Title	Market Incident Report - Increased Use of MIP as the Market Solver - September 2010
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Introduction

The purpose of this document is to inform Participants on the reasons behind the increased instances of publication with MIP during the month of September 2010.

SEMO regularly reports on the number of schedules published with MIP in the "Monthly Market Operator Report"[1], where it can be noted that since we began including this data in October 2009, there have been on average only one or two instances per month of schedules published with MIP, with a maximum of three in July 2010. In September 2010, this number increased to eight. On three occasions, the schedules from the default LR solver included an SMP greater than €500, which is classed as a price event in SEMO policy "Use of MIP for Determination of Market Schedules"[2]; however, the remaining five had infeasible solutions with cases of Over or Under Generation.

As such a high frequency of infeasible solutions has not been previously observed in the SEM, this report aims to clarify the circumstances around this.

Executive Summary

SEMO has observed that the Single Ramp Rate calculation as set out in the Trading and Settlement Code sections N33 and N35, is not in keeping with the intention of the SEM rules of accurately representing the physical capabilities of the Generator Unit in the MSP software. The use of half-hour Average Availability to determine the lowest bound of the Output Range artificially decreases the calculated Ramp Rate when the conditions of a low first Ramp Rate and a change in Minimum Stable Generation are met. This will occur in particular, when Generator Units are coming back from an outage partway through a Trading Period. This is an unintended consequence of the Single Ramp Rate calculation.

Due to the computational limitations of the LR Unit Commitment, the Single Ramp Rate as set out in the T&SC is only used to model Start Up and Shut Down profiles. However, in Economic Dispatch, the Single Ramp Rates are applied in all Trading Periods for which a Generator Unit is committed. The difference in how the Single Ramp Rate is used within the MSP software can give rise to infeasible solutions with Over and Under Generation events.

By eliminating the causes of artificially low Single Ramp Rates, occurrences of infeasible solutions could be minimised and it would result in a more accurate calculation of Market outputs.

SEMO therefore has raised a modification to the T&SC to address the calculation of the Single Ramp Rate. Please refer to MOD_42_10[3] for details.

In addition to raising this Modification, SEMO also observed that the impact of changes to Minimum Stable Generation, coupled with a very low first Ramp Rate could be prevented with revised Technical Offer Data submissions whenever possible. All changes to TODs must be validated by the relevant TSO.

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[1] http://www.sem-o.com/MarketOperatorPerformance/Pages/PerformanceReports.aspx

[2] 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

[3] http://www.sem-o.com/MarketDevelopment/Modifications/Pages/Modifications.aspx?Stage=Active

Continued adherence to the SEMO policy on the use of the MIP solver is also recommended to ensure only feasible market solutions are published.

Background

In September 2010, the LR program produced 27 infeasible solutions including Over or Under Generation events, across two Ex-Post Indicative and three Ex-Post Initial runs. Appendix A contains a list of the Trading Periods affected to date (week ending the 19th November 2010).

An Over Generation event means that excess megawatts were scheduled relative to the required MSP Schedule Demand. This will produce a Shadow Price at Price Floor (currently set at -€100). An Under Generation event means that not enough megawatts were scheduled to meet the MSP Schedule Demand and will generate a Shadow Price at Price Cap (currently set at €1000).

As per the SEMO policy "Use of MIP for Determination of Market Schedules"[4], if the LR schedule is infeasible, the alternate optimisation solver, MIP, will be run for comparison and published where a feasible solution is found. For all these Trading Days, the schedules were all published with feasible solutions from the MIP solver.

An infeasible solution is a potential event but has been rare in the SEM experience to date. Before July 2010, SEMO only had two occurrences of Under Generation with Price Cap on the Ex Post Indicative run for the 19th September 2009 and on the Ex Post Initial run for the 20th January 2010. In both cases the total megawatts scheduled were short of the MSP Demand by very small amounts (less that 0.05MW). As previously reported by SEMO to Participants[5], this was due to a rounding inconsistency between the MSP software stages, which was addressed in the Market Software release in May 2010. No Over Generation event had been produced up to that point.

The instances of Over or Under Generation in September 2010, show errors well above rounding levels; in many cases the delta between total MSQ and the Schedule Demand requirement was greater than 100MW (see Appendix A for details). SEMO carried out an investigation to determine the cause of these infeasible events occurring with the LR solver only.

Please note that over the same period three more schedules were produced and published with MIP. Feasible solutions with prices greater than €500, as set out in the MIP policy, are regular occurrences and are not considered in this analysis.

[4] 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

[5] http://www.sem-o.com/Publications/General/Market%20Incident%20Report%20January%2020th%202010.pdf

Analysis

In all affected schedules, there were instances of both Over or Under Generation. As shown on the graph below, for Trading Day September 13th, too many generators have been scheduled unnecessarily when the Over Generation occurred between 03:00am and 03:30am and a large amount of generation was available but not used between 07:30am and 11:00am when the Under Generation occurred.

