MSP Software Penalty Cost Parameters
Proposed Values for 2011

Document History

Version	Date	Author	Comment
1.0	31st Aug 2010	SEMO	Report for submission to Regulatory Authorities

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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 2010 was performed. With reference to this analysis, this document proposes values for the year 2011.

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 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 both August 2008 (AIP/SEM/08/104B) and August 2009 (AIP/SEM/097A). Both reviews resulted in no change to the original values chosen. Further, analysis has been undertaken by SEMO described in this report that demonstrates the suitability of the chosen values.

1.4 Existing Values

Existing values used in MSP software

Parameter	Penalty Setting for 2010
Over Generation MSP Constraint Cost	73
Under Generation MSP Constraint Cost	73
Aggregate Interconnector Ramp Rate Constraint Cost	292
Energy Limit MSP Constraint Cost	38
Tie-Breaking Adder	0.001

Previous reports remarked on the absence of any price events in the market where the penalties were incurred. This in itself has been a good measure of the suitability of parameters, considering the number of runs of the MSP Software that would have taken place over this period.

During 2010, however, there have been three Trading Days featuring a Price Cap event and one Trading Day featuring a Price Floor event, all incurred by the LR solver. In these cases, SEMO opted to run the MIP solver, in line with our published policy regarding price events and in all cases the price event did not re-occur in MIP[1]. However, 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.

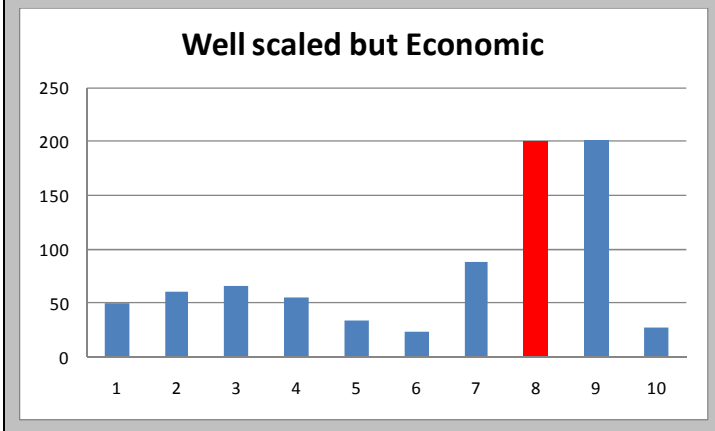
Additional testing was carried out on a number of other days from 2009 and 2010 in a manner similar to previous years to ensure that the values proposed for 2011 are robust.

It should be noted that this set of values 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.

Box 1: 'Well Scaled and Not Economic'

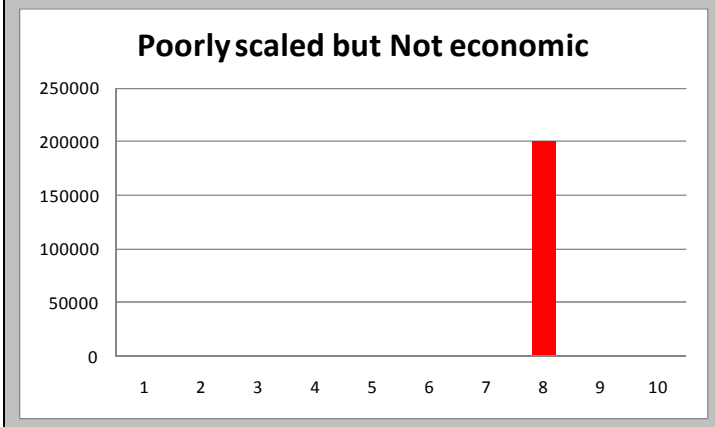
The following simple example is shown here to illustrate at a high level how a suitable value is chosen for the penalties on the slack variables. The value in red in the example represents the penalty and the other values are offers from Price Maker Generator Units.



