regulation Up		No of GRFs Not Scheduled For Regulation with Excess Regulation Down	
		No. of GRFs	Total MW	No. of GRFs	Total MW	No. of GRFs	Total MW	No. of GRFs	Total MW
18 April 2009 Period 46	Excess Regulation Up = 48.21 MW	12	31.56 MW	0	0 MW	7	32.27 MW	2	5.87 MW
23 April 2009 Period 1	Excess Regulation Down = 71.68 MW	0	0 MW	12	73.24 MW	7	18.7 MW	0	0 MW
28 April 2009 Period 16	Excess Regulation = 0 MW	5	37.32 MW	6	34.41 MW	6	33.88 MW	3	10.69 MW

* Based on System-wide Excess Regulation Data

The results in Table 4 reflect the following trends:

a) Individual GRF may respond in opposite direction to system-wide regulation pulses

Based on system-wide regulation provision data as reflected in the second column of Table 4, Period 46 on 18 April 2009 showed a system-wide excess regulation up of 48.21 MW. This implies that all GRFs providing regulation should be pulsing up but there were 2 GRFs which effectively pulsed down for a total of 5.87MW.

Similarly, in Period 1 on 23 April 2009, there was a system-wide excess regulation down pulses of 71.68MW, but 7 GRFs were observed to have provided excess regulation through regulation up instead.

As such, when individual GRFs move in the opposite direction to the system-wide regulation response, this would increase the excess regulation burden on other GRFs.

b) Individual GRFs may provide excess regulation, even when there is no excess regulation at the system-wide level

In Period 16 on 28 April 2009, while there was no excess regulation provision on a system-wide level, some individual GRFs were providing excess regulation up/down which effectively off-set each other.

9. Introducing a Regulation Effectiveness Factor

The results discussed in Section 7 showed that excess regulation provision on a system-wide basis was insignificant in both cases of occurrence and monetary impact. There is therefore no strong justification to provide compensation to regulation providers, since the net regulation amount is generally within that already paid for by users of the regulation service.

However, the results in Section 5.2 indicate that even when there is no significant excess regulation provision at the system-wide level, there could be significant excess regulation provision by individual GRFs. The results in Section 8 reinforce this observation. This could stem from the responsiveness of GRFs to regulation needs and, in certain cases, even responding in the opposite direction. Thus, there is a case to consider addressing this issue by adjusting existing regulation payments to GRFs based on their responsiveness in providing regulation.

Methodology

Table 5 below shows an example of regulation payments to 4 GRFs for a given dispatch period under both the existing regulation payment methodology and the proposed methodology using a Regulation Effectiveness Factor (REF).

Under this proposed methodology, the total amount of regulation payments is fixed. However, each GRF is now assigned an REF to calculate their respective adjusted regulation quantities. The adjustment to the regulation quantity effectively redistributes the total regulation payment amount and determines the regulation payment amount that each GRF receives. This determination is done using the ratio of the individual GRF’s adjusted quantity to the sum of adjusted quantities, in determining its share of total regulation payments for a given dispatch period. GRFs with higher REFs relative to other GRFs would receive a higher share of regulation payments as these GRFs would have higher effective quantities.

Table 5: Comparison of existing regulation payment methodologies with regulation payment methodology using REF

Regulation Price = $40/MWh Regulation Requirement = 36MWh (or 72MW)						
Regulation Provision Effectiveness	**GRF**	**Scheduled Regulation (in MWh)**	**Regulation Payment Methodology without REF (existing methodology)**	**Regulation Payment Methodology with REF**		
			Payment Amount	**REF**	**Adjusted Quantity**	**Payment Amount**
↑ Highest	G1	12	12MWh x $40/MWh = $480	1	12	(12/30) x $1440 = $576
	G2	10	10MWh x $40/MWh = $400	0.9	9	(9/30) x $1440 = $432
	G3	8	8MWh x $40/MWh = $320	0.75	6	(6/30) x $1440 = $288
Lowest	G4	6	6MWh x $40/MWh = $240	0. 5	3	(3/30) x $1440 = $144
Total	**-**	**36 MWh**	**$1440**		**30 MWh**	**$1440**

<u>Discussion</u>

As reflected in Table 5, the existing regulation payment methodology in the SWEM does not distinguish across GRFs, whereby all GRFs receive regulation payments based on the full amount of their scheduled quantities regardless of their respective regulation responsiveness. The proposed regulation payment methodology, on the other hand, stratifies all GRFs based on their responsiveness to regulation needs using the REF.

Table 5 shows that G1, which is assigned an REF of 1, is considered the most effective GRF. Under this proposed methodology, G1 would be paid $576, which is about 20% higher than the amount it would have been paid under the existing methodology. On the other hand, the most ineffective GRF, G4, would only receive about 60% of the regulation payment amount it would have received under the existing regulation payment methodology ($144 instead of $240).

As such, this proposed payment methodology rewards GRFs that are more responsive in providing regulation, and conversely penalises less responsive GRFs. This payment methodology is fairer, by ensuring that more responsive GRFs are incentivised to be more responsive in providing regulation.

The Regulation Effectiveness Factor for a given GRF can be determined in two ways:

a. Determined by PSO based on PSO's **technical assessment** of each individual GRF's effectiveness

Currently, the reserve market adopts a similar payment methodology. Prior to participation in the market, any GRF that intends to provide reserve is required to undergo a technical assessment conducted by PSO to determine its effectiveness in providing reserve during an actual disturbance event. This GRF (and loads providing reserve) is then assigned a reserve provider group, with a corresponding reserve effectiveness factor, which in turn determines the amount of reserve that each GRF would effectively be scheduled and paid for reserve provision.

