Issue	Revision
1	0

The Statement of the Constraint Cost Target Modelling Methodology

Effective from 1 April 2011

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 Energy Balancing Cost Target Modelling Methodology
- The Statement of the Ex Ante or Ex Post Treatment of Modelling Inputs Methodology

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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

1.1 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…"

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

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

1.3 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 NGET Electricity Transmission (NGET) and the Gas and Electricity Markets Authority (GEMA).

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

Where:

p

The scheme period

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

$ENERGY\_COST\_TARGET_p$

Defined in the statement of the Energy Cost Target Modelling Methodology.

$CONSTRAINT\_COST\_TARGET_p$

Defined in Paragraph 1.5

$BSCT_p$

The black start cost target

1.4 The target constraint cost is made up of the costs associated with the balancing mechanism and the headroom replacement costs.

$$CONSTRAINT\_COST\_TARGET_p = DF \times TARGET\_BM\_costs_p + TARGET\_HEADROOM\_REPLACEMENT\_COST$$

Where:

DF

A discount factor (to promote efficient cost management)

TARGET_BM_costs

Defined in Paragraph 2.4
TARGET_HEADROOM_REPLACEMENT_COST
Defined in Paragraph 6.3

1.5 The incentive on constraint management encourages NGET to develop innovative configurations for running its substations and to develop and agree mechanisms for Users to provide actions post-fault to manage the impact of faults.

Principles

1.6 The principles applied when modelling constraints costs are as shown in Figure 1 below:

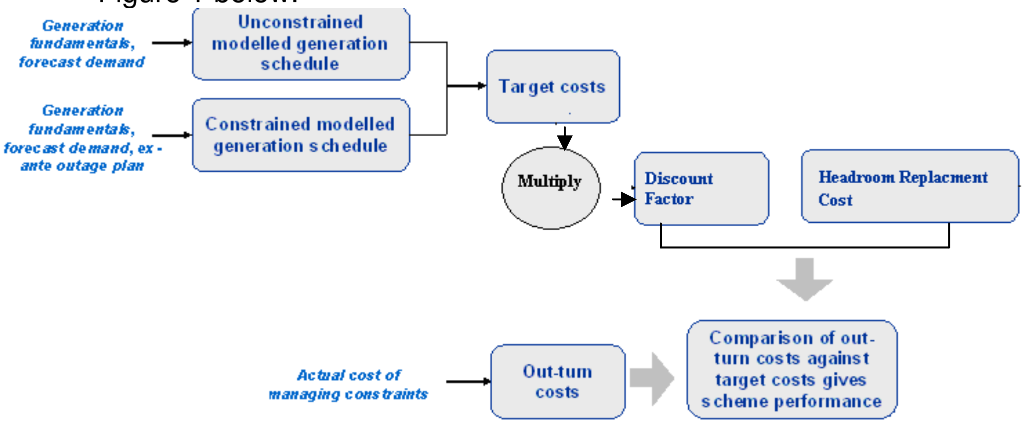

Figure 1: Overview of constraint modelling process

1.7 The 'generation fundamentals' capabilities of Plexos are used to generate a schedule of plant running to meet demand. The output of this schedule is 'unconstrained' – i.e. it assumes infinite transmission capacity. The model is then re-run with a boundary model applied, which represents the ability of the transmission network to transfer power between pre-defined zones. The boundary capabilities of each zone are modified to represent the transmission outage plan for the period covered by the scheme. Where a boundary's capability is exceeded, resulting constraints are resolved by re-scheduling plant using a representation of offer/bid prices in the balancing mechanism, to give an overall 'constrained' schedule of plant running to meet demand.

1.8 The cost arising from moving the system from the unconstrained run to the constrained one gives a modelled target direct cost, which is then reduced by a discount factor to reflect efficiencies gained via contracts. The sum of this discounted modelled direct cost with the Headroom Replacement Cost gives the incentive target against which NGET's out-turn will be compared to determine its performance under the SO incentive.

Chapter 2: Plexos Model

Model overview

2.1 NGET has procured a new piece of software to assist in the modelling of constraint costs. The use of the Plexos software model for constraints modelling is based on the application of optimisation techniques aimed at minimising total costs.

2.2 The key output of the model is the anticipated total cost of constraints incurred by NGET in adjusting the self-dispatch of generators to maintain a security standard on the network.

2.3 The first run of the model consists of a simulation of market behaviour whereby, assuming an efficient market, the self-dispatched position of generators, in order to meet forecast demand, is defined by minimising the short run marginal cost subject to a number of plant dynamics constraints such as minimum run time, minimum time between runs, run up rates, run down rates, etc.

2.4 The Modelled Target Cost for constraints represents the result from the second run of the model, which looks for the minimum cost of moving the system from its initial condition (resulting from the first run) to a feasible condition (given the transmission system constraints) via actions presumed to be taken in the balancing mechanism.

$$\text{TARGET\_BM\_costs}_p = Min \sum_{mp} Balancing\ mechanisms\ \cos ts_m$$

Subject to:

i. Power flows being within limits of constrained boundary model
ii. Supply equals demand (transmission system is lossless)
iii. Generator dynamic ratings are not exceeded

Where: p is the scheme period (2 years)
m is a particular month in the period under consideration.

The balancing mechanisms used are described below.

Modelled network

2.5 The modelled network has been developed in line with the models used in operating timescales and the boundary capabilities have been calculated to represent the transmission outage plan for the period covered by the scheme.

2.6 The modelled network is made up of nodes, lines and interfaces. Each node represents an area of the country which is defined by a unique combination of interfaces (boundaries). The properties of a node are its Load participation factor and the generators located in that particular region of the country. The sum of the Load participation factors of all the nodes must be equal to 1.

2.7 A line is used to join two nodes and represents a virtual connection between them (not the physical network). Therefore, the Min and Max Flows are ±99999 MW. Also applied is a Wheeling Charge of 0.0001 £/MWh. A Wheeling Charge is the Plexos term for a charge on the flow of power on a Line. This is used to ensure shortest routes for flow through a network[1]. The charge is very small so that it does not affect the overall results.