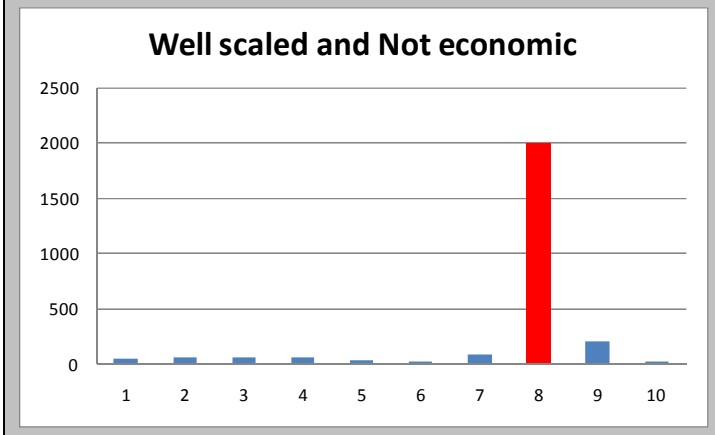
A unit commitment problem featuring the above offers would be regarded as well scaled as the offers can easily be differentiated by their magnitudes. On there other hand the penalty is too close to other offers and there is a chance that it would be incurred for economic reasons in place of another

[1] One of the Price Caps that occurred was published as the market price. It was subsequently disputed and a re-run was completed using the MIP solver.

similarly priced Generator Unit. So this value would not be suitable.



All offers in the above example except for the penalty offer are the same as in the previous example; however, due to the large magnitude of the penalty, they can no longer be seen 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 impacts on the mathematical solver's ability to solve the problem. On the other hand, 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. This value would not be suitable either.



All offers in this final example except for the penalty offer are the same as in the previous examples; 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 offers would be regarded as well scaled as the offers can still be differentiated by their magnitudes. In addition, 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. 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 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 higher than the lower bound. This level has proved to achieve the objective being 'well scaled and not economic' and over the hundreds of runs of the MSP Software to date, the penalties have only been incurred to resolve infeasibilities.

Note: The MSP software multiplies these penalty settings 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.

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 a price and quantity is 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 price is set to 73 and the quantity is set to 10000 (This value is not relevant as this is the last step and there is no limit on the quantity that can be scheduled).

The maximum generator offer is

€380.89

The effective penalty will be

73×5×€380.89= €139024.85

The quantity of violation allowed will be infinite.

A penalty will only be incurred if it results in a lower production cost or if the schedule would be infeasible otherwise. In accordance with appendix N paragraph 17.4 of the Trading and Settlement code, the MSP software shall include the following variables which allow such constraint limits to be violated at a high cost if no feasible solution would otherwise exist.

The specific penalty functions are

1 The Over-Generation MSP Constraint Cost

2 The Under-Generation MSP Constraint Cost

3 The Aggregate Interconnector Ramp Rate MSP Constraint Cost

4 The Energy Limit MSP Constraint Cost

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
- Shadow Price > 500
- System Marginal Price >500
- 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 an infeasibility.

2.1 Under Generation MSP Constraint Cost

2.1.1 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, an Under Generation penalty will result in the shadow price being set equal to the price cap (PCAP).

2.1.2 Analysis

The existing value for the UG constraint is 73.

Price Cap (PCAP) events

SEMO included two of the Trading Days where PCAP occurred in its 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 PCAP did not arise from the breaching of a constraint for economic reasons. The third case was not included as it arose from a defect that has been since corrected.

The UG penalty constraint had been used in the cases where the PCAP had occurred. To show that this occurred to solve an infeasibility, the cost of the UG slack was increased to a very large number. 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 an infeasibility.