Similarly, PSO can assess if it is able to determine an REF for each GRF, whereby GRFs which are more responsive in providing regulation are assigned a higher effectiveness factor. These GRFs would in turn receive a higher share of regulation payment of a dispatch period as reflected in the example in Table 5. However, undertaking this proposal would require PSO to first verify if it is viable for PSO to determine the effectiveness of each GRF's regulation provision using technical test procedures and assign these GRFs into different regulation provider groups.

b. Introduce Regulation Effectiveness Factors that would apply across all GRFs which offer regulation based on a **historical assessment** of each individual GRF's regulation provision pattern

An alternative to the technical assessment approach described above would be to record each GRF's 1-year historical regulation provision patterns. The results gathered from this historical assessment would thereafter be used to determine a unique Regulation Effectiveness Factor for each GRF to be applied in the subsequent year. Similarly, GRFs with higher Regulation Effectiveness Factor would receive a higher share of regulation payments of a dispatch period.

These two methods are possible approaches to determine the REF, and its detailed methodology/implementation and/or other approaches could be discussed in further detail should the RCP decide to introduce the REF into the SWEM.

10. EMC's Recommendations and Consideration by the RCP at the 48th RCP Meeting

EMC presented the analysis reflected in Sections 7 to 9 above at the 48th RCP meeting and recommended that the RCP:

a. **do not implement** a compensation regime for regulation over-provision; and

b. decide on whether to **consider a Regulation Effectiveness Factor approach** into the SWEM

The RCP, having considered the analyses presented, agreed to support EMC's recommendation not to implement a compensation regime for regulation over-provision, but to consider whether to introduce a Regulation Effectiveness Factor approach into the SWEM.

The RCP then requested for the following information:

a. Compute the proposed Regulation Effectiveness Factor (REF) for Generation Registered Facilities (GRFs) using Gross Metering data for 2009 provided by SP Services.

b. Evaluate the cost and effort required in monitoring system-wide excess regulation provision data and computing REF

Sections 11 to 13 below were presented at the 49th RCP arising from the RCP's request above.

11. Proposed Determination of Regulation Effectiveness Factor

As discussed in Section 9, significant excess regulation could occur at the individual GRFs' level, even when there is none at the system-wide level. As such, EMC recommended that existing regulation payments to GRFs be adjusted based on these GRFs' responsiveness in providing regulation using an REF at the 48th RCP Meeting.

At that meeting, EMC suggested that the REF for a given GRF can be determined in two ways (Refer to Section 9):

a. Determined by PSO based on PSO's **technical assessment** of each individual GRF's effectiveness

b. Introduce Regulation Effectiveness Factors that would apply across all GRFs which offer regulation based on a **historical assessment** of each individual GRF's regulation provision pattern

Section 11.1 describes how the REF for each GRF is determined using method (b), followed by a summary of the results under this methodology in Section 11.2. Section 11.3 indicates the costs and effort involved in computing this set of data.

It is important to note here that in using historical metering/SCADA data, we can only assess both actual regulation requirements and actual regulation provided by each GRF based on the total energy outputs measured in a dispatch period. It is impossible to assess the regulation requirements and the amount of regulation that each GRF is providing on a second-to-second basis.

11.1 Determination of REF that can be applied to regulation payments

This section details the objectives that the REF should meet, and a breakdown of its computation steps.

11.1.1 Objectives

The proposed payment regulation methodology as discussed in Section 9 requires that the proposed REF meets the objectives set out below. These would be taken into consideration when computing an average REF for a given GRF.

a. The REF of an individual GRF should reflect the relative effectiveness of that GRF in providing regulation compared to other GRFs.

   This objective implies that GRFs more effective in providing regulation, based on historical data, should be assigned higher REFs, as compared to less effective GRFs.

b. GRFs responding in a direction opposite to the system-wide regulation required should have a lower REF for that dispatch period

   In a historical assessment of regulation provision patterns of individual GRFs, it was found that an individual GRF may respond in an opposite direction to the system-wide regulation required for a given dispatch period. Such a GRF should be assigned a lower REF, as other GRFs would have to increase their regulation provision in the correct direction.

c. Final averaged REF computed for the purposes of regulation payments should not require GRFs to pay for regulation on an average basis should they fail to provide regulation in the same direction as that needed by system-wide actual regulation

The intent of a computing an REF for each GRF is to determine its relative effectiveness in contributing to actual system-wide regulation needs relative to other GRFs. As such, the computed averaged REF for a GRF should not be negative, which results in the GRF being required to pay for regulation instead of being paid for regulation.

11.1.2 Steps in computing a single average REF that would apply across dispatch periods for a given GRF

There are several steps required to compute a single average REF, as follows:

i. Compute an REF for each GRF for each dispatch period for one year using historical data that meets pre-determined criteria

ii. Transform each of these REFs computed in (i) using a Hyperbolic Tangent function

iii. For a given GRF, compute an average REF from transformed REFs across all dispatch periods in a given year

iv. Apply each GRF's averaged transformed REF to determine regulation payments in future dispatch periods

A detailed description and rationale for each step is described in the following paragraphs.

Step (i): Proposed REF Equation for a Dispatch Period

The REF equation, labeled Equation 1, is conceptualised for the purposes of calculating an REF for each GRF for each dispatch period. These REFs, applicable to each GRF, would then be transformed, and then averaged to yield a single REF for that GRF that would apply to regulation payments in future dispatch periods.

