Title	**Pricing Events in the SEM: September 20th, 2010**
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Author	**SEMO**

Introduction

The purpose of this document is to provide a report to Participants and Parties to the SEM on the Market Schedule published for the Trade Date of September 20th 2010.

Executive Summary

For the Ex-Post Initial (EP2) run of the MSP software for the Trade Date of September 20th 2010, the solution contained the Price Floor (-€100)[1] for the Shadow Price with a final System Marginal Price of -€88.12[2] in one Trading Period. However, the load-weighted average System Marginal Price for this Trading Day was €59.31 and therefore, does not appear to have been overly impacted.

This solution was the result of using the alternate solver available to SEMO, the Mixed Integer Programming (MIP) algorithm. This was used after the Langrangian Relaxation program resulted in an infeasible solution. An investigation of the solution from the MIP solver showed that the while the solution contained Price Floor, the solution was feasible. Therefore, as per SEMO's policy **"Use of MIP for Determination of Market Schedules"[3],** available on the SEMO website, this schedule was published.

An investigation into the causes of the Price Floor event has demonstrated that the price is the result of a generator becoming marginal at 03:30 when this generator has been operating under a ramp rate constraint in all adjacent Trading Periods. This type of pricing has been discussed by SEMO before and is known as an Inter-temporal Ramp Constrained price. SEMO have confirmed that the price calculation is correct. However, we believe that the calculation of the Single Ramp Down Rate in this case, does not reflect the intent of the Trading & Settlement Code. This is because the rules result in a generator operating in the market in a manner that is not reflective of its actual physical characteristics. Although the market is not intended to be a correct replica of physical outputs, it is expected to model the technical characteristics to give an accurate approximation of the capability of each unit.

In this report, SEMO demonstrates how the Shadow Price of -€100 and the Single Ramp Down Rate for the relevant generator was calculated. SEMO also suggests some potential modifications to the Trading & Settlement Code to address this issue.

Background

For the Trade Date of September 20th 2010, SEMO completed the Ex-Post Indicative run of the MSP software on September 21st and the Ex-Post Initial run on September 24th. The Lagrangian Relaxation solver (LR) resulted in infeasible schedules with instances of over-generation and under-generation evident in both runs, each leading to multiple instances of Price Cap and Price

[1] Please note that all Market Prices are €/MWh.
[2] Per the Trading & Settlement Code, the rules of Price Cap and Price Floor are applied first to Shadow Price under paragraphs N.18.6a and N.18.6b, and then to the System Marginal Price under paragraph N.16.
[3] This could be found on SEMO website at http://www.sem-o.com/Publications/General/MIP_policy_V4%200%20-%20Use%20of%20MIP%20for%20Determination%20of%20Market%20Schedules.pdf

Floor. These outcomes were caused by difficulties encountered by the LR solver in modelling constrained ramp rates. This will be detailed further in a separate paper by SEMO.

In both cases, the MSP software was re-run with the MIP algorithm as per SEMO's published policy. Both the Ex-Post Indicative and Ex-Post Initial schedules from the MIP algorithm included the Shadow Price set to Price Floor for one Trading Period (04:00AM in the Ex-Post Indicative and 03:30 in the Ex-Post Initial). While this result has in the past been an indicator of an infeasible solution, an investigation on the day demonstrated that the load balance requirement of the system had been met and that the solution was feasible.

The result of the MIP run was therefore published as they were feasible and while the results of the LR program were infeasible.

Analysis

When we review the output of generators across the Trade Date of September 20th, we can see that there is an unusually long duration where a generator is ramping at full limit. This is demonstrated in the graph below where the MSQs are matched to the position of each generator in each Trading Period.

