MSP Software Penalty Cost Parameters
Proposed Values for 2012

Document History

Version	Date	Author	Comment
1.0	31st Aug 2011	SEMO	Report for submission to Regulatory Authorities

Table of Contents

1. Introduction

1.1 Purpose

Under Section N.25 of the Trading & Settlement Code, the Market Operator (MO) is required to propose values for the parameters used in the MSP Software for the coming year at least 4 months before the start of that year.

Proposed values for the following parameters are provided:

a) The Over-Generation MSP Constraint Cost
b) The Under-Generation MSP Constraint Cost
c) The Aggregate Interconnector Ramp Rate MSP Constraint Cost
d) The Energy Limit MSP Constraint Cost
e) The Tie-Breaking Adder

Analysis of the current values used for the year 2011 was performed. With reference to this analysis, this document proposes values for the year 2012.

1.2 Audience

The target audience for this document is the Regulatory Authorities and Market Participants.

1.3 Background

The core algorithm of the MSP software attempts to optimise a mixed integer non-linear objective function with non-linear constraints. On occasion the mathematical problem posed may be infeasible (i.e. there will be no solution that will satisfy all the constraints). In these cases, rather than return no answer, it is customary in numerical solutions to produce an answer where some of the constraints have been breached slightly. To achieve this, slack variables are introduced with suitably chosen cost coefficients that ensure that these variables are used only in the case of infeasibility. In addition, the setting of these coefficients can prioritise the order in which constraints will be breached for a given situation.

The current values of the parameters were determined in 2007/2008 using methods detailed in AIP-SEM-07-439. The values of the parameters were analysed in August 2008 (AIP-SEM-08-104B), August 2009 (AIP-SEM-097A), and August 2010 (AIP-SEM-10-065B). The reviews resulted in no change to the original values chosen. Further analysis, described in this report, has been undertaken by SEMO using data from between July 2010 and July 2011, which demonstrates the suitability of the chosen values.

1.4 Existing Values

Existing Values used in MSP Software:

PARAMETER	PENALTY SETTING FOR 2011
Over Generation MSP Constraint	73
Under Generation MSP Constraint	73
Aggregate Interconnector Ramp Rate MSP Constraint Cost	292
Energy Limit MSP Constraint Cost	38
Tie-Breaking Adder	0.001

Table 1: Existing Values used in MSP Software

Both the 2009 and 2010 reports remarked on the absence of any price events in the market where penalties occurred. The 2011 report included the testing of four Trading Days where a significant price event occurred, concluding that these events were caused due to infeasibility, rather than economic reasons. These reports, in themselves, show the robustness of the values used, considering the number of MSP runs which would have occurred over the periods.

There have been situations in this testing year where price events have occurred. There have been three Trading Days featuring a Price Floor event and three Trading Days with a Price Cap event, all of which occurred when using the LR solver. In these cases, SEMO used the MIP solver, in line with SEMO's published policy regarding price events 'MIP Policy V5.0 – Use of MIP for Determination of Market Schedules'. In all cases the price event did not recur when MIP was used as a solver. As these cases did occur when LR was used as the solver, tests were performed to ensure that any price events occurring were not due to inappropriately set MSP parameters.

Additional testing was carried out on a number of other days from 2010 and 2011 in a similar manner to those in previous years, to ensure that the values proposed for 2012 are robust.

It should be noted that the set of parameters chosen represents one of a range that could have achieved the objective of ensuring that the slack variables are only used to alleviate infeasibilities.

The bounds of this range are established from below at the point where the slack variables begin to be used for economic reasons and from above at the stage where the magnitude of the penalty prices causes the mathematical problem to become poorly scaled.

1.4.1 MSP Value Objective – Well Scaled but Not Economic

The following simple example is shown here to illustrate, at a high level, how a suitable value is chosen for the penalties on the slack variable. In the graph shown in Figure 1 the value in red represents the penalty set at €300/MWh, while the other values are offers from the Price Maker Unit Generators, ranging from €50/MWh to €300/MWh.