Equation 1:

$$\text{REF for a historical dispatch period} =$$

$$\underbrace{\left(\frac{\text{Actual Regulation}_{\text{GRF}}}{\text{Scheduled Regulation}_{\text{GRF}}}\right)}_{(a)} \times \underbrace{\left(\frac{\text{Scheduled Regulation}_{\text{System-wide}}}{\text{Actual Regulation}_{\text{System-wide}}}\right)}_{(b)} \times \max\underbrace{\left(1, \frac{\left|\text{Actual Regulation}_{\text{System-wide}}\right|}{\text{Scheduled Regulation}_{\text{System-wide}}}\right)}_{(c)}$$

where:

Actual $\text{Regulation}_{\text{GRF}}$
= Gross Metering Data_{GRF} – [½(Scheduled $\text{Energy}_{\text{GRF}}$)]

Actual $\text{Regulation}_{\text{System-wide}}$
= Total SCADA System-wide Actual Online System Generation $\text{Data}_{\text{System-wide}}$ – [½(Scheduled $\text{Energy}_{\text{System-wide}}$)]

Scheduled $\text{Regulation}_{\text{GRF}}$
= ½(Amount of regulation in MW as scheduled by the Market Clearing Engine for a given dispatch period)

Scheduled $\text{Regulation}_{\text{System-wide}}$

= ½(Amount of regulation in MW as determined by the PSO in MW for a given dispatch period)

The equation represented above can be split into 3 main components.

The first component, labeled (a), represents the ratio of the actual regulation provided by an individual GRF relative to its scheduled regulation.

Component (b) represents the ratio of scheduled regulation on a system-wide basis relative to the actual regulation required in the system.

Component (c) ensures that GRFs which provide regulation up to its scheduled regulation are not penalised in the event that actual system-wide regulation exceeds its total scheduled regulation amount.

These 3 components contribute to the value that REF takes on for a given dispatch period.

The equation above will be computed using one year's worth of historical gross metering data for each GRF (or regulation provider). However, dispatch periods with the following criteria will **not** be used in computing the REF:

a. Dispatch periods affected by forced outages(where any GRFs scheduled to provide more than 10MW of energy tripped or failed to start-up) will not be used to compute REFs for all GRFs

b. Dispatch periods in which a GRF is not scheduled for regulation will be excluded for computing REF for that given GRF

The worked example in Table 6 illustrates how these REFs can be computed using various scenarios.

A worked example of computing REF for a given GRF:

Table 6: Computed REFs based on various scenarios for a given GRF for a given dispatch period

Direction of system-wide regulation pulse	Scenarios	System-wide Scheduled Regulation (in MWh)	Actual System-wide Regulation (in MWh)	GRF's Scheduled Regulation (in MWh)	GRF's Actual Regulation (in MWh)	REF
Regulation Up	1	50	50	4	4	1
	2	50	50	4	8	2
	3	50	25	4	1	0.5
	4	50	50	4	- 8	-2
	5	50	100	4	12	3
Regulation Down	6	50	-50	4	4	-1
	7	50	-50	4	8	-2
	8	50	-25	4	-1	0.5
	9	50	-25	4	-8	4
	10	50	-100	4	4	-1

Table 6 above represents various scenarios that could occur in real-time in terms of both system-wide actual regulation required and the individual GRF's actual regulation provided in a dispatch period. The last column represents the computed REF based on these scenarios.

The scenarios are split into overall system-wide average Regulation Up and Regulation Down required, with each scenario attempting to capture specific characteristics as described below.

a) The GRF would receive an REF of 1 for a given dispatch period if the actual regulation provided at both system-wide level and GRF level exactly equal that of the corresponding scheduled regulation at both levels.

In Scenario 1, the GRF received an REF of 1 because its ratio of actual regulation to scheduled regulation equals the ratio of actual system-wide regulation to system-wide scheduled regulation, as computed below.

$$\text{REF for GRF}$$
$$= \left(\frac{\text{Actual Regulation}_{\text{GRF}}}{\text{Scheduled Regulation}_{\text{GRF}}} \right) \times \left(\frac{\text{Scheduled Regulation}_{\text{System-wide}}}{\text{Actual Regulation}_{\text{System-wide}}} \right) \times \max\left(1, \frac{\left|\text{Actual Regulation}_{\text{System-wide}}\right|}{\text{Scheduled Regulation}_{\text{System-wide}}} \right)$$
$$= \left(\frac{4\,\text{MWh}}{4\,\text{MWh}} \right) \times \left(\frac{50\,\text{MWh}}{50\,\text{MWh}} \right) \times 1$$
$$= 1$$

b) The GRF would receive a positive REF for a given dispatch period if the individual GRF's regulation provision is in the same direction as that of the system-wide actual regulation required and a negative REF for a given dispatch period if it regulation provision is in the opposite direction as that of the system-wide actual regulation required.

Under Scenario 6, although the GRF has provided an actual regulation amount of 4 MWh, which equal that of its scheduled regulation amount, its regulation provision was in the opposite direction to that of the system-wide actual regulation required of -50 MWh, as computed below.

$$\text{REF for GRF}$$
$$= \left(\frac{\text{Actual Regulation}_{\text{GRF}}}{\text{Scheduled Regulation}_{\text{GRF}}} \right) \times \left(\frac{\text{Scheduled Regulation}_{\text{System-wide}}}{\text{Actual Regulation}_{\text{System-wide}}} \right) \times \max\left(1, \frac{\left|\text{Actual Regulation}_{\text{System-wide}}\right|}{\text{Scheduled Regulation}_{\text{System-wide}}} \right)$$
$$= \left(\frac{4\,\text{MWh}}{4\,\text{MWh}} \right) \times \left(\frac{50\,\text{MWh}}{-50\,\text{MWh}} \right) \times 1$$
$$= -1$$

Scenarios 4 and 10 also reflect this characteristic. In Scenario 4, the GRF exacerbated this effect by providing regulation twice that of its scheduled amount in the opposite direction. As such, it is assigned an REF of -2. In Scenario 10, although the GRF responded in the wrong direction, it provided actual regulation of 4 MWh, which is equal to its scheduled amount. This implies that it contributed to less of the negative effect as compared to that under Scenario 4 and is assigned an REF of -1.

c) The GRF should receive a higher REF for a given dispatch period if its actual regulation amount exceeds its scheduled regulation amount and is responding in the same regulation direction as that of the system-wide actual regulation level.