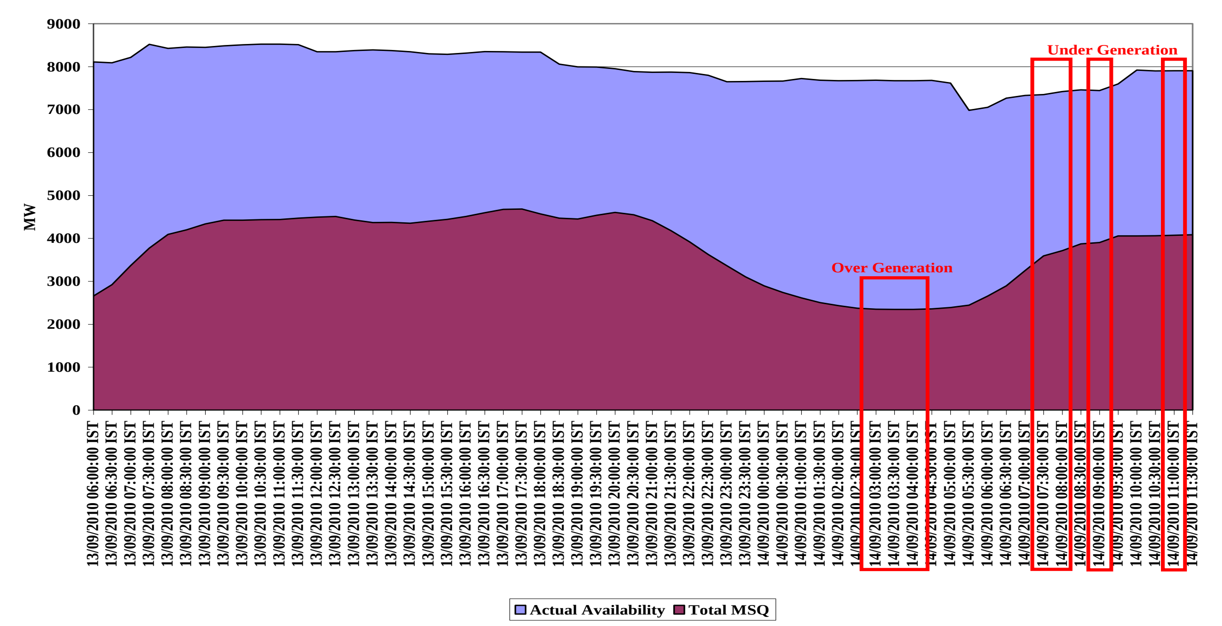

Figure 1 - Total Scheduled MSQ vs. Total Market Availability on Trading Date 13th September 2010

Fig.2 below shows the position of Generator Unit in each Trading Period. It can be seen that no Generator Unit is marginal when the infeasible events occurred, as they are all in a position constrained either by the Maximum or Minimum Availability or by their Ramp Rate.

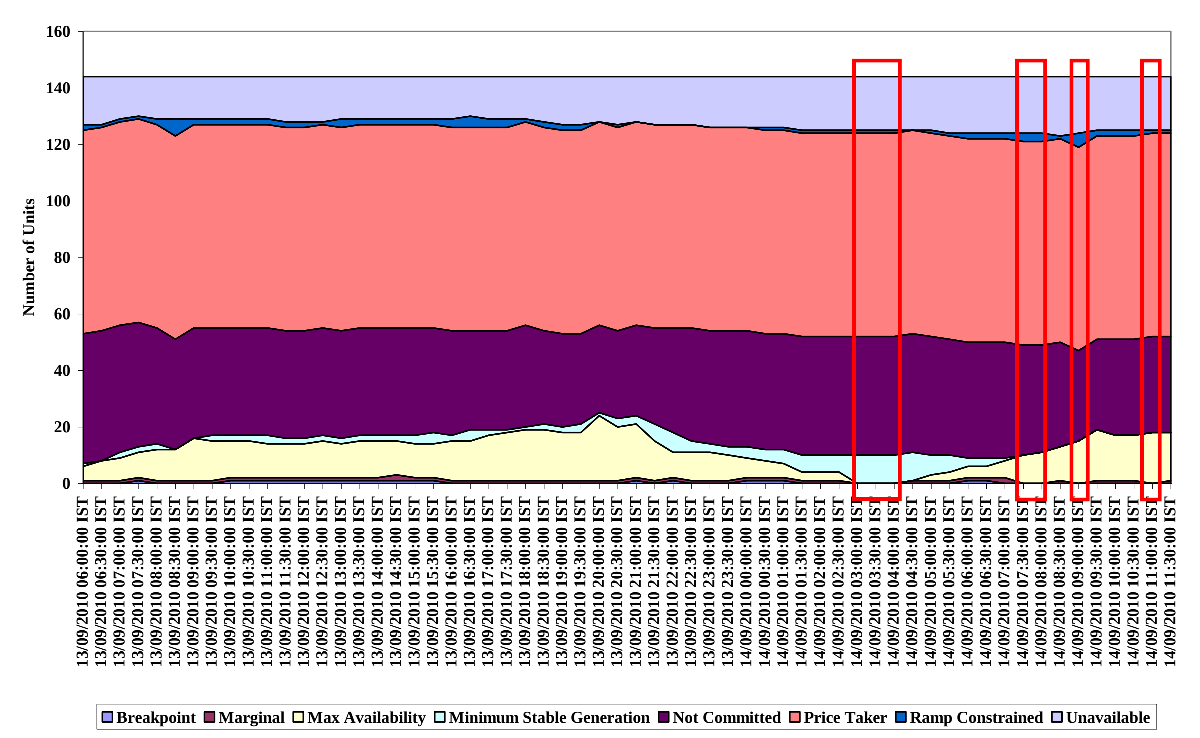

Figure 2: Count of Generators by their position in each Trading Period on the 13th September 2010

In periods with Under Generation, an increasing number of generators are reaching their Maximum Availability while there are between 32 and 39 Generator Units that are available but not committed.

In the Trading Periods between 03:00 and 04:00 when Over Generation occurs, there are eleven Generator Units committed on. Of these, ten are at Minimum Stable Generation but GU_400272 is actually ramping up and therefore increasing the level of Over Generation. To understand why this is the case, we have to look at the requirements for the rest of the Trading Day and the Optimization Horizon. Generator Unit GU_400272 has a Ramp Down Rate of 4.38MW/min. At this rate, the Generator Unit is capable of reducing its output to a level that would avoid Over Generation in the affected Trading Periods. The Table below show all Price Makers committed during the Over Generation and in the Trading Periods leading up to it.

	02:00	02:30	03:00	03:30	04:00
GU_400180	35	35	35	35	35
GU_400210	10	10	4	4	4
GU_400211	10	10	4	4	4
GU_400220	23	23	5	5	5
GU_400271	99	99	99	99	99
GU_400272	115.94	121.05	126.15	131.26	136.37
GU_400323	232	232	232	232	232
GU_400480	184	184	184	184	184
GU_400500	280.87	218.82	203	203	203
GU_400540	194	194	194	194	194
GU_500140	63	63	63	63	63
Total Original PPMG	**1246.81**	**1189.87**	**1149.15**	**1154.26**	**1159.37**
Over Generation Amount	**0**	**0**	**8.03**	**20.72**	**23.63**

Table 1 - LR Price Maker's schedule output during Over Generation Trading Periods

Between 03:00 and 04:00, all Generator Units are at Minimum Stable Generation except GU_400272, which is ramping up; this Generator Unit could instead be scheduled to a lower level to prevent the Over Generation in these Trading Periods, as follow:

	02:00	02:30	03:00	03:30	04:00
GU_400180	35	35	35	35	35
GU_400210	10	10	4	4	4
GU_400211	10	10	4	4	4
GU_400220	23	23	5	5	5
GU_400271	99	99	99	99	99
GU_400272	115.94	121.05	118.12	110.54	112.74
GU_400323	232	232	232	232	232
GU_400480	184	184	184	184	184
GU_400500	280.87	218.82	203	203	203
GU_400540	194	194	194	194	194
GU_500140	63	63	63	63	63
Total Original PPMG	**1246.81**	**1189.87**	**1149.15**	**1154.26**	**1159.37**
Over Generation Amount	**0**	**0**	**8.03**	**20.72**	**23.63**
Difference in GU_400272	**0**	**0**	**-8.03**	**-20.72**	**-23.63**
Total Revised PPMG	**1246.81**	**1189.87**	**1141.12**	**1133.54**	**1135.74**

Table 2 - Revised Price Maker's schedule output during Over Generation Trading Periods

GU_400272 has a Ramp Up Rate of just 0.17MW/min, which means that if the Generator Unit comes down to such a low level it would not be able to cover the Schedule Demand requirement later on the day causing more instances of Under Generation. This is because the following Trading Periods only have a small amount of spare margin left and without GU_400272 ramping to its full potential, the Schedule Demand would not be met in a larger number of Trading Periods.