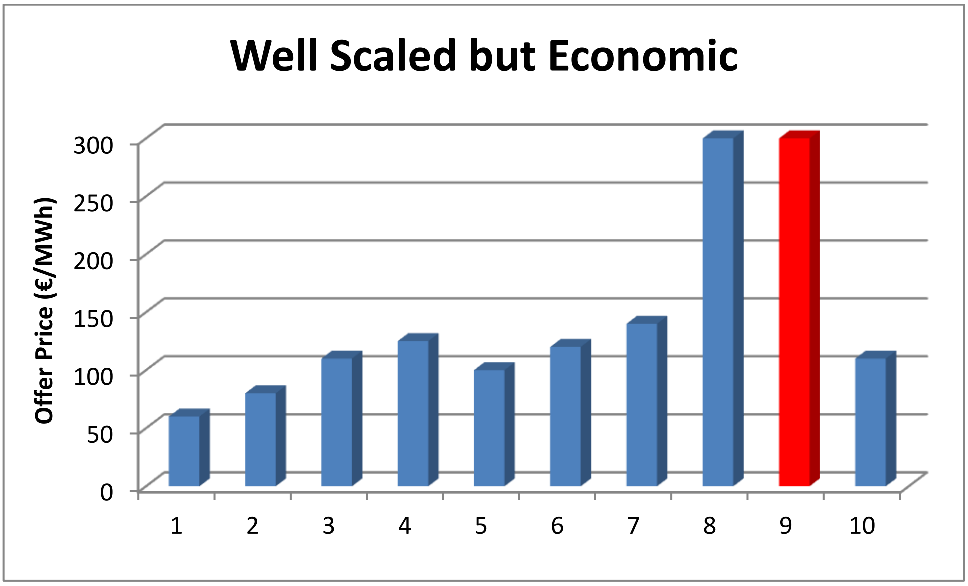

Figure 1: Well Scaled but Economic

A unit commitment problem featuring the above offers is regarded as well scaled as the offers can easily be differentiated by their magnitudes. However, the penalty is too close to other offers and there is a chance that it would be incurred for economic reasons in place of another similarly priced Generator Unit. Therefore this value would not be suitable.

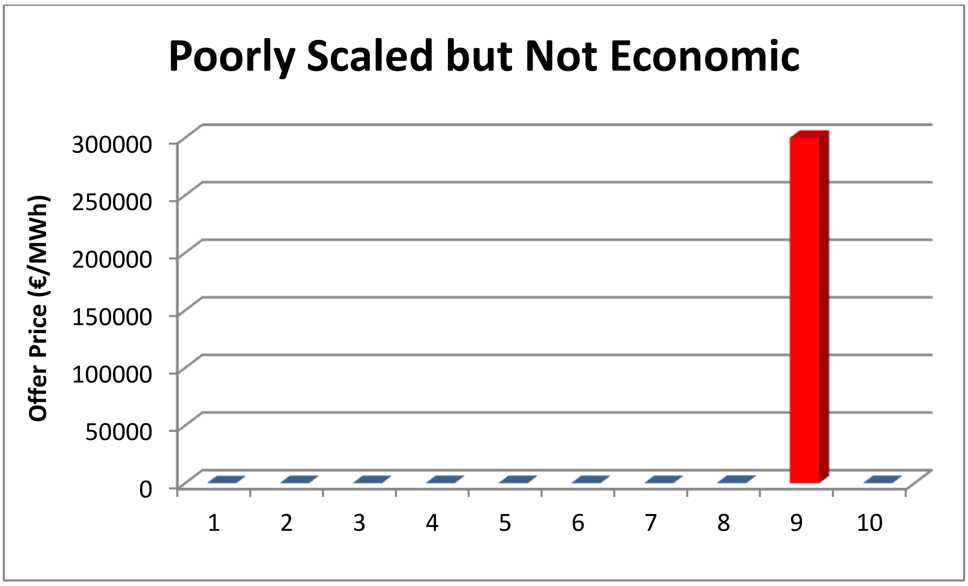

Figure 2: Poorly Scaled but Not Economic

All offers shown in Figure 2 are the same as for the previous example except for the penalty value which has been set to €300,000/MWh. However, due to the large magnitude of the penalty, they can no longer be distinguished on the scale. A unit commitment problem featuring these offers would be regarded as poorly scaled as the offers cannot easily be differentiated by their magnitudes. Poor scaling will impact the mathematical solver's ability to resolve the problem. In contrast to the previous example the penalty is much higher than the other offers and there is little chance that it would be incurred for economic reasons in place of another generator unit. However due to the large magnitude this value would not be suitable either.

