Issue	Revision
1	0

The Statement of the Energy Balancing Cost Target Modelling Methodology

Effective from 1 April 2011

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About this Document

This document contains one of three methodologies that National Grid Electricity Transmission plc (NGET) employs to calculate the Modelled Target Costs, against which its actual balancing costs will be compared, on a month-by-month basis, under the Balancing Services Incentive Scheme (the 'Scheme').

The remaining methodologies are as follows:

- The Statement of the Constraint Cost Target Modelling Methodology; and
- The Statement of the Ex Ante or Ex Post Treatment of Modelling Inputs Methodology.

This document has been published by National Grid in accordance with Special Condition AA5A of NGET's Transmission Licence. The methodology was developed as part of the Electricity System Operator (SO) incentives Review process.

If you require further details about any of the information contained within this document or have comments on how this document might be improved please contact the SO Incentives team by e-mail:

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Chapter 1: Modelled Target Costs

1. The Modelled Target Costs are defined in Special Condition AA5A as "…the target cost to the licensee of procuring and using balancing services (being the external costs of the balancing services activity)..." derived in accordance with the methodologies referred to in paragraph B2.

2. This document sets out the energy methodology referred to in paragraph B2 of Special Condition AA5A. It should be read in conjunction with the other methodologies:

   - The Statement of the Constraint Cost Target Modelling Methodology; and
   - The Statement of the Ex Ante or Ex Post Treatment of Modelling Inputs Methodology.

3. The Incentive Target Cost represents the sum of all energy-related and constraint-related balancing cost components (as described in the methodologies), plus the black start component, as agreed between National Grid Electricity Transmission (NGET) and the Gas and Electricity Markets Authority (GEMA).

   As a naming convention, the components of the energy cost target have themselves been assigned the suffix "TARGET", but this does not imply that they are individual targets under the Scheme, nor whether NGET will choose to treat them as such in practice.

$$INCENTIVE\_TARGET\_COST_p = MODELLED\_TARGET\_COSTS_p + BSCT_p$$

Where:

p
The scheme period

$MODELLED\_TARGET\_COSTS_p$
Defined in Paragraph 4

$BSCT_p$
The black start cost target

4. The Modelled Target Costs

For the purposes of Paragraph 3:

$$MODELLED\_TARGET\_COSTS_p = ENERGY\_COST\_TARGET_p + CONSTRAINT\_COST\_TARGET_p$$

Where:

$ENERGY\_COST\_TARGET_p$
Defined in Paragraph 5.

$CONSTRAINT\_COST\_TARGET_p$

The Statement of the Constraint Cost Target Modelling Methodology

5. The Energy Cost Component of the Balancing Cost Target

For the purposes of Paragraph 4

$$ENERGY\_COST\_TARGET_p = \sum_{m \in Start:End} ENERGY\_COST\_TGT_m + AS\_BM\_REMAINING_p$$

Where:

p The scheme period

m A particular calendar month in the scheme period

$ENERGY\_COST\_TGT_m$
A set of values of the energy cost target-component, to monthly resolution, each month uniquely identified by an index. Defined in Paragraph 6.

$AS\_BM\_REMAINING_p$
Defined in Paragraph 98.

6. The Modelled Monthly Energy Cost Target-Component

For the purposes of Paragraph 5:

$$ENERGY\_COST\_TGT_m = ENERGY\_IMBALANCE\_COST\_TARGET_m + MARGIN\_COST\_TARGET_m + FREQUENCY\_RESPONSE\_COST\_TARGET_m + FAST\_RESERVE\_COST\_TARGET_m + FOOTROOM\_COST\_TARGET_m + REACTIVE\_COST\_TARGET_m$$

Where:

$ENERGY\_IMBALANCE\_COST\_TARGET_m$
Defined in Paragraph 26.

$MARGIN\_COST\_TARGET_m$
Defined in Paragraph 30.

$FREQUENCY\_RESPONSE\_COST\_TARGET_m$
Defined in Paragraph 62.

$FAST\_RESERVE\_COST\_TARGET_m$
Defined in Paragraph 77.

$FOOTROOM\_COST\_TARGET_m$
Defined in Paragraph 89

$REACTIVE\_COST\_TARGET_m$
Defined in Paragraph 93.

7. Modelled Target Costs are determined on a monthly basis, using a combination of Ex Ante data and Ex Post data, as described in the document *The Statement of the Ex Ante or Ex Post Treatment of Modelling Inputs Methodology*.

Chapter 2: General Variables

This chapter defines variables that are used as input to more than one model.

Date & Time

8. Date-Time Indices:
   - p
     - The scheme period.
   - y
     - A particular financial year.
   - m
     - A particular calendar month of a particular year.
   - hh
     - A particular half-hour of a particular day of a particular year. It is mappable to a unique date and time.

9. Date & Time Variables & Functions:

   - SETTLEMENT_DATE
     - Defined in the Balancing & Settlement Code, Section X-1.
     - A representation of date, equivalent to text in the format 'dd-mon-yyyy', though in practice it may be represented numerically.

   - $TREND_m$
     - An integer equal to 1 where month *m* = April 2005 and incrementing by 1 for each successive month (continuing in successive years).

   - SETTLEMENT_PERIOD
     - Defined in the Balancing & Settlement Code, Section X-2.
     - An integer between 1 and 50 inclusive.
       - The maximum value for Settlement Period is 50, not 48, due to the change from BST to GMT, when an additional hour (two settlement periods) arises.

   - $UNSYNC\_MEL\_6A_{hh}$
     - The (nonzero) volume of power, in MWh, that could in principle be supplied (consistent with declared MEL), within no more than six hours, from generation that was planned to be unsynchronised at 6 hours ahead of the relevant half hour.

   - IS_EFA6_{hh}

  - An indicator, integer value 0 or 1, indicating (by value = 1) when half-hour *hh* falls within the *EFA 6* Block of the day, namely 19:00-23:00 local time.

- $IS\_MARKET\_PEAK_{hh}$
  - An indicator, integer value 0 or 1, indicating (by value = 1) when the half-hour *hh* falls within that part of the day corresponding to the *UK Peaks* product of the commercial electricity market. Specifically, EFA Blocks 3 to 5 inclusive. Equivalently, 07:00 ≤ *hh* < 19:00.

- $IS\_BST\_NGET_{hh}$
  - An indicator, integer value 0 or 1, of whether the given half-hour *hh* (as a unique date-time) falls within NGET's internal definition of the British Summer Time (BST) timezone period:
    $IS\_BST\_NGET_{hh}$ =
    If [1 April 00:00] ≤ *hh* < [1 November 00:00] then 1 else 0
    Note that this differs from the generally accepted definition of BST.

- $IS\_GMT\_NGET_{hh}$
  - An indicator, integer value 0 or 1, of whether the given half-hour *hh* (as a unique date-time) falls within NGET's internal definition of the Greenwich Mean Time (GMT) timezone period:
    $IS\_GMT\_NGET_{hh} = (1 - IS\_BST\_NGET_{hh})$
    Note that this differs from the generally accepted definition of GMT.

- Note:
  - SETTLEMENT_DATE and SETTLEMENT_PERIOD are defined according to *local* UK time - featuring BST and GMT clock-times, as opposed to for example the year-round use of GMT.
  - It is assumed that there are no time-gaps in the variables SETTLEMENT_DATE or SETTLEMENT_PERIOD.

10. Season Variables

- IS_WINTER_{hh},
  - An indicator, integer value 0 or 1, indicating (by value 1) if the stated half-hour *hh* falls into the Winter *season* (as opposed to half) of the year:
  - If *hh* is between 1 November 00:00 (inclusive) and 1 February 00:00 (exclusive) then 1 else 0.

- IS_WINTER_{m}
  - An indicator, integer value 0 or 1, indicating (by value 1) if the stated month *m* falls into the Winter *season* (as opposed to half) of the year:
  - If *m* is between November and January, inclusive, then 1 otherwise 0.

- IS_SUMMER_{hh},
  - An indicator, integer value 0 or 1, indicating (by value 1) if half-hour *hh* falls into the Summer *season* (as opposed to half) of the year:
  - If *hh* is between 1 June 00:00 (inclusive) and 1 September, exclusive, then 1 otherwise 0.

- IS_SUMMER_{m}
  - An indicator, integer value 0 or 1, indicating (by value 1) if month *m* falls into the Summer *season* (as opposed to half) of the year:
  - If *m* is between June and August (inclusive) then 1 otherwise 0.

- Note:
    - $IS\_SUMMER_{hh} \neq (1 - IS\_WINTER_{hh})$
    - $IS\_SUMMER_{m} \neq (1 - IS\_WINTER_{m})$

11. Market-Related Variables
    - FPN
        - Final Physical Notification.
    - MEL
        - Maximum Export Limit
    - NIV
        - Net Imbalance Volume
        - Defined in the Balancing & Settlement Code, Annex T-1, Paragraph 14.1.
    - SPNIRP
        - Single Price Net Imbalance Reference Price
        - Defined (as in Chapter entitled "CHAPTER 12: SPNIRP") to the time-resolution of a Settlement Period, hence half-hour.
        - In this document:
            - $SPNIRP_{hh}$ is equivalent to SPNIRP as defined above, hence to the time-resolution of a Settlement Period, hence half-hour.
            - $SPNIRP_{m}$ is to the time-resolution of a Month, obtained as the average of $SPNIRP_{hh}$.

12. Power-Related Variables
    - AVG_NUKE_{m}
        - The average Ex Post power generation level, in MW, from nuclear powered generation, over a particular month of a particular year.
    - AVG_WIND_{m}
        - The average Ex Post power generation level from settlement meters, in MW, from wind powered generation, over a particular month of a particular year.
    - $DEMAND_{hh}$ and hence $DEMAND_{m}$
        - The National Demand Forecast, Ex Ante. For the purposes of obtaining model coefficients, this should be the absolute value of the sum of all settlement metered energy taken from the transmission system (ES_TOTDEM_J_MWH)

Period of Historical Data

13. Except where otherwise stated, the Scheme assumes all modelled behaviours to be stationary. Hence unless otherwise specified, for the determination of coefficients, data are selected over the full range of available history, in practice from 1 April 2005, Settlement Period 1 to 31 March 2011, Settlement Period 48.

Data Correctness

14. The data are assumed to be correct. Thus where defined values exist, there is no provision for their abnormality detection or replacement.

Data Incompleteness & Repair

15. The data are assumed to be complete in terms of half-hourly time-stamps and also externally (to NGET) agreed variables such as NIV.
16. Any instances where (other) variables have undefined values (e.g. as indicated by Null, Blank, NaN, NA), numerical Replacement Values shall be used instead.
17. It is expected that the proportion of cases where such values are undefined will in practice be almost negligible.
18. The Replacement Values shall be fixed Default Values.
19. For each variable, its Default Value shall be computed from the mean of its values over the most recent financial year, namely 1 April 2010 Settlement Period 1 to 31 March 2011 Settlement Period 48.