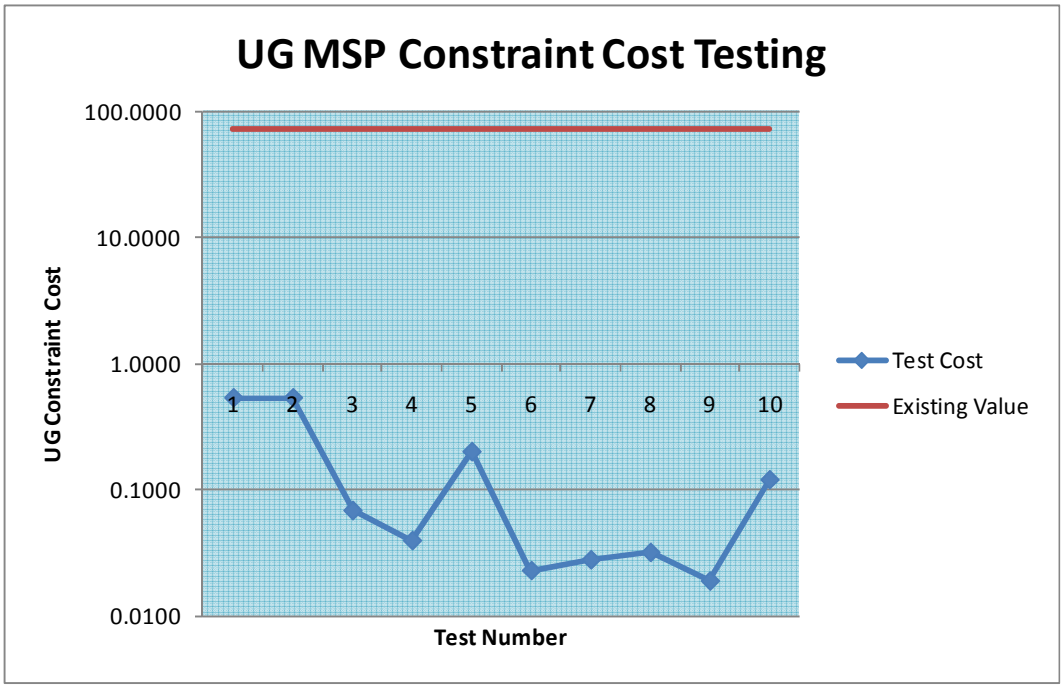
All Price Cap events encountered using the LR solver have been the result of defects in the Central Market System. These occurrences have been analysed and discussed with Participants and the Regulatory Authorities and have been addressed with the CMS vendors. Their resolution without any disruption to the operation of the market is an indication of the robustness of SEMO's internal

processes. We continue to have the MSP Software regularly re-certified and continuously monitor any occurrences of this nature.

Other test days

For the remaining eight 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. Plotted below (Figure 3.1) are the lowest possible values for each day tested in which the UG constraint is not used.

Figure 2.1



As can be seen from the above diagram, 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 .019 resulted in the penalty becoming binding for all test cases.

Note: The first two cases are the PCAP cases that were described in the previous section. In these cases the under-generation constraint is already binding and these two points represent the values where the cost of the penalty equals PCAP. Reducing the penalties further would result in the UG event being priced at a value lower than PCAP.

To prove that the UG constraint sets the shadow price for periods when the cost of the penalty is reduced we use the relationship

$$UnderGenerationPenalty = \frac{MaxShadow\,\mathrm{Pr}\,ice}{5 \times MaxOffer}$$

For example:

For a particular case where the PCAP was reached due to an UG event, if we decrease the cost of the penalty to .532 this corresponds to a shadow price of 1000 and so PCAP remains. However if the cost

is further decreased to 0.5 the highest shadow price reported becomes 939.125. To show that the UG constraint is causing this the above equation is applied,

$$.5 \times 375.65 \times 5 = 939.125$$

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.

2.1.3 Conclusion

With the cost of this penalty set to 73, the Under-Generation Penalty is only incurred to alleviate an infeasibility due to an Insufficient Capacity Event in line with paragraph N17.4 of the T&SC.

2.1.4 Recommendation

SEMO recommends retaining the Under-Generation MSP Constraint Cost setting of 73 for Year 2011.

2.2 Over Generation MSP Constraint Cost

2.2.1 Context

An Over Generation (OG) slack is in place to absorb extra MWs of 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 penalty in two situations.

1. To relieve an 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 more economical to schedule over generation 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 Over Generation penalty will result in the shadow price getting set equal to the price floor (PFLOOR).

2.2.2 Analysis

Price Floor (PFLOOR) events

Since August 2009, there has been one Trading Day featuring PFLOOR from an Ex-Post Indicative MSP Software run. In line with SEMO policy regarding price events of this nature, this was re-run

using the alternative MIP algorithm and the resulting published prices did not feature a PFLOOR. This case was discussed with Participants at the Market Operator User Groups (MOUGs).