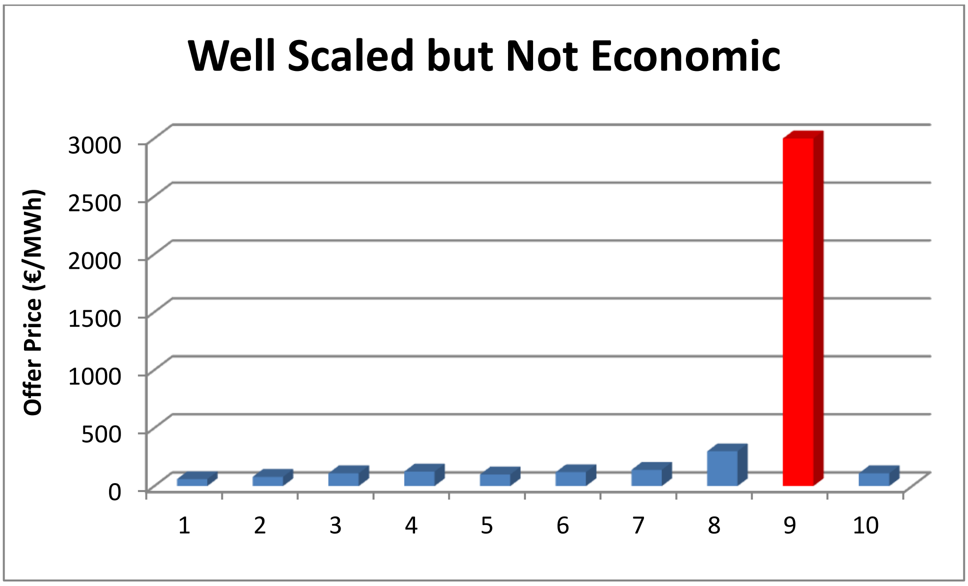

Figure 3: Well Scaled and Not Economic

All offers in this final example, shown in Figure 3, are the same as in the previous examples with the exception of the penalty value which was set at €3,000/MWh. The magnitude of the penalty is such that the difference in offers can be seen on the above graph. A unit commitment problem featuring these values is regarded as well scaled as the offers can still be differentiated by their magnitudes. Additionally, the penalty is much larger than the other offers and there is little chance that it would be incurred for economic reasons in place of another Generator Unit. This value would be a suitable choice of penalty as it strikes a balance between sufficiently well scaled and not being economic.

While it is possible to determine the lower bound with a good degree of confidence through the tests included here, the upper bound is more difficult to define.

The settings for the penalties used to date are two orders of magnitude greater than the lower bound. This level has achieved the objective of 'well scaled and not economic' and thus far, over the hundreds of runs of the MSP Software, the penalties have only been incurred to resolve infeasibilities.

Note: The MSP software multiplies these penalty factors by an additional variable, which is equal to five times the maximum daily bid price. The proposed penalty used by the MSP software is thus a much higher value than those listed above in Table 1.

2. Analysis of MSP Parameters

The MSP software allows for 20 price-quantity pairs for each slack variable constraint that can be violated. For each step, price and quantity values may be set by the operator. The prices and quantities must be strictly monotonically increasing. The price of the last offer step of the slack variable is multiplied by a factor equal to five times the maximum offer submitted by Generator Units for that day. Regardless of the quantity offered for the last step, the MSP internally imposes no limit on the quantity that can be scheduled for the final step.

The proposed method for setting the penalties is to use just one offer step and to enter a relatively low penalty factor in the cost field. This factor effectively sets the penalty used internally to be that factor multiplied by five and multiplied by the greatest offer price during the day (assuming that offer price exceeds 0.1). This approach results in penalty values that vary from day to day; however, they will always be significantly higher than the maximum offer on that day.

Example:

- The penalty cost is set to 73 and the quantity is set to be 1750 (this value is not relevant as it is the last offer step and there is no limit to the quantity that can be scheduled).
- The maximum generator offer for the day is €547.68/MWh
- Therefore, the effective penalty will be:
  73 x 5 x €547.68/MWh = €199,903.20/MWh
- The quantity of violation allowed will be infinite.

The specific penalty functions are:

1. Over Generation MSP Constraint Cost
2. Under Generation MSP Constraint Cost
3. Aggregate Interconnector Ramp Rate MSP Constraint Cost
4. Energy Limit MSP Constraint Cost

Setting penalties is not arbitrary. A penalty will only occur if it (a) results in a lower production cost than other options available or (b) if the schedule would be infeasible otherwise. If the penalties are set incorrectly then constraints could be violated simply because it is cheaper to do so. In other words the penalties could be incurred for purely "economic" reasons. In accordance with Appendix N paragraph 17.4 of the Trading & Settlement Code, this should not occur and the penalties should only be incurred in cases where the schedule would otherwise be infeasible.

To test the adequacy of the current costs of breaking the slack variables, a selection of days were chosen for analysis. The days chosen for testing had one of the following characteristics:

- Price Cap was reached
- Price Floor was reached
- System Marginal Price > €500/MWh
- Shadow Price was high
- Shadow Price was low

Tests were carried out on the ten chosen days to ensure that the penalties are set sufficiently high so that they are only incurred to alleviate infeasibility. The days tested were spread throughout the calendar year, yet most price events occurred during the autumn and winter months, as expected with higher levels of generation.

2.1 Over Generation MSP Constraint Cost

2.1.1 Context

An Over Generation (OG) penalty is in place to absorb extra power in order to match supply to demand in the case where the Schedule Demand is less than the total output of the Price Maker Generation Units.

The MSP software can use the over generation slack variable in two situations:

1. To relieve an over generation infeasibility: In certain situations the software may be unable to reduce the power output from physical units adequately to allow generation to equal demand. In this case the over-generation slack is used to absorb the extra power.