Table 3 below shows the original schedule of all committed Generator Units for the remainder of the Trading Day and the Optimization Horizon. More Generator Units have been committed on as the Schedule Demand increases; however, in three Trading Periods all Generator Units are running at maximum output, either ramping up or at MaxGen and unable to meet the required level.

The outcome would be different if the scheduled amount of Generator Unit GU_400272 had been lowered to prevent Over Generation as in Table 2 above. In that case the Generator Unit output for subsequent periods, would be limited by its low Ramp Up Rate of 0.17MW/min therefore forcing other committed Generator Units to make up for the difference. As shown in Table 4 below, this is not sufficient to avoid Under Generation for an extra four Trading Periods on top of the four in the original schedule in Table 3 (all adjustments made to the original schedule are shown in blue).

	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30
GU_400180	35	35	35	35	35	73.86	190	190	190	207.33	210	210	210	210	212
GU_400200	0	0	0	0	0	0	0	0	0	14.44	21	21	21	21	21
GU_400201	0	0	0	0	0	0	0	0	0	12	22	22	22	22	22
GU_400202	0	0	0	0	0	0	0	0	0	12	19	19	19	19	19
GU_400203	0	0	0	0	0	0	12	24	24	24	24	24	24	24	24
GU_400210	4	10	10	10	10	10	10	10	10	10	10	10	10	10	10
GU_400211	4	5.17	10	10	10	10	10	10	10	10	10	10	10	10	10
GU_400220	5	23	23	23	23	23	23	23	23	23	23	23	23	23	23
GU_400260	0	0	0	0	0	0	0	0	0	1	1.9	2.8	3.7	4	4
GU_400271	99	99	99	138.16	187.11	236.05	285	285	285	285	285	285	285	285	285
GU_400272	141.47	146.58	151.68	156.79	161.9	167	172.11	177.21	182.32	187.43	192.53	197.64	202.74	207.85	212.96
GU_400311	0	0	0	0	0	0	0	0	0	0	104	104	104	104	104
GU_400323	232	232	232	232	232	390.77	468	468	468	468	468	468	468	468	468
GU_400480	184	184	184	214.05	230	321	321	321	321	321	321	321.8	324	324	324
GU_400500	203	203	262.9	383	383	383	383	383	387.67	388	388	388	388	388	388
GU_400540	194	194	194	195	364.01	380	380	380	382.8	386	386	386	386	383.6	381
GU_500100	0	0	0	0	0	0	54	113.4	156.17	170	163.41	145.46	160.79	170	163.75
GU_500130	0	0	0	0	0	0	0	68	155	155	155	155	155	155	155
GU_500140	63	63	63	63	63	63	89	89	89	89	89	89	89	89	89
GU_500901	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0
GU_500902	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0
Total Original PPMG	**1164.47**	**1194.75**	**1264.58**	**1460**	**1699.02**	**2057.68**	**2397.11**	**2541.61**	**2683.96**	**2769.2**	**2898.84**	**2881.7**	**2905.23**	**2917.45**	**2915.71**
Under Generation Amount	**0**	**0**	**0**	**0**	**0**	**0**	**-21.7**	**-99**	**0**	**-100.35**	**0**	**0**	**0**	**-6.68**	**0**

Table 3 - LR Price Maker's schedule output leading up to Under Generation Trading Periods

	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30
GU_400180	35	35	35	35	35	73.86	190	190	190	207.33	210	210	210	210	212
GU_400200	0	0	0	0	0	0	0	0	0	14.44	21	21	21	21	21
GU_400201	0	0	0	0	0	0	0	0	0	12	22	22	22	22	22
GU_400202		0	0	0	0	0	0	0	0	12	19	19	19	19	19
GU_400203	0	0	0	0	0	0	12	24	24	24	24	24	24	24	24
GU_400210	4	10	10	10	10	10	10	10	10	10	10	10	10	10	10
GU_400211	9.62	10	10	10	10	10	10	10	10	10	10	10	10	10	10
GU_400220	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
GU_400260	0	0	0	0	0	0	0	0	0	1	1.9	2.8	3.7	4	4
GU_400271	99	99	99	138.16	187.11	236.05	285	285	285	285	285	285	285	285	285
GU_400272	117.85	122.96	128.07	133.18	138.29	143.4	148.51	153.62	158.73	163.84	168.95	174.06	179.17	184.28	189.39
GU_400311	0	0	0	0	0	0	0	0	0	0	104	104	104	104	104
GU_400323	232	232	232	232	239.62	414.37	468	468	468	468	468	468	468	468	468
GU_400480	184	184	184	230	230	321	321	321	321	321	321	321.8	324	324	324
GU_400500	203	221.79	286.51	383	383	383	383	383	387.67	388	388	388	388	388	388
GU_400540	194	194	194	202.66	380	380	380	380	382.8	386	386	386	386	383.6	381
GU_500100	0	0	0	0	0	0	54	113.4	170	170	170	169.04	170	170	170
GU_500130	0	0	0	0	0	0	0	68	155	155	155	155	155	155	155
GU_500140	63	63	63	63	63	63	89	89	89	89	89	89	89	89	89
GU_500901	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0
GU_500902	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0
Total Revised PPMG	**1164.47**	**1194.75**	**1264.58**	**1460**	**1699.02**	**2057.68**	**2373.51**	**2518.02**	**2674.2**	**2745.61**	**2881.85**	**2881.7**	**2890.87**	**2893.88**	**2898.39**
Under Generation Amount	**0**	**0**	**0**	**0**	**0**	**0**	**-45.3**	**-122.59**	**-9.76**	**-123.94**	**-16.99**	**0**	**-14.36**	**-30.25**	**-17.32**

Table 4 - Revised Price Maker's schedule output leading up to Under Generation Trading Periods

The solution chosen by the Economic Dispatch phase is preferable, because it achieves three instances of Over Generation and four of Under Generation versus eight instances of Under Generation in the case when GU_400272 was not ramping all the way through the Over Generation periods. This meets the requirement to minimise MSP Production Cost by incurring the penalty cost of an infeasible solution in less Trading Periods.