Under Scenario 2, the GRF's actual regulation was double its scheduled amount and it responded in the same direction as that of the system-wide actual regulation required. As such, it is assigned an REF of 2. This allotment of a REF of more than 1 can also be seen in Scenarios 5 and 9.

d) Actual system-wide regulation required affects the REF assigned to a GRF for a given dispatch period

Under Scenario 9, although the GRF's actual regulation was double that of its scheduled amount, it received a higher Raw REF of 4 instead of 2 as is the case under Scenario 2.

This is because in Scenario 9, the actual system-wide regulation required, at 25 MWh (in the regulation down direction), is half that of the scheduled system-wide regulation of 50 MWh. This situation implies that the GRF contributed to about 32% (8MWh out of 25MWh required) of the actual regulation required in the system, as compared to 16% (8MWh out of 50MWh required) under Scenario 2, and should therefore be paid more.

<u>Step (ii): Transformation of REF for each dispatch period using the Hyperbolic Tangent function</u>

The REF equation described above meets objectives (a) and (b) described in section 11.1.1, where the difference in regulation contribution of a GRF is reflected in the different REF values across various dispatch periods.

However, it does not meet objective (c) as the GRF can be assigned negative REF values under certain circumstances. If these negative REF values are used for regulation payments to GRFs, GRFs with average negative REFs will have to pay for providing regulation. The proposed REF scheme is intended to reward more responsive GRFs and not cause less responsive GRFs to pay for regulation.

In addition, arising from the proposed REF equation, a infinitely small value of "Scheduled $\text{Regulation}_{\text{GRF}}$" and "Actual $\text{Regulation}_{\text{System-wide}}$" would result in a relatively large REF value. This mathematical effect may lead to instances with large extreme values, which may skew average REF values.

Due to these limitations, we propose that the REF value of a given GRF for each dispatch period for one year be transformed using a Hyperbolic Tangent function (see Annex 3), as represented by the equation below.

Equation 2:

$$\text{Transformed REF for a historical dispatch period} =$$
$$0.5 \text{ x Tanh}\left[\left(\frac{\text{Actual Regulation}_{\text{GRF}}}{\text{Scheduled Regulation}_{\text{GRF}}}\right) \times \left(\frac{\text{Scheduled Regulation}_{\text{System-wide}}}{\text{Actual Regulation}_{\text{System-wide}}}\right) \times \max\left(1, \frac{\left|\text{Actual Regulation}_{\text{System-wide}}\right|}{\text{Scheduled Regulation}_{\text{System-wide}}}\right)\right]$$
$$+ 0.5$$

This function would eliminate these limitations, but at the same time, retain the relative effectiveness between GRFs in providing regulation. All transformed REF values would also take on values of between 0 and 1.

<u>Step (iii) Computing an average REF that would apply to regulation payment for a given GRF in future dispatch periods</u>

This step involves computing a single REF for a given GRF through averaging the transformed REFs, derived using Equation 2 above, relevant to the given GRF for one year.

This implies there will be 30 averaged transformed REF values if there are 30 GRFs that provide regulation in the market.

<u>Step (iv) Apply this averaged transformed REF to regulation payment to a GRF</u>

Each GRF that provides regulation would be assigned a single average transformed REF based on the computations reflected in Steps (i) to (iii).

This single average transformed value is thereafter applied using the steps described in Section 9 to reallocate regulations payments to all GRFs scheduled for regulation for a given dispatch period.

11.2 Summary of Results using 2009 Gross Metering Data

Table 7: Summary of Averaged Transformed REF of GRFs that provided regulation in 2009

GRF	Effective REF Periods	Average REF before transformation	Max REF before transformation	Min REF before transformation	Averaged Transformed REF[12]
1	30	-22.747	424.778	-671.183	**0.459**
2	16359	0.0176	4348.971	-12825.81	0.579
3	15998	-0.820	2616.740	-9435.372	0.519
4	15843	-1.869	39.179	-27.688	**0.248**
5	15783	-9.383	70.006	-99.033	**0.212**
6	14312	1.798767541	6529.693	-2933.231	0.591
7	15006	2.193	7695.486	-5260.019	0.596
8	13211	3.577	20751.223	-2900.676	0.606
9	11966	-0.508	16590.257	-40899.991	0.517
10	12191	1.664	4974.960	-884.288	0.589
11	3083	0.943	565.78808	-628	0.628
12	4977	0.662	727.594	-4795.122	0.658
13	4992	6.332	18034.762	-877.164	0.674
14	7457	2.258	8084.315	-1217.626	0.568
15	14223	0.879	20798.824	-3743.460	0.522
16	16284	-0.236	5887.036	-3842.358	0.530
17	5434	0.103	340.235	-863.283	0.528
18	2778	-0.813	601.116	-913.737	**0.479**
19	10620	10.113	73315.20	-2465.845	0.544
20	14575	6.054	19133.52	-2017.162	0.552
21	16213	4.100	26845.5	-14546.667	0.596
22	2897	0.544	1574.553	-438.413	0.534
23	2380	-0.017	347.520	-354.188	0.548
24	11302	12.676	124833.082	-16326.975	0.590
25	1899	-1.464	2358.768	-6951.621	0.577

Table 7 above shows a summary of the averaged transformed REFs of each GRF that provided regulation in 2009. The second column documents the number of effective dispatch periods that qualify for REF computation (i.e. excludes periods whereby the GRF was not scheduled for regulation and excludes periods affected by outages of GRFs scheduled for more than 10 MW of Energy).

