Constraint Costing Methodology

September 2011

Version Control

Date	Version	Notes
31.08.11	1.0	Initial version
28.09.11	2.0	Incorporated comments (including clarification of the term 'marginal price per MW of MEL') from CBSG[1] meeting on 7 September 2011.

[1] Commercial Balancing Service Group established by National Grid to discuss and develop commercial balancing services with the industry.

Contents

1 Introduction

This document sets out the methodology employed by National Grid for determining costs associated with managing congestion on the National Electricity Transmission System.

The methodology has four key stages:

1. Flagging constraint actions
2. Analysis of supporting information
3. Calculation of constraint costs
4. Addition of ancillary service costs

The first three stages above are briefly described below. Stage three is the core element of the methodology and the remainder of the document (from section 2 onwards) is dedicated to this stage.

At stage 4 the payments for ancillary services, such as intertrip arming or constraint management contracts, are added to the total from the first three stages.

As the reasons for a constraint are known through the planning and operational process each cost can be attributed to a specific location based on the problem experienced on the transmission system. By this route costs can be assigned to specific outages, planning groups or boundaries and geographical regions such as Scotland, Cheviot or England and Wales.

1.1 Flagging Constraint Actions

When issuing Bids or Offers in the Balancing Mechanism (BM) or undertaking Pre-Gate closure BM unit Transactions (PGBTs) or BMU Specific trading transactions, National Grid's Control Room staff flag actions taken to manage transmission constraints in line with the System Management Action Flagging (SMAF) methodology statement[2]. These flags can be viewed on the BM Reports website[3].

All BM and pre-gate closure actions undertaken by National Grid are flagged either "True" or "False" depending on whether the action affects power flows across a transmission system boundary or boundaries which would otherwise be constrained (e.g. for thermal, voltage or stability reasons). Further information on how this is carried out can be found in the SMAF methodology statement.

[2] http://www.nationalgrid.com/NR/rdonlyres/4945D234-247E-4C56-B0C4-B552A047C1E9/38314/SMAF_Review1.pdf
[3] http://www.bmreports.com/bsp/DisaggregatedBSAD.htm

1.2 Analysis of Supporting Information

Once data associated with these actions has been loaded into National Grid's database systems, further off-line analysis is performed (assimilating information from separate sources) to determine which BMUs and actions have been taken to manage constraints (and hence would not otherwise have been taken if no constraint existed). Further information is also captured regarding which outages (if any) and constraint group or groups are being managed by each action.

National Grid maintains databases which capture and collate information on the actions undertaken in the management of the system. This information is compared to information available in:

- Internal feedback from Control and Planning engineers;
- Planning documentation;
- System Action Flags;
- Analysis of the effects on the system of the actions taken; and
- Trading Advice.

Based on this information, a tag is placed on those actions which are believed to be for the management of transmission system constraints and would not have been taken for other system reasons such as the creation of margin. This can result in a difference between the "tag" for constraint actions and the "flag" set for the imbalance price calculation. These differences are explored in the Flagging Accuracy Reports published on National Grid's website[4]. Information on the reasons for the constraint is also captured allowing individual actions to be assigned to specific outages, groups and geographical regions.

1.3 Calculation of Constraint Costs

The identified actions (sections 1.1 and 1.2) are fed into a software tool which calculates the costs incurred for managing transmission system constraints as a result of these actions. The software calculates the incremental costs of actions taken as part of system operation relative to the costs of just resolving market length (Energy Imbalance). For constraint costs, consideration is also given to the impacts on positive and negative reserve and any additional costs that have been incurred in maintaining sufficient margins, such that:

Total cost of constraints = Direct cost of constraints +
Cost of replacing any positive reserve[5] +

[4] http://www.nationalgrid.com/uk/Electricity/Balancing/transmissionlicencestatements/

[5] 'headroom' which is no longer available following a constraint action taken to reduce output.

Cost of replacing any negative reserve[6]

Section 2 provides an overview of the above calculation, and section 3 provides details behind this calculation.