Chapter 3: Model Production and Execution

Production of the Half-Hourly Regression Models

This section defines how the half-hourly linear regression models will be built.

20. For the purposes of the Scheme, the required linear regression models will be produced during May 2011. This will allow the regressions to use out-turn data up to 31 March 2011, prior to the models being run for the first time with the first month's Ex Post data.
21. It is intended that this set of models will remain unchanged for the duration of the Scheme. However there is provision in the Licence for model updates as part of an Income Adjusting Event, e.g. to correct errors.
22. There shall be no prior removal of outliers.
23. Unless otherwise stated, the time-span of data used for determining coefficients shall be from 1 April 2005, Settlement Period 1 to 31 March 2011, Settlement Period 48, inclusive.
24. Unless otherwise stated, the values of coefficients are determined by Ordinary Least Squares (OLS) linear regression fitting the *dependent variable* to the given input (explanatory) variables over outturn data covering a given period of time.

Naming Conventions

The suffix "EXPECTED" is used for any variable produced by a model that is itself assumed to represent an unchanging (mathematically stationary) dynamic relationship with regard to its input values. As regards cost-associated variables, NGET is essentially incentivised to do better than expected.

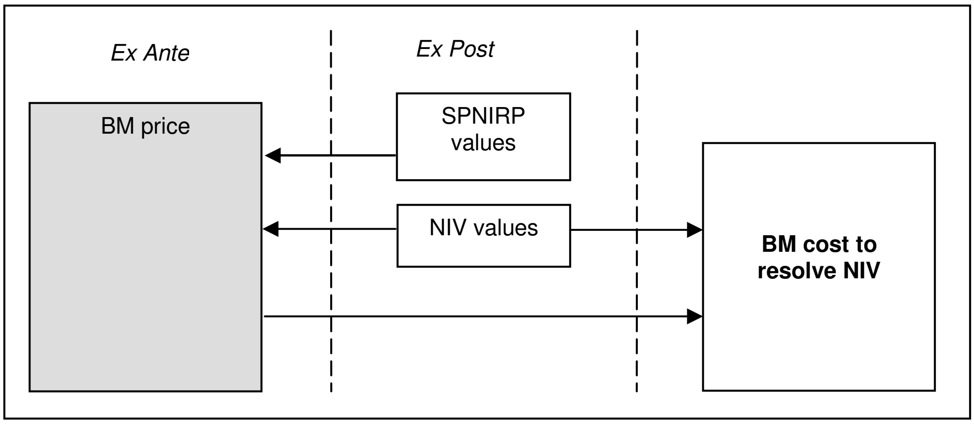
The suffix "TARGET" is used loosely, not only to identify a cost target per se but also any variable *contributing to* a cost target.

Chapter 4: Model for the Energy Imbalance Cost

Model Overview

25. Model Overview

The Energy Imbalance model is a function of Ex Post values of Single Price Net Imbalance Reference Price (SPNIRP) and Net Imbalance Volume (NIV). Internally, this function assumes a relationship, determined Ex Ante (with respect to the Scheme) but assumed stationary, where Balancing Mechanism price depends on SPNIRP and NIV. The model is as follows:



Calculation of Energy Imbalance Cost Target

26. Calculation of the Monthly Energy Imbalance Cost Target

For the purposes of Paragraph 6.

The Monthly Energy Imbalance cost-target is computed as the monthly sum of that same quantity at half-hour resolution.

$$\text{ENERGY\_IMBALANCE\_COST\_TARGET}_m = \sum_{hh \in Start:End} \text{EnImbalCostTgt}_{hh}$$

Where:

$\text{EnImbalCostTgt}_{hh}$
A set of values of expected energy imbalance costs, to half-hour resolution, each uniquely identified by the index *hh*. Defined in Paragraph 27.

Start and *End* span the period of the calendar month *m*.

27. Half-hourly Expected Cost of Energy Imbalance

For the purposes of Paragraph 26:

The half-hourly expected cost of Energy Imbalance is computed as the product of the corresponding half-hourly expected Balancing Mechanism price and half-hourly actual Net Imbalance Volume. The expected Balancing Mechanism price is a varying quantity that derives from a further model, itself regarded as representative of an unchanging (mathematically stationary) relationship between that price and other variables. The model in question is defined further below, under "Calculation of Half-Hourly Expected Balancing Mechanism Price".

$$EnImbalCostTgt_{hh} = NIV_{hh} * BM\_PRICE\_EXPECTED_{hh}$$

Where:

NIV_{hh} Net Imbalance Volume (in MWh), for the half hour *hh*. Defined in Chapter 2: General Variables.

$BM\_PRICE\_EXPECTED_{hh}$ A value for Balancing Mechanism price, modelled rather than actual, for a given half-hour. Defined in Paragraph 28.

Balancing Mechanism Price

28. Balancing Mechanism Price

For the purposes of Paragraphs 27, 34, 65:

The expected Balancing Mechanism price is a varying quantity that derives from a model, as defined below, regarded as representative of an unchanging (mathematically stationary) relationship between that price and other variables.

$$\begin{aligned} BM\_PRICE\_EXPECTED_{hh} = \; & C0 \\ & + C1 * \log(SPNIRP_{hh}) \\ & + C2 * IS\_SHORT_{hh} \\ & + C3 * IS\_SHORT_{hh} * SPNIRP_{hh} \\ & + C4 * IS\_SHORT_{hh} * \log(SPNIRP_{hh}) \\ & + C5 * IS\_SHORT_{hh} * NIV_{hh} * SPNIRP_{hh} \\ & + C6 * IS\_SHORT_{hh} * NIV_{hh} * \log(SPNIRP_{hh}) \end{aligned}$$

Where:

The values of the coefficients, C0, C1, C2, C3, C4, C5, C6, are determined by OLS linear regression fitting BALANCING MECHANISM PRICE as the *dependent variable* to the above input (explanatory) variables over outturn data covering a given period of time.

$SPNIRP_{hh}$ SPNIRP for the half hour *hh*, where SPNIRP is as defined in CHAPTER 12: SPNIRP.

log()	The *natural* logarithm (to base *e*). In principle the base of the logarithm is immaterial, provided it is consistent between determination of coefficients and model usage, but for simplicity in practice we define a specific base.
IS_SHORT_{hh}	An indicator of whether the market is *short* for the half hour *hh*. If $NIV_{hh} \geq 0$ then 1 else 0.
NIV_{hh}	Net Imbalance Volume (in MW Hours) for the half hour *hh*. Defined in Chapter 2: General Variables.

Determining the Coefficients

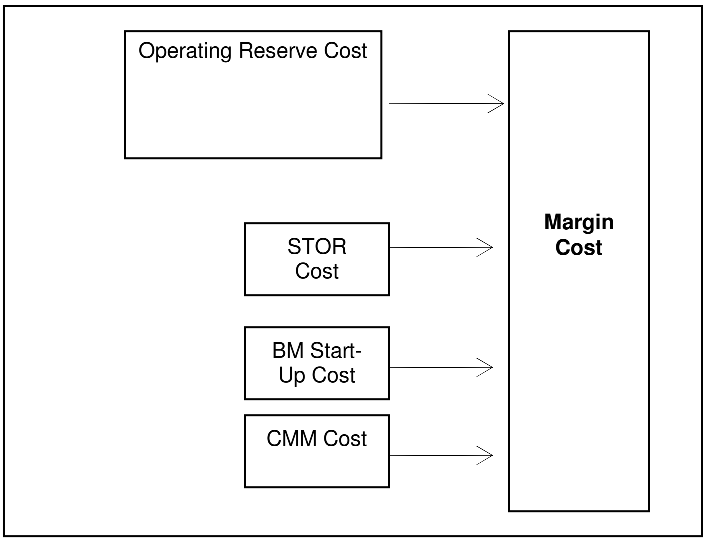
Coefficients C0 to C6 are determined by OLS regression based on data from 1 April 2005 to 31 March 2011.

Chapter 5: Model for the *Margin* Cost

Model Overview

29. Model Overview

Margin model accounts for the sum of the costs of providing Operating Reserve and Short-Term Operating Reserve (STOR), as well as the costs of Balancing Mechanism (BM) Start-Up and Constrained Margin Management (CMM). There is a separate sub-model for each of these components.



Calculation of the Cost of Maintaining Adequate Margin

30. Expected Margin Cost

For the purposes of Paragraph 6.

The expected Margin cost, in £, is computed to a monthly resolution, as follows:

$$\begin{aligned}\text{MARGIN\_COST\_TARGET}_m = &\ \text{OP\_RESERVE\_COST}_m \\ &+ \text{STOR\_AVAIL\_COST}_m \\ &+ \text{BM\_START\_UP\_COST}_m \\ &+ \text{CMM\_COST}_m\end{aligned}$$

Where

m A particular calendar month in continuous time (as opposed to per-year).

OP_RESERVE_COST_m
Defined in Paragraph 31

STOR_AVAIL_COST_m
The monthly cost of STOR Availability
Defined in Paragraph 59

$\text{BM\_START\_UP\_COST}_m$
Defined in Paragraph 60

CMM_COST_m
The monthly cost of CMM
Defined in Paragraph 55.

OOM Cost for Operating Reserve

31. Expected Monthly Operating Reserve OOM Cost

For the purposes of Paragraph 30, 58:

The expected Monthly Operating Reserve OOM cost is computed as the monthly aggregate (sum) of that same quantity at half-hour resolution.

$$\text{OP\_RESERVE\_COST}_m = \sum_{hh \in Start:End} \text{OP\_RESERVE\_COST}_{hh} + \text{VOLUME\_DISPLACEMENT\_COST}_m$$

Where:

$\text{OP\_RESERVE\_COST}_{hh}$
A set of values of operating reserve cost targets, to half-hour resolution, each uniquely identified by an index. The method of computation of these values is defined in Paragraph 32.

$VOLUME\_DISPLACEMENT\_COST_m$
Defined in Paragraph 38

Start and *End* span the period of the given calendar month *m*.

32. The expected Half-Hourly Operating Reserve cost

For the purposes of Paragraph 31:

$$OP\_RESERVE\_COST_{hh} = (OP\_RESERVE\_PRICE_{hh} * OP\_RESERVE\_VOLUME_{hh})$$

Where

$OP\_RESERVE\_PRICE_{hh}$
Expected half-hourly price for Operating Reserve.
Defined in Paragraph 34

$OP\_RESERVE\_VOLUME_{hh}$
Expected half-hourly volume for Operating Reserve.
Defined in Paragraph 36

OOM Price for Operating Reserve

33. Calculation of Expected Monthly OOM Price for Operating Reserve

For the purposes of Paragraphs 40, 46, 49, 52, 55, 58, 60:

$OP\_RESERVE\_PRICE_m$
The Expected Price for Operating Reserve Price, in £/MWh, is computed to monthly resolution as a volume-weighted average of the same quantity to half-hourly resolution, itself defined in Paragraph 34.