The third column, "Average REF", is computed using the sum of REFs before applying the transformation and averaged across the effective dispatch periods. This set of data would not be applied in regulation payments, but merely used as a form of comparison with the transformed data reflected in the last column. It can be seen that these values take on a large range of between -22.747 to 12.676, possibly due to the extreme values in some dispatch

[12] The maximum Transformed REF and minimum Transformed REF are 1 and 0 respectively for all GRFs.

periods. For example, the high REF value of 12.676 under G24 can be attributed to the large "Maximum REF before Transformation" of 124,833.082, as seen in the fifth column.

The large range of REF values give rise to complexity in conceptualising a fair regulation payment system with some GRFs receiving a significant sum of regulation payments, while other GRFs with negative REFs having to pay to provide regulation. As discussed under Step (ii) in Section 11.1.2, these issues can be addressed using a "Hyperbolic Tangent" transformation function.

The last column reports this averaged transformed REF that would be applied to regulation payments to GRFs, whereby all REFs fall between the range of 0.212 and 0.674. Although G5 previously had an REF of -9.838, it can be seen that following transformation, its REF value is revised to 0.212. These averaged transformed REF values show that most GRFs are generally effective in providing regulation, with most taking on an REF of between 0.5 to 0.7, with only G1,G4, G5 and G18 falling below 0.5.

11.3 Proposed timeline for revision of averaged transformed REF value for a given GRF

A consideration when implementing the proposed REF is the length of applicability for an REF for a given GRF that provides regulation.

A single average transformed REF could be recalculated for each dispatch period for a given GRF and revised accordingly on a rolling-basis, whereby this half-hourly revised REF would be applied to regulation payment for that given dispatch period. This would capture changes in regulation capability of the GRF in each dispatch period. However, revising the REF on an half-hourly basis would require substantial systems modifications and costs. Also, given that a year's worth of data would be used to compute this value, the single average transformed REF should not vary significantly between one dispatch period and the next.

As such, we are proposing that the single averaged transformed REF be applicable and revised for a given GRF **every 6 months**. This value will be used to compute regulation payments to that GRF for every dispatch period that it provides regulation for the next six months, using the methodology described in Section 9. This method of revision will also ensure a balance between reflecting changes to the GRF's regulation provision capability with cost considerations.

11.4 Effort and Cost Required in Computation of Proposed REF

Table 8 shows a breakdown of effort and cost required from the various parties involved in the computation using the REF methodology discussed in the sections above. The summary below only includes effort required in a manual computation of the REF for all GRFs that have provided regulation in 2009. A detailed study on the implementation costs and system changes required would be done in the event that the RCP decides to implement the proposed REF methodology.

Table 8: Effort and Cost required in Computation of Proposed REF

Relevant Party	Data Required	Tasks	Effort Required	Cost $
EMC	• Scheduled Energy and Regulation by Generation Unit	1. Collection of data	5 business days	**6750**[13]
		2. Computation of gathered data	4 business days	

[13] Based on $750 per day

Relevant Party	Data Required	Tasks	Effort Required	Cost $
SP Services	• Gross Metering data by Generation Unit	1. Submit individual GRF's Gross Metering Data every 6 months	27 Man-days	One-time IT development cost **$32,000**
				Cost per batch run/report **$2000**
PSO	• System-wide Actual Online Generation	No information was received from PSO		
		Total	**One time Cost** **Recurring Cost**	**$32000** **$8750**

12. System-wide Excess Regulation

At the 48th RCP meeting, EMC presented a summary of system-wide excess regulation for the period of January 2009 to June 2009, including the total excess regulation amount (in both MW and dollar-terms). The RCP then requested that EMC evaluate the cost and effort involved in reporting this set of data on an on-going basis to the RCP.

This section presents a system-wide excess regulation amounts as well as a breakdown of costs and effort involved in computing this set of data on an on-going basis.

12.1 System-wide Excess Regulation Amount

Table 9 below presents a summary of system-wide excess regulation provision for the periods between 1st July 2009 to 31 December 2009.

Table 9: Summary of System-Wide Excess Regulation Provision for 1st July 2009 to 31 December 2009

No.	Data Type	Excess Regulation Up	Excess Regulation Down	Total (Regulation Up and Regulation Down)
1	No of Periods with Excess Regulation	517 (191)	96 (163)	613 (354)
2	Total Number of Periods with Outages that has excess regulation	1 (1)	2 (2)	3 (3)
3	No of Periods with Excess Regulation (excl. Outages)	516 (190)	94 (161)	610 (351)
4	Total Number of Dispatch Periods (excl. Periods with outages)	8784 (8685)		
5	System Wide Excess Regulation Periods	5.88% (2.19%)	1.09% (1.85%)	6.98% (4.04%)

	(%)			
6	Average Excess Regulation Amount (in MW) as a % of Regulation Requirement	19.21% (34.87%)	5.71% (25.52%)	16.33% (30.83%)
7	Total Regulation Payments	$38,770,862.04 ($21,988,000)		
8	Total Excess Regulation Compensation	$581,546.37 ($127,860.00)	$22,715.17 ($63,930.00)	$604,261.54 ($195,139.41)
9	Total Excess Regulation Compensation (as a % of Total Regulation Payments)	1.5% (0.6%)	0.06% (0.29%)	1.56% (0.89%)

Note: Figures in brackets reflet corresponding figures for 1st January 2009 to 30 June 2009

There were a total of 613 dispatch periods (excl. periods with outages) with excess regulation provision on a system-wide basis, with more excess Regulation Up instances (516 periods) compared to Regulation Down instances (94 periods). Relative to the total number of dispatch periods, the number of periods whereby excess regulation was provided at a system-wide level was small at only 6.98%.