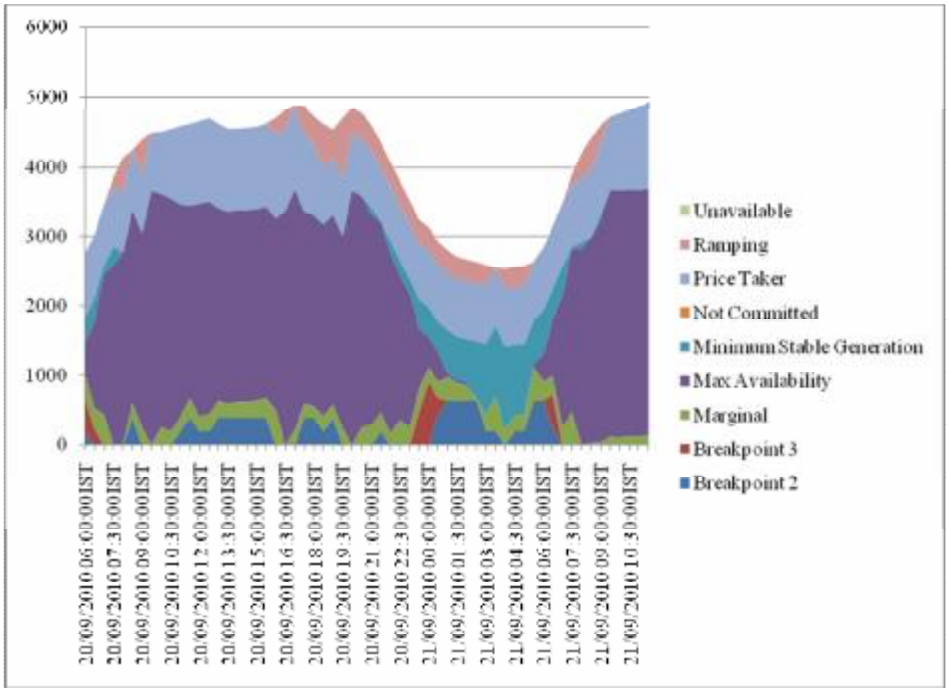

Figure 1 - Total MSQ by Generator Position

The green portion towards the bottom of the graph indicates the total MSQ being provided by the generator that is considered marginal at a given time, the large purple section during the main part of the day, is the total MSQ being provided by generators at their Maximum Availability, and so on. Normally, generators will appear to be ramp constrained during the morning rise. This can be noticed here where portions of the total MSQ are in pink colour in the Trading Periods around 9:00AM. This position often gives rise to the phenomenon described as “Inter-temporal Ramp Constrained Pricing”. This was discussed by SEMO at the Market Operator User Group in September 2009 where the calculation of Shadow Price in these circumstances was explained.

When looking at the above graph, however, we note that a large section of the total MSQ is delivered by a generator operating under a ramp rate constraint over a period of eleven hours from 18:30 to 05:30AM the following morning. Being ramp constrained for this length of time is unusual. The generator is GU_500040 and is ramping from 408MW at 18:30 to a low of 292.11MW at 05:30AM. The unit is moving at a Ramp Rate of 0.18MW per minute which equates to a slow rate of change of 5.4MW per Trading Period.

While we see the generator is constrained by its Ramp Rate through all of these Trading Periods, it is in fact in a marginal position at 03:30AM when it can deliver a small increase or decrease in output to meet changes to the system load. This was tested by re-running the schedule, which

involved adjusting the output in that Trading Period, first increasing the load by 0.5MW and then decreasing it 0.5MW. In each case, the MSQ for GU_500040 was adjusted to meet the changes in the system load.

Trading Period	*System Load*	*Non-Wind Gen*	*Wind Gen*	*MSQ for GU_500040*
21/09/2010 03:30:00	2553.64	2013.17	540.47	313.77
21/09/2010 03:30:00	2553.14	2012.67	540.47	313.27
21/09/2010 03:30:00	2554.14	2013.67	540.47	314.27

Table 1 - Results when System Load adjusted

The graph below shows the MSQ output for GU_500040 with the impact of the slow ramp down rate visible.