1 Another approach would be to apply notional losses to each line, but this will then contradict the definition of demand and demand will no longer equal supply.

Interfaces and Boundaries

2.8 An interface is a collection of lines. An interface is the Plexos representation of a boundary in NGET terminology. The interface is used to limit the flow across the boundary. The limit can be in a single direction across the interface, or in both directions. The limit can be time-varying. Each line that crosses the Interface is a member of the Interface. A line may be a member of more than one interface.

2.9 The final property to be defined for an Interface is the Flow Coefficient. This is a 'secondary property' as it is a property of a specific line and interface. If the reference line flow is defined in the same direction as the Interface, the Flow Coefficient is 1. If the reference line flow is opposite to the Interface, the Flow Coefficient is -1.

2.10 The location and number of boundaries have been selected by NGET based on the most common current and most likely future bottlenecks in the system, according to the operational experience of its Power System Engineers.

Zonal demand and generation

2.11 The GB electricity system has been broken down into a set of nodes. Each node represents an area of the country which is defined by a unique combination of interfaces (boundaries). The Node is a member of a zone. The location and number of zones have also been selected by NGET based on the most common current and most likely future bottlenecks in the system, according to the operational experience of its Power System Engineers.

2.12 Zonal demand has been derived based on the historical percentage of each zone's demand with relation to the total GB system demand. The demand for each zone is applied to the node representing that zone by applying a participation factor which is the percentage of total demand, derived from 2009/2010 data.

2.13 Zonal generation has been defined by the physical location of plant on the system. The generation in each zone is applied to the node representing that zone via a manual process using system diagrams.

2.14 The diagrams below represent the simplified model of the GB electricity network with nodes being connected by the lines across interfaces.

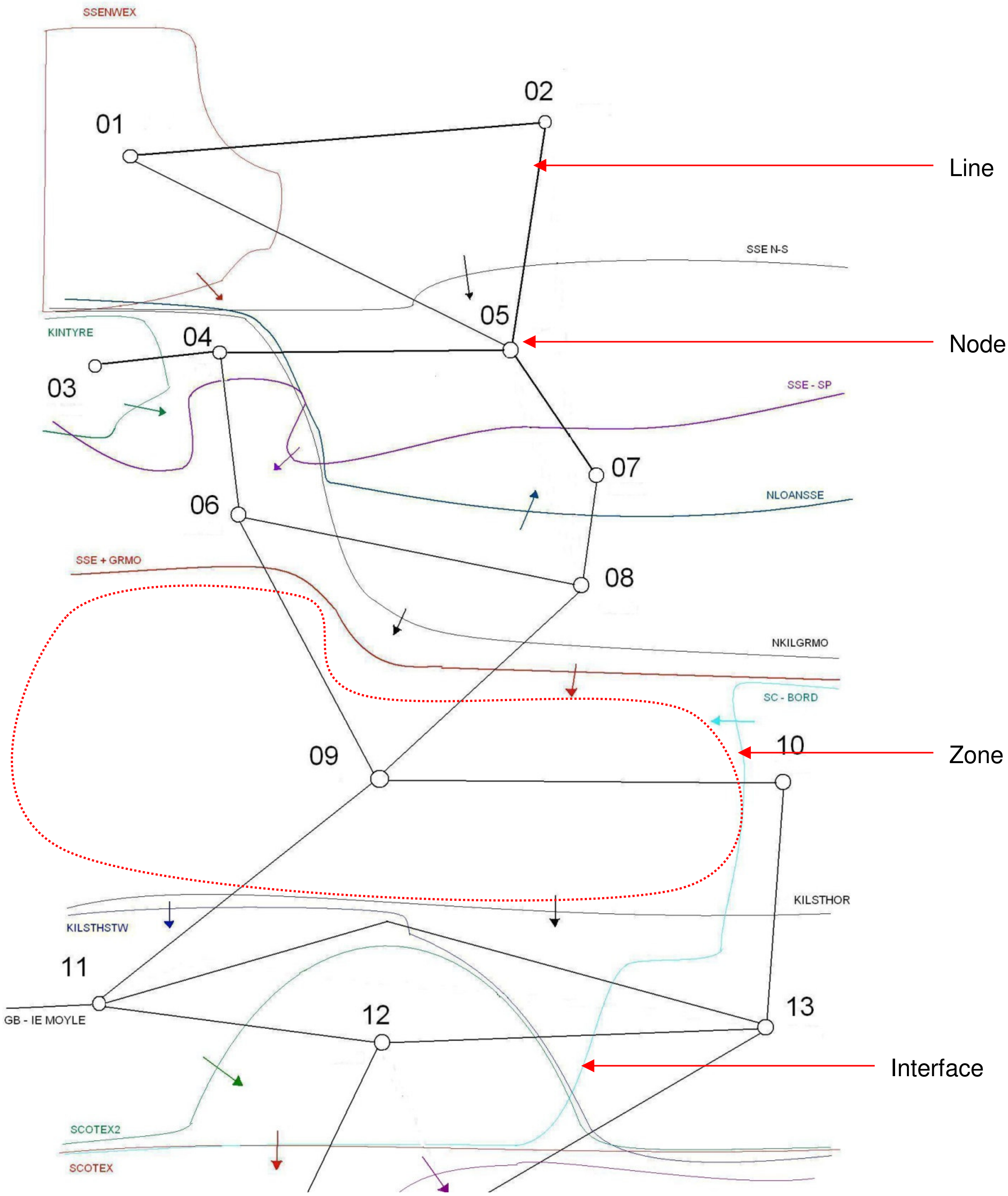

Figure 2 showing model of Scotland electricity network (Source: Redpoint)