2 Overview of Constraint Costing Process

The constraint costing methodology goes through a number of steps in determining the costs incurred in managing constraints. These steps determine the direct cost of constraints, the cost of replacing any reserve following a constraint action, and re-apportioning costs between types of system operation activity. This process is described below, and the details of the steps for determining the constraint cost are shown in Figure 1.

2.1 Direct cost of constraint actions

The first step is to calculate the cost of the constraint management action itself and any replacement balancing energy (required to maintain a neutral ‘energy’ position). This is known as the “direct cost” of the constraint.

For Offers or for BMU Specific Buy Trades which synchronise a BMU which was not otherwise intending to run, the price of the action is compared to the price of other synchronising actions taken for the creation of positive reserve (margin). This is then used to apportion the costs of the synchronising constraint action between the margin and constraint categories. For ease of comparison, the prices are normalised with respect to the volume of reserve created (in terms of MEL) and this is carried out by calculating the marginal price per MW of MEL[7] of the non-constraint synchronising actions (based on actions taken in that half hour) and then comparing the price per MW of MEL of the constraint synchronising to this value.

Where the constraint synchronising action is at a lower price than the marginal price of margin synchronising actions, all of the costs are transferred to margin and the constraint cost will be zero. Where the marginal price of margin synchronising actions is lower than the constraint synchronising price, then the value of the constraint synchronising action, up to the marginal price of margin in that half

[6] ‘footroom’ which is no longer available following a constraint action taken to increase output

[7] The marginal price per MW of MEL is the value that the creation of the last MW of additional MEL brought on to the system had. This is a function of the offer price of the unit, the minimum stable generation of that unit and the MEL of the unit. The first two give the volume and cost of the offer to bring the MEL on to the system whilst the latter dictates the quantity of MEL received for this cost.

hour, are re-allocated as margin costs. The remaining cost is retained as a constraint cost.

For Bids, no comparison is made at this time to actions taken for negative reserve. This is because this situation is much rarer than that for Offers and margin. Future developments may include this step.

2.2 Cost of Replacing Reserve

After determining the direct cost of constraint action, the impact of the constraint action and the wider constraint group on actions taken to ensure sufficient positive reserve (Bids) or negative reserve (Offers) is calculated. In doing this, the total amount of reserve 'sterilised'[8] within the constraint group is calculated and then compared to the total amount of reserve created elsewhere on the system. Starting from the most expensive reserve action, the cost of replacing sterilised reserve is then apportioned to the BMUs used to manage the constraint. Consideration is also made for reserve that can no longer be accessed within the constraint group on BMUs which have not had actions taken on them.

2.3 Re-apportioning Costs between System Operation Activities

Finally some costs are re-apportioned across all system actions, including but not limited to constraints, which arise from the need to rebalance the system when volume of system actions taken is greater than the market length in that half hour. The need to carry this out as a separate activity arises from issues with directly equating specific Bids or Offers from system wide activities with other Bids or Offers undertaken either for locational or other system wide activities.

[8] The amount of reserve which is no longer available following a constraint action.