34. Calculation of Expected Half-Hourly OOM Price for Operating Reserve

For the purposes of Paragraphs 32 and 33:

The Expected OOM Price for Operating Reserve, in £/MWh, is computed to a half-hourly resolution as follows:

$$OP\_RESERVE\_PRICE_{hh} = OP\_RESERVE\_CASH\_PRICE_{hh} - BM\_PRICE\_EXPECTED_{hh}$$

Where

$OP\_RESERVE\_CASH\_PRICE_{hh}$.
Defined in Paragraph 35.

$BM\_PRICE\_EXPECTED_{hh}$
Defined in Paragraph 28.

35. Calculation of Expected Half-Hourly Cash Price for Operating Reserve

For the purposes of Paragraph 34:

The Expected Cash Price for Operating Reserve, in £/MWh, is computed to a half-hourly resolution as follows:

Note that the following has no C0 coefficient, meaning no intercept offset.

$$
\begin{aligned}
OP\_RESERVE\_CASH\_PRICE_{hh} = \; & C1 * IS\_MARKET\_PEAK_{hh} * IS\_GMT\_NGET_{hh} \\
& + C2 * IS\_MARKET\_PEAK_{hh} * IS\_GMT\_NGET_{hh} * SPNIRP_{hh} \\
& + C3 * IS\_MARKET\_PEAK_{hh} * IS\_GMT\_NGET_{hh} * SPNIRP_{hh}\hat{}2 \\
& + C4 * IS\_MARKET\_PEAK_{hh} * IS\_GMT\_NGET_{hh} * \\
& \quad SPNIRP_{hh} * UNSYNC\_MEL\_6A_{hh} \\
& + C5 * IS\_MARKET\_PEAK_{hh} * IS\_BST\_NGET_{hh} \\
& + C6 * IS\_MARKET\_PEAK_{hh} * IS\_BST\_NGET_{hh} * SPNIRP_{hh} \\
& + C7 * IS\_MARKET\_PEAK_{hh} * IS\_BST\_NGET_{hh} * SPNIRP_{hh}\hat{}2 \\
& + C8 * IS\_MARKET\_PEAK_{hh} * IS\_BST\_NGET_{hh} * \\
& \quad SPNIRP_{hh} * UNSYNC\_MEL\_6A_{hh} \\
& + C9 * IS\_EFA6_{hh} * IS\_BST\_NGET_{hh} \\
& + C10 * IS\_EFA6_{hh} * IS\_BST\_NGET_{hh} * SPNIRP_{hh} \\
& + C11 * IS\_EFA6_{hh} * IS\_BST\_NGET_{hh} * SPNIRP_{hh}\hat{}2 \\
& + C12 * IS\_EFA6_{hh} * IS\_BST\_NGET_{hh} * SPNIRP_{hh} * UNSYNC\_MEL\_6A_{hh}
\end{aligned}
$$

Where

All inputs are as defined in Chapter 2: General Variables.

Determination of Coefficients

Coefficients C1 to C12 are determined by OLS regression based on Ex Post data from 1 April 2005 to 31 March 2011. The Operating Reserve price data reflects the OOM price.

36. Calculation of Expected Half-Hourly Volume for Operating Reserve

For the purposes of Paragraph 32

The Expected Volume, in MWh, for Operating Reserve, is computed to a half-hourly resolution as follows:

Notes with respect to the following:

- There is no *C0* coefficient, meaning no intercept offset.
- Operating Reserve cannot be negative, therefore the distribution of outcomes is considered in statistical terms to be *censored*. As a result, a special sort of regression model, a *Tobit* model, is required to overcome the bias that would flow from use of the standard regression model

$OP\_RESERVE\_VOLUME_{hh}$ =

tobit(Xβ, σ)

Where, determined by Tobit regression as defined in Chapter "Tobit Regression":

Xβ =

$$\begin{aligned}
& C1 * IS_MARKET_PEAK_{hh} * IS_GMT_NGET_{hh} \\
& + C2 * IS_MARKET_PEAK_{hh} * IS_GMT_NGET_{hh} * IS_POST_NOV_2008_{hh} \\
& + C3 * IS_MARKET_PEAK_{hh} * IS_GMT_NGET_{hh} * NIV_{hh} \\
& + C4 * IS_MARKET_PEAK_{hh} * IS_GMT_NGET_{hh} * HEADROOM_FLEX_{hh} \\
& + C5 * IS_MARKET_PEAK_{hh} * IS_BST_NGET_{hh} \\
& + C6 * IS_MARKET_PEAK_{hh} * IS_BST_NGET_{hh} * IS_POST_NOV_2008_{hh} \\
& + C7 * IS_MARKET_PEAK_{hh} * IS_BST_NGET_{hh} * NIV_{hh} \\
& + C8 * IS_MARKET_PEAK_{hh} * IS_BST_NGET_{hh} * HEADROOM_FLEX_{hh} \\
& + C9 * IS_EFA6_{hh} * IS_BST_NGET_{hh} \\
& + C10 * IS_EFA6_{hh} * IS_BST_NGET_{hh} * IS_POST_NOV_2008_{hh} \\
& + C11 * IS_EFA6_{hh} * IS_BST_NGET_{hh} * NIV_{hh} \\
& + C12 * IS_EFA6_{hh} * IS_BST_NGET_{hh} * HEADROOM_FLEX_{hh}
\end{aligned}$$

σ is the scale parameter

And:

$IS\_PRE\_NOV\_2008_{hh}$
[If *hh* < 2008-11-01 00:00 then 1 else 0]

$IS\_POST\_NOV\_2008_{hh}$
[If *hh* ≥ 2008-11-01 00:00 then 1 else 0]
The name, perpetuated for historical reasons, is slightly misleading since the indicator has the value 1 for the date in question itself.

$HEADROOM\_FLEX_{hh}$
Defined in Paragraph 68

(All other inputs are as defined in Chapter 2: General Variables).

Note:
The behaviour of the implicit model of the data has been empirically determined to differ prior to and following November 2008. This structural break was due to the change in the methodology utilised to define the operating reserve policy. Consequently, the explicit model is supplied with indicator data of these two periods of time, enabling it to separately account for the two corresponding behaviours.

Determining the Coefficients:
Use *Tobit* linear regression, with left (lower value) limit of zero but no right (upper value) limit. Data from 1 April 2005 to 31 March 2011.

Margin Displacements

37. Margin Displacements

The difference in cost due to having contracted ahead (as compared to Balancing Mechanism trades) to allow for deviations from historic margin requirements due to wind generation (unpredictability) as well as any differences in required levels of STOR, Static Response and Firm Frequency Response.

38. Calculation of Expected Monthly Cost of Volume Displacement

For the purposes of Paragraph 32, 58:

The expected cost, in £, of margin volume displacement by Wind, STOR, Static Response, and Firm Frequency Response (FFR) is computed to a monthly resolution as follows:

$$VOLUME\_DISPLACEMENT\_COST_m = WIND\_DISPLACEMENT\_COST_m + STOR\_DISPLACEMENT\_COST_m + STATIC\_RESPONSE\_DISPLACEMENT\_COST_m + FFR\_DISPLACEMENT\_COST_m$$

Where:

$WIND\_DISPLACEMENT\_COST_m$
See Paragraph 40.

$STOR\_DISPLACEMENT\_COST_m$
See Paragraph 46.

$STATIC\_RESPONSE\_DISPLACEMENT\_COST_m$
See Paragraph 49.

$FFR\_DISPLACEMENT\_COST_m$
See Paragraph 52.

Margin Displacement by Windpower

39. Explanation of Windpower Effect on Margin

Currently, and as envisaged for the duration of the Scheme, the instantaneous power generated by windpower is essentially an independent variable, offering no controllability hence no contribution to margin. At any instant, the greater the amount of windpower generated, the smaller the degree of power from more flexible generation on the system

40. Calculation of Expected Cost of Margin Displacement by Windpower

For the purposes of Paragraph 38:

The expected cost adjustment, in £, of the displacement of margin volume due to windpower, is computed to a monthly resolution as follows:

$WIND\_DISPLACEMENT\_COST_m =$
$OP\_RESERVE\_PRICE_m$
*
$WIND\_DISPLACEMENT\_VOLUME_m$

Where:

$OP\_RESERVE\_PRICE_m$
Monthly volume-weighted average price for Operational Reserve.
Defined in Paragraph 33.

$WIND\_DISPLACEMENT\_VOLUME_m$
Total volume over the month *m*.
Defined in Paragraph 41.

41. Calculation of Monthly Wind-Displaced Margin Volume

For the purposes of Paragraph 40:

$WIND\_DISPLACEMENT\_VOLUME_m =$
(
$AVG\_WIND\_MARGIN\_REQUIREMENT_m$
$- EXPECTED\_WIND\_MARGIN\_REQUIREMENT_m$
)
*
WIND_MARGIN_EFFECT_ON_OP_RESERVE

Where:

$AVG\_WIND\_MARGIN\_REQUIREMENT_m$
The average historical requirement for margin power, in MW, to allow for the typical intermittency of wind generation in the given month *m*. Based on historical outturn data.
Defined in Paragraph 42.

$EXPECTED\_WIND\_MARGIN\_REQUIREMENT_m$
The average expected requirement for margin power, in MW, to allow for the typical intermittency of wind generation in the given month *m*.
Defined in Paragraph 43.

WIND_MARGIN_EFFECT_ON_OP_RESERVE
A constant value.
Defined in Paragraph 45

42. Calculation of Average Monthly Margin Requirement for Wind

For the purposes of Paragraph 41:

$$AVG\_WIND\_MARGIN\_REQUIREMENT_m = \frac{Sum(HISTORIC\_WIND\_VOLUME_m * HISTORIC\_OP\_RESERVE\_POLICY_m * HISTORIC\_OP\_RESERVE\_WEIGHTING_m)}{Sum(HISTORIC\_OP\_RESERVE\_WEIGHTING_m)}$$

Where

$HISTORIC\_WIND\_VOLUME_m$
Historical monthly average volume, in MWh, for Wind generation.

$HISTORIC\_OP\_RESERVE\_POLICY_m$
Annual Operating Reserve policy, by month (as a proportion).

$HISTORIC\_OP\_RESERVE\_WEIGHTING_m$
A numerical weight, either the value 0 or 1, essentially used to select/deselect the given month *m* (in continuous time, as opposed to annually) from the weighted-averaging process.