2. To reduce MSP Production Costs: In certain situations it may be more economical to schedule the OG penalty than it is to curtail physical generator units. In this case the over-generation slack is used.

If the over generation penalty is to be used, the penalty cost applies to each Trading Period on a per MW rate of violation. Using the current value of the over-generation slack variable, an OG penalty will result in the shadow price getting set equal to the price floor (PFLOOR).

2.1.2 Analysis

Price Floor (PFLOOR) events:

Since July 2010, there have been three Trading Days featuring a PFLOOR. Of these, two occurred from Ex-Post Indicative MSP Software runs and the Ex-Post Initial MSP Software run of one of these also featured a PFLOOR. In line with SEMO policy regarding price events of this nature, they were re-run using the alternative MIP solver algorithm and the resulting published prices did not feature a PFLOOR.

These cases were included to confirm that the current settings continue to be fit for purpose in that they are ‘well scaled and economic’ – i.e. that the PFLOORs did not arise from the breaching of a constraint for economic reasons.

The OG penalty constraint was used in each case where a PFLOOR event had occurred. To show that this occurred to solve infeasibility, the cost of the OG slack was increased to a very large number (10,000). The OG penalty was still used irrespective of how expensive the penalty became.

This indicates that the value of the OG penalty was not the reason for the use of the OG constraint. If it had been then it would have ceased to be breached when the value became sufficiently high. Therefore the OG penalty was breached to resolve infeasibility.

Infeasibilities of this nature are rare in occurrence and are related to the manner in which the LR algorithm solves the unit commitment problem under certain conditions. The occurrence of these PFLOOR events and their resolution without any disruption to the operation of the market is an indication of the robustness of SEMO's internal processes. SEMO continues to have the MSP Software regularly re-certified and continuously monitor any occurrences of this nature.

Additional Days:

In other cases the OG penalty was reduced to the lowest possible value but as expected the penalty was not used in any situation. This is shown in the plot below in Figure 4.

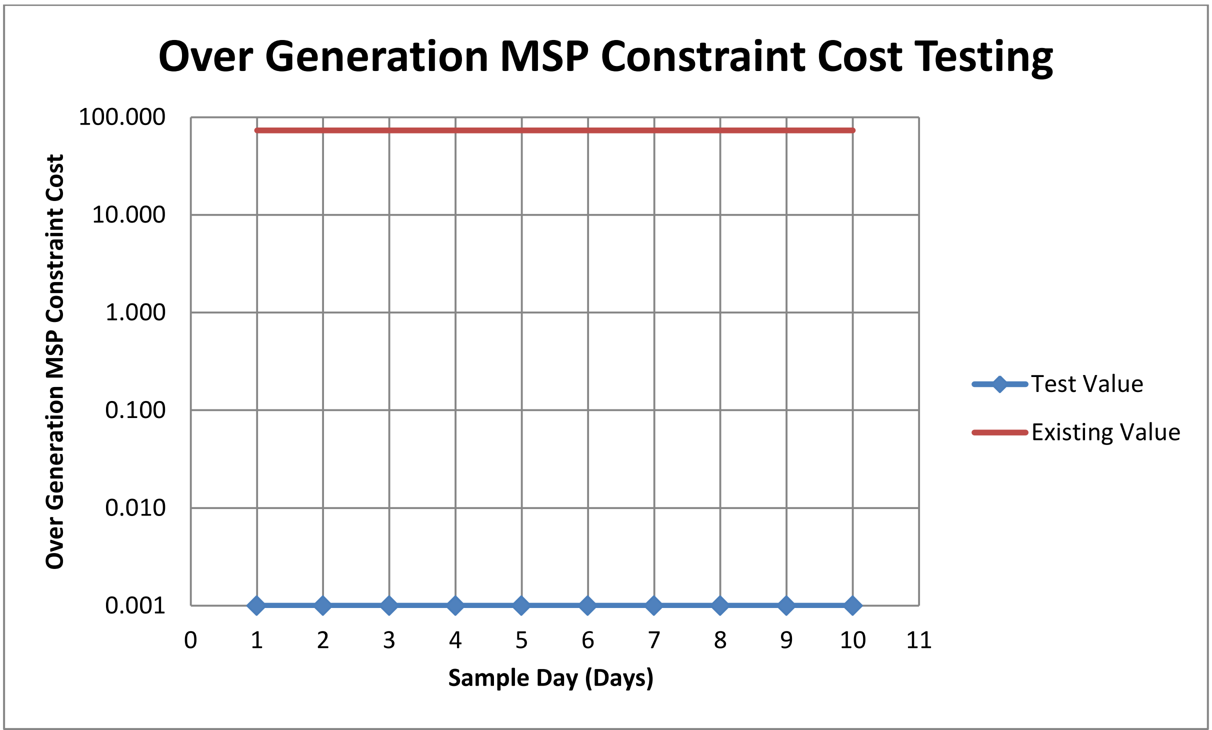

Figure 4: Over Generation MSP Constraint Cost Testing

To further examine this penalty, the demand was forced negative for each of the test cases and the penalty was incurred as expected. Similar to the PFLOOR cases, the OG penalty was increased to a very large number but was still used due to infeasibility. The shadow price was reduced to PFLOOR when the OG penalty was used.