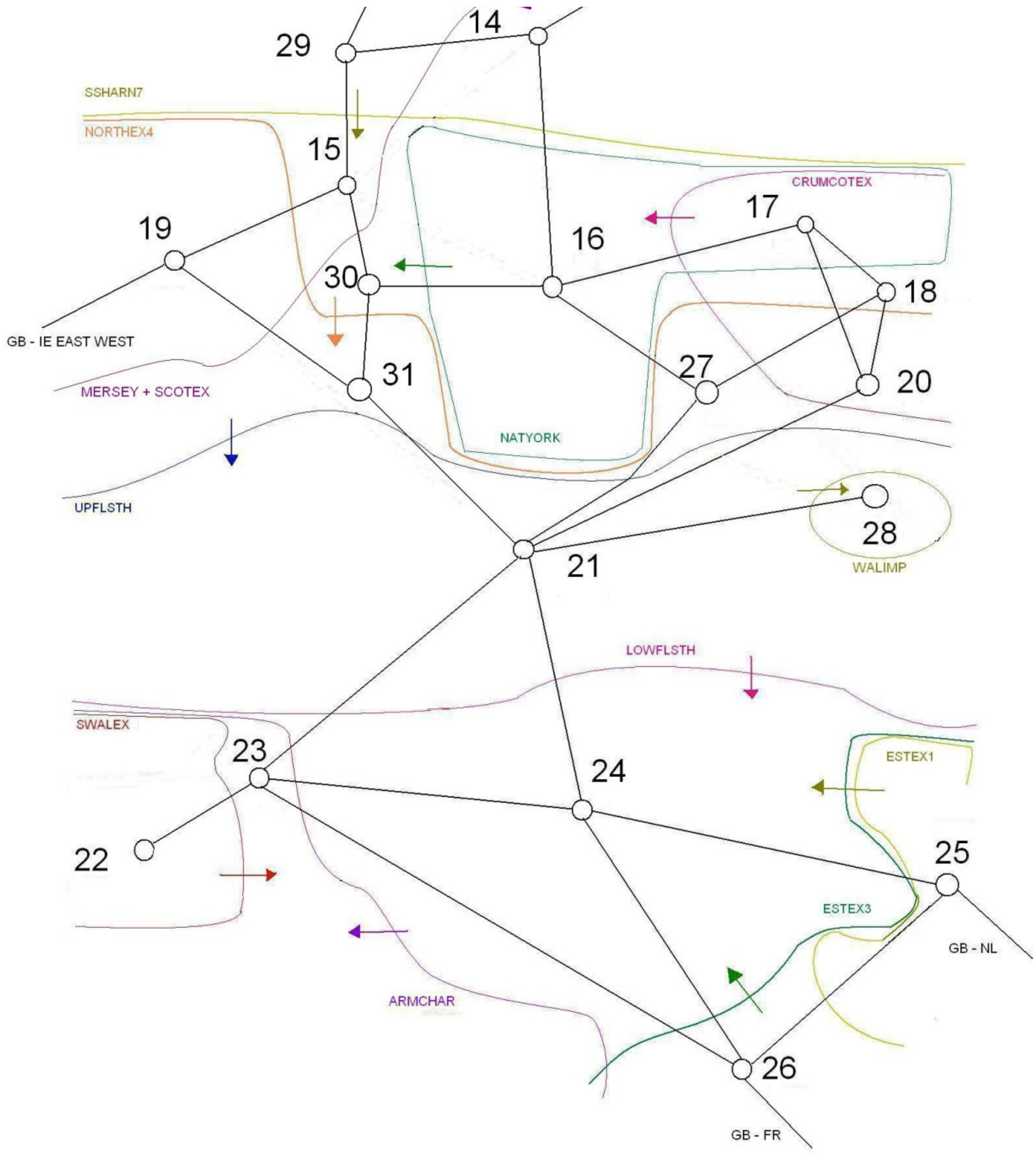

Figure 3 showing model of E&W electricity network (Source: Redpoint)

Boundary limits during outage conditions

2.15 Boundary limits during outage conditions are calculated through the development of offline power system studies.

2.16 For each boundary, a subset of the outages planned to take place throughout the outage year are selected. The selection process is based on historic data and the operational experience of power system engineers, and represents the most significant outages in relation to their impact on boundary transfer capabilities. Less significant outages planned during the outage year will therefore hide behind those selected in relation to their impact on boundary transfer capabilities.

2.17 The offline power system studies are used to calculate the maximum power flow that can be accommodated across a particular boundary. For each boundary, multiple contingencies (circuit trips) are run to establish the most onerous fault conditions. For the most onerous fault conditions, the maximum power flow that can be achieved across the boundary is calculated according to NETSQSS requirements.

2.18 In the case of a thermal constraint, the boundary limits have been calculated using the 20 minute short term rating of the worst overloaded circuits. This means that the maximum power flow across a boundary will be calculated to ensure that the power flows on these overloaded circuits can be reduced to their post fault continuous rating within 20 minutes. It's important to realise that this limit is achieved by selecting the most effective generation available in reducing those overloaded circuits. The post fault generator effectiveness is considered in a similar way for other types of constraint that can occur.

2.19 Limits are also a function of generation and demand backgrounds and can for example change between night and day or weekday and weekend.

2.20 The calculated boundary limits are applied to the interfaces between the interconnected nodes.

Out of scope

2.21 Transmission system losses are ignored in order to ensure that total demand equals total supply.

Chapter 3: Unconstrained model

Overview

3.1 The objective function of the unconstrained model is to minimise the sum of the short run marginal cost when no boundary limits are present.