43. Calculation of Expected Monthly Margin Requirement for Wind.

For the purposes of Paragraph 41:

$$EXPECTED\_WIND\_MARGIN\_REQUIREMENT_m = AVG\_WIND_m * WIND\_POLICY_m$$

Where

AVG_WIND
Defined in Chapter 2: General Variables.
.

$WIND\_POLICY_m$
Defined in Paragraph 44.

44. Calculation of Monthly Wind Policy

For the purposes of Paragraph 43:

$WIND\_POLICY_m =$
max(0,
(
(AVG_WIND_m – GEN_SYNC_REQ)
*
OP_RESERVE_WIND_RATIO
)
/
$WIND\_POWER\_ACTUAL_m$
)

Where

AVG_WIND_m
Defined in Chapter 2: General Variables.

GEN_SYNC_REQ
A constant value, in MW, reflecting the quantized nature of a typical generation unit when synched and de-synched.

OP_RESERVE_WIND_RATIO
A constant value to compute the margin required to allow for windpower intermittency.

45. Calculation of Expected Monthly Wind Effect on Operating Reserve

For the purposes of Paragraph 41

WIND_MARGIN_EFFECT_ON_OP_RESERVE =
EFFECTIVE_HOURS_PER_DAY
* $NUMBER\_OF\_WORKING\_DAYS_m$
* SEL_MEL_RATIO

Where

EFFECTIVE_HOURS_PER_DAY
A constant value.

$NUMBER\_OF\_WORKING\_DAYS_m$
The number of working days in month *m*. Excludes Sundays and Bank Holidays but includes Saturdays.

SEL_MEL_RATIO
A constant value.

Margin Displacement by STOR

46. Calculation of monthly cost of STOR Displacement

For the purposes of Paragraph 38:

The expected cost adjustment, in £, of the margin displacement for Short Term Operating Reserve, is computed to a monthly resolution as follows:

$STOR\_DISPLACEMENT\_COST_m$ =
  $OP\_RESERVE\_PRICE_m$
  * $STOR\_DISPLACEMENT\_VOLUME_m$

Where:
$OP\_RESERVE\_PRICE_m$
  Monthly volume-weighted average price for Operational Reserve. Defined in Paragraph 33.

$STOR\_DISPLACEMENT\_VOLUME_m$
  Defined in Paragraph 47

47. Calculation of expected monthly volume of displacement by STOR

For the purposes of Paragraph 46.

$STOR\_DISPLACEMENT\_VOLUME_m$ =
  (
  $HISTORIC\_STOR\_VOLUME_m$
  - $STOR\_VOLUME\_EXPECTED_m$
)
  *
  $STOR\_EFFECT\_ON\_OP\_RESERVE_m$

Where:

$HISTORIC\_STOR\_VOLUME_m$
  Historical monthly average volume, in MWh, for STOR.
  For each month *m*, the average is based on selected periods over the range 1 January 2005 to 31 March 2011, inclusive.

$STOR\_VOLUME\_EXPECTED_m$
  Supplied from engineer judgement.

$STOR\_EFFECT\_ON\_OP\_RESERVE_m$
  Defined in Paragraph 48.

48. Calculation of STOR Effect on Operating Reserve in a given month

For the purposes of Paragraph 47:

$STOR\_EFFECT\_ON\_OP\_RESERVE_m$ =
  EFFECTIVE_HOURS_PER_DAY
  * TYPICAL_NUMBER_OF_DAYS_PER_MONTH
  * SEL_MEL_RATIO
  * $STOR\_BM\_AVAILABILITY\_VOLUME_m$

Where

EFFECTIVE_HOURS_PER_DAY
  Constant value.

TYPICAL_NUMBER_OF_DAYS_PER_MONTH

The typical number of days in any given month.
A constant value.

SEL_MEL_RATIO
A constant value

$STOR\_BM\_AVAILABILITY\_VOLUME_m$
Availability, as a proportion, of STOR on the BM

Margin Displacement by Static Response

49. Calculation of monthly cost of Static Response Displacement

For the purposes of Paragraph 38

The expected displacement of margin cost, in £, for Static Response, is computed to a monthly resolution as follows:

$$STATIC\_RESPONSE\_DISPLACEMENT\_COST_m = OP\_RESERVE\_PRICE_m * STATIC\_RESPONSE\_DISPLACEMENT\_VOLUME_m$$

Where:

$OP\_RESERVE\_PRICE_m$
Expected monthly volume-weighted average OOM price for Operational Reserve. Defined in Paragraph 33.

$STATIC\_RESPONSE\_DISPLACEMENT\_VOLUME_m$
Defined in Paragraph 50.

50. Calculation of Expected Monthly Displacement Static Response Volume

For the purposes of Paragraph 49:

$$STATIC\_RESPONSE\_DISPLACEMENT\_VOLUME_m = (HISTORIC\_STATIC\_VOLUME_m - STATIC\_VOLUME\_EXPECTED_m) * STATIC\_EFFECT\_ON\_OP\_RESERVE_m$$

Where:

$HISTORIC\_STATIC\_VOLUME_m$
Historical monthly average volume, in MWh, for Static Response. For each month m, the average is based on selected periods over the range 1 January 2005 to 31 March 2011, inclusive.

$STATIC\_VOLUME\_EXPECTED_m$
Supplied from engineer judgement.

$STATIC\_EFFECT\_ON\_OP\_RESERVE_m$
Defined in Paragraph 51.

51. Calculation of Static Effect on Operating Reserve in a given month

For the purposes of Paragraph 50:

$$
\begin{aligned}
STATIC\_EFFECT\_ON\_OP\_RESERVE_m = \; & EFFECTIVE\_HOURS\_PER\_DAY \\
& * NUMBER\_OF\_WORKING\_DAYS_m \\
& * SEL\_MEL\_RATIO \\
& * STATIC\_RESPONSE\_AVAILABILITY_m \\
& / \; LF\_RESPONSE\_FACTOR
\end{aligned}
$$

Where

EFFECTIVE_HOURS_PER_DAY
Constant value.

$NUMBER\_OF\_WORKING\_DAYS_m$
The number of working days in the month *m*. Excludes Sundays and Bank Holidays but includes Saturdays.

SEL_MEL_RATIO
A constant value

$STATIC\_RESPONSE\_AVAILABILITY_m$
Expected availability of static response, as a proportion, in the month *m*.

LF_RESPONSE_FACTOR
Constant value.

Margin Displacement by FFR

52. Calculation of Expected cost of margin displacement due to Firm Frequency Response (FFR).

For the purposes of Paragraph 38:

The expected cost adjustment, in £, of the displacement of margin volume by FFR is computed to a monthly resolution as follows:

$FFR\_DISPLACEMENT\_COST_m =$
$OP\_RESERVE\_PRICE_m$
$*$
$FFR\_DISPLACEMENT\_VOLUME_m$

Where:

$OP\_RESERVE\_PRICE_{hh}$
Expected monthly volume-weighted average price for Operational Reserve. Defined in Paragraph 33.

$FFR\_DISPLACEMENT\_VOLUME_m$
Defined in Paragraph 53.

53. Calculation of Expected Monthly Displacement by Firm Frequency Response (FFR) Volume (Contracted)

For the purposes of Paragraph 52:

$FFR\_DISPLACEMENT\_VOLUME_m =$
(
$HISTORIC\_FFR\_VOLUME_m$
$- FFR\_VOLUME\_EXPECTED_m$
)
$*$
$FFR\_EFFECT\_ON\_OP\_RESERVE_m$

Where:

$HISTORIC\_FFR\_VOLUME_m$
Historical monthly average volume, in MWh, for FFR.
For each month m, the average is based on selected periods over the range 1 January 2005 to 31 March 2011, inclusive.

$FFR\_VOLUME\_EXPECTED_m$
Supplied from engineer judgement.

$FFR\_EFFECT\_ON\_OP\_RESERVE_m$
Defined in Paragraph 54

54. Calculation of FFR Effect on Operating Reserve in a given month

For the purposes of Paragraph 53:

$FFR\_EFFECT\_ON\_OP\_RESERVE_m =$

$EFFECTIVE\_HOURS\_PER\_DAY$
$* NUMBER\_OF\_WORKING\_DAYS_m$
$* SEL\_MEL\_RATIO$
$/ LF\_RESPONSE\_FACTOR$

Where

EFFECTIVE_HOURS_PER_DAY
Constant value.

$NUMBER\_OF\_WORKING\_DAYS_m$
The number of working days in the month *m*. Excludes Sundays and Bank Holidays but includes Saturdays.

SEL_MEL_RATIO
A constant value.

LF_RESPONSE_FACTOR
Constant value.

Constrained Margin Management (CMM)

55. Calculation of Expected Cost of Constrained Margin Management (CMM)

Constrained Margin Management is defined in CHAPTER 14: Glossary.

For the purposes of Paragraph 30:

$$CMM\_COST_m = EXPECTED\_CMM\_VOLUME_m * MARGIN\_COST\_RATIO\_EXPECTED_m * OP\_RESERVE\_PRICE_m$$

Where:

m A particular calendar month of a particular year.

$EXPECTED\_CMM\_VOLUME_m$
Defined in Paragraph 56

$MARGIN\_COST\_RATIO\_EXPECTED_m$
Defined in Paragraph 57

$OP\_RESERVE\_PRICE_m$
Monthly (volume-weighted average) OOM price for Operational Reserve.
Defined in Paragraph 33.

CMM Volume

56. Calculation of CMM Volume

For the purposes of Paragraph 55:

The expected volume, in MWh (over the given month), for Constrained Margin Management (CMM) is computed to monthly resolution as follows:

$EXPECTED\_CMM\_VOLUME_m =$
max(0,
C0
+ C1 * $SCOTEX\_VOLUME_m$
+ C2 * $SCOTEX\_VOLUME_m$^2
+ C3 * $SCOTEX\_VOLUME_m$^3
)

Where:

$SCOTEX\_VOLUME_m$ is an output from the Constraints Forecast Model, the sum of bids taken in units located in Scotland.

Determining the Coefficients:

Coefficients C0 to C3 are determined by OLS regression based on data from 1 April 2005 to 31 March 2011. For the purposes of the regression, $SCOTEX\_VOLUME_m$ is the monthly sum of bids tagged as Constraint taken on units located in Scotland.

57. Calculation of Expected Monthly Margin OOM Cost Ratio

Expected monthly cost ratio for OOM margin displacement actions

For the purposes of Paragraph 55

$MARGIN\_COST\_RATIO\_EXPECTED_m =$
C0
+ C1 * $TOTAL\_MARGIN\_VOLUME_m$

Where:

$TOTAL\_MARGIN\_VOLUME_m$
Defined in Paragraph 58.