As with the PCAP cases, this case was included 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 PFLOOR did not arise from the breaching of a constraint for economic reasons.

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

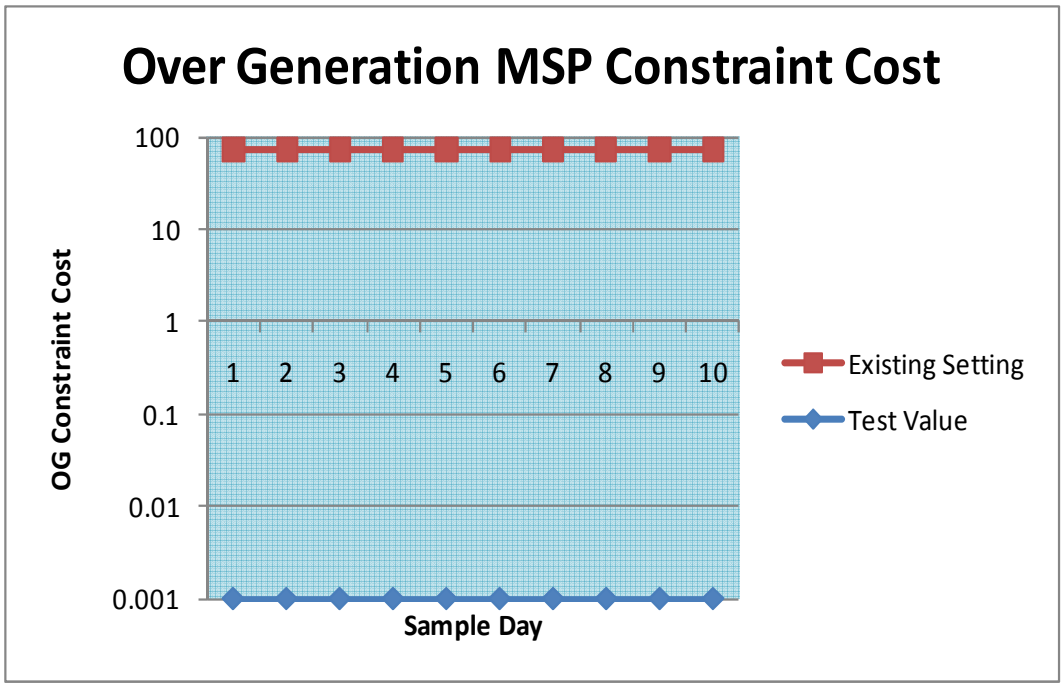
This illustrates that the value of the penalty was not the reason for the use of the OG constraint. If it was, it would have ceased to be breached when the penalty value became sufficiently high. Therefore, the OG constraint was breached to resolve an infeasibility.

As with the occurrences of PCAP, infeasibilities of this nature are rare in their occurrence and are related to the manner in which the LR algorithm solves the unit commitment problem under certain conditions. The occurrence of this PFLOOR event and its resolution without any disruption to the operation of the market is an indication of the robustness of SEMO's internal processes. We continue to have the MSP Software regularly re-certified and continuously monitor any occurrences of this nature.

Other 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 (Figure 3.2)

Figure 2.2



To further examine this penalty, the demand was forced negative for each of the test cases and the penalty occurred as expected. Similarly to the PFLOOR case, the OG penalty was increased to a very

large number but was still used due to the infeasibility. The shadow price is reduced to PFLOOR when the OG penalty is used.

To prove that the OG penalty was being used for the case when PFLOOR was reached, the cost of the penalty was changed. The cost of the penalty is normally 73 which causes the software to produce a PFLOOR. For a particular case the value of the constraint was reduced to .001. The solver no longer reaches PFLOOR as the cost of the penalty is not large enough. However, the OG penalty is still being used but now sets the value at a higher value of -1.88 €/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

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

.001 x 376.93 x 5 = 1.88

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 1.88€/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.