The total excess regulation amounts (Regulation Up and Regulation Down) in dollar terms totalled $604,261.54 over a six month period, translating to 1.56% of total regulation payments.

12.2 Effort and Cost required to Monitor System-wide Excess Regulation Provision

Table 10 summarises the effort required to monitor system-wide excess regulation provision and present it in the format as reflected in Table 9. It would be included as part of the "Monitoring List" if the RCP decides to go ahead with examining this set of data on an on-going basis.

Table 10: Effort and Cost Required to Monitor System-wide Excess Regulation Provision on an on-going basis.

Relevant Party	Data Required	Tasks	Effort Required	Recurring Cost $
EMC	• Total scheduled energy • Total scheduled regulation	1. Collection of data	5 business days	6000[14]
		2. Computation of gathered data	3 business days	
PSO	• Total Actual System-wide Online Generation	No information was received from PSO		

13. EMC's Recommendation and Consideration by the RCP at the 49th RCP Meeting

[14] Based on $750 per day.

EMC presented sections 11 to 13 to the RCP at the 49th RCP Meeting and recommended that the RCP:

a. Consider if the proposed REF methodology should be introduced into the Singapore Wholesale Electricity Market (SWEM)

b. Decide if data on System-wide Excess Regulation Provision should be monitored on an on-going basis

At the 49th RCP Meeting, the Panel noted that the proposed REF methodology using historical metered data is one of the many methods that could be applied to compute the effectiveness of regulation provision.

The decision of whether to continue refining the proposed REF methodology was thereafter put to a vote.

The following VOTED to continue with the approach:

Mr. Dallon Kay, representative of the trader class of market participant
Mr. Philip Tan, representative of generation licencee
Mr. Luke Peacocke, representative of generation licencee
Mr. Daniel Lee, representative of generation licencee
Dr. Goh Bee Hua, representative of consumers of electricity in Singapore

The following VOTED NOT to continue with the approach:

Mr. Kenneth Lim, representative of EMC
Mr. Lawrence Lee, representative of market support services licencee
Mr. Chan Hung Kwan, representative of transmission licencee
Mr. Michael Lim, representative of consumers of electricity in Singapore
Mr. Robin Langdale, person experienced in financial matters in Singapore

Given the equal number of votes, the Panel requested the PSO to provide information on how the Automatic Generation Control (AGC) works in relation to regulation to better understand the situation before the Panel decides whether to pursue the REF method further.

The Panel also agreed that system-wide excess regulation should be monitored every 6 months. The computation of this data would require PSO to submit "System-wide Actual Online Generation" data to EMC every 6 months to facilitate this computation.

14. Deliberation by the RCP at the 50th RCP Meeting

This section discusses 2 issues, namely, on excess regulation provision and on the monitoring of system-wide excess regulation.

14.1 Discussion and Decision on Excess Regulation Provision

At the 50th RCP, arising from the RCP's decisions discussed in section 13, the RCP requested for the following from the PSO:

1. Whether PSO could determine the regulation effectiveness of a GRF from a technical perspective
2. For PSO to provide information on how AGC works in relation to regulation provision
3. For PSO to submit "System-wide Actual Online Generation" data to EMC every six months to monitor system-wide excess regulation.

This section summarises the RCP's discussion and decision in response to the above issues.

In response to (1) above, Mr Kng, the PSO representative on the RCP, conveyed that a generator's output at a given point in time is influenced by both primary and secondary control systems. He elaborated that the primary system refers to a GRF's governor response to frequency changes. The secondary system, on the other hand, refers to AGC commands sent out by the PSO as well as the generator's internal control system. These commands depend on prevailing system conditions and plant conditions. As such, it is difficult to apportion the GRF's output according to each of these controls with reasonable accuracy. Also, these data reside with the generators and not the PSO. Therefore, he concluded that it was not possible for PSO to undertake a technical assessment on the regulation effectiveness of a GRF.

In response to (2) above, Mr Kng pointed out that the GRF's primary control typically reacts first while AGC only kicks in after it measures the system frequency and calculates the output required (in MW terms) to bring system frequency deviations back to acceptable levels. Total output required is then allocated to all GRFs that are participating in regulation provision. However, AGC aims to make corrections over time and not instantly. He added that the concept of AGC is rather complex.

In response to Mr Philip Tan's enquiry on methods to identify generators that are unresponsive to regulation, Mr Kng communicated that the PSO conducts regular checks on whether GRFs are responding to regulation, failing which the PSO could request that these units ceases offering regulation. He added that this practice is in line with the Market Rules, which states that the PSO may request for GRFs to modify its offers if these units do not comply with dispatch instructions.

Mr Philip Tan reiterated that the proposed REF methodology using historical data is one of the many approaches that can be adopted when measuring a GRF's regulation provision effectiveness. As further refinements would need to be made if the RCP decides to continue with this proposed methodology, it could result in returning to the conceptualisation stage and repeating the entire exercise.

The RCP, having considered discussions thus far, concluded on the following:

1. There are already regular checks by the PSO on whether GRFs respond to regulation provision based on dispatch instructions, which ensures that GRFs can effectively provide regulation when called upon.

2. It is not possible for PSO to conduct a technical assessment of a GRF's regulation effectiveness.

3. Given that it is not possible to use the technical assessment approach, further refinements would have to be made to the proposed REF methodology using historical data. The RCP recognises that this is one of the many approaches to determine REF and it is hard to assess the accuracy of the methodology.