58. Calculation of Expected Monthly Operating Reserve Displacement Volume

For the purposes of Paragraph 57:

$$TOTAL\_MARGIN\_VOLUME_m = \frac{VOLUME\_DISPLACEMENT\_COST_m + OP\_RESERVE\_COST_m}{OP\_RESERVE\_PRICE_m}$$

Where:

$VOLUME\_DISPLACEMENT\_COST_m$
Defined in Paragraph 38

$OP\_RESERVE\_COST_m$
Defined in Paragraph 31

$OP\_RESERVE\_PRICE_m$
Defined in Paragraph 33.

STOR BM Availability

59. Calculation of Expected Cost of STOR BM Availability

For the purposes of Paragraph 30:

The expected cost, in £, of STOR BM Availability is computed to a monthly resolution as follows.

$$STOR\_AVAIL\_COST_m = STOR\_AVAIL\_FEE\_EXPECTED_m * STOR\_CONTRACTED\_VOLUME\_EXPECTED_m * STOR\_HOURS_m * STOR\_AVAILABILITY\_EXPECTED_m$$

Where:

$STOR\_AVAIL\_FEE\_EXPECTED_m$
Expected value of availability fee in £/MW/hr

$STOR\_CONTRACTED\_VOLUME\_EXPECTED_m$
From engineering judgement, based on tenders and historic

$STOR\_HOURS_m$
Engineering judgement

$STOR\_AVAILABILITY\_EXPECTED_m$
Engineering judgement

60. Calculation of Expected BM Start-Up Cost

For the purposes of Paragraph 30:

$BM\_START\_UP\_COST_m =$

$$C0 + C1 * OP\_RESERVE\_PRICE_m * IS\_BST\_NGET_m + C2 * OP\_RESERVE\_PRICE_m$$

Where:

$OP\_RESERVE\_PRICE_m$
Monthly volume-weighted average price for Operational Reserve. Defined in Paragraph 33.

$IS\_BST\_NGET_m$
Defined in Chapter 2: General Variables.

Determination of Coefficients:

The coefficients C0...C2 are determined by OLS regression based on data from 1 Nov 2006 to 31 March 2011. The start date (1 Nov 2006) reflects that on which the BM Start-up contracts came into existence.

Chapter 6: Model for the Expected *Frequency Response* Cost

Model Overview

61. Model Overview

The expected Frequency Response cost is modelled in terms of the following components:

- Frequency Response bid costs
- Frequency Response offer costs
- Frequency Response Ancillary Services (AS) costs

Calculation of Expected Cost for Frequency Response

62. Calculation of Expected Cost for Frequency Response

For the purposes of Paragraph 6.

The Frequency Response cost-target, in £, is computed to a monthly resolution, as follows:

$$FREQUENCY\_RESPONSE\_COST\_TARGET_m = FREQ\_RESP\_BID\_COST_m + FREQ\_RESP\_OFFER\_COST_m + FREQ\_RESP\_AS\_COST_m$$

Where:

FREQ_RESP_BID_COST$_m$
Defined in Paragraph 64

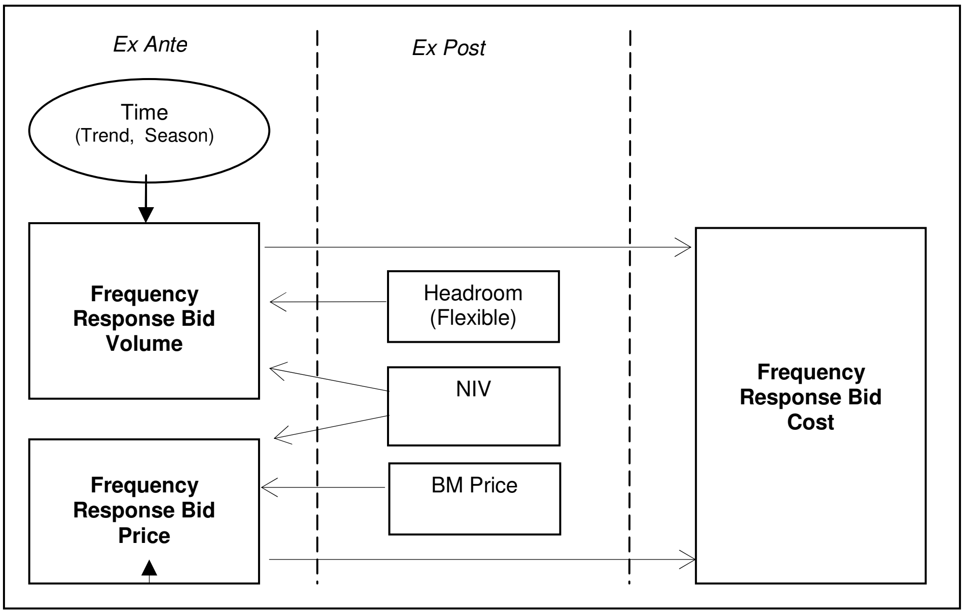
FREQ_RESP_OFFER_COST$_m$
Defined in Paragraph 71

FREQ_RESP_AS_COST$_m$
Defined in Paragraph 75

Frequency Response Bids

63. Frequency Response Bids - Overview

The typical cost, in £, of Frequency Response bids, is computed from the respective price and volume. The typical bid-price is computed by linear model (regression) from NIV and BM price. The typical volume is computed by linear model (regression) from NIV, Headroom and time, both in the sense of the continuous passage of time (trend) and whether or not it is Winter.



64. Calculation of Frequency response Bid Cost

For the purposes of Paragraph 62:

The Frequency Response Bids component of the Frequency Response expected cost, in £, is computed to a monthly resolution, as follows:

FREQ_RESP_BID_COST$_m$ =

FREQ_RESP_BID_PRICE$_m$
*
FREQ_RESP_BID_VOLUME$_m$

Where:

$FREQ\_RESP\_BID\_PRICE_m$
The bid price, in MWh, associated with frequency response bids. Computed by regression, as defined in Paragraph 65.

$FREQ\_RESP\_BID\_VOLUME_m$
The energy volume, in MWh, associated with frequency response bids. Computed by regression, as defined in Paragraph 66.

Frequency Response Bid Price

65. Calculation of the Expected Frequency Response Bid Price

For the purposes of Paragraph 64:

The expected Frequency Response Bid Price, in £/MWh, is computed to a monthly resolution, as follows.

$$FREQ\_RESP\_BID\_PRICE_m = C0 + C1 * BM\_PRICE\_EXPECTED_m$$

Where:

$BM\_PRICE\_EXPECTED_m$
Volume-weighted average of $BM\_PRICE\_EXPECTED_{hh}$ over the month *m*, where $BM\_PRICE\_EXPECTED_{hh}$ is as defined in Paragraph 28.

Frequency Response Bid Volume

66. Calculation of the Expected Frequency Response Bid Volume

For the purposes of Paragraph 64:

The expected Frequency Response Bid Volume, in MWh, is computed to a monthly resolution, as follows:

$$FREQ\_RESP\_BID\_VOLUME_m = \max(0, C0 + C1 * NIV_m + C2 * TREND_m + C3 * HEADROOM\_FLEX_m + C4 * IS\_WINTER_m * HEADROOM\_FLEX_m)$$

Where:

NIV_m Net Imbalance Volume for month *m*.

$TREND_m$, IS_WINTER_m
Defined in Chapter 2: General Variables.

$HEADROOM\_FLEX_m$
Defined in Paragraph 67

67. Headroom of Flexible Generation, Monthly

For the purposes of Paragraph 66

The Monthly average Headroom is computed from the monthly aggregate (sum) of that same quantity at half-hour resolution.

$HEADROOM\_FLEX_m$ =

$$\frac{\sum_{hh \in Start:End} \text{HEADROOM\_FLEX}_{hh}}{\text{Number of half hours}}$$

Where:

$HEADROOM\_FLEX_{hh}$
Defined in Paragraph 68.

Start and *End* span the period of the given calendar month *m*.

68. Headroom of Flexible Generation, Half-Hourly

For the purposes of Paragraphs 36, 67:

Flexible Headroom is computed to Settlement Period (half hour) resolution as follows:

$HEADROOM\_FLEX_{hh}$ =

$$\sum_{b \in Coal, Oil, Gas(CCGT)} \text{HEADROOM}_{b,hh}$$

69. General Headroom, Half-Hourly

For the purposes of Paragraph 68:

Headroom for any given BMU (flexible or otherwise) is computed to Settlement Period (half hour) resolution as follows:

$HEADROOM_{b,hh}$ =

$$\max(0, MEL_{b,hh} - FPN_{b,hh}), \text{ where } MEL_{b,hh} > 0 \text{ and } FPN_{b,hh} > 0$$

Where:

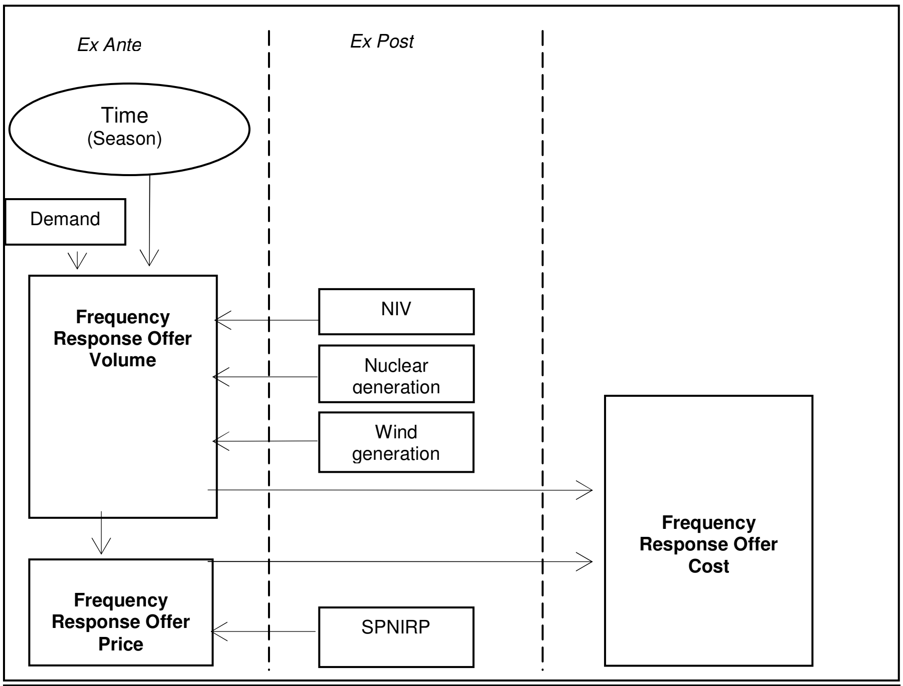
$MEL_{b,hh}$ The average over the given half hour (datetime) *hh* of the final values of the Maximum Export Limit (MEL) declared for a particular BMU *b*.

$FPN_{b,hh}$ The average over the given half-hour (datetime) *hh* of the Final Physical Notice (FPN) values for a particular BMU *b*.