To prove that the OG penalty was being used for the cases when the PFLOOR was reached, the cost of the penalty was changed. The cost of the penalty is normally 73, from which the software produces a PFLOOR. For a particular case the value of the constraint was reduced to 0.001. The solver no longer reached PFLOOR as the cost of the penalty was not large enough. However, the OG penalty was still being used but now set the value at an increased value of - €4.44/MWh for the periods in which there had been a PFLOOR.

To prove that the OG constraint is setting the shadow price for this period we use the equation:

$$Over\ Generation\ Penalty = \frac{Max\ Shadow\ Price}{5 \times Max\ Offer}$$

$$0.001 \text{ x } €887.44/\text{MWh} \text{ x } 5 = €4.44/\text{MWh}$$

The negative value arises from the fact that the OG slack variable is negative. If the demand were to increase infinitesimally, the production costs would decrease by €4.44/MWh. This illustrates how the OG penalty is setting the shadow price. It is important to note that the penalty will not necessarily set the shadow price in all cases where over-generation occurs. If the OG penalty is used it can, in some cases, change the generator schedule in certain ways which may result in a different variable setting the shadow price.

2.1.3 Conclusion

With the value set to 73, the Over Generation penalty only occurs to alleviate infeasibility due to an Excessive Generation Event in line with paragraph N17.4 of the T&SC.

2.1.4 Recommendation

SEMO recommends retaining the Over-Generation MSP Constraint Cost setting of 73 for Year 2012.

2.2 Under Generation MSP Constraint Cost

2.2.1 Context

The Under Generation (UG) penalty is in place to match supply to demand in the case where the Schedule Demand is greater than the total output of all Price Maker Generator Units.

The MSP software will use the under generation slack variable in two situations:

1. To relieve an under generation infeasibility: In certain situations the software may be unable to increase the power output of physical units by the required amount to meet the demand. In this case the demand is met by scheduling the under generation slack.

2. To reduce MSP Production Costs: In certain situations it may be more economical to schedule the UG penalty to meet the demand than it is to schedule the next cheapest generator.

If the under generation slack is used, the penalty cost applies to each Trading Period on a per MW rate of violation. The under generation slack should only be used in cases of infeasibility and so the cost of using this slack should always be greater than the cost of changing the output of Price Maker Generator Units. Using the current value of the under-generation slack variable, the UG penalty will result in the shadow price being set equal to the price cap (PCAP).

2.2.2 Analysis

Price Cap (PCAP) events:

There have been three Trading Days during which PCAPs have occurred since July 2010. SEMO has included these in the analysis to confirm that the current settings continue to be fit for purpose in that they are 'well scaled and not economic', i.e. that the PCAPs did not arise from the breaching of a constraint for economic reasons.

The UG penalty constraint has been used in the cases where the PCAPs have occurred. To show that this occurred to solve infeasibility, the cost of the UG slack was increased to a very large number (10,000). The UG penalty parameter was still used irrespective of how expensive the penalty became.

This illustrates that the value of the penalty was not the reason for the use of the UG constraint. If it was it would have ceased to be breached when the penalty value became sufficiently high. Therefore, the UG constraint was breached to resolve infeasibility.

The occurrence of these PCAP events and their resolution without any disruption to the operation of the market is an indication of the robustness of SEMO's internal processes. SEMO continues to have the MSP Software regularly re-certified and continuously monitors any occurrences of this nature.

Additional Days:

For the remaining test cases that did not already feature under generation, the value of the penalty was successively reduced from 73 to test at what order of magnitude it becomes economical for the solver to use the penalty over a physical unit. The graph below in Figure 5 illustrates the lowest possible values for each day tested in which the UG constraint is not used.