Given the above considerations, the RCP unanimously agreed **not to pursue** refining the proposed REF methodology.

14.2 Discussion and Decision on the Monitoring of System-wide Excess Regulation

At the 49th RCP Meeting, the RCP agreed for system-wide excess regulation to be monitored every 6 months, which would require PSO to submit "System-wide Actual Online Generation" data to EMC every 6 months to facilitate this computation.

At the 50th RCP Meeting, Mr Kng declined to provide the requested data for the purposes of monitoring system-wide excess regulation, on grounds that it would increase cost. In addition, Mr Kng added that the PSO's functions and obligations under Chapter 1, Section 5.1 of the

Market Rules do not include provision of information on a regular basis to either EMC's Market Administration Team or the RCP. He was of view that monitoring of the market is under the purview of the MSCP and the PSO will provide data on "System-wide Actual Online Generation" if the MSCP includes it as part of its catalogue of data.

Annex 1: Regulation Requirement Determination in Other Jurisdictions

	Market Operator	Duration of Trading Period	Name of Regulation-Related Product(s)	Requirement determined every:	Methodology Used to Determine Regulation Requirement
1	Australian Energy Market Operator (AEMO)	5 Minutes	Regulating Raise Service	5 minutes	For regions outside of Tasmania: FCAS dispatch constraints will set regulation to 130MW raise if the time error* is within the + 1.5 second band. If the time error is outside this band then an extra 60MW of regulation per 1 second deviation outside the band will be added with an upper limit of 250MW. **Dispatch raise requirement** **= Min (250MW,130MW + (-1 x Min(-1.5 seconds, Time Error) – 1.5) x 60)** Tasmania: 50 MW *Time error measures the frequency deviation from the system standard frequency of 50Hz. It is calculated using the difference in the time between a clock measuring the power system frequency (i.e it will speed up or slow down dependent on the power systems deviation from 50Hz) and another clock which is driven independently.
			Regulation Lower Service		For regions outside of Tasmania: FCAS dispatch constraints will set regulation to 120MW if the time error is within the - 1.5 second band. If

	Market Operator	Duration of Trading Period	Name of Regulation-Related Product(s)	Requirement determined every:	Methodology Used to Determine Regulation Requirement
					the time error is outside this band then an extra 60MW of regulation per 1 second deviation outside the band will be added with an upper limit of 250MW. **Dispatch lower requirement = Min (250,120 + (Max(1.5, Time Error) – 1.5) x 60)** Tasmania: 50 MW
2	California Electricity Market	Hourly	Regulation Up		The system operator sets its regulation requirement as a percentage of the CAISO Forecast of CAISO Demand for the hour based on its need to meet the regional (WECC) and national (NERC) reliability performance standards. There is no specific definition on how this percentage is set, but it depends on various factors that affect demand in the day. There is a cap for this service.
			Regulation Down		Same as above except that there is no regulation requirement floor.
3	Pennsylvania Jersey Maryland (PJM) Interconnection	5 Minutes	Regulation	Hour	On-peak (0500-2359): 1% of forecast peak load for the day Off-Peak (0000-0459): 1% of forecast valley load for the day PJM Interconnection may adjust the requirement percentage provided that it is consistent with the

	Market Operator	Duration of Trading Period	Name of Regulation-Related Product(s)	Requirement determined every:	Methodology Used to Determine Regulation Requirement
					maintenance of the NERC control standards.
4	Independent System Operator-New England (ISO-NE)	Hourly	Regulation and Frequency Response Service	Hour	The Regulation Requirement is determined based on historical control performance using data on month, day-type and hour. The requirement is selected by the ISO to meet ISO, NERC and NPCC control standards. It may be adjusted by the ISO to ensure continued compliance with these standards. During Emergency Conditions, the ISO may deviate from the Regulation Requirement to maintain system reliability.

Annex 2: Selected Periods of Individual GRFs' Excess Regulation Provision

GRF	18 April 2009 Period 46					23 April 2009 Period 1					28 April 2009 Period 16				
	Excess Regulation Up = 48.21 MW (Based on system-wide excess regulation data)					Excess Regulation Down = 71.68 MW (Based on system-wide excess regulation data)					Excess Regulation = 0 MW (Based on system-wide excess regulation data)				
	Average Scheduled Energy	Scheduled Reg.	Actual Generation (SCADA)	Excess Reg. Up	Excess Reg. Down	Average Scheduled Energy	Scheduled Reg.	Actual Generation (SCADA)	Excess Reg. Up	Excess Reg. Down	Average Scheduled Energy	Scheduled Reg.	Actual Generation (SCADA)	Excess Reg. Up	Excess Reg. Down
G1	20.00	0.00	21.79	1.79		0	0	0			107.5	0	99.07		8.43
G2	20.00	0.00	21.68	1.68		0	0	0			150	0	158.55	8.55	
G3	252.50	10.00	268.19	5.69		273.5	10	260.09		3.41	259.5	10	252.74	0	0
G4	257.50	9.00	266.79	0.29		273.5	9	253.67		10.83	261	9	254.13	0	0
G5	329.51	6.00	337.46	1.96		300	8	287.73		4.27	305	6	296.85		2.15
G6	328.00	6.00	335.73	1.73		270	0	272.39	2.39		305	6	296.61		2.39
G7	217.11	5.78	225.42	2.53		208.22	6	198.12		4.10	106.5	0	114.61	8.11	
G8	0.00	0.00	0.00	0.00		221	3.99	210.34		6.67	187.5	5	181.96		0.54
G9	0.00	0.00	0.00	0.00		0	0	0	0	0	0	0	0	0	0
G10	0	0	0	0.00		0	0	0	0	0	0	0	0	0	0
G11	0	0	0	0	0	170	4	161.13		4.87	145	3.87	158.70	9.83	
G12	130.18	0	125.46	0.00	4.72	0	0	0	0		150	3	150.83	0	0
G13	200	5	207.90	2.89		170	5	159.59		5.41	127.5	3	124.24		0.26
G14	0	0	0	0		0	0	0	0	0	0	0	0	0	0
G15	130	0	129.75	0.00		139	0	142.88	3.88		131	0	130.25		
G16	165	0	170.014	5.01		139	0	140.99	1.99		131	0	129.33		1.67
G18	330	5	334.52	0.00		275	8	270.41	0	0	265	7	273.75	1.75	
G19	330	10	341.26	1.26		277.5	8	265.58		3.92	265	7	278.06	6.06	
G20	330.00	10	341.99	1.99		277.50	9	267.94		0.56	265.00	8	280.85	7.85	