Frequency Response Offers

70. Frequency Response Offers - Overview

The typical Frequency Response Offer cost is computed from the respective offer price and offer volume. The typical price is computed by linear model (regression) from SPNIRP and the typical Offer Volume. This typical Offer Volume is computed by linear model (regression) from NIV, average levels (in MW) of Nuclear generation and Wind generation (relevant since they are both inflexible) and of Demand (Ex Ante, i.e. forecast), also Time, in the sense of whether or not it is Winter or Summer (but there is no trend with continuous time).



71. Frequency Response Offers Cost

For the purposes of Paragraph 62:

The expected Frequency Response Offers component of the Frequency Response cost-target, in £, is computed to a monthly resolution, as follows.

$$FREQ\_RESP\_OFFER\_COST_m = FREQ\_RESP\_OFFER\_PRICE_m * FREQ\_RESP\_OFFER\_VOLUME_m$$

Where:

$FREQ\_RESP\_OFFER\_PRICE_m$
The expected price, in £/MWh, associated with frequency response offers.
Defined in Paragraph 72.

$FREQ\_RESP\_OFFER\_VOLUME_m$
The energy volume, in MWh, associated with frequency response offers.
Defined in Paragraph 73.

Frequency Response Offer Price

72. Frequency Response Offer Price

For the purposes of Paragraph 71:

The expected Frequency Response Offer Price, in £/MWh, is computed to a monthly resolution, as follows.

$$FREQ\_RESP\_OFFER\_PRICE_m = C0 + C1 * SPNIRP_m + C2 * FREQ\_RESP\_OFFER\_VOLUME_m$$

Where:

$SPNIRP_m$
Defined in Chapter 2: General Variables.

$FREQ\_RESP\_OFFER\_VOLUME_m$
Defined in Paragraph 73.

Frequency Response Offer Volume

73. Frequency Response Offer Volume

For the purposes of Paragraph 71:

The expected Frequency Response Offer Volume, in MWh, is computed to a monthly resolution, as follows.

$$
\begin{aligned}
FREQ\_RESP\_OFFER\_VOLUME_m = \\
&\max(0, \\
&\quad C0 \\
&\quad + C1 * IS\_SUMMER_m * AVG\_NUKE_m \\
&\quad + C2 * \log(DEMAND_m) \\
&\quad + C3 * IS\_SUMMER_m * \log(DEMAND_m) \\
&\quad + C4 * IS\_SUMMER_m \\
&\quad + C5 * AVG\_NUKE_m \\
&\quad + C6 * IS\_WINTER_m * AVG\_WIND_m \\
&\quad + C7 * NIV_m \\
&\quad)
\end{aligned}
$$

Where:

AVG_NUKE_m, AVG_WIND_m, $DEMAND_m$, NIV_m, IS_SUMMER_m, IS_WINTER_m

Defined in Chapter 2: General Variables.

Ancillary Services Frequency Response

74. Ancillary Services Frequency Response - Overview

The cost of Ancillary Services Frequency Response is computed by a linear model based on season, SPNIRP and volume of nuclear generation.

75. Ancillary Services Frequency Response – Calculation

For the purposes of Paragraph 62:

The expected Frequency Response Ancillary Services (AS) Cost, in £, is computed to a monthly resolution, as follows.

$$
\begin{aligned}
FREQ\_RESP\_AS\_COST_m = \\
&\max(0, \\
&\quad C0 \\
&\quad + C1 * IS\_SUMMER_m * SPNIRP_m \\
&\quad + C2 * IS\_SUMMER_m * AVG\_NUKE_m \\
&\quad)
\end{aligned}
$$

Where:

$SPNIRP_m$, AVG_NUKE_m, IS_SUMMER_m

Defined in Chapter 2: General Variables.

Determining the Coefficients:

Coefficients C0 to C2 are determined by OLS regression based on data from 1 January 2007 to 31 March 2011. Data prior to this are excluded because they predate the implementation of frequency response amendments as identified in CAP 107.

Chapter 7: Model for the Expected *Fast Reserve* Cost

Model Overview

76. Model Overview

The expected costs of Fast Reserve are modelled in terms of the following components:

- Fast reserve bid costs
- Fast reserve offer costs
- Fast reserve Ancillary Services (AS) costs

Each of these components is modelled separately.

Fast Reserve

77. The Fast Reserve cost-target, in £, is computed to a monthly resolution, as follows:

For the purposes of Paragraph 6.

$$FAST\_RESERVE\_COST\_TARGET_m = FAST\_RSV\_BID\_COST_m + FAST\_RSV\_OFFER\_COST_m + FAST\_RSV\_AS\_COST_m$$

Where:

$FAST\_RSV\_BID\_COST_m$
Defined in Paragraph 79

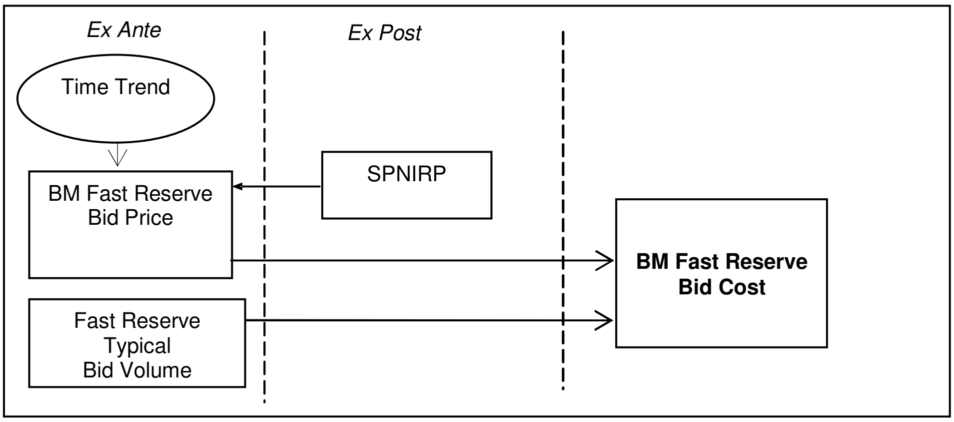
$FAST\_RSV\_OFFER\_COST_m$
Defined in Paragraph 83

$FAST\_RSV\_AS\_COST_m$
Defined in Paragraph 87

Fast Reserve Bids

78. Fast Reserve Bids - Overview

The Fast Reserve Bid cost model computes its result (in £) as the multiple of the corresponding volume and price. Fast Reserve Bid Volume is a constant value representing the typical volume. Prior to January 2008 such volumes were volatile but from that point onwards they have been relatively stable, hence the typical value is obtained as the average over the latter. Fast Reserve Bid Price is based on a linear model driven by SPNIRP (Ex Post) and a Trend with continuous time.



79. Fast Reserve Bids – Calculation

For the purposes of Paragraph 77:

The Fast Reserve Bids component of the Fast Reserve cost-target, in £, is computed to a monthly resolution, as follows.

$$FAST\_RSV\_BID\_COST_m = FAST\_RSV\_BID\_PRICE_m * FAST\_RSV\_BID\_VOLUME\_TYPICAL$$

Where:

$FAST\_RSV\_BID\_PRICE_m$
Defined in Paragraph 80.

FAST_RSV_BID_VOLUME_TYPICAL
Defined in Paragraph 81.

80. Fast Reserve Bid Price

For the purposes of Paragraph 79

$$FAST\_RSV\_BID\_PRICE_m = C0 + C1 * SPNIRP_m + C2 * TREND_m$$

Fast Reserve Bid Volume

81. Fast Reserve Bid Volume

For the purposes of Paragraph 79:

The Fast Reserve Bid Volume, in MWh, is a fixed (constant) value, as follows.

FAST_RSV_BID_VOLUME_TYPICAL =

$\text{AVERAGE}(\text{FAST\_RSV\_BID\_VOLUME}_{hh})$

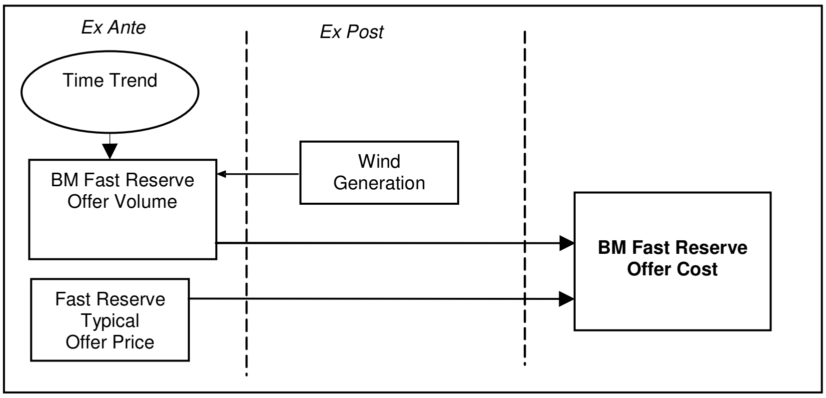
Where

hh ≥ 1 January 2008 00:00

Fast Reserve Offers

82. Fast Reserve Offers – Overview

Similarly to the corresponding Bids model, the Fast Reserve *Offers* cost model computes its result (in £) as the multiple of the corresponding volume and price. Fast Reserve Offer Volume is estimated from a linear model accounting for its historical trend (in continuous time) and the influence of the volume of wind generation (Ex Post). Fast Reserve Offer Price is based on its typical historical value (volume-weighted) since the BETTA go-live.



83. Fast Reserve Offers – Calculation

For the purposes of Paragraph 77:

The Fast Reserve Offers component of the Fast Reserve cost-target, in £, is computed to a monthly resolution, as follows.

$$\text{FAST\_RSV\_OFFER\_COST}_m = \text{FAST\_RSV\_OFFER\_PRICE\_TYPICAL} * \text{FAST\_RSV\_OFFER\_VOLUME}_m$$

Where:

FAST_RSV_OFFER_PRICE_TYPICAL
Defined in Paragraph 84.

$\text{FAST\_RSV\_OFFER\_VOLUME}_m$
The energy volume associated with fast reserve offers, in MWh. Computed by regression, as defined in Paragraph 85.

84. Fast Reserve Offer Price

The typical Fast Reserve Offer Price, in £/MWh, is a fixed (constant) quantity obtained as the volume-weighted average of outturn costs and volumes over the period 1 April 2005 to 31 March 2011.

For the purposes of Paragraph 83:

FAST_RSV_OFFER_PRICE_TYPICAL =

$$\frac{\sum_{m \in period} FAST\_RSV\_OFFER\_COST_m}{\sum_{m \in period} FAST\_RSV\_OFFER\_VOLUME_m}$$

Where:

period is 1 April 2005 to 31 March 2011.

$FAST\_RSV\_OFFER\_COST_m$
The outturn cost, in £/MWh, of fast-reserve offers over the given month *m*.