It has to be noted that a Ramp Up Rate as low as 0.17MW/min for Generator Unit GU_400272, is atypical considering the size of the unit and the flexibility that is actually achieved in real time. As shown in the graph below the Generator Unit output ramps up at a much faster pace than its MSQs in the Market.

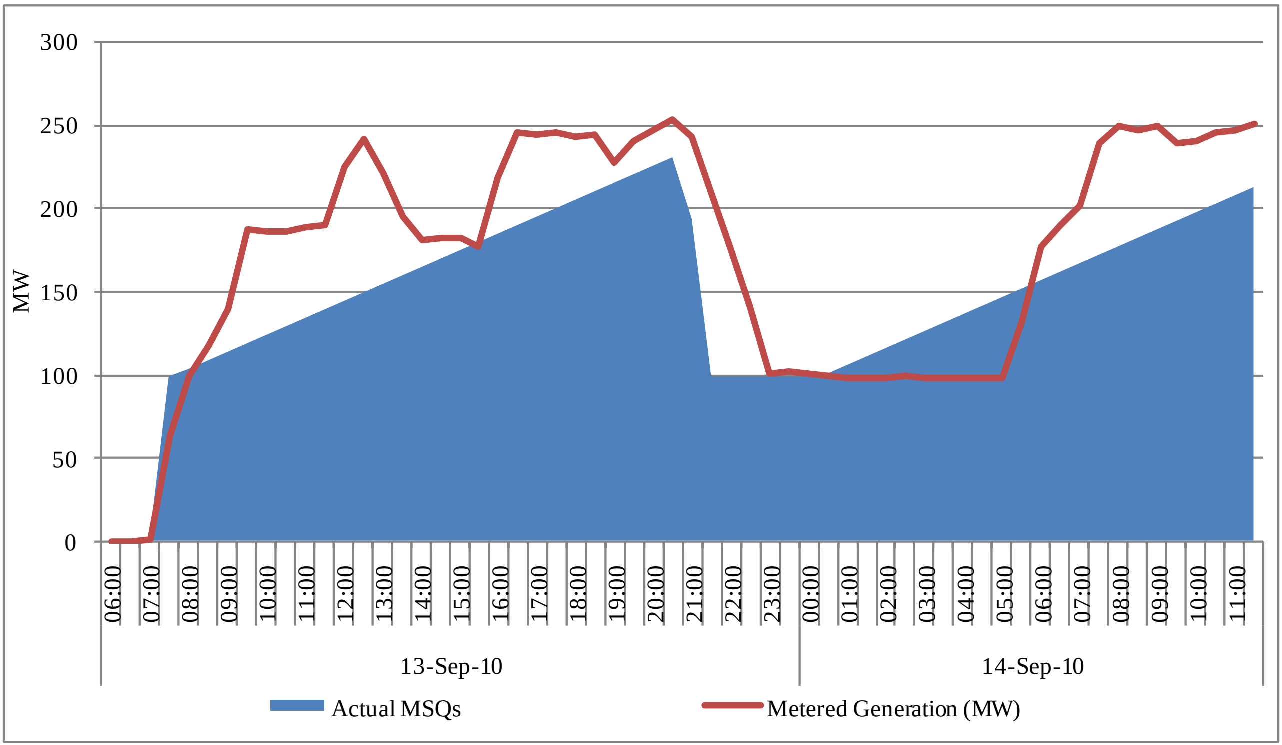

Figure 3 - GU_400272 comparison of Metered Generation and MSQs on Tading Day 13th September 2010

The calcuated Ramp Up Rate is much lower compared to other Trading Days when the Generator Unit submitted the same technical characteristics and declared the same Maximum and Minimum Availability. For example on the 14th September the Ramp Up Rate is 1.63 and all relevant values for the Generator Unit are the same. The only difference is that on the 13th the Unit is coming back from an outage at 7:21am.

Coming back from outage has no impact on the way the different Ramp Rates determine the exported generation or the Dispatch Quantities, however it does affect the Ramp Rates used for the Market Schedule Quantity in a way that does not reflect the purpose of the T&SC to accurately represent the physical characteristics of the Generator Units.

Ramp Rates cannot be used in the Central Market Systems as submitted by the Generator Units in accordance with the T&SC; the complexity these would add to the optimization formulation, would make it increasingly difficult for the software to solve in an operationally timely manner. Ramp Up Rates are modelled in the Central Market Systems through the Single Ramp Up Rate calculation as per section N33 in Appendix N of the T&SC:

$$
\begin{aligned}
&\mathit{if}\quad RampUpTime + DwellTime \neq 0\ \mathit{then}\\
&\qquad SingleRampUpRate = \left(\frac{OutputRange}{RampUpTime + DwellTime}\right) \times 60 \times TPD\\
&\mathit{else}\\
&\qquad SingleRampUpRate \quad \text{will be set to a non-limiting value}
\end{aligned}
$$

The Output Range is the gap, across the Trading Day, between the minimum value of Minimum Stable Generation and the maximum value of Availability Profile.calculated according section 4.49 of the T&SC. The Single Ramp Rate is then calculated as the time in minutes it would take a generator to move from the lower to the higher point of the Output Range using the Technical Offer Data submitted by that generator.

When the Minimum Stable Generation changes significantly, as in the case of a Generator Unit coming back from an outage, the Average Availability for that Trading Period will produce an unrealistic Output Range. If this is coupled with a very small first Ramp Up (or Down) Rate in the Technical Offer Data, the calculated Single Ramp Rate could deviate significantly from what the Generator Unit can do in reality. This means that the final schedule of that Generator Unit could be constrained by a slow rate which represents a significant deviation from its physical capabilities. Although the SEM is not intended to be a correct replica of physical outputs, it is expected to model the technical characteristics in such a way as to give an accurate representation of the overall capability of each Generator Unit.