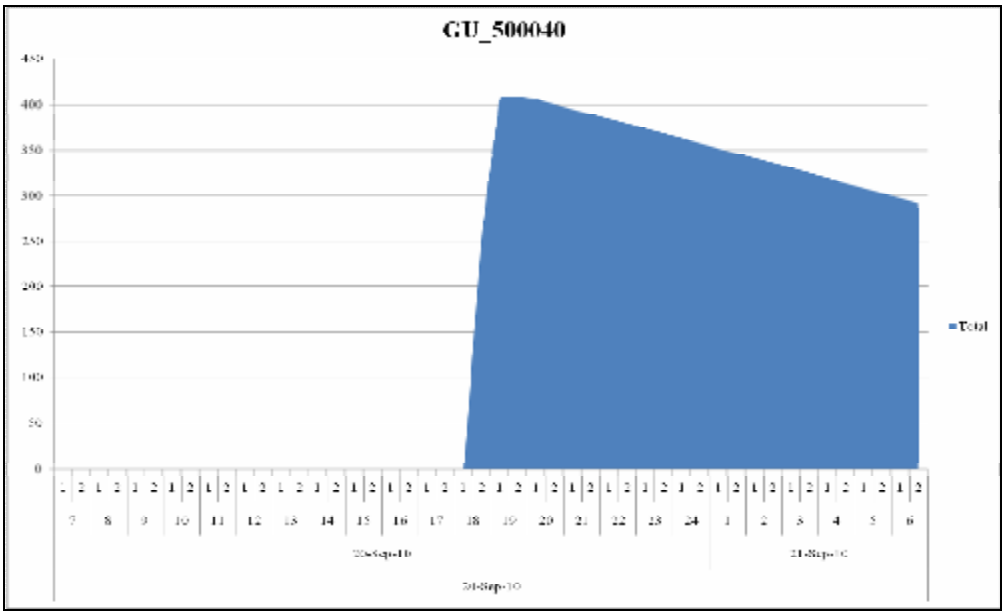

Figure 2 - MSQ for GU_500040

Now that we know which generator is technically marginal at this time, we can conclude that the Shadow Price is being determined as an "Inter-temporal Ramp Constrained Price".

We have previously demonstrated this calculation to be[4]

$$SPh = MOPuh + \sum_{h\ in\ t} (MOPuh - SPh)$$

Where

1. SPh is the Shadow Price in Trading Period h;
2. MOPuh is the Market Offer Price of Generator Unit u in Trading Period h, calculated as per paragraph 4.133 of the Trading & Settlement Code;
3. the summation is over all Trading Periods h in Trading Day t where Generator Unit u is under a ramp constraint.

This means that in this case the Shadow Price is calculated by taking the Market Offer Price of GU_500040 in the relevant Trading Period and calculating the delta between its Market Offer Price and the Shadow Price in all other Trading Periods where it is subject to a ramp rate constraint. This is demonstrated in the table below. What should be noted here is that the delta between the Shadow Price and the Market Offer Price is not always a positive value. Because this ramp constraint applies across the evening peak and the Generator in question has relatively low Market Offer Prices, this means that for a large number of Trading Periods the Shadow Price is greater than the Market Offer Price for GU_500040 resulting in negative values being included in the Shadow Price calculation at 03:30.

[4] This calculation is in accordance with Appendix N, Section 18.6 of the Trading and Settlement Code.

Trading Period	*Shadow Price (SP)*	*GU_500040*	*Rate of Change*	*Market Offer Price (MOP)*	*MOP - SP*
20/09/2010 17:30:00 IST	45.09	260	-148	27.01	
20/09/2010 18:00:00 IST	44.72	408	0	28.33	
20/09/2010 18:30:00 IST	45.09	408	2.16	28.33	
20/09/2010 19:00:00 IST	44.97	405.84	5.41	28.33	-16.64
20/09/2010 19:30:00 IST	45.21	400.43	5.42	28.33	-16.88
20/09/2010 20:00:00 IST	52.49	395.01	5.42	28.33	-24.16
20/09/2010 20:30:00 IST	45.21	389.59	5.41	28.33	-16.88
20/09/2010 21:00:00 IST	45.09	384.18	5.42	28.33	-16.76
20/09/2010 21:30:00 IST	45.09	378.76	5.41	28.33	-16.76
20/09/2010 22:00:00 IST	45.09	373.35	5.42	28.33	-16.76
20/09/2010 22:30:00 IST	44.72	367.93	5.41	28.18	-16.54
20/09/2010 23:00:00 IST	33.04	362.52	5.42	28.18	-4.86
20/09/2010 23:30:00 IST	31.42	357.1	5.42	28.18	-3.24
21/09/2010 00:00:00 IST	31.2	351.68	5.41	28.18	-3.02
21/09/2010 00:30:00 IST	30.18	346.27	5.42	28.18	-2
21/09/2010 01:00:00 IST	29.73	340.85	5.41	28.18	-1.55
21/09/2010 01:30:00 IST	26.72	335.44	5.42	28.18	1.46
21/09/2010 02:00:00 IST	26.72	330.02	5.41	28.18	1.46
21/09/2010 02:30:00 IST	24.48	324.61	5.42	27.01	2.53
21/09/2010 03:00:00 IST	23.99	319.19	5.42	27.01	3.02
21/09/2010 03:30:00 IST	-116.68 (Capped at -100)	313.77	5.41	27.01	
21/09/2010 04:00:00 IST	23.99	308.36	5.42	27.01	3.02
21/09/2010 04:30:00 IST	26.72	302.94	5.41	27.01	0.29
21/09/2010 05:00:00 IST	26.72	297.53	5.42	27.01	0.29
21/09/2010 05:30:00 IST	26.72	292.11	-67.92	27.01	0.29