$FAST\_RSV\_OFFER\_VOLUME_m$
The outturn volume, in MWh, of fast-reserve offers over the given month *m*.
Defined in Paragraph 85

Fast Reserve Offer Volume

85. Fast Reserve Offer Volume

For the purposes of Paragraphs 83, 84:

The Fast Reserve Offer Volume, in MWh, is computed to a monthly resolution, as follows:

$FAST\_RSV\_OFFER\_VOLUME_m$ =

max(0,

C0
+ C1 * IS_WINTER_m * AVG_WIND_m
+ C2 * $TREND_m$
)

Where:

$TREND_m$, IS_WINTER_m

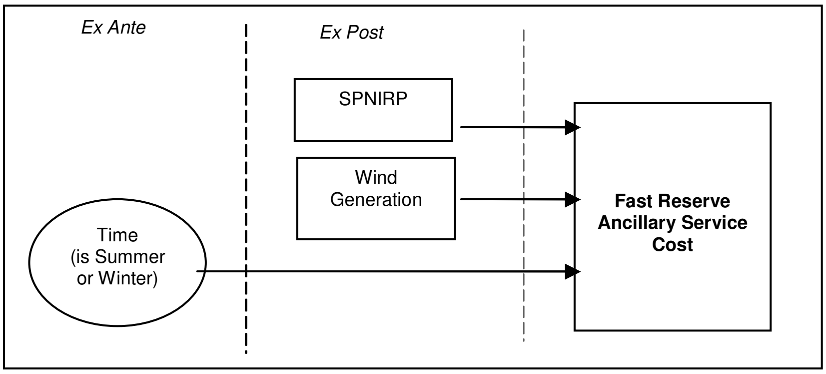
Defined in Chapter 2: General Variables.

AVG_WIND_m
Defined in Chapter 3: General Variables.

Fast Reserve AS Cost

86. Fast Reserve AS Cost - Overview

The cost of Fast Reserve associated with Ancillary Services contracts is estimated by a linear regression model driven by average wind output (Ex Post) to capture a volume element and SPNIRP to reflect contract pricing of the service. The model incorporates Summer and Winter coefficients to reflect seasonal changes in Volume (typically lower in the Summer) and Price (typically higher in the Winter).



87. Fast Reserve AS Cost – Calculation

For the purposes of Paragraph 77:

The Fast Reserve Ancillary Services (AS) Cost, in £, is computed to a monthly resolution, as follows.

$$FAST\_RSV\_AS\_COST_m =$$

$$\max(0, \; C0 + C1 * AVG\_WIND_m + C2 * IS\_WINTER_m * SPNIRP_m + C3 * IS\_SUMMER_m + C4 * SPNIRP_m)$$

Where:

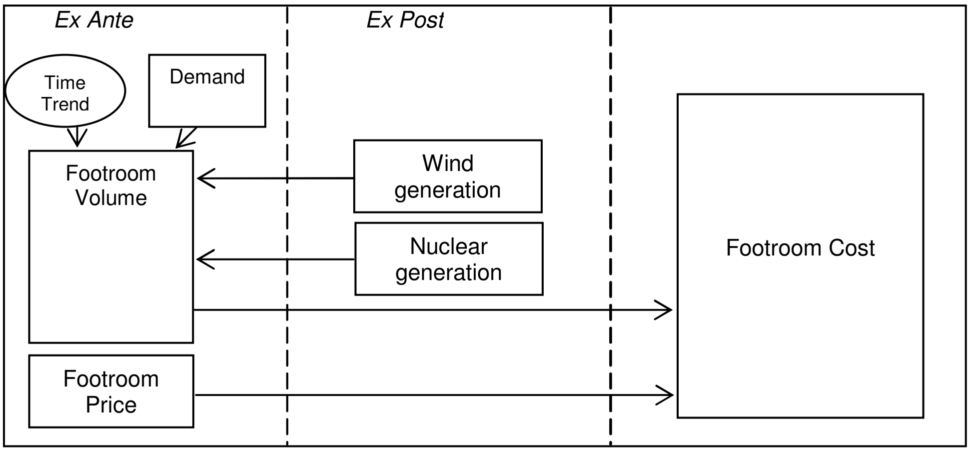
IS_SUMMER_m, IS_WINTER_m, AVG_WIND_m, $SPNIRP_m$
Defined in Chapter 2: General Variables.

Chapter 8: Model for the Expected *Footroom* Cost

Model Overview

88. Model Overview

The Footroom cost model derives Footroom Cost (in £) from the multiple of a Footroom Price and an estimated Footroom Volume. Footroom price is a fixed value reflecting the typical historical price. Footroom Volume is estimated by an Ex Ante regression driven by Ex Post inputs of wind and nuclear generation volumes.



Footroom

89. Footroom – Calculation

For the purposes of Paragraph 6.

The monthly Footroom component of the cost-target is computed as the product of an (unchanging) expected Footroom Price and monthly expected Footroom Volume:

$$\text{FOOTROOM\_COST\_TARGET}_m = \text{FOOTROOM\_PRICE\_TYPICAL} * \text{FOOTROOM\_VOLUME\_EXPECTED}_m$$

Where:

FOOTROOM_PRICE_TYPICAL
A fixed (constant) value representing an historical volume-weighted average.
Defined in Paragraph 90.

$\text{FOOTROOM\_VOLUME\_EXPECTED}_m$
A value for Footroom Volume (in MWh), modelled rather than actual, for a given month.
Defined in Paragraph 91.

Footroom Price

90. Footroom Price

For the purposes of Paragraph 89

The typical Footroom Price, in £/MWh, is a fixed (constant) quantity obtained as the volume-weighted average of outturn costs and volumes over the period 1 April 2005 to 31 March 2011.

FOOTROOM_PRICE_TYPICAL =

$$\frac{\sum_{m\in period} \text{FOOTROOM\_COST\_OUTTURN}_m}{\sum_{m\in period} \text{FOOTROOM\_VOLUME\_OUTTURN}_m}$$

Where:

period is 1 April 2005 to 31 March 2011.

Footroom Volume

91. Footroom Volume

For the purposes of Paragraph 89:

The expected Footroom Volume is a varying quantity that derives from a model, as defined below, regarded as representative of an unchanging (mathematically stationary) relationship between that price and other variables.

$\text{FOOTROOM\_VOLUME\_EXPECTED}_m$ =

max(0,

C0
+ C1 * log(DEMAND_m)
+ C2 * AVG_NUKE_m
+ C3 * AVG_WIND_m
+ C4 * IS_SUMMER_m * AVG_WIND_m
+ C5 * IS_WINTER_m * AVG_WIND_m
)

Where:

log()

The *natural* logarithm (to base *e*). In principle the base of the logarithm is immaterial, provided it is consistent between determination of coefficients and model usage, but for simplicity in practice we define a specific base.

$DEMAND_m$, AVG_NUKE_m AVG_WIND_m, IS_SUMMER_m, IS_WINTER_m
Defined in Chapter 2: General Variables.

Determination of Coefficients

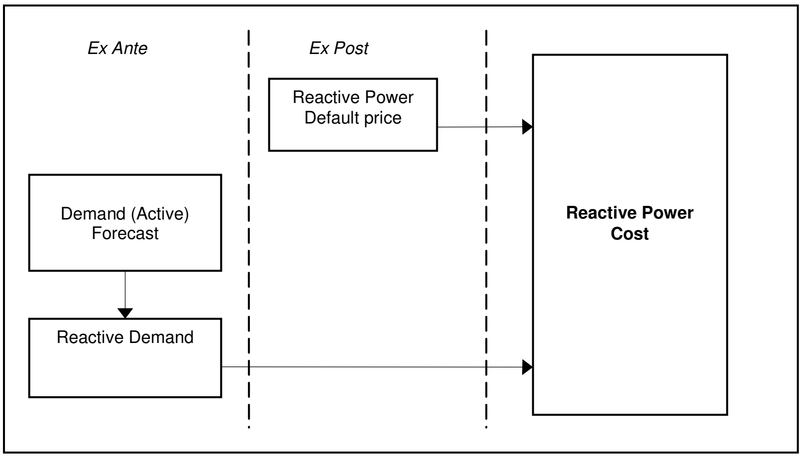
The values of the coefficients, C0, C1, C2, C3, C4, C5, are determined by OLS linear regression fitting as *dependent variable* to the above input (explanatory) variables over outturn data covering a given period of time.

Chapter 9: Model for the Expected *Reactive* Cost

Model Overview

92. Model Overview

The Reactive Power model derives Reactive Power cost (in £) from the multiple of a forecast reactive demand (in MVar-h) and an assumed (“default”) price of reactive power. Reactive demand is estimated as a proportion of active-demand forecast. Reactive Power price is estimated from RPI and wholesale electricity price inputs (in accordance with the CUSC reactive power default price calculation).



Reactive Cost

93. Reactive Cost

For the purposes of Paragraph 6.

The expected Monthly Reactive cost is, in the absence of provision from a reactive market, as follows:

$$REACTIVE\_COST\_TARGET_m = Reactive\_Default\_Cost_m$$

Where:

$Reactive\_Default\_Cost_m$
Defined in Paragraph 94.

94. Reactive Default Cost

For the purposes of Paragraph 93:

The expected Monthly Reactive Default cost is computed as the sum of the following monthly components:

$$Reactive\_Default\_Cost_m = REACTIVE\_PRICE\_DEFAULT_m * REACTIVE\_VOLUME\_DEFAULT_m$$

Where:

$REACTIVE\_PRICE\_DEFAULT_m$
Defined in Paragraph 95.

$REACTIVE\_VOLUME\_DEFAULT_m$
Defined in Paragraph 96.

Reactive Power Default Price

95. Origin of Monthly Reactive Power Default Price

For the purposes of Paragraph 94:

$REACTIVE\_PRICE\_DEFAULT_m$
This is a varying quantity derived in a manner consistent with *Utilisation Payment* as defined in CUSC Schedule 3.

Reactive Power Volume

96. Calculation of Monthly Reactive Power Volume

For the purposes of Paragraph 94:

$$REACTIVE\_VOLUME\_DEFAULT_m = DEMAND_m * ReactiveProportion$$

Where

$DEMAND_m$
As defined in Chapter 2: General Variables.

ReactiveProportion
A fixed (constant) value indicating the proportion of active demand to be assumed for reactive demand (absolute i.e. regardless of sign). This is based on historical experience (over the period 2009-2011)

CHAPTER 10: Remaining AS & BM Costs

97. AS & BM Costs – Overview

These account for energy model costs not covered by the other sub-models of the energy model.