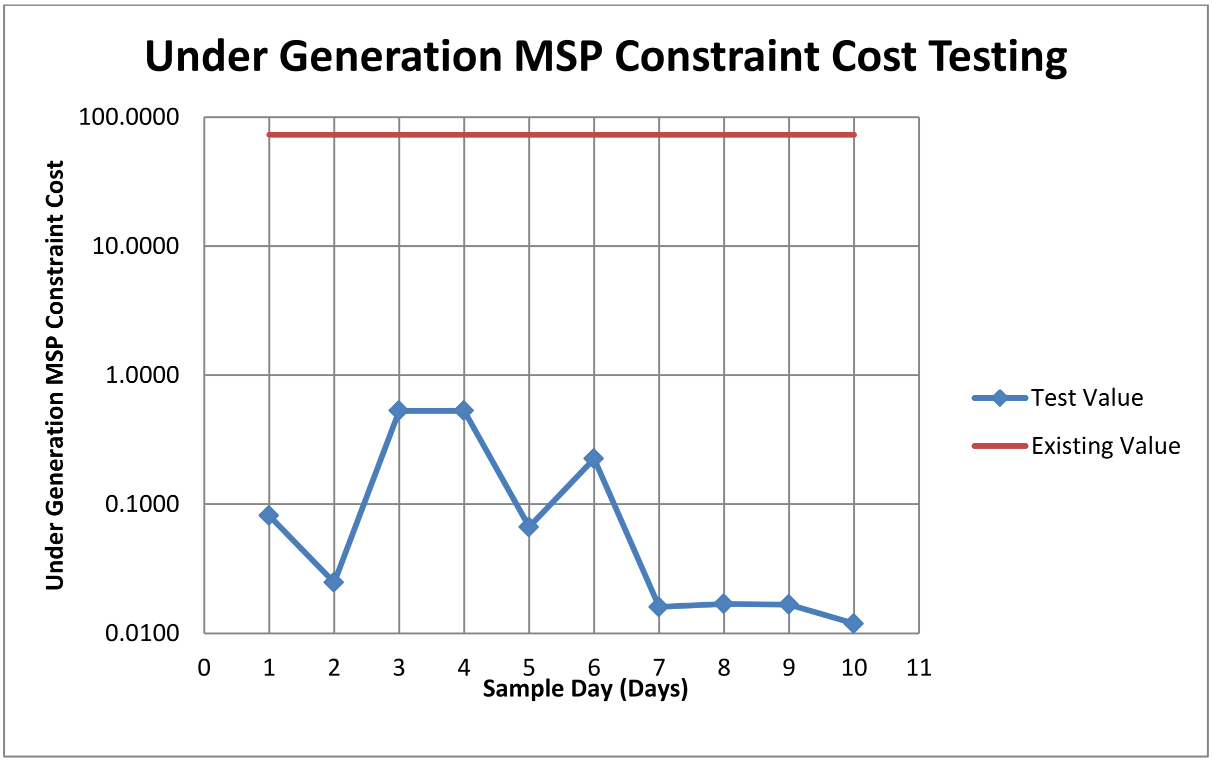

Figure 5: Under Generation MSP Constraint Cost Testing

As can be seen from the graph, the upper bound of the lower plot is two orders of magnitude less than the current setting of 73. Reducing the cost of the UG constraint to below 0.011 resulted in the penalty becoming binding for all cases.

Note: Case numbers 3, 4, and 6 represent the cases where the UG is already binding. These three points represent the values where the cost of the penalty equals the PCAP. Reducing the penalties further would result in the UG event being priced at a value lower than the PCAP.

For a particular case where the PCAP was reached due to an UG event, if the cost of the UG penalty is decreased to 0.53088 this corresponds to a shadow price of €1000/MWh and so PCAP remains. However if the cost is further decreased to 0.52 the highest shadow price reported becomes €979.50/MWh. To prove that the UG constraint sets the shadow price for periods when the cost of the penalty is reduced we use the relationship:

$$Under\ Generation\ Penalty = \frac{Max\ Shadow\ Price}{5 \times Max\ Offer}$$

$$0.52 \text{ x } €376.73/\text{MWh x } 5 = €979.50/\text{MWh}$$

Therefore, it has been shown that the highest Shadow Price is being set by the UG penalty parameter. It is important to note that the penalty will not necessarily set the shadow price in all cases where under generation occurs. If the UG penalty is used it can, in some cases, change the generator schedule in certain ways that result in Generator Units and the UG penalty setting the shadow price.

2.2.3 Conclusion

With the UG penalty value set to 73, the Under Generation Penalty only occurs to alleviate infeasibility due to an Insufficient Capacity Event in line with paragraph N17.4 of the T&SC.

2.2.4 Recommendation

SEMO recommends retaining the Under Generation MSP Constraint Cost setting of 73 for Year 2012.

2.3 Aggregate Interconnector Ramp Rate MSP Constraint Cost

2.3.1 Context

A single ramp rate applies for the interconnector. This can be violated in either direction, i.e. increasing or decreasing flow between Trading Periods beyond the allowed ramp rate. The penalty cost applies to each Trading Period on a per MW rate of violation of the ramp rate.

Interconnector Ramp Rate penalties will only be incurred if the Interconnector Ramp Rate is binding on a particular day, the penalty will never be incurred unless this is the case. To ensure that the penalty would not be incurred in these instances for economic reasons, a number of tests were carried out where the Interconnector Ramp Rate was binding to determine the level at which this would occur.