Table 2 - Calculation of Shadow Price

The total amount of the delta between the Shadow Price and the Market Offer Price is -143.69 which has resulted in a Shadow Price calculated in accordance with the "Inter-temporal Ramp Constrained Price" formula as follows:

SPh = €27.01-€143.69 = -€116.68

This can also be seen in the graph below. The MSQ for GU_500040 can be noted at the bottom of the diagram where again the slow Ramp Rate is evident. An increase in System Load at 03:30 means that the MSQ output of GU_500040 must change in all adjacent ramp constrained Trading Periods before and after 03:30. This means that the calculation for the cost of the increase for this Trading Period must take account of the cost of the increase in output of GU_500040 in all other affected Trading Periods but also the saving brought about by the reduction of the output of the marginal generator in all these Trading Periods. This is represented above as (Market Offer Price – Shadow Price).

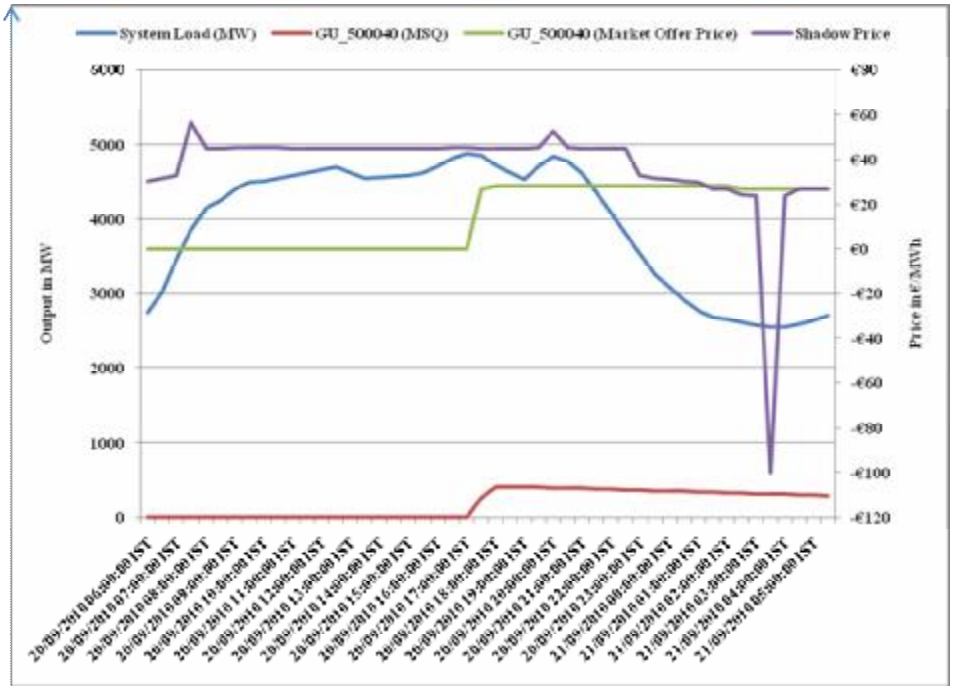

Figure 3 - Load and Price information for GU_500040

Because of the rules on the application of Price Floor and Price Cap to the Shadow Price, this means that the calculated Shadow Price of -€116.68 is replaced with the Price Floor.

While this explains the Price calculation, we must also examine why GU_500040 is ramp constrained for such a prolonged period. Looking at the calculation as set out in Appendix N of the T&SC as follows

$$\textit{if } RampDownTime + DwellTime \neq 0 \textit{ then}$$

$$SingleRampDownRate = \left(\frac{OutputRange}{RampDownTime + DwellTime} \right) \times 60 \times TPD$$

else

$SingleRampDownRate$ will be set to a non - limiting value

The Output Range is calculated as being the gap between the minimum and maximum values of Average Availability across the 30 hour Optimisation Horizon. This will generally equate to the gap between a generator's Minimum Stable Generation and their maximum generation value. The Ramp Down Time is then calculated as the time in minutes that it will take a generator to move from the lower to the higher point of the Output Range using the submitted technical characteristics of the generator.