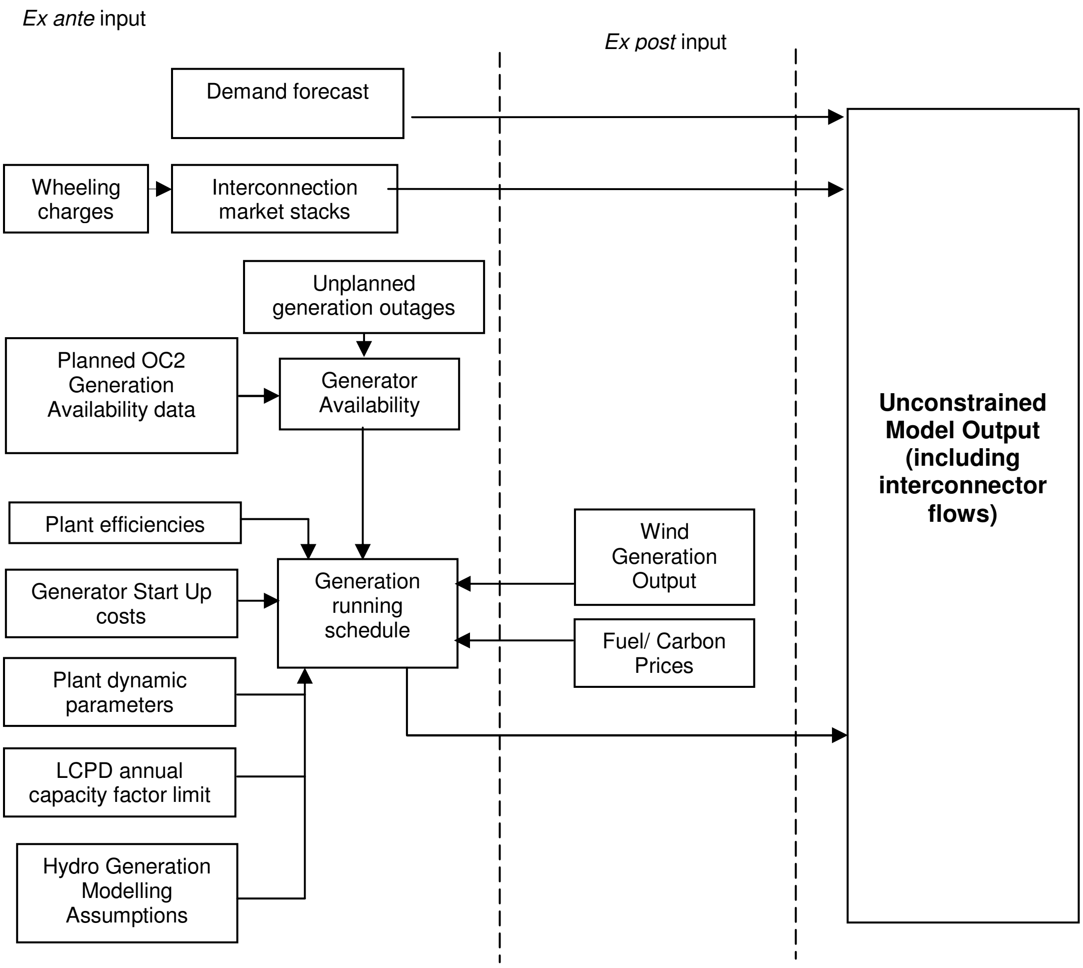

Figure 4: Unconstrained Output Model

3.2 The diagram above illustrates this initial run of the model which determines an unconstrained generation output. The diagram shows which inputs are to be ex ante and which inputs are to be ex post – this is explained in further detail below.

3.3 'Wheeling charges' are also applied to interconnectors in the model. Wheeling is a term applied when interconnector users export power from, for example, the GB market via one interconnector and then import power via another interconnector back into the GB market (thus creating a wheeling effect). Application of this charge means that a certain price differential across the interconnector is required before such flows will occur. A wheeling charge in Plexos is a variable cost applied to interconnector flows. These can be used to represent any actual charges faced by interconnector users which influence flows.

Total generation costs

3.4 Using demand forecast, fuel and carbon prices, plant efficiencies, start up costs, generator availability and wind and hydro generation data, a generator running schedule is developed that minimises the short run marginal cost of generation under unconstrained conditions. Using this generator running schedule and the total forecast, including interconnector flows, the unconstrained model costs are modelled.

Inputs

3.5 The first crucial data required is the demand forecast which is to be met by generation in the model. Demand forecast, an ex-ante input, is obtained through the well established processes within NGET. Demand is forecast at a GB level and apportioned to grid supply points based on observed and understood relationships. The demand forecast is based on average weather (over a 30 year period) and uses underlying historical data from the previous three years. Based on the recent trend in demand profile for weather corrected and seasonal adjusted demand, the future trend can be forecast.

3.6 To achieve the initial run from a supply or generation perspective (the unconstrained dispatch), a number of inputs are provided for each generation unit:

- Fuel price
- Carbon prices
- Plant efficiencies
- Start up costs
- Plant dynamic parameters
- Availability

Fuel and carbon prices

3.7 In order to input large amounts of time varying data, input data files are used. The fuel prices are measured in £/GJ, and the carbon price is measured in £/kg. For the carbon price, a Shadow Price property has to be entered. This is identical to the Price property. Emissions costs are included in dispatch decisions based on the shadow price to the generator. For the unconstrained model, they are as follows:

Data file name	Description	Source
Gas price	Daily gas price in £/GJ	Bloomberg[2]- Day Ahead Spot price at NBP
Coal price	Weekly coal price in £/GJ	Bloomberg – Generic CIF ARA Coal forward price
Carbon price	Annual carbon price in £/kg	Bloomberg – European Futures Contract for Carbon
Oil	Monthly price in £/kg	Bloomberg – Crude Oil, Brent Futures Price

Table 1 describing the input data files (Source: Redpoint)

The data files should be csv files, one per fuel, with five columns: Year, Month, Day, Period and Value. In all rows of the file; Period should be 1.

[2] The Bloomberg indices used as source data are NBPGDAHD, MSCMUSDT, ICEDEUA and EUCRBRDT. The Bloomberg exchange rates used to convert the prices into GBP are GBPUSDBGN and GBPEURBGN.

Plant dynamic parameters, efficiencies and start up costs

3.8 Plant dynamic parameters for existing units will be obtained from historical submissions in the balancing mechanism; for future units, they can be estimated from similar existing units.

3.9 Data sources used by generation plants are given in the table below:

Input	Source
BMU Heat rates	Ex ante, based on historic generation.
VO&M cost	Ex ante, based on market intelligence.
Start cost	Ex ante, based on market intelligence.
Technical plant parameters	Ex ante, based on market intelligence.