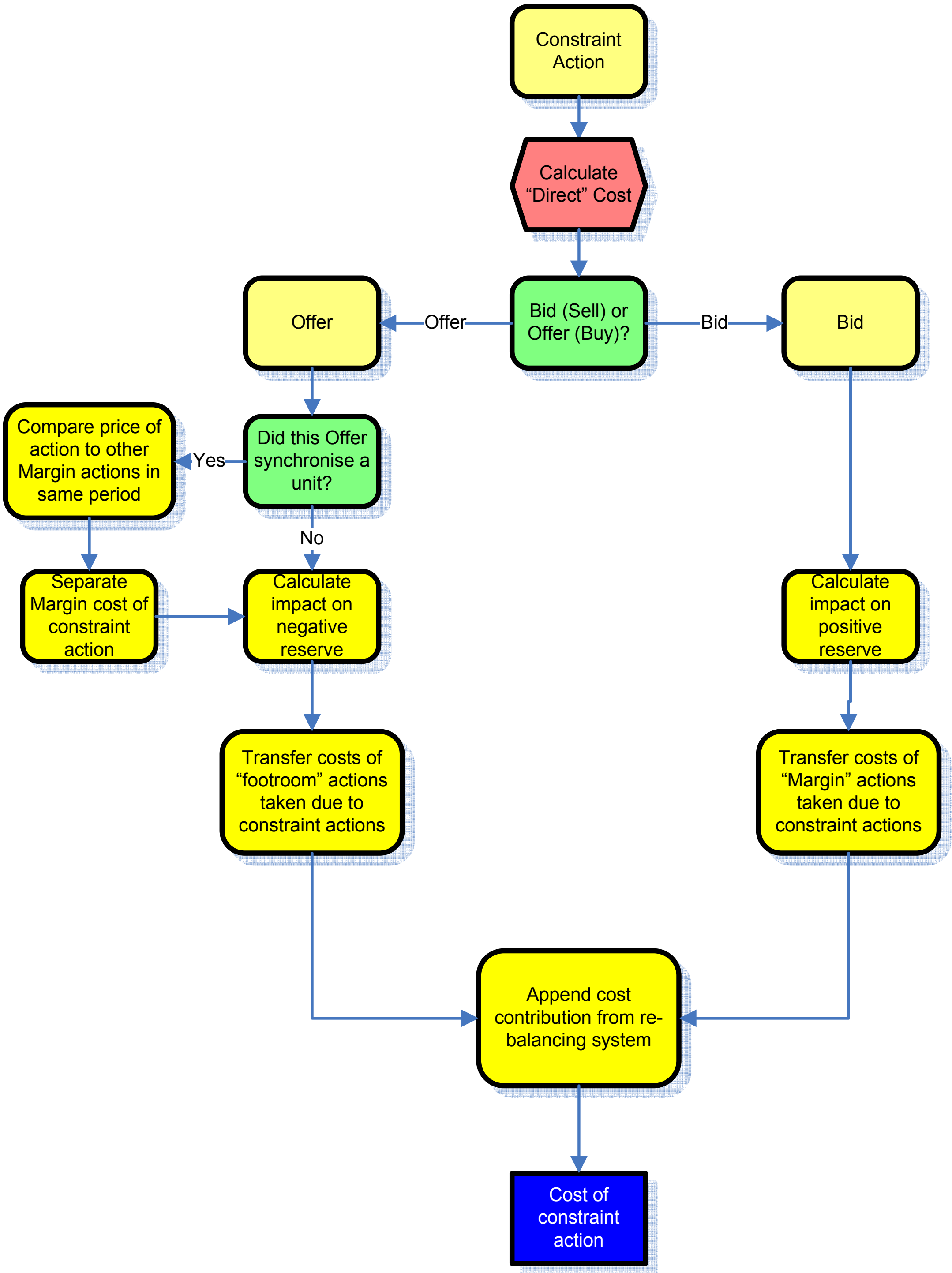


Figure 1: Constraint Cost Overview

3 Details of Constraint Cost Calculation

3.1 Direct Cost of Constraints

If National Grid did nothing but balance generation and demand (i.e. no constraints), then we would:

- Only take Bids or Offers up to the value of the Net Imbalance Volume (NIV); and
- Take the lowest cost actions available.

This leads to the concept of an "Energy Reference Price" (ERP) which is calculated as the volume weighted average of submitted[9] prices to resolve NIV in any given Settlement Period. For simplicity, this calculation ignores dynamics parameters such as run-up and run-down rates, notice to deviate from zero, minimum non-zero times and/or two shift limits.

ERP is used to reflect the price of energy within the Balancing Mechanism in a particular half hour and is used in subsequent calculations to reflect the cost of replacing energy where required and also to estimate the differential between pure energy balancing and the costs of resolving both a constraint and energy imbalance simultaneously (the latter being known as the "out of the money" cost of 'system' actions within the NIV stack).

Any action National Grid undertakes for system reasons is likely to be at a higher cost to National Grid than ERP. This is due to the following reasons:

- Location;
- Nature of service provided;
- Need to take actions that are in the opposite direction to the market length e.g. Offers in a long market; and
- Need to take larger volumes than market length.