For GU_400272 the submitted Technical Characteristics on the 13th September 2010 were as follow:

Ramp Rate 1 (MW/min)	***Ramp Rate 2 (MW/min)***	***Ramp Rate 3 (MW/min)***	***Ramp Rate 4 (MW/min)***	***Ramp Rate 5 (MW/min)***
0.05	3	0.05	3	1
Break Point 1(MW)	***Break Point 2(MW)***	***Break Point 3(MW)***	***Break Point 4(MW)***	
100	174	175	266	

Table 5 - Ramp Up Characteristics of GU_400272

With Minimum Stable Generation normally at a level of 99MW and Maximum Availability at 285MW for the full day, the Ramp Up Rates apply as follows.

- From Minimum Stable Generation to Break Point 1, Ramp Up Rate 1;
- From Break Point 1 to Break Point 2, Ramp Up Rate 2;
- From Break Point 2 to Break Point 3, Ramp Up Rate 3;
- From Break Point 3 to Break Point 4, Ramp Up Rate 4;
- From Break Point 4 to Maximum Availability , Ramp Up Rate 5;

To express this using the submitted values, the total Ramp Up Time is as follows:

Start Point	***Start Point (MW)***	***End Point (MW)***	***Ramp Up Time***
Minimum Stable Generation	99	100	20
Break Point 1	100	174	24.66666667
Break Point 2	174	175	20
Break Point 3	175	266	30.33333333
Break Point 4	266	285	19
Total			***114***

Table 6 - Standard Calculation of Ramp Up Time for Unit GU_400272

This results in a Ramp up Time of 114 minutes which, when applied to the normal Output Range of 186MW, results in a Single Ramp Up Rate of 1.63MW/min.

On September the 13th, GU_400272 was on an outage for part of the day becoming available at 07:21am. Although this new spot declarations were to the normal minimum and maximum values of 99MW and 285MW, the average profiled values for the Trading Period when the Generator Unit comes back from zero are 29.7MW and 85.5MW respectively[6]. This

[6] The re-declaration of availability is at 07:21 therefore the declared values only apply for nine minutes; the Availability Profile is calculated as (99*9)/30 and (285*9)/30 for the Trading Period between 07:00 and 07:29.

artificially low Minimum Stable Generation limit causes an increase of the Output Range to 255.3MW. As Ramp Rate 1 value, which normally applies for just 1 MW, is considerably lower than the average of all the other Rates, the increase of the range when this Ramp Rate is applied has a noticeable impact to the Ramp Up Time for the Generator Unit. This changes as follows:

Start Point	*Start Point (MW)*	*End Point (MW)*	*Ramp Up Time*
Minimum Stable Generation	29.7	100	1406
Break Point 1	100	174	24.66666667
Break Point 2	174	175	20
Break Point 3	175	266	30.33333333
Break Point 4	266	285	19
Total			***1500***

Table 7 - Calculation of Ramp Up Time for Unit GU_400272 on September 13th 2010

The Single Ramp Up Rate in this case becomes 0.17MW/min for the whole Trading Day; however, this is not reflective of the actual capabilities of the Generator Unit. The value of 29.7MW as the Minimum Stable Generation is not used in real time dispatch and it distorts the Ramp Up capability of the Generator Unit to artificially low level. The level of distortion depends on the actual time the Generator Unit comes back from an outage. The values will be closer to the typical Ramp Up Rate, if the Generator Unit comes back at the beginning of the Trading Periods and will be further out if it comes back at the opposite end of the Trading Period, causing inconsistency in the Single Ramp Rate which can fluctuate considerably from one Trading Day to the next with no operational justification.

The difference in the potential output for the Generator Unit on the September 13th is evident in the following graph which compares the actual MSQs of the Generator Unit, limited by the calculated Single Ramp Up Rate, versus what could have been achieved if the Output Range had not been impacted by the change in its Minimum Stable Generation.

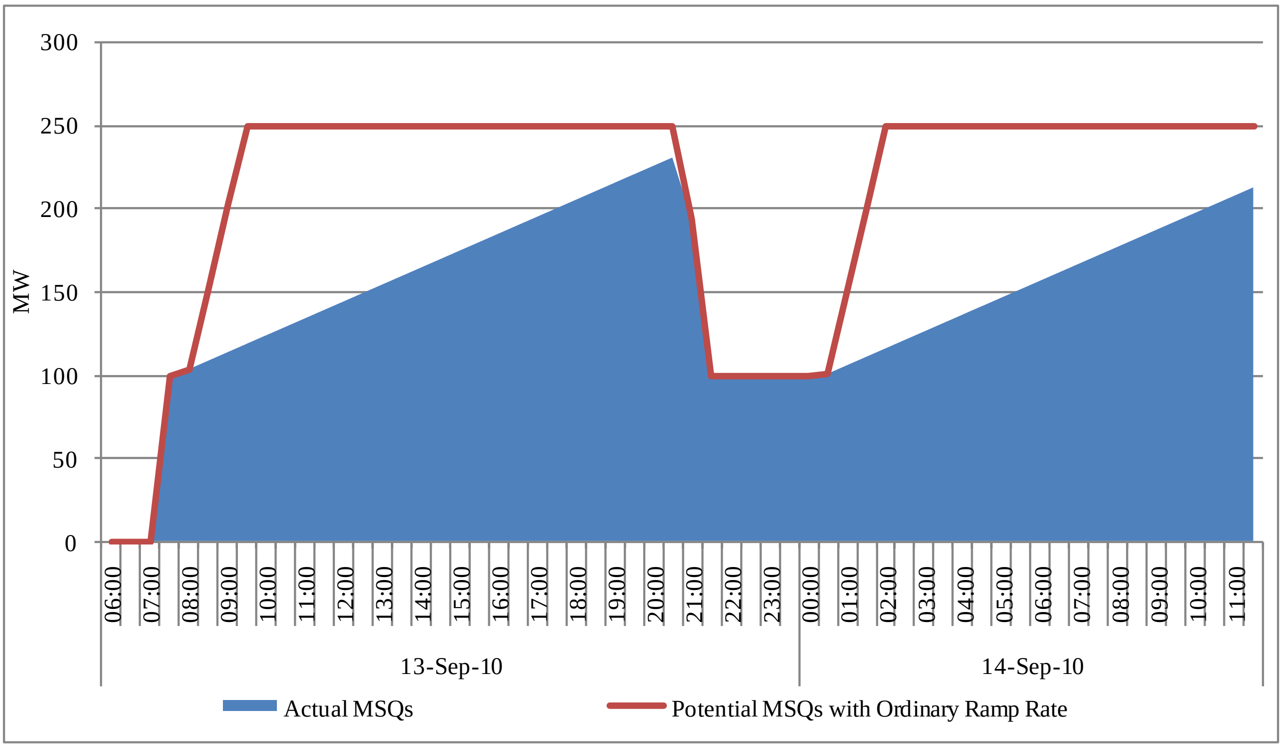

Figure 4 - MSQ comparison with different Ramp Up Rates for unit GU_400272

With a normal Ramp Up Rate for this Generator Unit, both instances of Over and Under Generation could have been prevented on the 13th of September.