Table 2 describing data sources for generation plants (Source: modified from Redpoint)

Plant availability

3.10 BMU heat rates are the energy input required for 1MWh of output.

Heat rate = Potential Energy [GJ]/Electrical Energy output [MWh]

Efficiency = Electrical Energy Output [GJ]/Potential Energy Input [GJ]

Since, 1MWh = 3.6 GJ,

BMU heat rates= 3.6/Efficiency

3.11 VO&M (Variable Operation and Maintenance) charge is a component of the incremental cost of generation per megawatt hour. It is used to recover maintenance costs which are a direct function of generation such as wear and tear and other servicing costs. It is factored into units' short-run marginal costs.

3.12 For the specific units, each of their VO&M costs have been specified as a result of Redpoint Energy resources and GB market experience accumulated over the years. VO&M costs mostly vary in the units fuel type, for example Coal units' VO&M costs consider coal milling costs and other consumables that would be unique to coal plants. Nuclear plants' VO&M costs, unlike other plants, factor in the fuel (Uranium) costs itself as oppose to specifying the fuel cost separately. As a result of this and factoring in a Nuclear plant's contribution to decommissioning into their VO&M costs cause their VO&M costs to be high relative to other plant types.

3.13 Start up costs for existing units are estimated in a similar way as that of efficiencies, i.e. through simulating historic market conditions and adjusting the costs until a reasonable match is reached.

3.14 Plant availabilities can, broadly speaking, be split into two groups: planned and unplanned. Planned outages will be based on submitted information by generators through the OC2 process (taken on 31st March 2011) and refreshed for the second year of the scheme on 31st March 2012.

3.15 Unplanned outages are random in nature and can occur at any time; hence they will be included as a percentage forced outage rate to allow for stochastic modelling in the ex ante dataset agreed prior to the start of the scheme.

Input	Source
Forced outage	Ex ante, % rate input, based on observed forced outages.
Maintenance	Ex ante, Forward looking OC2 data updated on 31st March 2011 and on 31st March 2012

Table 3 showing outage data sources (Source: modified from Redpoint)

3.16 The Forced Outage Rate represents the expected proportion of the year that a unit will be unavailable due to unplanned outages. By their nature, outturn forced outages are likely widely from year to year for individual units. In the model, they are set by plant type as shown in the table below:

Plant type	Forced Outage Rate	Source
Coal	12%	Redpoint's GB Power Market knowledge
CCGT	12%	Redpoint's GB Power Market knowledge
Nuclear	20%	Total Historic Availability of Magnox and AGR units, corrected for standard maintenance

Table 4 showing forced outage rates (Source: Modified from Redpoint)

3.17 The mean time to repair sets the outage length when a forced outage occurs. Bearing in mind the deterministic modelling set up and the impact on model results, the standard forced outage length is 24 hours so that outages are distributed throughout the year.

3.18 In addition to the above, further inputs are required to fully represent generation levels on the system. These are:

- Hydro generation running assumptions
- Treatment of Large Combustion Plant Directive (LCPD) opted out plant
- Interconnector assumptions

These are described in further detail in Chapter 5: Generation.

Outputs

3.19 The unconstrained model comes up with a number of outputs which are written to a file as shown in the table below. These are then used as inputs for the constrained model.

Data file name	Description
FPN	Generation, used as Offer Base input
Minus FPN	Desynch Bid volume, The negative value of the FPN, calculated by multiplying the FPN by a factor of -1
MEL	Available capacity
FPN to SEL	The difference in volume between generation and generator's stable export limit. This is calculated by looking for the maximum between that difference or 0 and then multiplying it by a factor of -1 (-Max(0, Generation - SEL))
IsOperating	Will have a value of True if the unit is generating and False at all other times

Table 5 showing unconstrained model outputs (Source: Redpoint)

Chapter 4: Constrained Model

Overview

4.1 The forecast of constraint costs is done by running a simulation of the unconstrained system followed by a run with boundary limits included, using the result from the first run as the starting position of the generating units. Each unit is assigned a set of prices as part of the balancing mechanism explained below and the optimisation engines looks at the minimum cost to move the system from the original position to a feasible position, given the transmission constraints. The diagram below illustrates the second run of the model which will determine the generation output of the constrained system. The inputs are BM bid/offer prices and transmission constraint boundary limits (explained in paragraph 4.16).

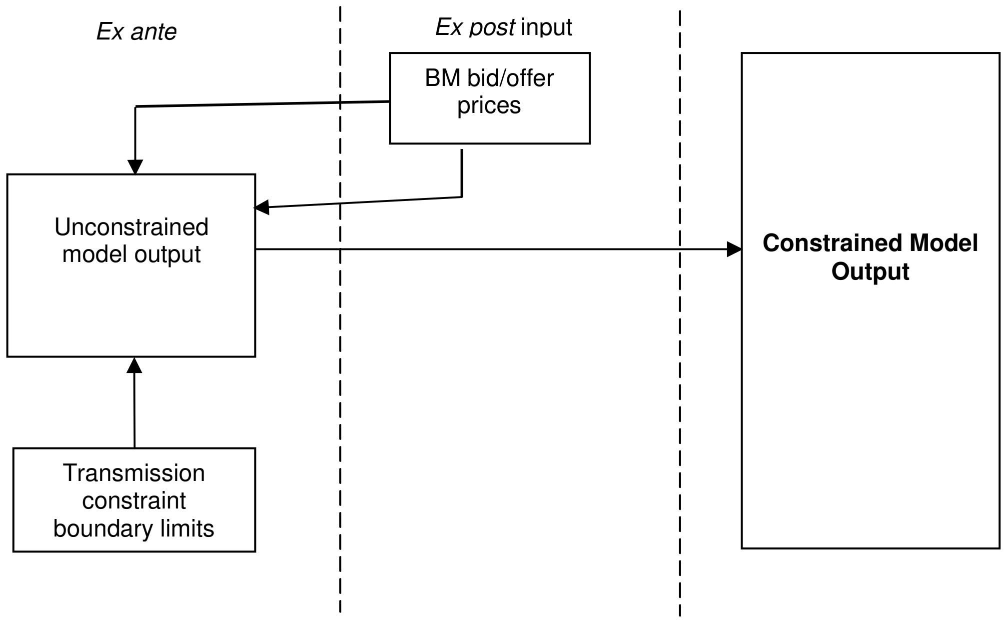

Figure 5: Constrained Output Model

4.2 This second run of the model factors in the limitations of the transmission network, where the difference between the two runs represents the model's assessment of the required volume and associated cost of constraint management activities. The generation output levels from the unconstrained model are therefore used as inputs to the constrained model where Plexos re-dispatches generation to meet demand in light of the boundary constraints applied and the prices for re-scheduling plant.