As the ERP is used to represent both "out of the money" and replacement energy, the "direct cost" of the constraint action is calculated as:

$$\textit{Direct Cost}_{(action)ij} = \textit{Volume}_{ij} * (\textit{Price of Action}_{ij} - \textit{ERP}_{j})$$

Where 'i' refers to a BMU and 'j' refers to Settlement Period.

9 When taking actions for 'system' reasons, such as for constraint management purposes, some actions which would have been 'in merit' to resolve NIV may not be taken and are now not required as a single action has resolved market length and the constraint. Using submitted prices for the Energy Reference Price allows the incremental cost of these out-of-merit actions to be determined.

3.2 *Cost of Replacing Positive Reserve (Margin) – Export Constraint*

When the output of a BMU is restricted (e.g. due to an export constraint), it can be assumed that any capacity above its operating point is no longer available to use (i.e. the maximum level of generation which can be achieved with the synchronised plant is lower than maximum capacity). On the basis that the generation output within an active constraint group is reduced to the point where the constraint is just resolved, this assumption can be extended to cover every BMU within the constraint group; every BMU is now at its maximum achievable output and any headroom which would have existed on these BMUs is now unavailable. This is referred to as "sterilised headroom". Figure 2 illustrates this for a single BMU.

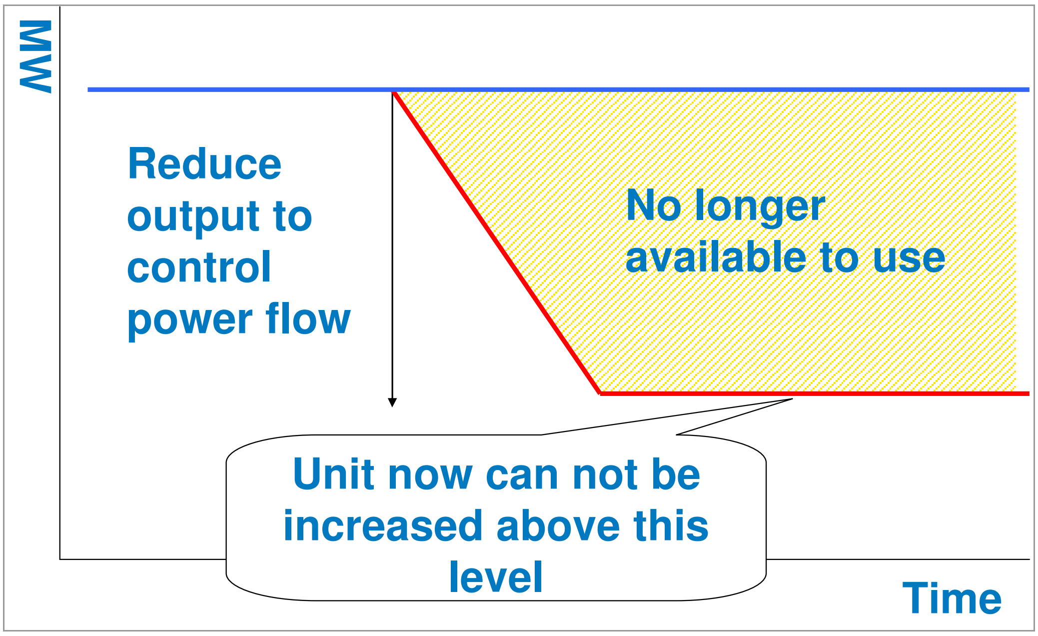


Figure 2: Export Constraint

Sufficient headroom must be maintained on synchronised BMUs in order to cope with short-term changes in demand, plant losses and to provide services such as frequency response. Where there is insufficient headroom provided by the market, National Grid will create the required headroom by bringing on additional BMUs at a cost. The specific volume of additional BMUs will vary with the BMU distribution supplied by the market and the calculated reserve requirements for a given level of demand.

As an export constraint will reduce the overall headroom available, this can create the need to bring on additional BMUs where this was not previously required[10]. In order to determine whether (and which) headroom creation actions are due to the constraint, we undertake the following steps for each half hour:

A. Calculate how much headroom has been sterilised by constraints on the system;
B. Calculate how much headroom has been added by National Grid;
C. Starting from the most expensive MW, work backwards until each MW of sterilised headroom is accounted for or all of the headroom under point B is exhausted.