2.2.3 Conclusion

With the cost of the over-generation penalty set to 73, the over-generation penalty is only incurred to alleviate an infeasibility due to an Excessive Generation Event in line with paragraph N17.4 of the T&SC

2.2.4 Recommendation

SEMO recommends retaining the Over-Generation MSP Constraint Cost setting of 73 for Year 2011.

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 MW/Trading Period 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. There will never be cases of Interconnector ramp rate penalties being incurred unless this is the case. As the Modified Interconnector Unit Nominations (MIUNs) are calculated such that they are feasible for interconnector ramp rates, it is unlikely that there will ever be incidences where the interconnector ramp rates are binding in the MSP software with the current level of interconnector capacity. However, for the purpose of the tests the interconnector ramp limits were forced to be binding.

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/Trading Period would allow an additional 1MW to flow 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.

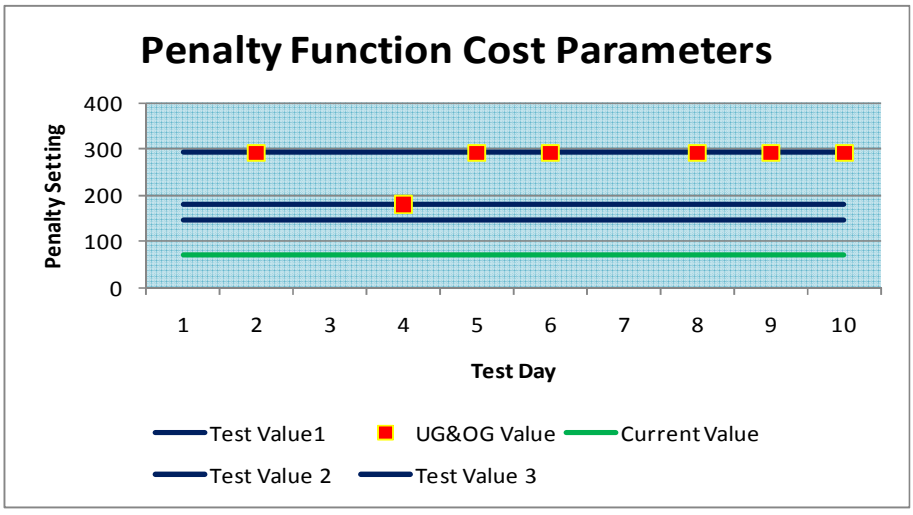
It is desirable that the MSP software uses the UG and OG penalties before it uses the interconnector ramp rate penalty. To ensure this is the case, the penalty for the ramp rate violations is set significantly higher than both the UG and OG penalties. Tests were performed to confirm that the occurrences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

2.3.2 Analysis

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 a number of 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. For all cases the UG event occurred first when the UG and OG penalties were at their existing values of 73. In all but one case the UG and OG penalties had to be raised to 292 before the interconnector ramp rate penalty was used first. In one case the interconnector ramp rate penalty occurred when the UG and OG were set to 180. In the cases where no value is reported, there was no flow on the interconnector and so the tests were not applicable. Below (figure 3.3) is a diagram showing the values at which UG and OG penalties needed to be set in order for the interconnector ramp rate penalty to be used.

Figure 2.3



2.3.3 Conclusion

For periods where the ramp rate is binding, the interconnector can be used to alleviate an infeasibility by breaching the ramp rate constraint. However, due to the relative costs of the penalties, an UG penalty will be used first to solve an under-generation event. Similarly, if there is an over-generation event the OG penalty is used before the interconnector ramp rate penalty. A value of 292 ensures that the penalty would only be used to alleviate an 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 2011.

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 a particular day for the energy limit to occur.

For the energy limit to be breached on a given day, two criteria must be met.

1. The energy limit 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 schedule of the unit must allow for an increase of Output in at least one Trading Period.