4.3 Where a boundary's capability is exceeded, resulting constraints are resolved by re-scheduling plant using a representation of offer/bid prices determined as part of the balancing mechanism explained below, to give an overall 'constrained' schedule of plant running to meet demand.

4.4 The difference in cost between the constrained and unconstrained runs is given by the net sum of accepted bids and offer costs. This difference in cost will give the modelled target costs against NGET's out-turn and will be used to determine its performance under the incentive.

4.5 The following section describes the way in which the model is constructed, including simulation of the Balancing Mechanism.

Balancing Mechanism

4.6 The objective function used for the constrained model is to minimise total amount of money spent on the Balancing Mechanism subject to the boundary limits set in the model above.

4.7 The Balancing Mechanism is exclusively used in the Constrained Model. It is simulated through 4 Bid/offers price-quantity pairs, explained below, and using the unconstrained dispatch model as an initial condition.

4.8 The unconstrained dispatch shall be changed to respect interface limits, and where arbitrage opportunities exist between generators, they shall be taken.

4.9 Offer Base is the Unconstrained Generation (Final Physical Notification - FPN). This is the generator self-dispatch level and therefore the base level for each generator in the balancing mechanism.

4.10 Offer Prices are read in three bands and are conditional on whether the generator is operating. When generating the three bands are to move between FPN and off (desynch bid), SEL (Energy Bid) and Max availability (MEL). When not generating, the first two bands are 0, and the third band is to take the generator up to max capacity (Synch Offer).

4.11 Four prices are used because there are broadly four categories of actions in the BM that have different price drivers; they, and their drivers, are as follows:

- De-sync Bids - the submitted bids on a unit to reduce its output from SEL to zero. One would expect the price to reflect the value of the fuel saved, and also the cost of increased maintenance due to the extra synchronisation caused.
- Energy Bids - the submitted bids on a unit to reduce its output from FPN towards SEL. One would expect the price to reflect the value of the fuel saved.
- Energy Offers - the offers on a synchronised unit above SEL. One would expect the price to reflect the cost of fuel used.
- Sync Offers - the submitted offers on a unit to switch the unit on and increase its output to SEL. One would expect the price to reflect the cost of fuel used, and the maintenance cost due to the synchronisation event.

4.12 To calculate the prices for the 4 Plexos bands described above, the volume weighted average per half hour, per BMU of the offer price of these bands are used. These are calculated from the capped physical notification (CPN) which is defined as the minimum value of the final physical notification and the maximum export level. Using the CPN, the offer prices can be calculated for their corresponding offer quantities. From these, the weighted average per half hour per BMU for each band can be found. These are the prices used in the constrained model.

4.13 The tables below give the relationship between the 3 Plexos bands and the corresponding offer prices and quantities.

Offer Price Band	Operating	Off
1	Desynch Bid	0
2	Energy Bid	0
3	Energy Offer	Synch Offer

Table 6 showing offer price bands (Source: Redpoint)

Band	Offer Quantity Operating	 Off
1	Negative FPN	0
2	SEL - FPN	0
3	MEL	MEL

Table 7 showing offer quantity bands (Source: Redpoint)

4.14 Offer quantities are calculated based on unconstrained dispatch. Negative quantities are used for bands 1 and 2 to denote bids for reducing output below FPN. Note that the effective Offer Quantity band 3 for operating generating units is actually MEL minus FPN; the generator's total output will be capped by its availability, which is set to MEL in constrained dispatch. MEL can therefore be applied as the Offer Quantity for band 3 in both the operating and off conditions. The three Offer Quantity bands for an operating generator are illustrated in the following diagram.

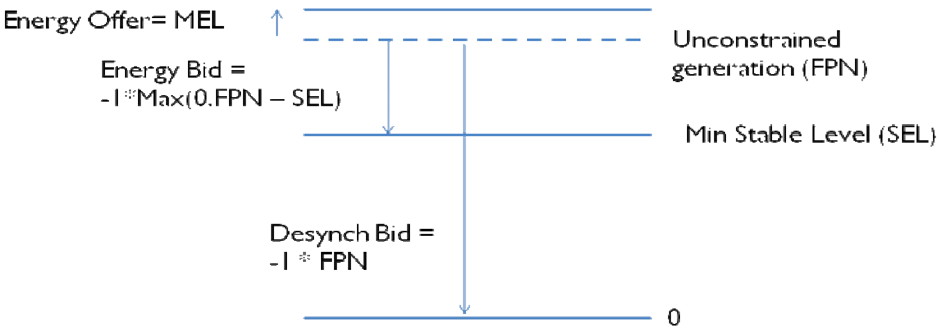

Figure 6 showing the balancing mechanism price-quantity relationships (Source: Redpoint)

4.15 The model will only take one of the above actions in the BM on a particular unit if it is feasible to do so, given its dynamic parameters.