Similarly, this happens with Single Ramp Down Rate modelled in the market according to Section N35 in Appendix N as follow:

$$\begin{array}{l} \text{if } RampDownTime + DwellTime \neq 0 \text{ then} \\ \quad SingleRampDownRate = \left(\dfrac{OutputRange}{RampDownTime + DwellTime} \right) \times 60 \times TPD \\ \text{else} \\ \quad SingleRampDownRate \text{ will be set to a non-limiting value} \end{array}$$

On the same Trading Day, Generator Unit GU_500040 re-declared its availability at 12:07pm bringing the lowest calculated Minimum Stable Generation for the Trading Day from the typical value of 260MW to 150MW. In this case, the impact to the Generator Unit's capability is driven by a Ramp Down Rate 1 of 0.1MW/min. The Technical Offer Data of the Generator Unit is as follows:

Ramp Rate 1 (MW/min)	***Ramp Rate 2 (MW/min)***	***Ramp Rate 3 (MW/min)***	***Ramp Rate 4 (MW/min)***	***Ramp Rate 5 (MW/min)***
0.1	18.5	18.5	18.5	18.5
Break Point 1 (MW)	***Break Point 2 (MW)***	***Break Point 3 (MW)***	***Break Point 4 (MW)***	
260	261	261	261	

Table 8 - Ramp Down Characteristics of GU_500040

By applying the logic of the Single Ramp Down calculation, a Single Ramp Down Rate of 18.5MW/min is produced (the Ramp Rate of 0.1MW/min is applied between the Minimum Stable Generation of 260MW and the Break Point 1 which is 260MW therefore has no impact). However when the Minimum Stable Generation changes to 150MW, the time for the Ramp Down of the Generator Unit changes dramatically as shown below.

Start Point	***Start Point (MW)***	***End Point (MW)***	***Ramp Down Time***
Minimum Stable Generation	150	260	1100
Break Point 1	260	261	0.054054054
Break Point 2	261	261	0
Break Point 3	261	261	0
Break Point 4	261	390	6.972972973
Total			***1107.027027***

Table 9 - Calculation of Ramp Down Time for Unit GU_500040 on September 13th 2010

This results in a Single Ramp Rate of just 0.22MW/min which is radically different from its typical Single Ramp Rate of 18.5MW/min. Although the Generator Unit was not on in the market during the periods of Over and Under Generations, its potential output earlier on the day could have been very different with a higher Ramp Down Rate, as shown in fig.5 below, and would have had an impact on other Generator Units and on the rest of the Schedule.

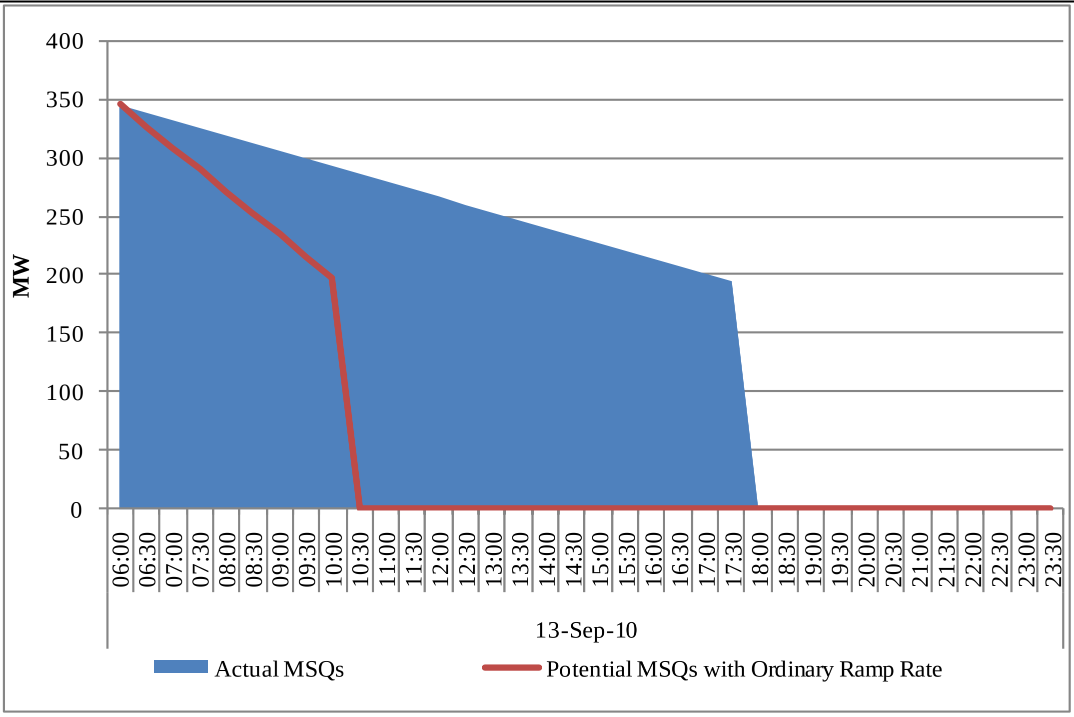

Figure 5 - MSQ comparison with different Ramp Down Rates for unit GU_500040

In this case, the set of TOD submitted could be modified to avoid the impact of any change in Minimum Availability. It has been confirmed by the TSO that a very low Ramp Down Rate is necessary to model a very slow rate of de-loading that this Generator Unit uses for a short interval just before reaching its Minimum Stable Generation of 260MW. It is not intended to be applied for a prolonged length of time. The Generator Unit could achieve this by modifying the submission of TOD to ensure that the rate is only applied for this intended short range as discussed below.

With the TOD as submitted on the 13th of September, a change in Minimum Stable Generation for GU_500040 from 260MW to 150MW brought the Single Ramp Rate from 18.5MW/min to 0.22MW/min.