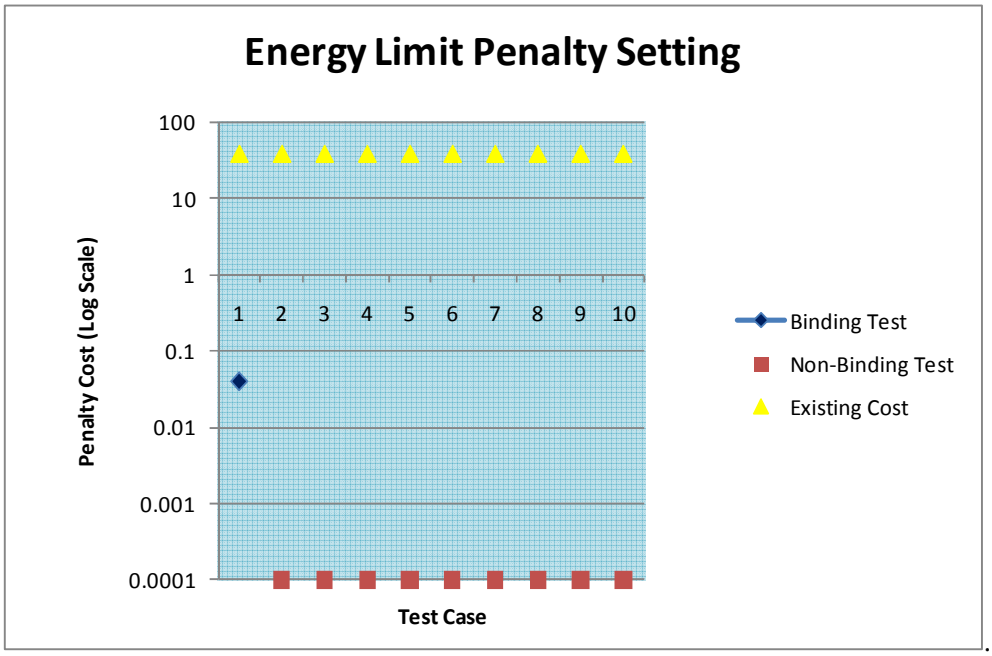
Energy limit costs are measured per MWh, whereas over- and under-generation penalties are measured per MW. Therefore, a penalty equal to half of the UG penalty would be equivalent for one Trading Period.

2.4.2 Analysis

It was not possible for the software to incur the penalty in all but one of the test cases as either the Energy Limit was not binding or the availability of the energy limited unit was binding.

Shown below (Figure 3.4) are the values tested to determine the energy limit penalty for each of the test cases. The existing cost of the penalty of 38 is included. This illustrates that there was only one case in which the energy constraint was breached. It was only possible to incur the penalty for this case and so, irrespective of how low the penalty was reduced in the other cases, the energy limit constraint will not be binding.

Figure 2.4



Similar to the Interconnector Ramp Rate, breaking an Energy Limit could be used to alleviate an 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 of 36.5/MWh would be equivalent to the Under/Over-Generation penalties of 73/MW. Setting the Energy Limit penalty at 38/MWh ensures that the Under- and Over-Generation 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 an 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 2011.

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 to be specified without material loss of precision, the tie-breaking feature cannot be operated so as to apply an adder significantly less than one cent (e.g. €0.001) while being reflected in prices and costs for any price or cost above €9,999.99. 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.

2.5.3 Conclusion

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

2.5.4 Recommendation

SEMO recommends retaining a Tie-breaking Adder of €0.001 for Year 2011.

3 Recommendations

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.

Analysis of the current values used for the year 2010 was performed. With reference to this analysis, this document proposes values for the year 2011.

SEMO proposes that the MSP Constraint Parameters retain their existing values for 2011(unless significant changes in the T&SC rules dictate their re-evaluation).

The proposed parameter settings are as follows.

Parameter	Penalty Setting for 2011
Over Generation MSP Constraint Cost	73
Under Generation MSP Constraint Cost	73
Aggregate Interconnector Ramp Rate Constraint Cost	292
Energy Limit MSP Constraint Cost	38
Tie-Breaking Adder	0.001

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

Parameter	Penalties to be used by MSP software for 2011
Over Generation MSP constraint	73 x 5 x *Max Offer*
Under Generation MSP constraint	*73 x 5 x Max Offer*
Aggregate Interconnector Ramp Rate constraint cost	*292 x 5 x Max Offer*
Energy Limit MSP Constraint	*38 x 5 x Max Offer*
Tie-Breaking Adder	0.001

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.