Inputs

4.16 In addition to the inputs to the unconstrained model, the constrained model has additional data file inputs for the Balancing Mechanism and the boundary limits. These are as follows:

Input name	Description	Source
FPN	Used as Offer Base input. Half-hourly generation level of each asset.	Unconstrained model
Minus FPN	Desynch Bid volume, only applied when the generator is operating	Unconstrained model
MEL	Energy offer volume, also used for the Synch Offer volume	Unconstrained model
FPN to SEL	Energy Bid volume, only applied when unit is generating	Unconstrained model
IsOperating	Flag to indicate what state the generator was in when unconstrained.	Unconstrained model
Desynch	Bid price to turn off	Volume weighted average

Input name	Description	Source
Bid		of bid prices submitted in the BM between SEL and 0, subject to the condition that FPN > 0
Synch Offer	Offer price to turn on. Only used when plant is off in the unconstrained solution	Volume weighted average of offer prices submitted in the BM between 0 and SEL, subject to the condition that FPN = 0
Energy Bid	Price to turn down from present level to SEL (minimum stable level)	Volume weighted average of bid prices submitted in the BM between FPN and SEL, subject to the condition that FPN > SEL
Energy Offer	Price to turn up from present level to max capacity.	Volume weighted average of offer prices submitted in the BM between FPN and MEL, subject to the condition that 0 < FPN < MEL
Import Limit	Limit on flow across an interface in a south-north direction, at weekly detail	Determined by NGET (explained below)
Export Limit	Limit on flow across an interface in a north-south direction, at weekly detail	Determined by NGET (explained below)

Table 8 showing input sources for the unconstrained model (Source: Redpoint)

4.17 If the relevant prices are not available, then a number of options exist. These are listed below in order of preference and subject to data availability:

1. The last relevant price can be used
2. Else, the average of all units of the same fuel type at the Plexos node can be used
3. If none of the above is possible, then the average of the same fuel type at neighbouring Plexos nodes.
4. Alternatively, the average price of the same fuel type within the country can be used.
5. Finally, the average price of the same fuel type within GB can be used.

Out of scope

4.18 Intertrips are not modelled as this model assumes that all constraints are resolved by the BM and that any efficiencies gained through intertrips and other contracts will be dealt through the discount factor.

Outputs

4.19 The outputs from the constrained model are the actions taken and the extent of congestion, giving the constraint volumes (cleared offer quantities) in total and per generator along with the cleared constraint costs. The total of the cleared offer costs are to be used as the target for the incentive scheme. This is the sum of all units' cleared offer costs.

Chapter 5: Generation

5.1 This section describes how non-typical forms of generation are treated within the model.

Wind

5.2 Wind is an intermittent generator which currently has little capability to respond to price signals or instruction from Grid (it can turn down/off, but can not turn up)

5.3 A single wind profile (through the data file Variable Wind) is applied to all wind generators in model. This has been calculated based on aggregate metered output. Any locational information available would not be captured in the model.

5.4 Wind is modelled using the percentage of available capacity and ex post wind output data. This will be half hourly metered wind output data.

Input	Description	Source
Variable wind	Ex post half hourly wind generation	Settlement metering, adjusted for any bids taken on the unit

Table 9 showing the wind data input to the model

Monitoring of the commissioning of wind farms

5.5 It is important to ensure that as new wind farms are connected to the network, the model is kept up to date to ensure that the metered output of the wind farms ex post can be input. Hence, a list of all wind farms along with the nodes at which they are connected and their connection dates will be maintained and checked against any metered data available from Elexon on a monthly basis in order to ensure that the models are updated in a timely manner.

Hydro

5.6 Hydro is modelled in two ways – pumped storage and reservoir.

5.7 Reservoir is modelled by assuming a monthly water inflow into a head pond. Plexos then optimises the release of this water to generate electricity. The observed monthly hydro generation is used to calculate the average value.

5.8 Pumped storage is dispatched based on price differential within a day. If there is sufficient price differential during the day, there will be pumping at times of low price and generation at times of high price.

5.9 Pumped storage plants are modelled as a closed system comprising a Head Storage and a Tail Storage, shared between the multiple BM Units at each plant. There are no energy flows into or out of the head or tail storages other than from generating or pumping. A Pump Efficiency is also defined for each pumped storage generator.

5.10 Pumped storage utilisation is optimised on a daily basis. In the unconstrained model, pumped storage will arbitrage between peak and off-peak periods in order to lower system-wide generation costs in the objective function.

5.11 The treatment of pumped storage units with respect to unconstrained model outputs is as follows.

- The unconstrained period-level output of each generator, including pumped storage units, is passed to the constrained model run.
- When pumped storage units are pumping rather than generating, this is reported by Plexos as pump load rather than negative generation. The FPN file is only populated by generation values, and so pumping schedules are not explicitly passed to the constrained model run.

- However, across the system as a whole, the unconstrained generation output will increase in order to meet pumping load.

5.12 The starting position for the constrained model run is therefore a balanced schedule, with the sum of generator FPNs exceeding customer demand when pumped storage units were pumping in the unconstrained schedule. The unconstrained output of pumped storage units, passed through as FPNs, implies a required level of pump load for each pumped storage system. However, the timing of this pumping activity is not fixed for individual pumped storage facilities.

5.13 In the constrained model, deviations in pumped storage generation from the initial FPN position are optimised in the same manner as for other generators.

5.14 The current Plexos model design does not support BM price-quantity pairs for deviations in pumping load, as opposed to generation. Deviations in pumping load in the constrained schedule are treated at cost, but any corresponding changes in the output of other generators will be priced at the input bid-offer prices. Other things being equal, reductions in pump load will lead to accepted bids on other generators, while increased pump load will require accepted offers on other generators.

Large Combustion Plant Directives (LCPD)

5.15 The LCPD limits the operating hours of a series of plants in the UK. The latest BM Reports data provides LCPD plant cumulative running hours as of 31/12/2010. The table below shows the remaining hours, the current Plexos model assumptions on closure dates, and the implied maximum annual capacity factor for each plant stack.