Both of these values are unrealistic: 18.5MW/min does not take account of slow Ramp Down Rate of 0.1MW/min because Break Point 1 is equal to Minimum Stable Generation; 0.22MW/min is not realistic because the slow Ramp Down Rate is applied for too long. A change in the Availability Profile would not have such a radical impact if the TOD submission of the Generator Unit were as follow:

Ramp Rate 1 (MW/min)	***Ramp Rate 2 (MW/min)***	***Ramp Rate 3 (MW/min)***	***Ramp Rate 4 (MW/min)***	***Ramp Rate 5 (MW/min)***
18.5	0.1	18.5	18.5	18.5
Break Point 1 (MW)	***Break Point 2 (MW)***	***Break Point 3 (MW)***	***Break Point 4 (MW)***	
260	261	262	262	

Table 10 - Proposed Ramp Down Characteristics for GU_500040

With the same change in Availability the Generator Unit would go from a Ramp Down Rate of 7.66MW/min to 10.47MW/min if the Minimum Stable Generation changes from 260MW to 150MW respectively. These values better represent the capability of the Generator Unit. This approach has already been discussed between SONI TSO and the Participant and it has already been resubmitted by the Generator Unit; however, this solution is only possible for Generator Units that do not make full use of all 5 possible Ramp Rates.

It is clear that the Single Ramp Rate calculation fails to achieve the intent of the T&SC to accurately model the technical characteristics when certain conditions are met. We believe it is not appropriate that changes to Minimum Stable Generation can have such a large impact on the Market Schedule. This is particularly true of cases when Generator Units are coming back from outage or when very low Ramp Rates, intended to be applied for a limited range, are extended artificially.

This anomaly is responsible for a number of the infeasible solutions produced by the LR program observed in September 2010. In these events, the solver did not commit (or de-commit) the correct amount of Generator Units to achieve a feasible solution. The reasons behind this are linked to the nature of the LR optimisation logic.

As previously advised by SEMO, the MSP software is run in three phases to solve a market schedule. These are

- Unit Commitment, which produces a commitment schedule with basic MW quantities,
- Economic Dispatch, which produces Shadow Prices and final MSQs based on the input from the Unit Commitment phase, and
- Post Scheduling and Price Processing, which calculates Uplift and determines the final SMP.

This is illustrated in the figure below.

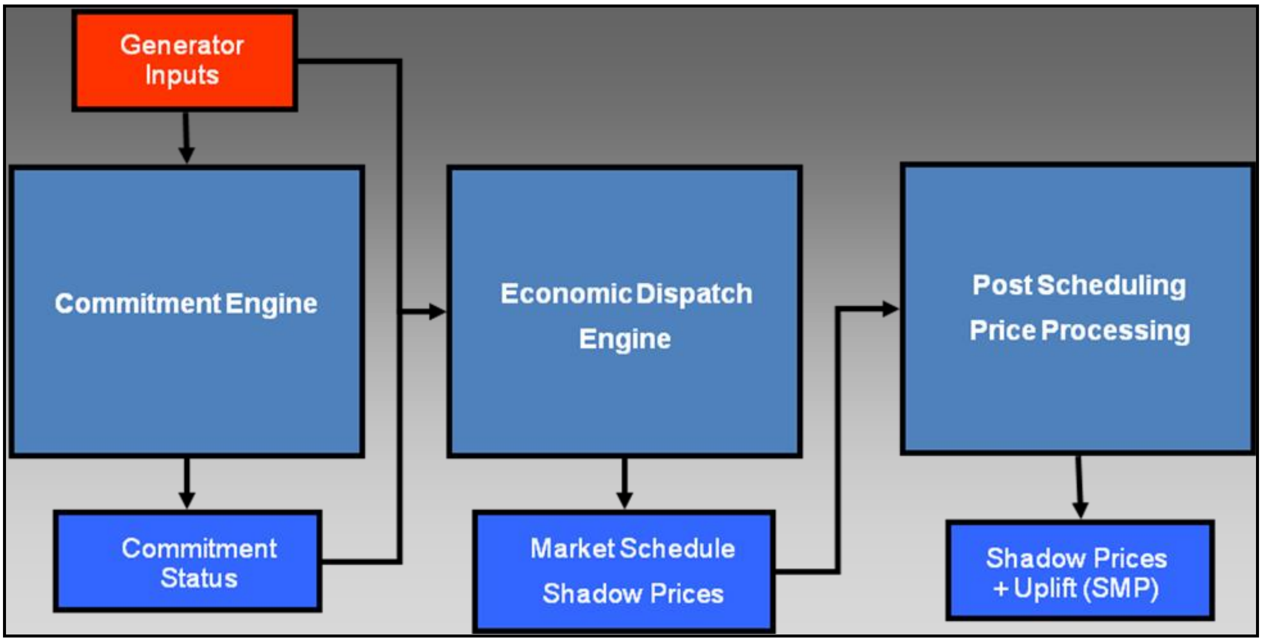

Figure 6 - Phases of the MSP Software

The solver choice (LR or MIP) is in the Unit Commitment phase while all other stages are not impacted by it.

To have an Over or Under Generation event to occur in the Economic Dispatch, it means that not enough or too much generation has been committed in the Unit Commitment stage.

The reason for this lies in the complexity of the optimization calculation in LR, where some simplifications, in particular regarding the application of Ramp Rates, are necessary to guarantee the timely resolution of the solver. Due to the computational limitations of the LR Unit Commitment, the Single Ramp Rate is only used to model Start Up and Shut Down profiles. However, in Economic Dispatch, the Single Ramp Rates are applied in all Trading Periods for which a Generator Unit is committed. This can give rise to issues where a Generator Unit is constrained by an artificially low Single Ramp Rate, there is no Shut Down and the Generator Unit has completed its Start Up profile. For Unit Commitment, once the Start Up profile is completed, the Ramp Rate limits are not modelled. As a result, the Economic Dispatch phase may not be able to set the Market Schedule Quantity to a sufficient level because of the Single Ramp Rate.

Introducing Ramp Rate limitations increases the number of validations to keep track of binding constraints. This, in turn, amplifies exponentially the search space in which LR operates[7]. The solver in choosing the schedule output for a Generator Unit in a single Trading Period, needs to consider if this is possible (based on its previous outputs) or if this would limit the output in future Trading Periods in line with the restrictions of its characteristics. LR does not use an actual ramp rate, but repeatedly determines the hourly upper/lower generation limits for each Generator Unit and although the results obtained might not be optimal, the efficiency of this method enhances significantly the computational requirement both in terms of run time and storage[8].

Discrepancies could arise with the Economic Dispatch phase where the Single Ramp Rate is modelled in every Trading Period. Economic Dispatch cannot adjust the schedule in cases where not enough or too many Generator Units are committed by LR. This becomes more evident if the value of the Single Ramp Rate is artificially low increasing the impact it could have on the schedule in Economic Dispatch, while the Unit Commitment phase schedules the Generator Unit in a more realistic way.