In adding additional headroom to the system an amount of headroom equal to the MEL[11] of the unit is added by accepting a volume of Offers equal to the SEL[12] of the unit. Therefore in order to calculate a price per MW of additional headroom we utilise a SEL to MEL ratio.

Figure 3 illustrates how the sterilised headroom is allocated to constraint actions.

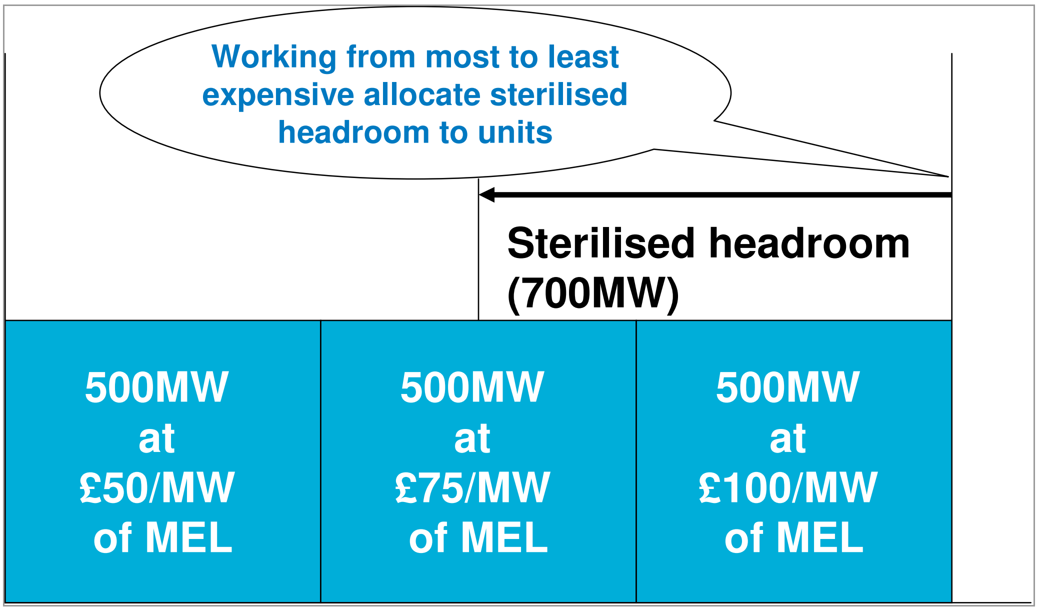


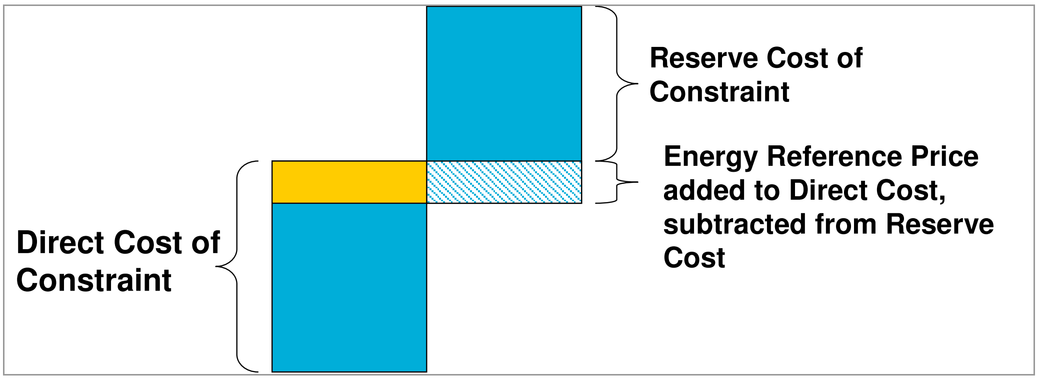
Figure3: Allocation of Sterilised Headroom

As BMUs only come in full unit sizes, we can not be certain if the middle BMU in Figure 3 above was an overshoot from the unconstrained margin requirement or was only required due to the constraint. In these circumstances, we assume that the unit was not required due to the constraint and is therefore a margin cost and not a constraint cost.