Calculation of Remaining Ancillary Services and Balancing Mechanism Costs

98. AS & BM Costs – Calculation

For the purposes of Paragraph 5

$$AS\_BM\_REMAINING_p = UNCLASSIFIED\_BM_p + AS\_BM\_GENERAL_p$$

Where

p The scheme period

$UNCLASSIFIED\_BM_p$
Defined in Paragraph 99

$AS\_BM\_GENERAL_p$
Defined in Paragraph 100

Calculation of Unclassified BM Actions

99. Unclassified BM Actions

For the purposes of Paragraph 98:

BM actions that could not be assigned to any single classification.

$$UNCLASSIFIED\_BM_p = (UNCLASSIFIED\_BM_{2005\text{-}2011} / BM\_COSTS_{2005\text{-}2011}) * BM\_COSTS_p$$

Where:

$UNCLASSIFIED\_BM_{2005\text{-}2011}$
Costs of BM actions that could not be assigned to any single classification, over the financial years 2005-2011.

$BM\_COSTS_{2005\text{-}2011}$
The sum of Energy Imbalance, Margin, Footroom, Fast Reserve, BM_Response, over the financial years 2005-2011.

BM_COSTS_p
The sum of Energy Imbalance, Margin, Footroom, Fast Reserve, BM_Response, over the period of the Scheme.

Calculation of AS & BM General

100. Ancillary Services (AS) and Balancing Mechanism (BM) Actions

For the purposes of Paragraph 98:

$$AS\_BM\_GENERAL_p = \left(AS\_BM\_GENERAL_{2005\text{-}2011} / BM\_COSTS_{2005\text{-}2011} \right) * BM\_COSTS_p$$

Where:

$AS\_BM\_GENERAL_{2005\text{-}2011}$
Costs of small AS and BM actions over the financial years 2005-2011.

$BM\_COSTS_{2005\text{-}2011}$
BM costs over the financial years 2005-2011.

BM_COSTS_p
The sum of BM costs from Energy Imbalance, Margin, Footroom, Fast Reserve, BM_Response, over the Scheme period.

CHAPTER 11: Calculation of Transmission Losses Reference Price

101. Transmission Losses Reference Price

The Transmission Losses Reference Price over the period of the Scheme is computed as the straight (not volume-weighted) average of SPNIRP values which are themselves defined to the resolution of a Settlement Period (hence half-hour):

$TLRP_{scheme\_period}$ =
Average($SPNIRP_j$)

For:
j within *scheme_period*

Where:

j	A particular Settlement Period (hence half-hour). It is mappable to a unique date and time.
$SPNIRP_j$	Defined in chapter entitled "CHAPTER 12: SPNIRP",

CHAPTER 12: SPNIRP

This chapter defines the Single Price Net Imbalance Reference Price (SPNIRP), which is a form of market reference priced used by National Grid in its BSIS models.

As of March 2011, SPNIRP is defined as part of the Transmission Licence, in support of the definition of NIA. However the Scheme will not include NIA. For that reason, the definition of SPNIRP is presented here.

SPNIRP shall be derived as follows:

(i) where $APXUKHH_j$ and $APXUK4H_j$ data are published in respect of the relevant settlement period j then:

$$SPNIRP_j = (0.5 * APXUKHH_j) + (0.5 * APXUK4H_j)$$

(ii) where $APXUKHH_j$ data are published and $APXUK4H_j$ data are not published in respect of the relevant settlement period j then:

$$SPNIRP_j = APXUKHH_j$$

(iii) where $APXUKHH_j$ data are not published and $APXUK4H_j$ data are published in respect of the relevant settlement period j then:

$$SPNIRP_j = APXUK4H_j$$

(iv) where neither $APXUKHH_j$ data nor $APXUK4H_j$ data have been published in respect of the relevant settlement period j then:

$SPNIRP_j = SPNIRP_{j-1}$

where:

$SPNIRP_j$ means the single price net imbalance volume reference price for each settlement period j.

j in all cases shall mean a settlement period (being a half an hour) as defined in the BSC.

j-1 the settlement period immediately preceding the relevant settlement period j.

$APXUKHH_j$ means the APX Power UK volume weighted reference price for each settlement period j based on the traded prices of half hourly spot contracts.

$APXUK4H_j$ means the APX Power UK weighted average price in respect of all four (4) hour block market contracts delivered within the EFA block applying to those settlement periods j. In order to derive the APXUK4Hj price in respect of each relevant settlement period j the EFA block containing the relevant settlement period j shall be used.

EFA Block means the six four hourly blocks within the EFA day (being 23.00 hours to 23.00 hours in the immediately following day) as set out in the table below:

EFA Block	Time
1	23:00 to 03:00
2	03:00 to 07:00
3	07:00 to 11:00
4	11:00 to 15:00
5	15:00 to 19:00
6	19:00 to 23:00

CHAPTER 13: Tobit Regression

For models where the distribution of outcomes/results is considered in statistical terms to be *censored*, meaning the underlying (real-world) values have been limited (clipped) to a fixed minimum and/or maximum threshold value, use of the standard linear modelling technique would produce biased results.

Such bias can arise, especially for model result values near to the clipping thresholds, because any realistic data will be subject to some degree of random error ("noise"), and as we approach such a threshold, some part of the noise component's distribution will develop a sharp peak at the single value corresponding to that threshold.

To avoid this we can instead use a special type of regression model, the *Tobit* model.

$$E[y] = \Phi\left(\frac{X\beta}{\sigma}\right)\left[X\beta + \sigma\lambda\left(\frac{X\beta}{\sigma}\right)\right]$$

Where:

$$\lambda\left(\frac{X\beta}{\sigma}\right) = \frac{\phi\left(\frac{X\beta}{\sigma}\right)}{\Phi\left(\frac{X\beta}{\sigma}\right)}$$

which is the inverse Mills ratio.

CHAPTER 14: Glossary

The following definitions are intended to assist the reader's understanding of this document. In the event of conflict with definitions given elsewhere, those used in the Transmission Licence, Grid Code, Balancing and Settlement Code and Connection and Use of System Code take precedence.

Term	Definition
CMM	Constrained Margin Management CMM actions are actions taken which have the *combined* (difficult or impossible to apportion) effects of: a) Replacing operating reserve that is *sterilised* (unable to operate at full potential) due to being behind a constraint boundary: b) Increasing the amount of positive reserve available for operation: If a reserve action is undertaken that completely replaces sterilised operational margin, then the costs are assigned to constraint costs. For the action to be assigned to CMM costs, the action must only *partially* replace sterilised operation margin and *partially* increase the amount of positive reserve available. Typically CMM actions will utilise relatively expensive generation, the cheaper generation having already been committed for non constraint-associated purposes.
CUSC	Connection and Use of System Code, the contractual framework for connecting to, and use of, National Grid's high-voltage transmission system. The CUSC derives in part from the National Grid Transmission Licence, also from Users' licences. http://www.nationalgrid.com/uk/Electricity/Codes/ https://www.nationalgrid.com/uk/Electricity/Codes/systemcode http://www.nationalgrid.com/uk/Electricity/Codes/systemcode/contracts/ CUSC Schedule 3 (referred to in this document): http://www.nationalgrid.com/NR/rdonlyres/513F95AA-4EBC-468E-BE70-2FA25FA5CFB0/40480/CUSC_Sch3V16_CAP173_1April2010.pdf
Ex Ante	*Ex Ante* data is data reflecting events that have yet to happen, in relation to a (given or implicit) point in time. By implication, such data, if required, has to be estimated or predicted.
Energy Reference Price (ERP)	The price of energy, in £/MWh, in the Balancing Mechanism, for a given Settlement Period. The ERP is derived by taking a volume-weighted average of all submitted bids and offers required to meet market length as measured by the Net

Term	Definition
	Imbalance Volume (NIV) for the given Settlement Period. This is in the context of a hypothetical "hub" transmission system. having no complications such as constraints.
Ex Post	*Ex Post* data is outturn data, i.e. data reflecting events that have happened. by a (given or implicit) point in time, such as the beginning of the Scheme or a point at which costs are computed (within the Scheme). A model driven entirely by Ex Post data should not necessarily be referred to as an Ex Post model. Where it is derived (trained, regressed) from data existing before the Scheme, i.e. Ex Ante data, then it is said to represent an Ex Ante *relationship*, even if the Scheme holds that relationship to be stationary (invariant in time).
Headroom	Also known as "Free Reserve". Reduced output from self-dispatched generation units, coupled with a longer market.
Margin	According to *Electricity SO Incentives Initial Proposals for 1st April 2011*: "Margin costs are incurred when National Grid synchronises additional units onto the system in order to ensure that the Short Term Operating Reserve Requirement (STORR) is met" (demand not met <= 1/365 days). MARGIN = STORR + NIV – HEADROOM
NIV	Net Imbalance Volume. Essentially the length of the market. If NIV ≥ 0 then the market is technically Long, otherwise it is Short (though obviously the magnitude can in principle vary considerably).

OOM	Out of (the) Money. Formally: An adjective referring to the component of balancing actions costs beyond (positively or negatively) those that would be implied by the Energy Reference Price (ERP). Intuitively: The remaining part of balancing costs after those due to pure energy-balancing have been removed (such costs are accounted separately). The hypothetical "pure energy-balancing" scenario excludes such complications as faults, constraints, ramp-rates and forecasting error, hence for example it excludes frequency-response actions. An OOM price is the *premium* paid beyond the normal Balancing Mechanism (BM) price in order to cope with complications such as those mentioned earlier. For example the SO may on occasion need to take bids and offers on generation at certain nodal locations, such as either side of a constraint boundary, almost regardless of their price. The premium is typically positive, but could in principle be negative. Note: the expression "Out of (the) Money" itself has no precise intuitive explanation in the context of the Scheme, where it is best regarded as an established but arbitrary phrase. Possibly it is based on general financial terminology, where it means the difference between an option strike-price and the market price. If an option were exercised at a time when the option price exceeded the market price, one would in some sense be "out of pocket" according to the difference (and the volume of purchase).
Operating Reserve	A significant, but not the only, component of Margin.
SPNIRP	Essentially, the wholesale power-price. Single Price Net Imbalance Reference Price for each settlement period, derived from the United Kingdom Power Exchange (UKPX) volume-weighted reference-price. . Based on the four-hour and half-hour trade products on the APXUK power exchange for a given settlement period. Believed generally to correlate well with wholesale prices. Defined in the BSIS Reference Document[1], repeated in the current document, Chapter entitled **CHAPTER 12: SPNIRP**.

1 http://www.nationalgrid.com/NR/rdonlyres/06D6679A-1304-48FF-AC23-701645507161/44157/BSISReferenceDocument2010.pdf

Sterilised Operating Margin	Sterilised operating margin refers to BMUs which are unable to achieve maximum output as they are located behind a constraint boundary which cannot transmit all of the necessary power through the available assets.
TQEI	Market length. Defined in the Transmission Licence.

Revisions

Issue 1	Modifications	Changes to Pages
Revision 0	First Issue	