LR might limit the number of committed Generator Units if it is able to reach the Schedule Demand requirements with a small number of generators based on its computation of ramp capability. As the primary problem is decomposed to solve each Generator Unit separately, an approximation of the schedule is produced to make sure the final output is feasible. However, any method used for the derivation of Ramp limitations cannot guarantee that LR Unit Commitment will produce a schedule that can satisfy the ramp constraints even if such schedule exists[9]. When the Economic Dispatch phase refines the schedule, the limitation of Ramp Rate in each Trading Period means that the number of Generator Units committed might result in an infeasible schedule if not enough margin is available to adjust the outputs of other generators upward or downward.

It is academically recognised that relatively simple ideas, such as Generator Unit ramping constraints, can result in extensive research and algorithmic developments in the case of LR, while the corresponding MIP formulation is straightforward[10] and can be modelled in detail. The same problem, therefore, does not occur with a commitment schedule produced by MIP because, as the same formulation of Economic Dispatch is used to calculate Ramp Up and Down Rates, no discrepancy arises between the two stages.

The modelling used by LR is efficient and adequate for most application However, it might not be sufficient for cases where there are relatively large changes in Schedule Demand, few Generator Units can respond to this change and the Ramp constraints in Economic Dispatch are different. Flexibility in the schedule helps to prevent infeasibilities; however, this has so far masked the negative impact of the Single Ramp Rate. In the cases observed in September 2010, Pump Storage Generator Units were unavailable. If they had been available they could have possibly absorbed the excess or the shortage in the schedule, as they do not go through a commitment phase and their schedule is determined in Economic Dispatch as needed. This still means that, although the overall schedule would have been feasible, the affected Generator Unit's schedule would be constrained by Single Ramp Rates unreflective of reality, with implications on the revenue stream for that and the rest of the Generator Units. This impacts on the Energy and Constraints Payments and has repercussions on the SMP.

As demonstrated before, the current T&SC Rules do not achieve this efficiently with regard to Ramp Rates modelling. Although we do not have access to the details of the provisional schedule produced by Unit Commitment before Economic Dispatch, it is evident that, for the

[7] 'Price-Based Ramp-Rate Model for Dynamic Dispatch and Unit Commitment' - Fred N. Lee, Leo Lemonidis, Ko-Chih Liu

[8] 'Price-Based Ramp-Rate Model for Dynamic Dispatch and Unit Commitment' - Fred N. Lee, Leo Lemonidis, Ko-Chih Liu

[9] 'Modeling Unit Ramp Limitations in Unit Commitment' - Arthur I. Cohen

[10] 'A Mixed Integer Programming Solution for Market Clearing and Reliability Analysis' - Dan Streiffert, Russ Philbrick, Andrew Ott

solver to be satisfied that the correct number of Generator Units was committed on, it had to apply a higher Ramp Rate than Economic Dispatch, therefore more similar to the typical Ramp of the Generator Unit.

When the solver commits Generator Units in such a way that the maximum of their abilities is necessary to meet the Schedule Demand requirement and no back up is available from flexible plants, any discrepancy with the parameters used by the Economic Dispatch is likely to cause an infeasible solution with instances of Over or Under Generation.

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 reflective of generator capabilities when the Minimum Stable Generation changes significantly over the Trading Day.
2. This calculation has led to some generator's MSQs being constrained by an artificially low Ramp Rates. The application of the Single Ramp Rate differs between the LR Unit Commitment and Economic Dispatch phases of the MSP software. Certain circumstances can give rise to an artificially low Single Ramp Rate being calculated and it is possible that a final schedule with Over or Under Generation is delivered. The likelihood of this increases if no flexible Generator Units are available to make up for any shortage or excess in the schedule.
3. This is resulting in more occurrences of infeasible solutions from the LR program and the more frequent use of the MIP solver by SEMO.
4. SEMO published all the affected dates with feasible schedules produced by the alternate solver MIP, as per SEMO policy on "Use of MIP for Determination of Market Schedules".

Recommendation

SEMO does not recommend a software change to the LR Unit Commitment program to address this issue as this is a recognised limitation of the LR solver and the alternate solver MIP can provide a feasible solution as required.

To alleviate the impact of this issue SEMO has raised a Modification to the current rules set out in the T&SC for the calculations of the Single Ramp Rates in Appendix N (MOD_42_10).

While this is in progress, SEMO, in association with the TSO, suggests a review of the TOD submissions for those Generator Units which employ very low rates between the Minimum Stable Generation and Break Point 1, where possible. All TOD submissions should be discussed with the relevant TSO prior to submission and will continue to be validated by the relevant TSO.

In the interim continued adherence to the SEMO policy on the use of the MIP solver will be applied to ensure only feasible market solutions are published.

Appendix A

List of all trading periods with infeasible schedule delivered by LR:

Run Type	*Trade Date*	*Optimization horizon?*	*Over or Under Event*	*Size of event (MW)*	*Time*	*SMP (€/MWh)*	*Shadow Price (€/MWh)*
EP1	13-Sep-10	N	O	49.67	03:00	-76.32	-100
		N	O	74.58	03:30	-75.7	-100
		N	O	97.7	04:00	-75.08	-100
		N	O	79.51	04:30	-74.47	-100
		N	O	63.6	05:00	3.55	-100
		N	O	3.01	05:30	4.16	-100
		Y	U	-1.69	08:00	1000	1000
		Y	U	-34.79	08:30	1000	1000
		Y	U	-103.45	09:00	1000	1000
		Y	U	-122.91	09:30	1000	1000
		Y	U	-117.99	10:00	1000	1000
		Y	U	-104.02	10:30	1000	1000
EP2	13-Sep-10	N	O	8.03	03:00	-13.98	-100
		N	O	20.72	03:30	-13.98	-100
		N	O	23.63	04:00	-13.98	-100
		Y	U	-21.7	07:30	1000	1000
		Y	U	-99	08:00	1000	1000
		Y	U	-100.35	09:00	1000	1000
		Y	U	-6.68	11:00	1000	1000
EP2	20-Sep-10	N	U	-11.17	20:30	1000	1000
		N	U	-4.29	21:00	1000	1000
		N	O	6.6	03:30	-100	-100
		N	O	14.48	04:00	-100	-100
EP1	30-Sep-10	N	O	1.98	04:00	-82.86	-100
		Y	U	-12.04	09:30	1000	1000
EP2	30-Sep-10	Y	U	-66.03	09:30	1000	1000
		Y	U	-32.91	10:00	1000	1000