10 It is also possible that there is sufficient headroom to accommodate the constraint without the need for additional actions.
11 Maximum Export Limit
12 Stable Export Limit

The BMU at £100/MW of MEL is taken as having been needed to replace sterilised headroom and would not have been required if the constraint had not been present on the system. The costs of this BMU, having taken into account the Energy Reference Price, are then reallocated across all the export constraints on the system in that half hour, proportionate to the sterilised headroom on that BMU or group of BMUs.

The Energy Reference Price is accounted for such that when adding the direct cost and reserve replacement cost, this term is not double counted. This is illustrated in the diagram below.



3.3 Cost of Replacing Negative Reserve – Import Constraint

A constraint which requires the output of synchronised BMUs to be increased to create negative reserve ('footroom') will have a similar effect to that which an export constraint has on headroom.

The process here is analogous to that used for sterilised headroom in section 3.2:

A. Calculate how much footroom has been sterilised by constraints on the system
B. Calculate how much footroom has been created by National Grid by desynchronising units
C. Starting from the most expensive MW, work backwards until each MW of sterilised footroom is accounted for or all of the footroom under point B is exhausted.

Again, sterilised footroom is allocated to the constraint actions from the most to least expensive.

In addition, where an import constraint synchronises a unit, this will have benefits in terms of the headroom available on the system at that time. This may displace other actions which would otherwise have been taken (although potentially at a higher price) or may have been required to increase headroom and resolve the constraint simultaneously.

In order to offset these benefits, we go through the following steps, taking into account the Energy Reference Price throughout:

- Calculate the marginal price of headroom created on units which are not managing constraints themselves (£/MW of MEL)
- If this is higher than the price of the unit synchronised to manage the import constraint, then the import constraint action is treated as a headroom creation action (i.e. no import constraint cost)
- If the marginal price of margin is lower than the import constraint action, then all the costs up to the marginal value are treated as a headroom creation action. The remaining costs are then treated as the cost of the import constraint action.

Note: Wherever the costs are treated as being for headroom creation, they are entered into the sterilised headroom calculation for export constraints and treated in the same way as any other BMU.

3.4 Re-apportioning Costs between System Operation Activities

As actions are taken system wide and often perform multiple functions we can not directly equate Bids to Offers. On occasions this can leave some actions which are needed to rebalance the system after all "system" actions are taken and the final stage of the calculation is to reallocate the costs of these to system actions. Situations where this would arise are those such as where a higher volume of actions has been undertaken than would be required to resolve market length e.g. taking 600MW of Bids in a 500MW long market. Such a situation would require additional Offers to be taken in order to bring generation and demand back in line. These actions would not be taken for an identifiable system reason.

The cost of these actions are reallocated on a £/MWh basis to all actions (not just constraints) which are in the same direction as market length e.g. Bids in a long market, Offers in a short market.

4 Glossary of Terms

Term	Description
Constraint	A constraint exists if power transfer (generation – demand) across a boundary on the transmission network violates the secure transfer capability.
Energy Reference Price	Volume-weighted average of submitted prices to resolve Net Imbalance Volume in any given Settlement Period.
Export Constraint	A constraint where generation surplus (above demand) could violate secure transfer capability of the boundary.
Import Constraint	A constraint where demand surplus (above generation) could violate secure transfer capability of the boundary.
Margin	Same as positive reserve.
Maximum Export Limit (MEL)	Maximum level at which a BMU may be exporting at a given time.
Negative Reserve	Reserve required for reducing power output where there is unexpected increase in power.
Net Imbalance Volume	The difference between generation supplied by the market and the demand on the system.
Positive Reserve	Reserve required for increasing power output where there is unexpected reduction in power.
Stable Export Limit (SEL)	Minimum level at which a BMU can export under stable conditions.
Sterilised Footroom	The amount of Negative Reserve which is no longer available following a constraint action.
Sterilised Headroom	The amount of Positive Reserve which is no longer available following a constraint action.