Generator	Average capacity factor to date since 1/1/08	Remaining hours as of 31/12/10	Current model closure date	Implied remaining days	Implied annual max capacity factor
Ironbridge	25.5%	13295	31/12/2014	1461	37.9%
Kingsnorth	46.6%	7738	31/12/2012	731	44.1%
Didcot A	34.1%	11030	31/12/2013	1096	41.9%
Tilbury LCP 1 Boilers 7 & 8	43.3%	8614	31/12/2012	731	49.1%
Tilbury LCP 2 Boilers 9 & 10	45.0%	8160	31/12/2012	731	46.5%
Ferrybridge C Unit 1 & 2	28.5%	12500	31/12/2014	1461	35.6%
Cockenzie LCP 1 Units 1 & 2	61.3%	3885	31/12/2013	1096	14.8%
Cockenzie LCP 2 Units 3 & 4	55.0%	5520	31/12/2013	1096	21.0%

Table 10 showing the Plexos model assumptions for LCPD plants

Interconnected Markets

5.16 Interconnected markets can drive constraint levels across certain key boundaries, either as sink (export) or source (import). The GB system presently has two interconnectors (GB-France) and Moyle (GB-NI). Over the coming years, this is being expanded with BritNed (1000 MW to the Netherlands) and the 500 MW East-West interconnector from Deeside to the Republic of Ireland.

5.17 In order to model interconnected markets, a simplified stack is applied on the other end of the line, which is meeting a simplified demand profile. Through careful calibration this can provide better results than modelling a direct price process or constraining the flow to meet observed flow levels from history.

5.18 France is represented by a simple nuclear and gas stack while Ireland is modelled using a gas and coal mix.

5.19 Netherlands is represented as a single large gas-fired generator ("BB-NL"), gas being the predominant fuel at the margin in the Netherlands. However as BritNed is yet to open, there is no historical data to calibrate its line flow.

5.20 GB and Dutch forward power prices were used as the best available indicators of future BritNed line flows. The Peak and Off Peak GB and Dutch forward power prices provided by Platts (as of 07/02/2011) indicated that GB would net import from the Netherlands during off peak periods, while importing in summer peak and exporting in winter peak periods.

5.21 'Wheeling charges' are also applied to interconnectors in the model. Application of this charge means that a certain price differential across the interconnector is required before such flows will occur. A wheeling charge has not been set in either direction across the BritNed interconnector, as there is no historical data to support calibration. Moreover, it is expected that the partial allocation of BritNed capacity by market coupling should lead to efficient utilisation of the interconnector.

Chapter 6: Headroom Replacement Volume

6.1 Headroom represents spare capacity on operating generating units which NGET can potentially access to meet its reserve requirements. Headroom may become inaccessible due to transmission constraints in the case of generators located behind an export constraint boundary. The cost of replacing this 'sterilised headroom' can contribute materially to overall constraint costs. If an action is taken to completely replace sterilised operational margin, then the costs are assigned to constraint costs.

6.2 In order to calculate the constraint costs associated with headroom replacement volume, the inputs required are expected CMM volume and Margin Price, both obtained from the Energy Model. These are both defined in the "NGET Statement of Methodology for Energy Balancing".

6.3 Hence the headroom replacement costs for each month can be calculated as follows:

$$\begin{aligned}
\text{TARGET_HEADROOM_REPLACEMENT_COST}_m = \\
&+ C1 * \text{IS_BST_NGET}_m \\
&+ C2 * \text{IS_BST_NGET}_m * \text{EXPECTED_CMM_VOLUME}_m \\
&\quad * \text{OP_RESERVE_CASH_PRICE}_m \\
&+ C3 * \text{IS_GMT_NGET}_m \\
&+ C4 * \text{IS_GMT_NGET}_m * \text{EXPECTED_CMM_VOLUME}_m \\
&\quad * \text{OP_RESERVE_CASH_PRICE}_m
\end{aligned}$$

Where

- IS_BST_NGET_m
  - An indicator, integer value 0 or 1, of whether the given month *m* falls within NGET's internal definition of the British Summer Time (BST) timezone period:
    IS_BST_NGET_{hh} =
    If [April] ≤ *m* < [November] then 1 else 0
    Note that this differs from the generally accepted definition of BST.

- IS_GMT_NGET_m
  - An indicator, integer value 0 or 1, of whether the given half-hour *m* falls within NGET's internal definition of the Greenwich Mean Time (GMT) timezone period:
    $\text{IS\_GMT\_NGET}_m = (1 - \text{IS\_BST\_NGET}_m)$
    Note that this differs from the generally accepted definition of GMT.
- $\text{EXPECTED\_CMM\_VOLUME}_m$ is the expected volume, in MWh (over the given month), for Constrained Margin Management (CMM), as described in the The Statement of the Energy Balancing Cost Target Modelling Methodology
- $\text{OP\_RESERVE\_CASH\_PRICE}_m$ is the monthly volume weighted average of the Expected Half-Hourly Cash Price for Operating Reserve, as described in the The Statement of the Energy Balancing Cost Target Modelling Methodology

Determination of Coefficients

Coefficients C1 to C4 are determined by OLS regression based on Ex Post data from 1 April 2005 to 31 March 2011.

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**
BMU	Balancing mechanism units
CPN	Capped Physical Notification
Classes	Groups of Object types – e.g. Production class contains the Object types Generator, Storage, the Transmission class contains Lines and Nodes etc
Ex ante	*Ex ante* data is data reflecting events that have yet to happen by the time of the beginning of the Scheme. By implication, such data has to be estimated or predicted.
Ex post	*Ex post* data is outturn data, i.e. data reflecting events that have happened by the time of the beginning of 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).
FPN	Final Physical Notification
Memberships	A method to link two objects together. For example, a generator will have a membership to a fuel and a node.
MEL	Maximum Export Limit
Objects	Physical and financial features of electricity market – for example, Generator, Line and Company. They are defined by Properties, and their relationship to other objects is defined by memberships
Properties	They define an object. For example, a generator can be defined by a Max Capacity and a Heat Rate. It is typical for more properties to be used to define an object.
SRMC	Short Run Marginal Cost
SEL	Stable Export Limit
VO&M	Variable Operation & Maintenance

Revisions

Issue 1	Modifications	Changes to Pages
Revision 0	First Issue	