Annex 2: cont.

GRF	18 April 2009 Period 46					23 April 2009 Period 1					28 April 2009 Period 16				
	Excess Regulation Up = 48.21 MW (Based on system-wide excess regulation data)					Excess Regulation Down = 71.68 MW (Based on system-wide excess regulation data)					Excess Regulation = 0 MW (Based on system-wide excess regulation data)				
	Average Scheduled Energy	Schedule d Reg.	Actual Generation (SCADA)	Excess Reg. Up	Excess Reg. Down	Average Scheduled Energy	Scheduled Reg.	Actual Generation (SCADA)	Excess Reg. Up	Excess Reg. Down	Average Scheduled Energy	Scheduled Reg.	Actual Generation (SCADA)	Excess Reg. Up	Excess Reg. Down
G21	0	0	0	0		0	0	0	0	0	0	0	0	0	0
G22	0	0	0	0		0	0	0	0	0	0	0	0	0	0
G23	0	0	0	0			0		0	0		0	0	0	0
G24	0	0	0	0		0	0	0	0	0		0	0	0	0
G25	0	0	0	0		0	0	0	0	0	30	0	36.33	6.33	
G26	0	0	0	0		0	0	0	0	0	0	0	0	0	0
G27	0	0	0	0		0	0	0	0	0	0	0	0	0	0
G28	300	11	314.06	3.06		310	9	292.88	0	8.12	320.43	8	300.73		11.69
G29	300.00	0.00	316.03	16.03		320	9	302.017	0	8.9831	320.18	8	340	11.82	0
G30	310	11	318.08	0.00		313.944	9	306.40	0.0	0.00	329.90	5	329.28	0.00	0.00
G31	301.21	2	307.69	4.47		315.2305	2	301.40		11.83	330.95	1	312.57	0.00	17.38
G32	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0	0	0	0	0
G33	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0	0	0	0	0
G34	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0	0	0	0	0
G35	30	0.00	31.38	1.38	0.00	22	0	24.50	2.50	0	32	0.00	35.87	3.8686	0
G36	18.00	0.00	22.43	4.43	0.00	10	0	13.44	3.44	0	12	0.00	14.07	2.07	0
G37	90	0.00	91.95	1.9495	0.00	80	0	84.20	4.20	0	70	0.00	74.95	4.9497	0
G38	5	0.00	3.85	0.00	1.15	5	0	5.31	0.31	0	5	0.00	4.41	0	0.59
Total	**4394.01**	**90.78**	**4533.42**	**58.15**	**5.87**	**4370.39**	**99.99**	**4221.02**	**18.72**	**72.96**	**4611.96**	**89.87**	**4628.76**	**22.71**	**29.67**

Annex 3: A description of the Hyperbolic Tangent function

This annex gives a background on the proposed Hyperbolic Tangent function used to transform the REF.

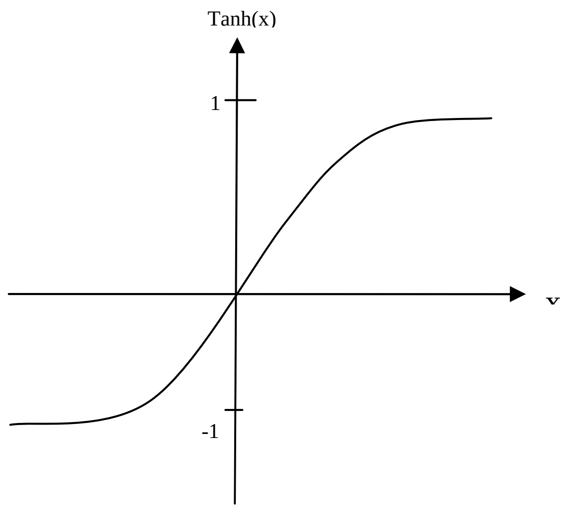
The generic Hyperbolic Tangent function is given by Equation A below, derived using exponential functions.

Equation A:

$$\tanh(x) = \frac{\sinh(x)}{\cosh(x)} = \frac{e^{2x} - 1}{e^{2x} + 1}$$, where $-1 \leq \tanh(x) \leq 1$

The natural hyperbolic tangent function falls between the values of -1 and 1 and is shown by the Graph A below.

Graph A: Natural Hyperbolic Tangent Function



The intent of the proposed REF methodology is towards ensuring that all GRFs are assigned a positive REF value. As such, we multiplied the natural hyperbolic tangent function by 0.5 and added another factor of 0.5 to ensure that all REF values will fall between 0 and 1, as represented by Equation 2 of the main paper. Graph B overleaf reflects this mathematical function.

Graph B: Transformed REF Function