For GU_500040, their technical characteristics are as follows:

MW/min (A)	***MW/min (B)***	***MW/min (C)***	***MW/min (D)***	***MW/min (E)***
0.1	18.5	18.5	18.5	18.5
Break Point MW (A)	***Break Point MW (B)***	***Break Point MW (C)***	***Break Point MW (D)***	
260	261	261	261	

Table 3 - Ramp Down characteristics of GU_500040

With Minimum Stable Generation of 260MW and Maximum Availability of 408MW, the Ramp Down Rates therefore apply as follows.

- From Minimum Stable Generation to Break Point A, Ramp Down Rate A;
- From Break Point A to Break Point B, Ramp Down Rate B;
- From Break Point B to Break Point C, Ramp Down Rate C;
- From Break Point C to Break Point D, Ramp Down Rate D;
- From Break Point D to Maximum Availability , Ramp Down Rate E;

To express this using the submitted values, this is as follows.

Start Point	*Start Point (MW)*	*End Point (MW)*	*Ramp Down Time*
Minimum Stable Generation	260	260	0
Break Point A	260	261	0.054054054
Break Point B	261	261	0
Break Point C	261	261	0
Break Point D	261	408	7.945945946
Total			***8***

Table 4 - Calculation of Ramp Down Time

This results in a Ramp Down Time of 8 minutes which when applied to the normal Output Range of 148MW results in Single Ramp Down rate of 18.5MW/Min.

However, on September 20th GU_500040 was on an outage for part of the Trade Date. The generator became available at 17:21. New spot Availability declarations were received into the SEMO systems for this time with Minimum Stable Generation and Maximum Availability set to the normal points of 260MW and 408MW. The calculation of the Average Availability for this Trading Period applies these spot values using a simple time-weighted average resulting in Minimum and Maximum Average Availability values of 78MW and 122.4MW respectively. Because the Output Range is determined as the gap between the Minimum and Maximum Availability values across the entire Optimisation Horizon, this means that 78MW will now be included in the calculation. Therefore, for September 20th, the calculation of the Ramp Down Time becomes as follows.

Start Point	*Start Point (MW)*	*End Point (MW)*	*Time To Ramp*
Minimum Stable Generation	78	260	1820
Break Point A	260	261	0.054054054
Break Point B	261	261	0
Break Point C	261	261	0
Break Point D	261	408	7.945945946
Total			***1828***

Table 5 - Calculation of Ramp Down Time, September 20th.

The inclusion of an additional 182MW below normal Minimum Stable Generation, where the Ramp Rate submitted is 0.1MW significantly change the results. Now, with an Output Range of 330MW and a Ramp Down time of 1,828 minutes, this yields a Single Ramp Down rate of 0.18MW/Min.

This anomaly has resulted in the severe ramp constraints noted in the schedules for September 20th and has given rise to the occurrence of an Inter-temporal Ramp Constrained Price calculated across twenty two Trading Periods.

We must note that the calculations are correctly implemented in the Central Market Systems as per the Trading & Settlement Code. Therefore, this price calculation, while unusual and the result of unforeseen consequences of the Single Ramp calculations, is correct.

We must also recognise that, because they have been observed to produce results that are so varied from the actual running potential of generators and therefore impact the MSQ of generators as well as the Shadow Price calculation, the Single Ramp calculations should be reviewed.

Conclusions

1. An unintended consequence of the Single Ramp Rate calculation in Appendix N of the Trading & Settlement Code is resulting in Ramp Rates that are not accurate to generator capabilities.

2. This calculation has led to a generator's running in terms of MSQ being constrained by an extremely low Ramp Rate.
3. This has led to the calculation of an Inter-temporal Ramp Constrained Price based over twenty two Trading Periods, resulting in a Shadow Price of -€116.68 in one Trading Period.

Recommendations

While the way in which the software is working is compliant with the rules as set out in the T&SC, SEMO believe that this phenomenon is not in keeping with the intention of the market rules. We therefore intend to raise a modification to the Trading & Settlement Code to address the calculation of the Single Ramp Rate. This modification will specifically address the calculation of the Output Range for a generator and will calculate this value based on static Availability values rather than half-hour average values.