If the interconnector was ramping up for 60 Trading Periods and its ramp rate was binding in every Trading Period, violating the ramp rate in the first Trading Period by 1MW would allow an additional 1MW to flow in each of the 60 Trading Periods. With the capacity of the current interconnector and a ramp rate of 10MW/min (currently used for calculating MIUNs on the Moyle Interconnector), it would only be possible to for the ramp rate to be binding for one Trading Period.

It is desirable that the MSP software uses the OG and UG penalties before it uses the Interconnector Ramp Rate penalty. To ensure this is the case, the penalty for the ramp rate violations is set significantly higher than both the OG and UG penalties. Tests were performed to confirm that the occurrences of OG or UG penalties take precedence in resolving infeasibility in the unlikely case where the ramp rates are binding.

2.3.2 Analysis

Using current settings, the Interconnector Ramp Rate was not binding for any day throughout the test year. Thus the Interconnector Ramp Rate was changed to an artificially low value of 1MW/Trading Period for a number of Trading Periods for each of the days tested. This resulted in several periods where the Interconnector Ramp Rate became binding.

To ensure that the UG and OG penalties take precedence over the ramp rate penalties, the cost of the UG and OG constraints were raised to different values for each test day. When the UG and OG penalties were at their existing values of 73, the Interconnector Ramp Rate penalty was incurred for every day, with the Ramp Rate set to 1MW/Trading Period. However, further testing was carried out with the Interconnector Ramp Rate set to 300MW/Trading Period. Using this setting, only four days were binding out of those tested. Out of these four days the Interconnector Ramp Rate penalty was not incurred on any day, even when the UG and OG constraints were both raised to, first 146, and then 292 respectively.

2.3.3 Conclusion

The Interconnector Ramp Rate Penalty can be used to alleviate infeasibility by breaching the ramp rate constant, during periods when the ramp rate is binding. However in the case of an under generation event the UG penalty will be breached first, likewise in the case of an over generation event, the OG penalty will be triggered. Therefore the value of current value of 292 ensures that the penalty would only be used to alleviate infeasibility in line with paragraph N17.4 of the T&SC.

2.3.4 Recommendation

SEMO recommends retaining the Aggregate Interconnector Ramp Rate MSP Constraint Cost setting of 292 for Year 2012.

2.4 Energy Limit MSP Constraint Cost

2.4.1 Context

This penalty applies to the MWh violation of energy limits, maximum reservoir levels and minimum reservoir levels. The Energy Limit needs to be binding on the particular day to incur the penalty; it will not be incurred otherwise. For the Energy Limit to be breached on a particular day, two criteria must be met:

1. The Energy Limit for that day must be binding – the total output of an individual Energy Limited Unit over a Trading Day, in energy terms, must equal the energy limit set for that unit on that Trading Day, i.e. a constraint cannot be breached unless it is binding.

2. The maximum generation must not be binding for at least one Trading Period – The Energy Limited Unit must be capable of increasing output in the period where the Energy Limit Penalty is incurred. Therefore the availability of the Energy Limited Unit must not be binding.

Energy Limit cost is measured per MWh, while OG and UG are measured in MW. This means breaking an Energy Limit in one Trading Period yields an extra generation of 2MW. Therefore a penalty equal to half of the OG and UG would be equivalent for one Trading Period.

2.4.2 Analysis

During the analysis the software was able to incur a penalty in all but one of the days. For this one day the Energy Limit was not binding. The graph below in Figure 6 shows the values tested to determine the energy limit.

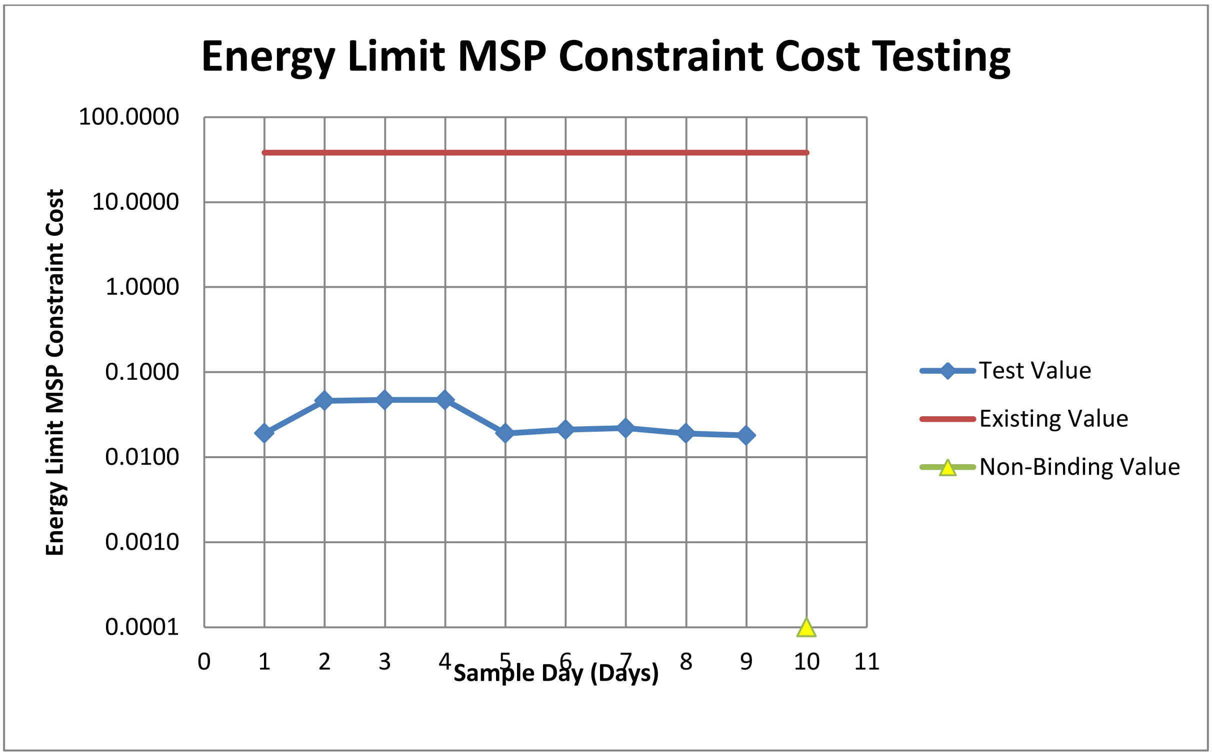

Figure 6: Energy Limit MSP Constraint Cost Testing

Similar to the Interconnector Ramp Rate, breaking an Energy Limit could be used to alleviate infeasibility due to an Insufficient Capacity Event or an Excessive Generation Event. It is desirable that the UG penalty is used for an Insufficient Capacity Event and an OG penalty is used for the Excessive Generation Event. As the Energy Limit is measured in MWh, a penalty parameter of 36.5 would be equivalent to the UG/OG penalty parameter of 73. Setting the Energy Limit penalty at 38 ensures that the UG and OG penalties take precedence.

2.4.3 Conclusion

It proposed that the current value of 38 be retained as it will ensure that the Energy Limit Penalty is only incurred to alleviate infeasibility in line with paragraph N17.4 of the T&SC.

2.4.4 Recommendation

SEMO recommends retaining the Energy Limit MSP Constraint Cost setting of 38 for Year 2012.

2.5 The Tie-Breaking Adder

2.5.1 Context

The Tie-breaking Adder is used to adjust prices for individual Generator Units in the event of a Tie-Break.

2.5.2 Analysis

While the MSP Software will allow prices and costs of up to €99,999.99/MWh to be specified without material loss of precision, the tie-breaking feature cannot be operated so as to apply an adder significantly less than €0.001/MWh while being reflected in prices and costs for any price or cost above €9,999.99/MWh. This is because the MSP Software records costs to a precision of seven significant figures and such a small tie-breaking adder would appear in the eighth significant figure over any number above €9,999.99/MWh.

2.5.3 Conclusion

A Tie-breaking Adder of €0.001/MWh is the lowest possible adder that can be resolved at seven significant figures up to €9999.99/MWh.

2.5.4 Recommendation

SEMO recommends retaining a Tie-breaking Adder of €0.001/MWh for Year 2012.

3. Recommendations

Analysis of the current values used for the year 2011 was performed. With reference to this analysis, this document proposes values for the year 2012.

SEMO proposes that the MSP Constraint Parameters retain their existing values for 2012 (unless significant changes in the T&SC rules dictate their re-evaluation).

The proposed parameter settings are shown below in Table 2:

PARAMETER	PENALTY SETTING FOR 2012
Over Generation MSP Constraint Cost	73
Under Generation MSP Constraint Cost	73
Aggregate Interconnector Ramp Rate MSP Constraint	292
Energy Limit MSP Constraint Cost	38
Tie-Breaking Adder	0.001

Table 2: Proposed Values for MSP Software in 2012

These values are processed internally to arrive at the actual penalty values used in the MSP Software runs as shown in Table 3:

PARAMETER	PENALTIES TO BE USED BY MSP SOFTWARE FOR 2012
Over Generation MSP Constraint Cost	73 x 5 x Max Offer
Under Generation MSP Constraint Cost	73 x 5 x Max Offer
Aggregate Interconnector Ramp Rate MSP Constraint	292 x 5 x Max Offer
Energy Limit MSP Constraint Cost	38 x 5 x Max Offer
Tie-Breaking Adder	0.001

Table 3: Internal Formulae used in MSP Software Run Calculations

The tests described in this report have demonstrated that the values are safely above the level where they would be breached for economic reasons and would only be breached in the case of infeasibility.